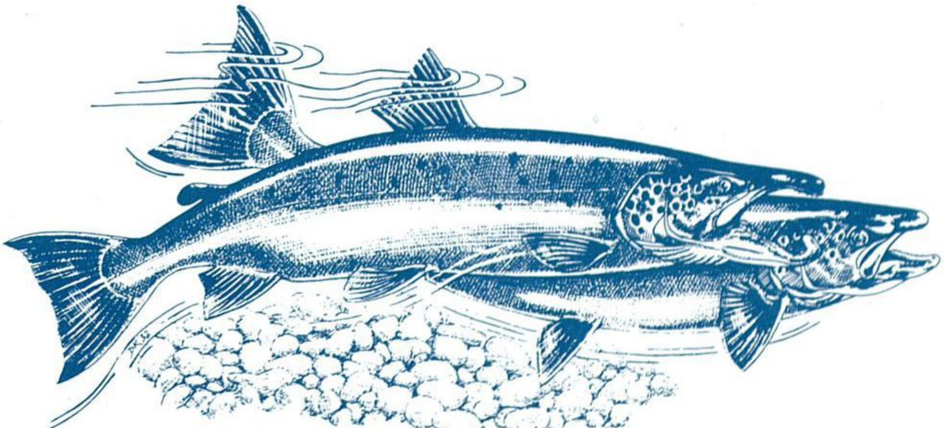
FACTORS AFFECTING NATURAL SMOLT PRODUCTION

Report of the Salmon Advisory Committee



Ministry of Agriculture, Fisheries and Food
Scottish Office Agriculture and Fisheries Department
Welsh Office Agriculture Department

Page

FACTORS AFFECTING NATURAL SMOLT PRODUCTION

1. INTRODUCTION

The Salmon Advisory Committee was established by Fisheries Ministers in October 1986. Its membership is shown at Appendix 1.

The terms of reference of the Committee are:

> "To examine and report on those matters relating to the conservation and development of salmon fisheries in Great Britain which are referred to it by Fisheries Ministers."

2. AIMS AND OBJECTIVES

Ministers have asked the Salmon Advisory Committee to examine the various influences on wild salmon stocks. These are numerous and varied, both in their nature and extent. We have therefore identified those human activities which may have significant and widespread effects on salmon and their environment and where there is a reasonable expectation that we can make constructive and practicable recommendations to alleviate undesirable effects. This report does not however address the impact of fishing on salmon stocks, an issue which the Committee is considering separately. The Committee is aware that developments in some of these activities can be rapid, and can change the nature of the problems and how they may be tackled. However, when we selected particular areas for study we felt that it was important to comment on the problems as they are perceived at the present time.

In presenting our report, we wish to emphasise the special vulnerability of Atlantic salmon in fresh water. Indeed, there is no known instance in Great Britain where a stock has been lost altogether as a result of legitimate fishing but many where extinction has followed obstruction or degradation of river or estuarine habitats.

The Committee recognises that many of these factors interact and notes that some affect more than one stage in the life cycle of the salmon. We also feel that the subject is too large to be addressed in a single report and that a convenient and logical way to proceed is to consider the factors in terms of their impact on distinct phases of the life cycle. We therefore decided to produce separate reports on the effects of human activities on Atlantic salmon and their freshwater habitat, covering the life stages egg to pre-migrating smolt, and emigrating smolts and returning adults.

This is the first of these reports, and it deals with human activities that affect the survival of juvenile salmon prior to their migration as smolts. It covers three main groups of factors: hydrology (eg. river regulation and abstraction), water quality (eg. pollution and acidification), and habitat (eg. riparian management and gravel extraction).

We are aware that perhaps the most important factors affecting the production of smolts are the number of successful spawners and their distribution in the river. These aspects will be addressed in the second report which will concentrate on factors affecting the emigrating smolts and returning adults in freshwater and estuaries.

3. INFLUENCES OF HABITAT ON JUVENILE SALMON

3.1 Introduction

The aim of this section is to describe the natural factors which affect the production of juvenile salmon and to consider variations from the ideal which are likely to influence survival and production. This provides a basis for considering the effects of the various human influences which are perceived to represent a threat to natural smolt production. The term 'juvenile salmon' is used in this report to cover all stages from egg to smolt as shown in the brief life history description below.

A brief description of the life history from egg to smolt

Salmon spawn in autumn or winter in excavations in the river bed known as redds. The eggs remain buried in these redds throughout their development. After hatching in the early spring, the young fish, known as alevins, remain in the redd and draw nourishment from their substantial yolk sacs. Mortality through these intra-gravel stages is generally low (less than 10%) though in less suitable or degraded environments it may be increased very substantially, sometimes to more than 90%.

When the yolk reserves are almost exhausted the fish emerge from the gravel, disperse and begin to feed. At this stage the fish are generally known as fry. In some areas the term fry is also used to describe the young fish after the dispersal stage for part or all of the first year of life. In this report, the term fry will not be used, and all stages following emergence will be referred to as parr.

The young parr set up territories in suitable habitats and defend these against competitors throughout the summer. In autumn and winter they may redistribute themselves, often moving into deeper water and sheltering under stones. Mortality of the fish during the early dispersal and territory forming stages is typically very high (greater than 80%). Subsequently the remaining parr population is subject to a reasonably steady rate of mortality, typically of the order of 65-70% per annum.

After a period of growth ranging from one to several years, the parr undergo morphological, physiological and behavioural changes to become smolts. At this stage the fish leave their nursery areas and migrate to sea.

Throughout this report standard nomenclature is used to describe the various parr age classes. Fish in their first year are termed 0+, fish in their second 1+, third 2+, and so on.

3.2 Physical habitat for eggs and alevins

It is difficult to define the ideal situation for spawning and incubation, but it is possible to describe the conditions prevailing where natural spawning takes place, and to link them with the success or otherwise of spawning and the survival of the eggs and alevins. Observations on Pacific salmon are relevant to Atlantic salmon as their requirements in this respect appear to be similar.

Salmon typically select spawning sites where the water current is accelerating over gravel. Such a situation is usually conducive to intra-gravel flow of well-oxygenated water, essential for survival of the eggs. Size distribution of gravel varies widely but the percentage of fine material (particles measuring less than about 2.0 mm) will critically affect the permeability of more than 1 metre/hr which is considered necessary for successful emergence of alevins, and this corresponds to a maximum sand content of 12-15%. Compaction and concretion, caused by the input of silt, can also have critical effects upon permeability and on the ability of alevins to emerge from the gravel. However, it appears that small quantities of sand and fine gravel may prevent the penetration of detritus. Thus a gravel of constant size may quickly become clogged with silt, whereas mixed natural gravels are much less permeable to fine material.

It is likely that in many situations the action by the fish itself in creating the redd will alter the distribution of the different sized components of the gravel, reducing the fine sediment component by winnowing; even the pink salmon, which has an average weight of only about 2 kg, shifts about 100 kg of gravel in creating a redd. How long this effect persists is uncertain.

It is important that spawning areas should offer a stable environment during incubation: very high discharges can cause gravel shifting, often destroying eggs and alevins; very low flows may expose redds; and very low temperatures coinciding with low flows can lead to redds freezing, killing eggs and alevins.

Water quality requirements for eggs and alevins are generally similar to those of parr and this is discussed further in Section 3.3 below.

3.3 Physical habitat for parr

Where two or more species of salmonid occur together in streams, the differences in their behaviour tend to become exaggerated. Salmon parr appear to prefer shallow, fast flowing water in summer and slightly deeper water in winter. Trout are more aggressive than salmon, and appear to dominate in slower water, but to be unable to compete in faster water. Thus a clear interactive segregation takes place, which serves to reduce direct competition. As it is rare to find Atlantic salmon juveniles in areas where trout do not also occur, care is needed in interpreting the niche occupied by each species.

Salmon parr are able to maintain position in fast flows with little effort by using their large paddle-shaped pectoral fins to keep themselves applied or close to the substrate, eg. on top of a large stone. In this respect they are better adapted to rapid flows than are any of the other salmonids.

Field studies have indicated highest densities of salmon parr occur at a fairly narrow range of stream velocities (50-65 cm/s). Stream tank experiments show that salmon less than 7 cm in length prefer shallow riffles (10-15 cm deep) with a pebbly substrate (1.5-6.5 cm stone diameter). As they grow larger their preference changes for deeper (more than 30 cm) riffles containing boulders (greater than 25 cm diameter). Both trout and salmon in their first year prefer shallow water (20-30 cm), especially in the margins of the large rivers, while older fish may spend long periods in pools.

For both salmon and trout, a relatively stable discharge appears to be advantageous. Streams with naturally stable flow, eg. chalkstreams, are often very productive as a salmonid habitat. This is probably largely a matter of lack of extremes, as both very low and very high discharges can be damaging. It is likely however that some fluctuation of discharge is desirable, to maintain habitat diversity and to clear away deposits of fine material.

Moderate overhanging vegetation can improve production by providing cover for young fish and a source of invertebrate food material. Excessive cover will, however, reduce river production by excluding light for plant growth.

3.4 Factors affecting carrying capacity.

Each stream or reach of stream has a finite limit for the number of juvenile salmon which it can support. This is known as the 'carrying capacity'. This limitation tends to level out fluctuations in population size by imposing higher mortality rates at densities above carrying capacity than at lower densities. The chance of survival is thought to be related to territorial behaviour. This operates largely by way of the aggressive behaviour of the parr; the young fish usually protect a territory around their feeding station by chasing away, and sometimes biting, intruders. The territory does not have firmly defined boundaries, and aggressiveness decreases with distance from the defended station. In some situations parr may aggregate in physically favourable areas where complex social hierarchies may develop.

Within the general habitat conditions already described, there is a range of factors which influence the stream carrying capacity:

(a) Area of river bed suitable for occupation. The areas suitable for fish of each age class may be rather limited, especially in larger streams and rivers.

(b) Age/size of fish. The size of territory increases with the size of fish. In stream tank experiments it appears that about a month after the young fish emerge from the gravel, individual territories are about 0.02-0.03 m^2 in a fairly tightly packed mosaic. Larger parr (up to 15 cm) may occupy a square metre or more.

(c) Visual obstructions. Where fish are unable to see one another, a higher density can be supported. In the stream-tank experiments, mean territory size was halved by exchanging gravel for rocks.

(d) Current speed. Highest densities of salmon parr under natural conditions have been found in water velocities of the order of 0.6 m/s. The progressive increase in density as velocities increase up to 0.6 m/s might occur because the fish are forced to vacate rock-top stations and shelter among the stones, decreasing visual contact. As water velocity increases fish can exploit invertebrate drift in a similar volume of water by commanding a smaller area or width of stream.

(e) Availability and type of food. As territorial defence is believed to be a feeding-motivated behaviour, it is likely that territories will be smaller where food supply is abundant as, for example, suggested above at higher current speeds. Stream tank experiments have demonstrated increased aggressive behaviour during periods of food deprivation.

(f) Presence of other year classes. Parr of different sizes or ages tend to select different habitat, but 1+ and older parr when present in high densities may reduce the number of younger fish in deeper water by chasing and occasionally eating them. However, stream tank observations show that small parr vacate their station and hide in the gravel nearby when a larger parr approaches. Thus it is possible for a small fish to occupy a territory within the much larger territory of a larger fish for considerable periods.

(g) Presence of other species. Where juvenile salmon and trout occur together, each species appears to be present at a lower overall density than when occurring alone but overall density tends to be higher as each species can thrive in areas which would be marginal to the other. Little is known of the effect of the presence of other fish species on the carrying capacity for salmon. However, if territory size is linked to food availability ((e) above) then it is possible that the presence of competitors for food (eg. eels, bullheads), might reduce the numbers of salmon territories tenable.

3.5 Other factors affecting production

The factors considered above are those which limit the carrying capacity of the stream for young fish. Other factors, for example poor water quality, extreme physical conditions and predation, may have effects which are less dependent on population density (though rarely completely so), and may reduce the population size below the carrying capacity of the stream.

3.5.1 Water quality

Good water quality is a requirement for healthy salmon production and deterioration affects the fish in a variety of ways:

(a) **Dissolved oxygen.** Salmonids require well-oxygenated water, and to enable them to maintain a high level of activity, eg. for swimming against strong currents, at least 50% of the saturation concentration is essential. (The saturation value at 20°C is 9.1 mg/l, and at 0°C is 14.8 mg/l.) There are water quality standards set by the European Community (EC) and these are listed in Appendix 2. Bacterial and fungal growths, decaying organic matter, organic discharges and some inorganic chemicals can cause a reduction in dissolved oxygen, sometimes to levels inadequate for fish.

(b) **Temperature.** Feeding, growth and movements of salmon may be affected by changes in water temperature. Salmon have been observed to spawn at water temperatures of 0-8°C. The preferred temperature for the growth and survival of newly-hatched fish is 14-15°C, while the preferred range for all parr is 9-17°C. The absolute lethal temperature for young salmon is around 27°C, but temperatures over 20°C will reduce growth and may create other problems such as increasing the chance of infection by diseases.

(c) **Acidity.** The pH (the index of acidity) of water is determined partly by the level of alkalinity which provides buffering against sources of acidity in the environment. The sensitivity of salmon to pH differs with life history stages. Eggs are generally the least sensitive but alevins and newly-emerged parr are much more sensitive. Most fish mortality caused by acidification results from episodic decreases in pH rather than chronic acid stress. Salmon can usually survive and reproduce at pH values down to about 5, but the effects of pH are significantly affected by the presence of other chemicals. Thus, in the absence of calcium, fish cannot survive even moderate pH levels (6.5), and aluminium, where it is present, becomes highly toxic at pH levels of 5-6. The EC Directive specifies the range of pH 6-9 as suitable for salmon, although many natural waters with a pH between 5 and 6 contain salmon populations.

(d) **Inert suspended solids.** Concentrations of inert suspended solids up to 25 mg/l seem to have no harmful effects on fish provided they remain in suspension. According to European Inland Fisheries Advisory Commission (EIFAC) evidence, good to moderate populations of salmon could still be maintained in water with suspended solids concentrations between 25 and 80 mg/l, although production might be lower than in waters with less. Temporarily high concentrations, even several thousand mg/l, may not kill fish over periods of several hours. To protect salmonid fisheries EIFAC recommends an upper limit of 25-80 mg/l. The EC recognise that floods are liable to cause particularly high concentrations of suspended solids for short periods of time and has therefore adopted an average concentration of 25 mg/l as the guideline standard for salmonid waters.

(e) Toxic chemicals. Many chemicals which occur naturally at very low concentrations, and may be essential for growth, can be toxic at higher levels, eg. if industrial discharges occur. Metals such as cadmium, lead, mercury, copper and zinc can be lethal to salmon, and EC Directives and EIFAC criteria specify maximum limits for such substances (see Appendix 2). Other chemicals, such as acids, alkalis, ammonia, chlorine, cyanides, nitrites and sulphides can be very toxic, and in a few cases maximum limits have been specified by EC Directives. High levels of these toxicants are directly and rapidly lethal, but lower concentrations, while allowing many fish to survive, may adversely affect physiological performance and thus overall productivity. A large number of organic substances, including pesticides, solvents and phenols may also be extremely toxic. The EC Directives indicate limits for certain organochlorine compounds, while an EIFAC recommendation refers to a maximum acceptable value for certain types of phenols.

(f) Chemicals affecting plant growth. Various chemicals introduced to water from agricultural and industrial sources and from treated sewage effluent may not in themselves be toxic but may encourage the growth of algae and rooted vegetation. This can increase the risk of low dissolved oxygen at night or when plant material decays. Algal blooms may also lead to turbid water, reducing the ability of fish to see food, while rooted vegetation may obstruct stream flow and increase the deposition of sediment.

3.5.2 Predation

Predation is a major proximate cause of mortality even if the primary constraint is one of food supply. Increased predation may reduce the population size below the normal carrying capacity; this will result in a real loss of smolt production with little scope for the population to compensate. Predation on emigrating smolts and returning adult fish is outwith the scope of this report. While predator populations tend to be in balance with their prey, quite dramatic fluctuations do occur. These may be influenced by human activities and may be more frequent or extreme in highly managed or modified stream environments. The effects of predation on salmon populations will be addressed separately by the Committee in more detail.

3.5.3 Diseases and parasites

Diseases and parasites rarely appear to limit natural populations of juvenile salmon but concern is often expressed that fish farming can cause a rapid spread of disease-causing organisms. Dense populations in farms could act as hosts for high concentrations of pathogens and infections could be spread in their effluent.

However, there is no evidence as yet of harm being done to wild salmon stocks in this country by these means. A more serious concern may be the possibility of diseases or parasites being introduced to wild stocks through stocking exercises. This may have been the way the parasite *Gyrodactilus salaris* was introduced into 33 Norwegian rivers.

4. HUMAN ACTIVITIES AFFECTING NATURAL SMOLT PRODUCTION

4.1 Introduction

The Committee obtained information on a range of human activities affecting smolt production from a variety of sources, including published information and oral and written presentations from experts. Information was also sought from individual scientists and fishery managers about the perceived relative importance of factors affecting their local rivers. It was evident that a large number of factors, arising from a broad range of human activities, were thought to adversely affect smolt production to varying degrees. Some gave rise to widespread concern and had a high perceived impact (eg. afforestation and pollution) whereas others were of only local significance with a relatively low perceived impact (eg. fish farms and road construction). However, the lack of any data to quantify the level of impact of these various factors made it difficult to rank them in terms of lost smolt production.

This section of the report therefore addresses those factors which, in the opinion of the Committee, present major problems for which either practical solutions can be identified or where further research is required. The factors have been considered either in relation to specific human activities (eg. fish farming) or in isolation where they apply to more than one activity (eg. pesticides). Although, as already noted, many of these factors both overlap and interact, the common format adopted here is designed to minimise the need for repetition.

4.2 Hydrological Effects of Afforestation

Definition and Description

Afforestation and land-drainage can adversely affect the hydrological characteristics of nursery areas for young salmon by reducing water yield, changing patterns of stream run-off, causing erosion and increasing sediment transport. Afforestation close to river banks can produce heavy shading thus reducing production and possibly affecting temperature regimes.

Scope of the Problem

Reduced yields of water have been reported as a result of conifer afforestation. The principal mechanisms responsible appear to be increased transpiration, and, more important, increased evaporation from the tree canopy. Losses of water are related to the area planted, planting density and tree size. The Forestry Commission's guidelines suggest that such water losses may amount to 2 per cent of the total yields from the catchment for every 10 per cent of the catchment which is afforested. Such losses may be critical to those streams where flows are already restricted.

The extensive drainage works associated with afforestation of moorland and bog may also cause changes in the flood response of streams. Such drainage works permit faster run-off of rainfall thereby giving rise to increased peak flows in the streams and more rapid changes in flows. Such flash floods may cause serious erosion problems with resultant loss of both bed and bank cover, so essential to juvenile stocks. The drainage works can increase significantly the transport of sediment in the drainage channel. Road construction to service the afforested or improved land may also initially increase the transport of sediment until such time as the exposed soil is stabilised.

Sediment yields are increased in the early stages of the forestry cycle and during clear felling. Such increases have been measured in a number of catchments. When such sediment loads are deposited, they blanket the stream bed, blocking the gravel, thereby preventing spawning or the successful development of fish eggs and parr and also reducing the availability of food for the fish. Deposition of suspended material also causes compaction of the gravel which reduces the flow of well oxygenated water through it, thus affecting the survival of eggs and alevins.

One of the major effects of afforestation of upland areas by conifers is that in some areas it exacerbates the acidification of the streams draining from such areas. This aspect is discussed in Section 4.3.

Possible Solutions

Various practical measures have been suggested for ameliorating the effects of afforestation on the nursery areas of salmon waters. These are described in the Forestry Commission's 'Forests and Water Guidelines' and include such measures as modifying draining and ploughing techniques. Ameliorative techniques are also described to cater for roadworks both during their construction and their maintenance, and advice is provided on minimising the adverse effects on streams of harvesting the forest. However, the guidelines do not address the issue of the location of forests.

The Scottish Development Department issued a circular (in May 1990) entitled 'Indicative Forestry Strategies' which gives guidance to planning authorities on the preparation of such strategies for forestry planting. The circular identifies categories of land for forest development as Preferred, Potential and Sensitive areas. Sensitive areas are those where the number, intensity or complexity of issues makes them extremely sensitive to forestry planting, and would include all land on which tree planting would lead to irrevocable damage to the identified interests. The Committee was disappointed that the Indicative Forestry Strategies do not include fisheries among the major land use interests requiring to be considered. We recommend that the Indicative Forestry Strategies be amended to take account of this and that this approach be adopted throughout Great Britain.

The Environmental Assessment (Afforestation) Regulations 1986 of the EC Directive on Environmental Assessment provides for a formal environmental assessment of proposed afforestation when this may lead to adverse ecological changes. At present, it applies only to those proposals for which grant aid is sought from the Forestry Commission and has a specified minimum area below which it is unlikely to require an assessment except for potentially damaging planting in National Nature Reserves and Sites of Special Scientific Interest. In addition, the present application of the regulations does not provide adequate protection against the progressive afforestation of an area through a series of small schemes.

The Committee suggests that an environmental assessment should be carried out by the National Rivers Authority (NRA), the Scottish Office Agriculture and Fisheries

Department (SOAFD) or District Salmon Fisheries Boards (DSFBs) for any afforestation proposal which, irrespective of its size, may have an adverse effect on nursery areas for salmon.

Much investigative work into the effects of afforestation and associated drainage works is being carried out by a number of organisations including the Forestry Commission, the Institute of Freshwater Ecology, SOAFD, NRA, the Nature Conservancy Council and the Countryside Commissions. We recommend that the nature, extent and objectives of these investigations should be reviewed to establish whether there is close liaison between these organisations and to ensure that particular attention is given to the identification, development and implementation of protective and remedial measures, taking full account of fisheries interests.

4.3 Acidification of Streams and Lakes

Definition and Description

Long-term acidification of streams and lakes in Britain is often attributed to the deposition of atmospheric pollutants on the surrounding catchment but other, short-term, influences have been identified. Four processes are of particular importance:

- Sea salts. High sodium concentrations in the rain displace hydrogen ions from the soil which in turn reduce the pH of the streams. This is usually a short-term effect over a matter of days.

- Oxidation of sulphur compounds. After long dry spells, various forms of organic and inorganic sulphur compounds can change to sulphates, which mobilise hydrogen and aluminium ions and are then carried by sub-surface drainage into streams. This effect is short-term (weeks) and is rare.

- Acid depositions. Long term depositions of sulphur compounds and other atmospheric pollutants, particularly from the burning of fossil fuels, can increase stream acidity by transporting hydrogen ions from the soil and in surface waters. This is a long-term acidification effect.

- Afforestation. While not a primary cause of acidification of freshwaters, coniferous trees are said to exacerbate it because they can filter out and concentrate atmospheric pollutants which are then washed down by rain on to the soil and into streams. Root systems also take up calcium and magnesium, two of the most important buffering elements, but the impact of this latter process has yet to be quantified.

These processes operate in areas of shallow, well leached soils overlying slow-weathering rock such as granite. The acid conditions produced may themselves be toxic to salmon or result in increased solubility of metals such as aluminium, which itself may be toxic to fish in slightly less acid conditions. (See Section 3.5.1(c)). Although most of the field investigations into this problem have concentrated on the effects on trout, studies on juvenile and adult salmon in rivers in Canada, the USA, and Norway have demonstrated the seriousness of the problem in these countries. The similarity of the geology of upland areas of Great Britain to that of acid-sensitive areas elsewhere is important in this context.

<u>Scope of the problem</u>

The most vulnerable areas are found in some parts of the uplands of Scotland, Wales and northern England where the soils are poorly buffered and therefore unable to counteract all of the acidifying input. In areas of deep peat, however, where the waters are naturally acid, survival of fish may be possible because aluminium combines with the humic acids in the water, converting the metal to a non-toxic form. The removal of the liming subsidy and the reduction in lime application may have affected the buffering capacity of some agricultural land in the uplands. Flushes of acid water (acid episodes) are most common during periods of heavy rain and rapid run-off when there is little opportunity for the buffering effect of any mineral soil to occur. Thus these episodes are likely to cause most damage at the times of upstream migration of adults and smolt migration downstream which tend to occur at times of increased flows.

The sensitivity of salmon to acid conditions varies with life stage. Eggs are vulnerable but have developed, in experimental conditions, at pH ~4.5. Hatching at this pH level may be unsuccessful because the hatching enzyme produced by the embryo functions best in slightly alkaline conditions and its action is blocked if the medium is too acid. Older juveniles can tolerate acid conditions more successfully than newly-hatched or very young parr partly because the lower proportion of gill area to body volume makes it easier to maintain the correct salt balance within the body. The physiological changes undergone by smolts at the time of migration also make them particularly vulnerable.

Figure 1 shows the distribution of known acid waters (pH <5.6) and regions classified as susceptible to acid deposition in Great Britain based on information about lithography and soil types. In Scotland, the main salmon rivers which could be affected by acidification are those with headwaters in the predominantly granitic Grampian Highlands (eg. parts of the Spey and Aberdeenshire Dee), and some of the smaller rivers in the south west such as the Cree and the Bladnoch. In recent years juvenile salmon populations have been poor in several of the tributaries of these rivers. Elsewhere in Great Britain the main salmon producing rivers affected by acidification are in central and northern Wales and the north-west of England. Some other rivers or sections of river in the shaded zones in Figure 1 also have acid head-waters, but may be inaccessible to salmon. Such areas often contain non-migratory trout populations and these are affected by the acid conditions.

The scale of the acidification problem is now considerable. For example, since 1980 some 95 km of Welsh rivers included in the River Quality Survey of England and Wales have been downgraded on the basis of pH. This represents an increase of about 25% in the length of Class 3 rivers in the Welsh region. Substantial levels of conifer afforestation have occurred within most of the catchment areas which they drain. The extent of the downgrading might be under-estimated because many small tributaries and feeder streams are excluded from the River Quality Survey. Estimates have been made of the losses of fishery resources in Wales resulting from acidification; these suggest that the present capital loss is between £1 million and £5 million.

Possible Solutions

The only satisfactory permanent solution to the problem of acidification of rivers supporting salmon may be to eliminate the many sources of acid deposition, principally from industry and the burning of fossil fuels. In the short-term, however, practical measures include chemical neutralisation of acid waters and modifying land use practices.

The main aim of any chemical treatment is to reduce the hydrogen ion concentration, which will also lower the solubility of toxic aluminium ions, and to build up an alkalinity to prevent further pH depressions. Calcium-containing compounds (lime products) are preferred as neutralising agents, and these may be applied to running water, lakes or the adjoining land. A variety of application techniques has been tested and different approaches may be appropriate in different situations. However, the effects of liming on the ecology of adjoining land must also be taken into account.

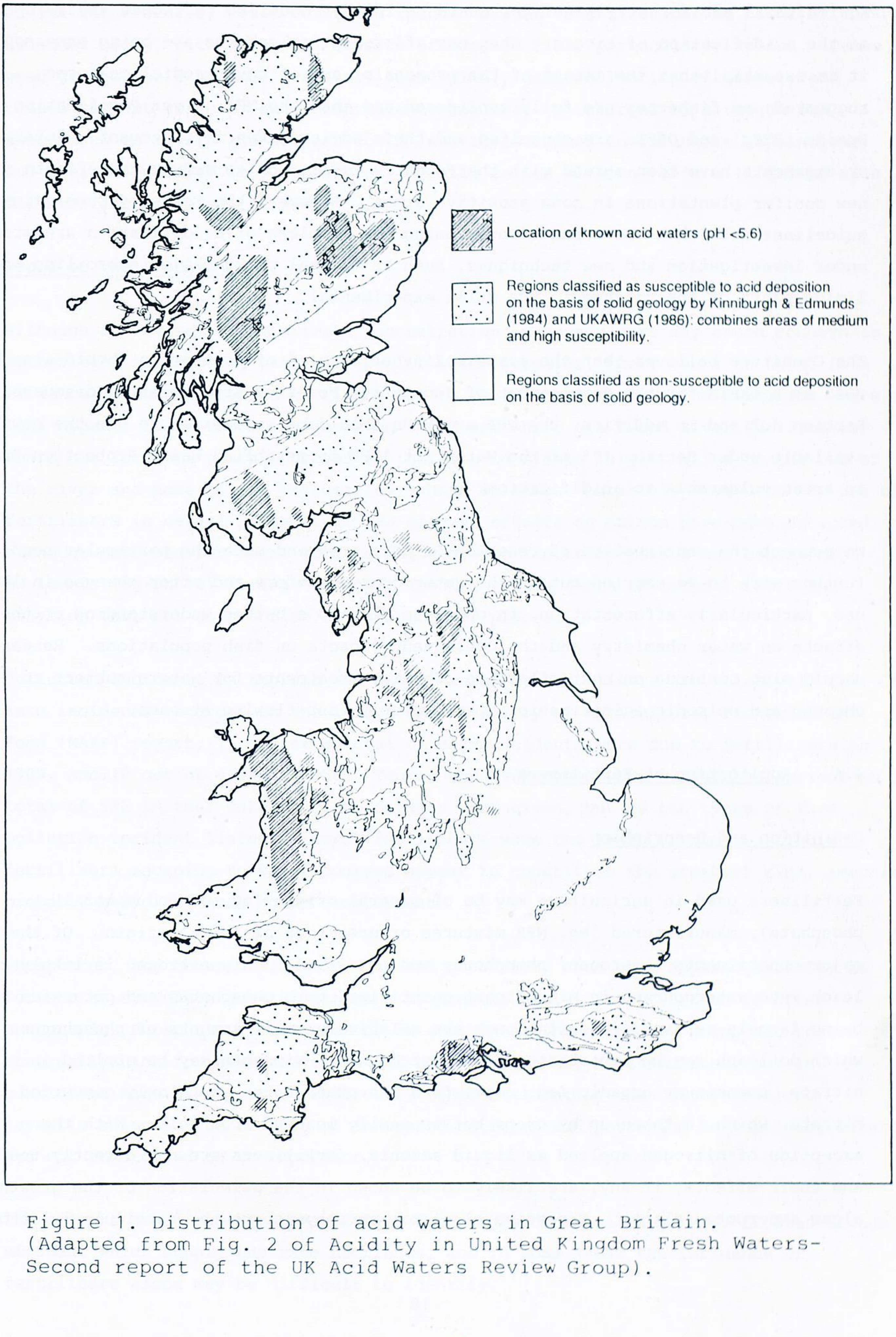


Figure 1. Distribution of acid waters in Great Britain. (Adapted from Fig. 2 of Acidity in United Kingdom Fresh Waters-Second report of the UK Acid Waters Review Group).

Agricultural and forestry practices could be further modified to reduce their impact on the acidification of rivers. When new afforestation schemes are being assessed, it is essential that the impact of the proposals, and of any remedial measures suggested, on fisheries are fully considered and that the NRA, River Purification Boards (RPBs) and DSFBs are consulted and their advice taken into account. Informal arrangements have been agreed with the Forestry Commission to reduce the effects of new conifer plantations in some sensitive areas. However, the Forestry Commission's guidelines note that the means of overcoming the problems of acidification are still under investigation and new techniques, such as minimal ploughing or subsoiling and liming parts of the catchment, are still experimental.

The Committee believes that the exacerbating effects of afforestation should also be used as a basis for the development of Indicative Forestry Strategies as discussed in Section 4.2 and in addition, the NRA and RPBs should be encouraged to use the powers available under Section 111 of the Water Act 1989 to establish Water Protection Zones in areas vulnerable to acidification.

We support the continuation of research in this area and note the particular need for further work to be carried out on the water courses before and after changes in land use, particularly afforestation, in order to develop a better understanding of the effects on water chemistry and the consequent impacts on fish populations. Research should also continue on cost-effective remedial treatments for waters subject to chronic and episodic acidification, particularly fast-flowing streams.

4.4 Application of Fertilisers

Definition and Description

Fertilisers used in agriculture may be of mineral origin (eg. ground mineral phosphate), manufactured (eg. NPK mixtures or urea), or of animal origin. Of the major constituents (nitrogen, phosphorus and potassium), only nitrogen is likely to leach into watercourses in significant quantities, both phosphorus and potassium being largely retained in soil though the relatively small amounts of phosphorus which do leach may be important in some catchments. Nitrogen may be applied in nitrate, ammonia or organic (eg. urea) form but other forms are slowly converted to nitrate, which is taken up by crops but is easily leached from soil. With the exception of nitrogen applied as liquid ammonia, fertilisers are not directly toxic and their effects, if any, are likely to be shown in the stimulation of the growth of algae and rooted plants. Excessive algal or macrophytic growth, particularly at high summer temperatures, could result in reduced oxygen concentrations at night or during seasonal decay, with potential adverse effects on fish, particularly salmon. Dense weed growth could harbour predatory fish (pike), cause siltation of gravel, and reduce current velocity and inconvenience anglers. Discharges of nitrogen and phosphorus to rivers and streams could lead to increased invertebrate populations, and thus an enhanced food supply for juvenile salmon although this will depend upon the nutrient state of the water.

Scope of the Problem

Although increases in the nitrate concentration in some rivers may cause concern to authorities abstracting water for public water supplies, there seems to be no firm evidence of eutrophication in rivers due to fertilisers alone. One situation where a link appears to be demonstrated is on the Tweed where the Tweed River Purification Board has for some years observed an increase in diatom (algal) slime on the bed of the river and some of its tributaries, which is almost certainly linked to the use of fertilisers in cereal production. No adverse effects on salmon have been detected although much heavier algal growths below sewage treatment plants has caused high pH levels (eg>pH 10) during daylight, leading to the death of salmon, trout and grayling (but not coarse fish) at a number of places.

Pollution incidents in England and Wales caused by fertilisers are relatively few. Of farm incidents recorded in the latest NRA/ Ministry of Agriculture, Fisheries and Food (MAFF) report, 15 out of a total of 2889 incidents were due to fertilisers in 1989, and 19 out of 4141 in 1988. Two of the 1989 cases were classed as serious in a total of 522 in that category. No details were given, but of ten types of farm pollution incident listed, mineral fertilisers were the least frequent. Liquid fertilisers escaping to water courses appear to constitute the greatest risk, ammonia probably being the most toxic constituent.

Phosphorus, and occasionally nitrogen and potassium, have been applied aerially to forests to stimulate growth, although at present aerial fertilisation is often uneconomic. Phosphate concentrations in streams draining treated areas can remain abnormally high for several years, and algal growth may be stimulated, but is considered more likely to be indirectly beneficial rather than detrimental to juvenile salmon. The effects of increased nitrogen and potassium on receiving waters are not considered to be important.

The effects noted can also result from discharges of animal slurry or treated sewage effluent which supply the same nutrients, and in some areas the influence of fertilisers alone may be difficult to identify.

Possible Solutions

Powers under the Water Act 1989 and EC Directives should be used to control nitrate and phosphate discharges throughout Great Britain. As with other chemicals, great care must be exercised in the storage and use of liquid fertilisers, particularly ammonia types, and the accidental discharge of liquid fertilisers to yard or field drains, or to streams, should be prevented.

The extent to which increased nitrate concentrations in rivers are due to fertiliser usage is a subject of continuing debate and further research is required on its effect on the ecology of freshwaters and fisheries. Research is also required on the effectiveness of river bank "buffer zones" designed to reduce inputs to the rivers. The possible effects of nitrogen and phosphorus discharges to rivers and streams, through the encouragement of algal or macrophytic growth, should be monitored by the NRA and RPBs.

4.5 Application of Pesticides

Definition and Description

Most of the pesticides available in Great Britain are used in agriculture, horticulture and silviculture and have been screened before approval to reduce the likelihood of substances with a high toxicity for non-target organisms (including fish and other wildlife) being used in circumstances where such species could be at risk. Damage to fisheries caused by pesticides (including herbicides) may not be as serious as it was more than 20 years ago when organochlorine pesticides such as DDT and dieldrin were widely used, but incidents do still occur. The organochlorines have been replaced by organophosphorus, carbamate, synthetic pyrethroid and other chemicals, and the methods of application have been improved both to reduce the amounts of chemical applied and to restrict the pesticide more closely to the target organism or crop.

The use of pesticides is subject to the control of Pesticides Regulations (1986) and guided by the MAFF/Health and Safety Commission (HSC) Code of Practice for the Safe Use of Pesticides (1990) which was issued under Section 17 of the Food and Environment Protection Act 1985, and approved by HSC under Section 16 of the Health and Safety at Work Act 1984. Several EC Directives limit the concentrations of a number of pesticides permitted in fresh waters for the protection of fish and aquatic life. These pesticides are HCH (under Directive 84/491/EEC), DDT and pentachlorophenol (86/280/EEC), and aldrin, dieldrin, endrin and HCB (included in 88/347/EEC). Most of these pesticides have been or are being phased out of use (see Appendix 2).

Scope of the Problem

The older organochlorines were a danger not only from their immediate toxicity (some modern chemicals are even more toxic) but because of their long-term persistence and their propensity for accumulating in fatty tissues. Thus they were retained for years in fish organs with the risk of causing damage after long periods. Predators on fish also accumulated high and sometimes toxic levels from their prey. Present day chemicals generally are not retained for long. Some are inactivated by absorption to soil, although the subsequent ingestion of soil particles by fish or invertebrates may still present a hazard.

The main causes of fish mortalities ascribed to pesticides still arise from careless handling and accidents. Spray tankers filled from streams present the risk of back-siphonage into the watercourse, and the toxic chemical should only be added to the tank when the tanker has been removed from the stream bank. Spraying machines may fall into streams, and surplus chemicals are sometimes flushed into drains or watercourses. Road accidents can result in spilt chemical being washed into streams or finding its way into field drains.

Sheep dips now contain organophosphorus chemicals or synthetic pyrethroids, and after use the liquor is frequently disposed of in a soakaway pit. These sometimes overflow or become saturated, the toxic liquor seeping into adjacent streams. The BOD of such liquor is potentially as hazardous as the pesticides contained in it, due to the faeces and urine present.

Pesticides are used in forestry to protect seedlings and clear weeds, and in the past aerial spraying of insecticides, particularly fenitrothion to control pine beauty moth, has been undertaken but no long-term damage to fisheries was detected. The organochlorines HCH and dieldrin and the fungicide pentachlorophenol are used in wood preservation, and spillage or leakage of these chemicals from premises using the process occasionally results in fish kills.

The mothproofing of wool (originally using dieldrin) now usually involves synthetic pyrethroids, which are less toxic to fish but can be lethal to certain invertebrates. They accumulate in sediments, and may have been involved in fish declines in the Tweed and in Yorkshire rivers.

In England and Wales sheep dip and pesticide pollution incidents totalled 67 in 1987, 70 in 1988, and 52 in 1989 (less than 2% of recorded farm incidents). Disposal of surplus pesticides or washings is a problem for many farmers.

In Scotland, the statistics available from the RPB's for 1987 to 1989 suggest that events arising from pesticides occur mainly from operational use rather than structural failure of units, as shown in the table below.

	Pesticides		Total Agricultural	
	Structural	Operational	Structural	Operational
1987	9	14	385	328
1988	4	27	240	332
1989	5	17	162	300

Experimental evidence suggests that currently-used pesticides may have a variety of long-term effects on the biota of streams including reduction of algae and macrophytic plant growth, elimination of sensitive invertebrates, reduction in fecundity and growth of fish, changes in fish behaviour and skeletal deformation. However, there is no indication that these effects would occur at the concentrations of pesticides either known or expected to be present in the streams.

Possible Solutions

The use of pesticides should be more closely controlled, although observance of the revised Code of Practice, issued by MAFF in 1990, should help to reduce damage to juvenile salmon. Increasing the use of low volume spray applications close to the crop will reduce spray drift. The disposal of surplus chemicals and containers also needs to be more carefully controlled, and techniques for removing chemicals from wash water and effluent are being developed. There is a possibility that disposal to soakaways may contravene the EC Groundwater Directive. Controlled disposal on land set aside as 'sacrificial areas' is currently being studied in Scotland and the results should be disseminated and utilised. The Committee welcomes the efforts which are being made to identify better methods of handling potentially harmful wastes.

Although all new chemicals are screened before approval is given for their use in agriculture, long-term effects on salmon populations may not be detectable at this stage. More research is needed to assess the extent of damage to aquatic ecosystems from chemical applications generally, from spray applications which reach static or running waters and from spillages. In view of the large variety of chemicals in use, particular attention should be given to those used most commonly or in the largest quantities.

Responsibility is divided with regard to the investigation and monitoring of the causes of fish kills; the accumulation of residues in fish likely to be used for human consumption; and of the effects of pesticides on the invertebrate fauna of streams. In England and Wales the NRA has an obligation to monitor and protect fish stocks. In Scotland the RPBs are responsible for ensuring that the quality of water is satisfactory for salmon fisheries, but have no responsibility for fish stocks. DSFBs (where they exist) have a responsibility for migratory fish stocks, but no in-house expertise or support services in respect of fish kills or other effects of pesticides. The Health and Safety Executive (HSE) has a role, as does SOAFD, but responsibility for research and monitoring is now unclear. Discharges of substances most dangerous to the aquatic environment (the Red List) will require consent of the RPBs in Scotland and the NRA (and in certain circumstances HMIP) in England and Wales.

4.6 Silage Liquor and Slurry Run-off

Definition and Description

The agricultural industry produces over 200 million tonnes of livestock slurry each year and makes over 40 million tonnes of silage. Agricultural processes also give rise to other liquid wastes, mostly associated with livestock production and dairy farming (eg. rain water from soiled yards, dairy washings, etc.) The pattern of production has changed significantly over the last thirty or so years. The quantity of silage produced has increased and has become the principal feed, and animal housing methods have changed leading to large areas being covered with concrete. These changes, together with an increase in the size of herds, have tended to concentrate the waste problem on to a smaller number of sites.

Scope of the problem

Farm waste is very highly polluting. Slurry from livestock systems has a BOD typically of the order of 30,000 mg/l whilst silage effluent has a BOD of around 80,000 mg/l and milk of 140,000 mg/l. In contrast raw domestic sewage has a BOD of about 400 mg/l.

The chemical quality and flow characteristics of our rivers and groundwaters are closely linked to the nature of the land through which they pass and the use which is made of it. Significant changes in, for example, land management, field drainage, housing of animals, storage and uncontrolled disposal of waste to land, have resulted in water resources being contaminated or put at risk with serious consequences for fish stocks. Slurry or silage pollution incidents frequently affect large stretches of river and kill large numbers of fish. Such pollution is more common in the small streams which act as nursery areas for salmon than pollution by sewage discharges. In fact, salmon are subject to the combined effects of a multiplicity of chronic discharges from many farms in juvenile production catchments together with shock loads associated with storm run-off, which usually pass unreported.

In recent years there has been growing concern about the number of reported farm pollution incidents, mainly from activities associated with livestock farming. For England and Wales the incidents have been detailed in a series of reports, the most recent of which was published by MAFF/NRA in 1990. In Scotland statistics from the RPBs for 1987 to 1989 show a similar problem.

<u>ENGLAND AND WALES</u>

	1987	1988	1989
Silage	1,003	815	245
Slurry	922	1,032	758
Land run off/treatment systems failure	391	550	556
Total, all farm causes	3,890	4,141	2,889

<u>SCOTLAND</u>

	1987	1988	1989
Silage	428	282	176
Slurry	67	74	66
Cattle, pigs, poultry and dung	78	81	65
Total, all farm causes	713	572	462

Possible solutions

The ultimate solution to this problem would of course be the reduction in the amount of these materials being produced by livestock farming. The Committee notes that the current move towards extensification may present opportunities for significant reductions in some areas where the salmon habitat is vulnerable. A wide range of existing and proposed Directives, laws, regulations, guidelines and codes have been aimed at the agricultural industry. However, achievement of the desired standards will depend largely on individual farmers. Unfortunately, many farmers do not act until they are visited by representatives of the appropriate authority.

Environment and Agriculture Ministers have recently issued a public consultation paper proposing regulations to control silage, slurry and agricultural fuel oil installations. The Committee welcomes this development and hopes that these proposals will be translated into firm regulations as soon as possible. We also recommend that research should be encouraged into the effectiveness of waste disposal techniques, including the consequences for freshwater habitats of direct application to land.

4.7 River Regulation and Dams

Definition and Description

River regulation means control of flow by impoundment and controlled release over a period, or by release from natural storage such as groundwater aquifers. This is usually undertaken to support abstraction downstream, normally with a minimum residual flow requirement. Most river regulation schemes involve a dam and storage reservoir filled by natural run-off but sometimes supplemented by diversion of water from neighbouring catchments or by pumped storage. Dams are also constructed to retain water for other purposes such as direct water supply and hydro-electricity generation. Under the Reservoir Act 1975 about 2500 dams with a storage capacity in excess of 25,000 cubic metres are registered in Great Britain.

Scope of the Problem

Dams frequently drown-out spawning and nursery areas for salmon as they are often constructed in the headwater tributaries of rivers. Any remaining spawning and nursery ground upstream of the impoundment is generally inaccessible to spawning fish unless a fish pass is incorporated; this is rarely done as it is expensive and the recovery of habitat may be small.

Regulation of streams downstream of a dam imposes significant changes in the habitat. These include:-

(a) modified flow regime, particularly:

- removal of most flow fluctuations (eg. spates) when the impoundment is not full;
- damping of flow fluctuations even when the impoundment is full and spilling;
- maintenance of a minimum flow by a compensation release (which may be greater than the natural drought flow);
- considerable enhancement of low flows when regulation or hydro-electric generation releases are being made.

(b) modified water quality, including:

- changes in the pattern of occurrence of low and high temperatures;
- reduction in turbidity by settlement in the reservoir;
- changes in water chemistry due to storage;
- changes in water chemistry due to submerged mineral sources (eg. mining waste);
- water of low temperature and low dissolved oxygen if a deep draw-off is used;
- changes in water due to diversions.

The reduction of spawning and nursery areas by drowning-out and cutting-off represent a loss that is difficult to replace. In some cases restocking schemes have been implemented as part of a compensation package; when these have proved ineffective, they are discontinued and nothing is provided in replacement. An ambitious "trapping and trucking" scheme (involving transporting both adult and juvenile migrants several miles by road) was developed at the Llyn Brianne Reservoir in Wales. The scheme was not successful and was discontinued.

The modified flow regime can have a considerable effect upon the upstream progress and spawning of adult salmon, denying access to potentially good nursery streams. Lack of high flows also reduces natural scouring of spawning gravel. Lack of scouring can lead to siltation and compaction of gravel. It also impairs the ability of the main river to cleanse itself of debris borne into it by side tributaries at times of spate flow in the tributaries. However in other ways regulated streams may make very good nursery grounds. The equable flow and temperature regime encourages high production of rooted plants, invertebrates and fish. For example, the River Meavy downstream of Burrator Reservoir in Devon supports some of the highest densities of young salmon and trout in Great Britain. In this case, regular spilling of the dam in autumn provides the flushing flows and the stimulus for adult immigration.

The modified water quality downstream of dams has occasionally been blamed for poor stocks of fish, but this is again usually linked with a failure to stimulate adult immigration for spawning.

Possible Solutions

As far as the loss of salmon habitat by drowning-out or cutting-off is concerned there is little that can be done. It is possible that new schemes could avoid particularly important nursery streams but choice of site is usually dictated by other factors. In new schemes, ensuring adequate conditions for salmon production should be a requirement for all reservoir operators. If this is not feasible a mitigation programme should be implemented to the satisfaction of the appropriate authorities. The operating rules (eg. residual and compensation flow requirements) for newly-licensed schemes should be provisional upon monitoring programmes indicating satisfactory results, to allow for appropriate adjustments. There is scope for regulated flows to be managed in such a way that they enhance habitats for juvenile salmon; however, if badly managed they may have adverse effects.

Maintained production equivalent to highest natural levels can be achieved by optimising flow conditions including:

- an appropriate compensation flow;
- use of reservoir surface water layers for releases;
- appropriate time of spilling (or large artificial release) for gravel cleaning and salmon migration and spawning.

A review of the effectiveness of natural salmon propagation in regulated streams is therefore recommended. This would allow identification of the critical factors associated with productive situations, to aid in setting operating rules for new schemes and for reviewing operation of existing schemes.

Where effective natural spawning cannot be induced, thoroughly planned and carefully executed stocking should be considered.

4.8 Water Abstraction

Definition and Description

This section covers direct abstraction of water from streams for supply and other purposes; reduction in stream flow downstream of direct supply reservoirs (but not river regulation); transfer of water to another catchment; and the effects of groundwater abstraction. Also covered are abstractions where the flow is only "borrowed" to be returned downstream, eg. for hydroelectric schemes (see Section 4.7), or for fish farms (see Section 4.12).

In England and Wales, most significant abstractions are licensed by the NRA. Licence conditions generally limit the environmental impact, but many abstractions which were taking place unchallenged at the time of the implementation of the Water Resources Act 1963 were granted 'licences of right' without conditions beyond the maximum abstracted volume. Until very recently certain major categories of user were exempt from licensing requirements, eg. agricultural users, fish farms, domestic users and private hydro-electric schemes. From September 1990 all abstractions exceeding $20m^3$/day will require a licence but existing exempt users were eligible to apply for a 'licence of entitlement', again without conditions.

In Scotland, water abstraction by Regional Authorities for domestic or industrial consumption is controlled by the Water (Scotland) Act 1980, which requires the promotion of a Water Order and approval by the Secretary of State. However, there is no overall system of control over water abstraction in Scotland. Rights to abstract may exist in common law, be authorised by statute or statutory order, or licensed under the Spray Irrigation Act 1964. Beyond that there is no authorisation procedure, nor, apart from a common law action brought by a riparian owner, is there any means of preventing persons abstracting water from a stream.

Conditions applied to licensed abstractions to limit their environmental impact include a prescribed minimum flow (pmf) requirement, which prevents depletion of low flows. This is often around the Q95, (ie. the flow that was exceeded for 95% of the time) which means that, in an average year, abstraction is not allowed for a total of 18 days; in dry years abstraction may be precluded for very much longer periods. Other possible methods of reducing impact include a percentage take (eg. 50% take above the pmf) and limiting the maximum abstracted volume with regard to the size of the stream.

Scope of the Problem

Water abstraction is a very widespread and intensive practice, with few catchments in Great Britain being immune. It can therefore have a very great potential for adversely influencing stocks.

The total volume of water supplied in England and Wales for public consumption in 1988/89 averaged 16,896 Ml/d. Forecasts suggest an increase in demand of the order of 1% per year for the foreseeable future. However, 20-30% of water abstracted for supply is lost by leakage before consumption. Further, demand for water is dependent upon the charging philosophy; metered supplies with a higher cost per unit volume would be likely to reduce overall consumption significantly. Although leakage prevention and metered supplies are costly, their feasibility and cost-effectiveness do of course depend upon the value placed upon the environmental impact of abstraction. Such value judgements also apply to the possible provision of a considerably greater storage of winter flows to reduce the impact of abstraction of low summer flows.

While most direct abstractions are from the lower reaches of rivers, removal of water does take place from potential salmon spawning and nursery areas, eg.:

- where spawning and rearing take place throughout the river;
- for local supplies in headwater areas;
- for certain industries with strict water quality criteria (eg. distilleries);
- for water cress and fish farms;
- for hydroelectric generation;
- for agricultural irrigation.

The problems posed by abstraction include:

- reduction in discharge at times of medium and low flows;
- where there is no pmf requirement, reduction of very low flows and even drying-out of the stream;
- the potential for fish to be drawn into intakes;
- decreased dilution of effluent.

Reduction of medium to low flows means that, often for protracted periods, discharge approximates to the pmf. This has the effect of reducing the wetted area of stream, and reducing water depths and velocities. Each of these is likely to reduce the carrying capacity of the stream for young salmon. In addition intolerably high water temperatures may be reached more often. The reduction of very high and potentially damaging flows is rarely enough to be of any benefit.

Depletion of very low flows can be very damaging to fish populations. Any tendency to dry out significant lengths of stream, even for a short period, can clearly have a disastrous effect on both stocks and food organisms.

The potential for fish to be drawn into intakes is a particular risk for migrating smolts. However, less well known is the functional redistribution of parr well before the smolt stage, usually downstream in direction. This usually takes place in autumn, winter or early spring when flows are high, reducing the likelihood of entrainment, but significant losses are possible.

Groundwater abstraction, particularly from chalk and greensand aquifers, is a widespread practice in southern Britain. The trend nowadays is to site boreholes well away from surface streams. These are pumped in summer and naturally recharged during winter and may affect summer flows very little. Indeed, if much of the abstracted water is eventually released to the stream via a cress bed, fish farm or sewage treatment works, for example, summer flows may be enhanced. Winter flows are reduced however which may have implications for flushing out of silt from the spawning gravels.

Although agricultural irrigation accounts for only a relatively small part of the overall water abstraction in Great Britain it can nevertheless be of considerable effect locally. Further, it is of course greatest during dry weather when stream flow is at its lowest.

Possible Solutions

The Committee welcomes the objectives set out by the NRA in their Corporate Plan for 1990/91 to develop and implement a water resources strategy which takes appropriate account of both environmental and abstraction requirements and which ensures that water resources plans are developed in a consistent manner throughout England and Wales. We consider this to be a commendable approach and recommend that it be considered for Great Britain as a whole. The Committee also welcomes the reference in the NRA's Corporate Plan to the proposed implementation of a plan of action for overcoming the impact of existing over-abstraction on some catchments. A review of the measurable effects of flow depletion on production of juvenile salmon is recommended. This would aid the setting of appropriate levels for new abstractions, changes to existing schemes, and the setting of minimal acceptable flows (under Section 127 of the Water Act 1989).

One of the most important considerations is that any abstraction must be limited according to the size of the stream. An abstraction of 50% of the flow in excess of a pmf is a useful guide, but each situation must be judged on its merits. An appropriate pmf is essential in order to safeguard fish and other wildlife at times of very low flows. Situations where streams are dried out by abstraction are unacceptable. Given that water must be provided from somewhere, head of tide abstractions are the best compromise where feasible. The effects are then restricted to fish movement into the river, which may be amenable to short-term modulation of abstracting, eg. 12 hours on, 12 hours off. Modern intake screen technology is highly advanced and there is no reason why effective fish screens should not be fitted to all major abstraction intakes.

The Committee suggests that a basic reconsideration of the acceptability of present water resource management policies is both likely and appropriate in view of the increasing public awareness of environmental issues, although it recognises that this is of much wider significance than for salmon production alone. As existing abstraction licence rules are based upon a concept used for many years, it is suggested that consideration be given to a basic re-appraisal of water resource management strategies, including increased winter storage, in relation to environmental impact. A particular concern is the large volume of water lost through leakage. As provisions for the control and licensing of abstraction in Scotland appear to be less satisfactory than for England and Wales, it is recommended that consideration be given to ways of improving the situation.

4.9 River and Riparian Management

Definition and Description

This section covers a number of related activities within the river, on its banks and on adjacent catchments which are not addressed by the Committee elsewhere in this report. These activities, which affect the juvenile habitat by modifying the fresh water environment, are:

- **Land use.** Hydrological effects of afforestation are considered elsewhere. Other aspects include arable farming, improved grazing, rough grazing, road building and heather burning.

- **Land drainage for arable farming or "improvement" of grazing.**

- **Management of river banks, including vegetation.**

- **Physical damage caused by livestock.**

- **Straightening or enlarging the channel for land drainage and flood prevention.**

- **Weed cutting for land drainage and angling.**

Scope of the Problem

Land use and land drainage can have a considerable effect upon juvenile salmon production. In parts of England, salmon streams with extensive upland catchments support healthy populations whereas those with catchments in intensively farmed areas have suffered considerable decline. In the Rivers Tamar and Torridge in South West England it is apparent that different spawning tributaries are differentially affected. The specific causes of these declines may vary, but include chronic or episodic agricultural pollution (see Sections 4.4 and 4.5), modified drainage and input of suspended solids.

Drainage of land for arable production and improved grazing has been extensively practised by providing underground pipes ("land drains") and drainage ditches, and by the dredging of main channels to lower the water table. This has the effect of increasing the speed of run-off so that the peak flows are greater and the base-flow reduced. Both these extremes are potentially damaging for juvenile production (Section 3).

Input of suspended solids as a result of farm practices can render gravel unsuitable for spawning and incubation.

The post-war intensification of arable farming practices has tended to increase the likelihood of serious soil erosion. For example, modern crop patterns often leave land vulnerable to erosion during the autumn and winter, when peak rainfall occurs.

This results in increased soil erosion to watercourses, particularly where the land gradient is steep or where low-lying land is prone to flooding during this period.

Access to the stream bank by grazing livestock can cause damage by destruction of bankside vegetation and breakdown of banks, allowing a considerable input of soil material into the water. In severe cases the banks may be destroyed, leading to considerable channel widening and shallowing and very high input of suspended solids.

Channelisation for land drainage and flood alleviation generally involves straightening and deepening the channel. This results in removal of much of the habitat diversity and in particular shallow areas important for salmon parr, and much spawning gravel. Considerable damage was done in the past, from which recovery has been slow. Publication of the "Rivers and wildlife handbook" by the Royal Society for the Protection of Birds and the Royal Society for Nature Conservation in 1984 was of major assistance.

Bankside cover can be important to juvenile salmon in small shallow streams. Clearing of such cover, either intentionally or by allowing intensive grazing, can significantly reduce the carrying capacity. On the other hand, domination of the banks by coniferous plantations can reduce light penetration and thus primary productivity, reducing fish production. It also greatly restricts the more valuable community of bankside vegetation.

Weed cutting is generally practised only in highly productive streams such as those fed from chalk and limestone aquifers. It is generally undertaken in a controlled manner and is unlikely to have any severe impact on stocks of juvenile salmon.

<u>Possible Solutions</u>

New drainage schemes are now less numerous and it is likely that some existing schemes, particularly in rural and upland areas, will slowly deteriorate. It is however important that the criteria for the maintenance of such capital schemes should now be reconsidered. Natural recovery from unsympathetic channelisation is slow but does occur, but improved awareness by river and estate managers should ensure that less damage is done in the future. A requirement to consult with appropriate bodies before any land drainage or channelisation work is undertaken could reduce the level of damage. Environmental assessments may also be required for new drainage and flood defence works where the project in question is considered likely to have significant environmental effects and schemes should be reviewed to determine whether fishery resources are adequately protected.

DAFS issued a number of leaflets explaining Farm and Conservation Grant Schemes, one of which specifically relates to arterial drainage and river works. However, no reference is made to the requirement for an environmental assessment if fisheries are considered to be at risk and the advisory leaflets should be revised accordingly. The leaflet stresses that before any such works for which grant is claimed are started then the prior approval of the Department is required, and where appropriate the owner of the fishing rights, the DSFB, the Angling Clubs and the RPB are consulted.

In England and Wales the NRA is responsible for the management of fisheries and for flood protection. The NRA has inherited established procedures for internal and external consultation which generally afford ample opportunity for ensuring that adequate measures are taken to protect fisheries as required by Section 113 of the Land Drainage Act 1976.

Input of silt from arable farming can be controlled by leaving uncultivated areas (ideally several metres wide) alongside the stream and any feeder tributaries. This also satisfies the requirement for bankside cover. Further, avoiding access by cattle in intensively grazed areas (except for limited drink areas) can prevent damage to bankside vegetation and to banks themselves. This is discussed in more detail in Section 5 below. Studies of the total sediment dynamics of streams are required. These should include the study of soil erosion from agricultural land and silt transport in streams. The results could be related directly to the success of salmon spawning and incubation in particular areas.

Several aspects of riparian management are believed to be having a widespread effect, especially in southern Britain, although the exact extent is unknown. Consideration should be given to an assessment of the geographical extent of these problems.

4.10 Gravel Extraction

Definition and Description

Extensive accumulations of gravel occur at intervals down most river systems. These are often exploited commercially, sometimes on a large scale, with the result that the physical and biological nature of the river bed can be substantially modified. Gravel accumulations at particular sites on rivers are often moved for land drainage or flood prevention purposes and to protect the riparian zone from erosion. Gravel extraction is therefore used here to describe any operation which involves the movement or removal of gravel from a river channel or its flood plain and which may influence salmon populations in the river.

Scope of the problem

Movements of gravel for pool and bank maintenance are undertaken in many British rivers. These and small scale gravel removals probably constitute little threat to salmon populations either in the short or long-term. Of greater concern however are the commercial scale operations which remove gravel from the river bed or adjacent land. The extraction of large quantities of material promotes a number of possible changes to the river which are harmful to salmon populations. These include:-

- removal of spawning gravel: reduces spawning area and removes parr habitat;
- channel degradation: disruption of stream bed dynamics promotes significant physical change to the river downstream of the extraction site (this may reduce habitat availability and quality for all salmon life-history stages);
- channel diversion: may reduce physical habitat quality and local food supply for juveniles;
- release of fine sediments: may clog spawning gravels, damage parr habitat and disrupt food supply through both the effects of increased turbidity and by changing the invertebrate community of the river bed, on which juveniles feed;
- mobilisation of pollutants: waste from previous industrial processes (eg. zinc and lead sulphides) may be remobilised from the stream bed (these could be toxic to life downstream).

These changes are thought to have caused a reduction in salmon populations in some rivers in Great Britain though there is little evidence to corroborate these reductions or show which of the factors listed caused them.

Most large-scale gravel extractions are short-lived. For example, gravel is regularly extracted from nearby rivers for road building work. When the road is complete the extraction operation ends. As a result the long-term impact of the operations on salmon populations may not be great, as natural re-habilitation should occur. Where long-term extraction programmes are in operation, however, the impact on salmon populations may be much greater.

Similarly, operations removed from the river channel should pose much less of a threat to salmon populations than those taking gravel direct from the river bed because the latter maximise the potentially harmful changes listed above.

Possible solutions

Gravel extraction operations are subject to various controls although these are not directly related to salmon protection. Commercial and large private extractions require local planning authority approval. The planning authorities increasingly seek comment on the proposals from the NRA in England and Wales and RPBs or DSFBs in Scotland, though this is not a legal requirement. However, we recommend that this should be a requisite for planning approval. Works in the main river require land drainage consent from the NRA in England and Wales. Under the Scottish Salmon Acts and the Salmon and Freshwater Fisheries Act 1975 it is an offence to disturb gravels on which spawning fish are present, or in which eggs are buried.

Existing controls have been used to restrict major gravel extraction works to the summer months in several areas and consent for extractions within the river channel is often denied. This greatly reduces the potential damage done to the river as only silt or pollutant release remains problematic. These are subject to discharge consents issued by the NRA or RPBs. Small gravel extraction operations are covered by legislation protecting salmon.

Given the widespread perception of gravel extraction as a problem for salmon populations, the Committee recommends that the NRA in England and Wales and the Scottish Office Environment Department (SOEnD) be invited to investigate and report.

4.11 Domestic and Industrial Waste Disposal

Definition and Description

Domestic and industrial waste materials entering water courses may be in solid, liquid or gaseous form. The polluted water may contain solids in suspension, dissolved solids or dissolved gases. Such waste material may enter surface waters directly as discrete discharges or may be discharged to underground sources and subsequently enter surface waters indirectly. Some waste material enters surface water as a consequence of deposition from atmospheric emissions while other wastes, mainly sewage and industrial, reach the aquatic environment as a result of controlled outfalls and accidental spillage from a variety of sources. Waste material may enter a river system anywhere from the upper reaches to the estuary.

Scope of the Problem

The processes of sewage treatment result in an effluent which contains suspended solids and has an oxygen demand. These characteristics of the discharge are strictly controlled by the consent conditions (emission standards) applied to it. Whilst these are generally specified in such a way as to protect the quality of the receiving waters (and thereby fisheries), there are still some discharges which are not sufficiently controlled and the receiving stream is subject to the deposition of solids and a reduced level of dissolved oxygen. There are instances of raw sewage being spilled from overloaded sewage works and from storm sewers.

Similar conditions pertain to the discharges of other readily decomposable organic wastes such as the effluent from food processing plants and from the brewing and distilling industries. Fish farms also discharge effluent (see Section 4.12 below). Discharges or run-off from landfill sites used for dumping municipal wastes may be particularly demanding on dissolved oxygen and are potentially very noxious.

Inert suspended material forming a waste product of such activities as coal washing, quarrying and other processes can blanket a stream bed and kill the organisms living in it, as well as reducing light penetration to flora.

Wastes containing either acids or alkalis are discharged from a number of industrial processes such as metal pickling and plating, and wool and tanning operations. They create an environment in which the pH value of the water lies outside the normal range suitable for salmon.

The effluent from some chemical processes such as the discharges from steel and tin works, from the paper industry and from mine workings, exert a chemical oxygen demand on a stream. The oxygen demand, which is often very high and is taken up rapidly, not only depletes the river of dissolved oxygen but usually leaves a deposit of oxide on the river bed resulting in anaerobic conditions below it.

A large class of chemical wastes cause pollution which, even at very low concentrations, are toxic to fish and may often also kill other fauna and flora. These include metals, cyanides, pesticides and phenols. Oil pollution from spillages and from oil refinery discharges can also, in some circumstances, have direct toxic effects on fish and cause damage to insects and plants in the food chain.

One other waste product discharged into rivers is hot water, usually from power stations and other plant, which must be cooled. Consequential elevated temperatures can be directly lethal; they can also exacerbate the effect of other pollutants and reduce the amount of dissolved oxygen in the water.

Possible Solutions

Continual steps must be taken to upgrade where necessary the quality of effluents and initiatives taken which will lead to accident prevention, and the adoption of quality assurance techniques by industry. Substantial effluents should be regularly monitored so that flows and key components are recorded and more automatic monitoring should be employed. Risk assessments should be undertaken for individual catchments so that steps can be taken to avoid incidents of pollution damage. Facilities such as ponding or stand-by oxygen injection plants, particularly for rivers which are more at risk from pollution, should be provided for the containment of pollution in the event of the failure of existing facilities.

Considerable progress has been made in the reduction of pollution by waste materials and has resulted in the return of migratory fish to some rivers after a lapse of many years. Advances in biotechnology offer potential improvements in the methods used for the treatment of many wastes and continuing research on this subject will be important for the quality of rivers in the future. The work of the NRA in England and Wales and the RPBs in Scotland will also continue to be important in policing discharges and leachates, monitoring river quality and ensuring appropriate treatment. The adoption and development of appropriate Water Quality Objectives in terms of the Water Act 1989 will help to protect and improve the quality of water in which young salmon grow.

4.12 Fish Farming

Definition and Description

An increasing number of waters are being used for the intensive farming of salmonids. The main species are Atlantic salmon, rainbow trout and brown trout. With salmon, the main objective is to supply smolts for sea cage rearing for eventual sale and domestic consumption. Rainbow trout are reared either for sale to the domestic market or for supplying for stocking. Sustainable fish farming depends upon the maintenance of water quality consistent with the requirements of the species reared. Any adverse changes in water quality will affect the farming operation and hence is not in the interests of the farmer. However, several ecological concerns have arisen from fish farming practices, notably from the use of chemicals, the enriching effect of waste feed and fish faeces, the introduction of fish diseases and the impact of farmed fish which are released or escape to the wild. The Water Act 1989 has ensured that discharge consents are also applied to cage farms, rectifying the unsatisfactory situation which had applied before 1989. Concerns have also been expressed about predation on young salmon by large trout released for fisheries.

Scope of the problem

The farming of salmon has expanded substantially over the last two decades and the industry is now a major producer of food; in 1989 some 15,000 tonnes of rainbow trout and 1,000 tonnes of Atlantic salmon smolts were produced in fresh water in the UK.

To combat disease, the direct application of disinfectants, pesticides and antimicrobials is commonplace. For example, farmers use chemicals in situ to treat some fish parasites; the impact and fate of these chemicals in the environment is uncertain. Fish are also treated by enteral administration of pharmaceutical products within the feed; the amounts reaching natural waters are low, but do affect microflora. Their long-term impact on wild fish is unknown.

Solids from waste feed and fish faeces can cause serious local problems. Solids are washed into rivers and build up below cages, enveloping the bed and producing an anoxic layer. It is now common practice to move cages to new sites periodically to avoid this build-up.

Important nutrients leach from fish feed, fish urine and faeces and from waste feed. Principal among these nutrients are compounds of nitrogen and phosphorus and typical values for the total amounts of nitrogen and phosphorus produced from salmon average at 67.5 and 15.7 kg/tonne of fish production per annum respectively. Such enrichment or eutrophication increases algal growths, potential deoxygenation of water, and a tendency for fish communities to change from domination by salmon to coarse fish. In 8 lochs with salmon cages, total loadings compared with limits proposed for maintaining trophic status showed (with one exception) that all the lochs exceeded permissible levels.

Legislation reflects the dangers of introducing diseases and parasites from abroad. For example, the Importation of Salmonid Viscera Order 1986 bans the import into Great Britain of dead ungutted salmon and trout and salmonid offal which may carry such serious fish diseases as Haemorrhagic Septicaemia (VHS) and Infectious Haematopoietic Necrosis (IHN).

One feature of fish farming is that many fish find their way into local waters by intentional release or escapes. The numbers involved are unpredictable, but such fish are likely to interact with native fish, for example, through predation and competing for space and food.

Possible Solutions

Substantial research needs to be carried out in this industry, including appropriate ways to treat effluents from salmon farms, the economy and ecological impact of comparable land-based and cage systems, biological (as opposed to chemical) control of parasites and the use of sterile stock. More research is also needed on the use of land-based units and discrete systems using smaller volumes of water, which can be controlled and treated so as to greatly reduce the dangers of disease, pollution and escape of fish.

It may be appropriate for research on the use of sterile stocks to be expanded and include studies of the behaviour of such fish in the wild, although the problems of consumer resistance to sterile fish must be considered. Incidence of disease, water quality and the fate of fish escaping from farms all require regular monitoring.

The recent House of Commons Committee on Fish Farming in the UK expressed its concern about the monitoring of cage farms and recommended that the Scottish Office and the Purification Boards should undertake a review of procedures to ensure that water quality is properly protected. We believe that cage rearing should only be permitted if the trophic state of the water will not be adversely affected.

Regulating authorities should consider the desirability of requiring farms to employ suspended solid settlement treatments when setting discharge consents.

4.13 Specific recommendations contained in Section 4.

4.13.1 Hydrological Effects of Afforestation

1. Indicative Forestry Strategies should be amended to take account of fisheries among the major land use interests requiring to be considered. (Section 4.2).

2. An environmental assessment should be carried out by the NRA, SOAFD or DSFBs for any afforestation proposal which, irrespective of its size, may have an adverse effect on nursery areas for salmon. (Section 4.2).

3. The nature, extent and objectives of the investigations into the effects of afforestation and associated drainage currently being carried out by various organisations should be reviewed to establish whether there is close liaison and to ensure that particular attention is given to the identification, development and implementation of protective and remedial measures, taking full account of fisheries interests. (Section 4.2).

4.13.2 Acidification of Streams and Lakes.

1. The exacerbating affects of afforestation on acidification of streams and lakes should be used as a basis for the development of Indicative Forestry Strategies; this approach should be adopted throughout Great Britain. (Section 4.3).

2. When new afforestation schemes are being considered it is essential that the impact of the proposals, and of any remedial measures suggested, on fisheries are fully considered and that the NRA, RPBs and DSFBs are consulted and their advice taken into account. (Section 4.3).

3. The NRA and RPBs should be encouraged to use the powers available under Section 111 of the Water Act 1989 to establish Water Protection Zones in areas vulnerable to acidification. (Section 4.3).

4. Research on acidification should continue and further work needs to be carried out on the water courses before and after changes in land use, particularly afforestation, in order to develop a better understanding of the effects on water chemistry and the consequent impacts on fish populations. (Section 4.3).

5. Research should continue on cost-effective treatments for waters subject to chronic and episodic acidification, particularly fast-flowing streams. (Section 4.3).

4.13.3 Application of Fertilisers.

1. Powers under the Water Act 1989, and EC Directives should be used to control nitrate and phosphate discharges throughout Great Britain. (Section 4.4).

2. Care must be used in the storage and use of liquid fertilisers; and accidental discharges of liquid fertilisers to yard or field drains, or to streams, should be prevented. (Section 4.4).

3. Further research is required on the effects on the ecology of freshwaters and fisheries of increased nitrate concentrations in rivers; on the extent to which they are due to fertiliser usage; and the effectiveness of river bank "buffer zones" designed to reduce inputs to the rivers. (Section 4.4).

4. The possible effects of nitrogen and phosphorus discharges to rivers and streams, through the encouragement of algal or macrophytic growth, should be monitored by the NRA and RPBs. (Section 4.4).

4.13.4 Application of Pesticides.

1. The use of pesticides and the disposal of surplus chemicals and containers need to be more closely controlled, although observance of the revised Code of Practice, issued by MAFF in 1990, should help to reduce damage to juvenile salmonids. The results of the current studies in Scotland on controlled disposal on land set aside as 'sacrificial areas' should be disseminated and utilised. (Section 4.5).

2. More research is needed to assess the extent of damage to aquatic ecosystems from chemical applications generally, from spray applications which reach static or running waters and from spillages, giving particular attention to those used most commonly or in the largest quantities. (Section 4.5).

4.13.5 Silage Liquor and Slurry Run-off.

1. Proposals to control silage, slurry and agricultural oil installations recently issued by Environment and Agricultural Ministers should be translated into firm legislation as soon as possible. (Section 4.6).

2. Research should be encouraged into the effectiveness of waste disposal techniques, including the consequences for freshwater habitats of direct application to land. (Section 4.6).

4.13.6 River Regulation and Dams.

1. Ensuring adequate conditions for salmon production should be a requirement for all operators of new reservoir schemes. If this is not feasible, a mitigation programme should be implemented to the satisfaction of the appropriate authorities, and operating rules should be provisional upon monitoring programmes indicating satisfactory results. (Section 4.7).

2. A review should be conducted of the effectiveness of natural salmon propagation in regulated streams. (Section 4.7)

4.13.7 Water Abstraction.

1. The NRA's approach to developing and implementing a national water resource strategy which takes appropriate account of both environment and abstraction requirements should be considered for Great Britain as a whole. (Section 4.8).

2. The measurable effects of flow depletion on production of juvenile salmon should be reviewed. (Section 4.8).

3. Consideration should be given to a basic reconsideration of the acceptability of present water resource management policies and a re-appraisal of strategies in relation to environmental impact. (Section 4.8).

4. Consideration should be given to ways of improving the control and licensing of abstraction in Scotland, perhaps bringing the legal framework into line with that operating in England and Wales. (Section 4.8).

4.13.8 <u>River and Riparian Management</u>.

1. The criteria for the maintenance of drainage schemes, particularly in rural and upland areas should be reconsidered. (Section 4.9).

2. The application of environmental assessments to land drainage and flood defence schemes should be reviewed to determine whether fishery resources are adequately protected. (Section 4.9).

3. The DAFS advisory leaflet on Farm and Conservation Grant Schemes should be revised to include a requirement for an environmental assessment if fisheries are thought to be at risk. (Section 4.9).

4. Studies of the total sediment dynamics of streams, including the study of soil erosion from agricultural land and silt transport, are required, with the results being related directly to the success of salmon spawning and incubation in particular areas. (Section 4.9).

4.13.9 <u>Gravel Extraction</u>.

1. The planning authorities should be required to seek comment on proposals for gravel extraction from the NRA in England and Wales and RPBs or DSFBs in Scotland. (Section 4.10).

2. The NRA and the SOEnD should be invited to investigate and report on the apparent problems associated with gravel extraction. (Section 4.10).

4.13.10 Domestic and Industrial Waste Disposal.

1. Substantial effluents should be continuously monitored so that flows and key components are recorded and more automatic monitoring should be employed. (Section 4.11).

2. Risk assessments should be undertaken for individual catchments so that steps can be taken to avoid incidents of pollution damage. (Section 4.11).

3. Facilities such as ponding or stand-by oxygen injection plants, particularly for rivers which have a high risk from pollution, should be provided for the containment of pollution in the event of the failure of existing facilities. (Section 4.11).

4.13.11 Fish Farming.

1. Substantial research needs to be carried out in the fish farming industry, including; appropriate ways to treat effluents from salmon farms; the economy and ecological impact of comparable land-based and cage systems; biological (as opposed to chemical) control of parasites; the use of sterile stock; and the use of land based and discrete systems using smaller volumes of water. (Section 4.12).

2. Incidence of disease, water quality and the fate of fish escaping from farms all require regular monitoring. (Section 4.12).

3. Cage rearing should only be permitted if the trophic state of the water will not be adversely affected. (Section 4.12).

4. Regulatory authorities should consider the desirability of requiring farms to employ suspended solid settlement treatments when setting discharge consents. (Section 4.12).

5. GENERAL RECOMMENDATIONS

5.1 Introduction

Throughout the previous section of this report, numerous recommendations are made concerning the individual activities discussed and their influence upon production of juvenile salmon. The Committee hopes that all of these will be considered by the relevant bodies and taken up as appropriate. However, the Committee believes that an important theme has emerged which deserves consideration as a major policy area, namely the need for a more effective integrated approach to all aspects of stream management on a local, directed and coordinated basis. A second general area relates to the value of the management of a "buffer zone" between agricultural activity and the watercourse.

5.2 Integrated Management

It is clear from the considerations in Section 4 of this report that a wide range of activities may impinge upon the well-being of stocks of juvenile salmon. Many of these impacts are local in effect, and some may inter-relate to compound the impact. The obvious conclusion from this is that effective management will largely be dependent upon the assessment of, and action upon, local conditions. Further, full account must be taken of the whole range of sometimes competing interests and activities likely to impinge upon salmon stocks. The concept of effective integrated management embraces the following principles:

- the integrated consideration of various functions including water resource management, water quality, fisheries, land drainage, land use, flood prevention, conservation and recreation;
- agreed management targets for the various functions;
- detailed action plans based upon reliable analysis of local conditions;
- full consultation between the various interests (including the public);
- monitoring of performance and achievement of management targets.

Realisation of this concept clearly requires that regulatory bodies with effective scope for operation exist and are willing and able to adopt such an approach. In England and Wales the NRA is well placed to do so, and it is understood that they are actively considering the feasibility of catchment management plans. In Scotland the regulatory framework appears to be less well developed. Throughout the country there are currently a range of consultation procedures which, the Committee suggests, should become mandatory for promoters of schemes to undertake.

The Committee believes that integrated management offers the most effective way forward in improving the protection and enhancement of juvenile salmon production. The development of appropriate regulatory frameworks throughout Great Britain is clearly a pre-requisite to such an approach and the regulatory powers and regional structure of the NRA seems to make it well placed to develop integrated catchment management throughout England and Wales. The Committee is aware of specific programmes already being developed by the NRA and by the appropriate authorities for some Scottish rivers and we welcome and encourage such initiatives. There is however a need for a stronger and more comprehensive framework in Scotland and we therefore recommend that the present regulatory structure there should be urgently reviewed in this context and be amended if appropriate.

5.3 <u>Riparian buffer zones</u>.

One attainable benefit of an integrated approach to catchment management would be the ability to create "buffer zones" adjacent to spawning and nursery streams. The potential benefits of such zones are several - fold, particularly in areas of intensive agriculture.

They include:-

- allowing bankside vegetation to develop to provide cover;
- providing food in the form of terrestrial invertebrates;
- reduction of input of fine solid material (eg. from ploughing);
- prevention of bank erosion and stream damage by grazing animals;
- reduction of risk of chemical pollution and input of silage liquor and slurry;
- reduction of input of fertilisers.

The "buffer zone" would require management rather than just being allowed to become overgrown, as dense tree cover can be as damaging to fish production as lack of cover. A grant scheme along the lines of the Government's "Set Aside" and "Extensification" schemes would be beneficial, both to attract farmers in the first instance and then to ensure continuing appropriate management. Two developments which are of particular interest are the Government's "Environmentally Sensitive Area" (ESA) Scheme and the Countryside Commission "Countryside Premium Scheme" (CPS).

The ESA Scheme identifies areas of particular landscape and wildlife value where reversion to or maintenance of traditional methods of farming would help to maintain this value. Several wetland areas are already so designated and farmers are paid a grant to adopt sensitive agricultural techniques. Requirements may include the maintenance of wetlands, no ploughing, wilting of silage, no inorganic fertilisers or application of pig and poultry manure, no pesticides and restriction on herbicides. Entry to the scheme is voluntary. One such scheme is operating in the Test Valley in Hampshire, a major but suffering salmon habitat. However, while the proposals for the Test Valley ESA are consistent with good river management and the well-being of salmon nursery areas, this is not the primary aim of the scheme.

The CPS Scheme is managed by the Countryside Commission and operates with the MAFF Set-aside Scheme. Additional grants are paid where the set-aside land is managed with one or more of five conservation aims in mind. One of the options, habitat restoration, would appear to be of particular relevance to salmon management. The intention has been to present a wide-ranging opportunity to restore habitats which have been damaged or modified by present farming practices, and few restrictions apply. Two major limiting factors are that the set-aside scheme (and thus the CPS) only applies to land under arable agriculture, and the CPS currently only operates in East Anglia.

The Agriculture Departments have recently introduced pilot extensification schemes for livestock farming in Great Britain with the intention of introducing national schemes during 1991. The Committee welcomes this and believes that the development of such schemes on a widespread basis could provide significant benefits for conservation of wildlife habitats, including that of salmon. The diversion of farm land for non-agricultural uses, for example under the Set-aside Scheme, could also serve to promote salmon conservation.

So far these schemes do not appear to have taken account of any fisheries management objectives. However, a development has been proposed by the Devon Farming and Wildlife Group under the Environmental Land Management Scheme (ELMS) promoted by the Country Landowners Association. The proposal is for investigation of the possibility of a "buffer zone" in parts of the Taw and Torridge catchments to enhance the river corridors as a wildlife habitat. Possibilities include permanent grassland or broad-leaved woodland strips, and restrictions on the use of pesticides and fertilisers.

The objectives of good salmon habitat management do not in any way conflict with the wider conservation aims of the schemes. There would therefore appear to be considerable scope for individual initiatives under these schemes to incorporate, or even have as the primary aim, the enhancement and restoration of juvenile salmon habitats.

The Committee therefore recommends that:

- the scope for existing schemes, (including the Environmentally Sensitive Area Scheme, the Countryside Premium Scheme, and the Environmental Land Management scheme) to be used to develop riparian management proposals for conservation, restoration and enhancement of juvenile habitat be actively examined; and

- if existing schemes prove not to be appropriate, the possibility of creating a scheme specifically for salmon or freshwater fisheries conservation and management be explored.

5.4 Guidelines and codes of practice

In its deliberations the Committee looked at a considerable number of published guidelines and codes of practice for a wide range of activities likely to have an impact upon juvenile habitat. We are aware of many others that we did not review. We concluded that many of these guidelines were excellent and very relevant to various recommendations made in Section 4 of this report. However, some of the publications were not known to us and others were difficult to locate. The Committee felt that the preparation of a single code of practice or a range of codes which applied specifically to the conservation of juvenile salmon habitat might be appropriate. This could draw upon the best features of existing codes, and could be made available to all with appropriate interests. However, as a first stage, it was felt that an annotated list of existing codes and guidelines should be prepared; this would provide the basis for further developments, or indeed could identify existing publications that precluded the requirement for a new set of guidelines. It would be a valuable document in its own right by bringing existing guidelines to the attention of those who should be using them.

The Committee therefore recommends that the contents of all existing codes of practice and guidelines which have a direct influence on the well-being of salmon nursery streams are reviewed, and an annotated list produced.

6. REFERENCES/FURTHER READING

Scottish Development Department, 1990: Indicative Forestry Strategies.

Ministry Of Agriculture, Fisheries And Food/National Rivers Authority, 1990: Water Pollution From Farm Waste 1989 (England and Wales).

Ministry Of Agriculture, Fisheries And Food/Health And Safety Commission, 1990: Code of Practice for the Safe Use of Pesticides on Farms and Holdings.

The annual reports of the Scottish River Purification Boards.

Department Of The Environment/Welsh Office 1990: Public Consultation on Proposed Regulations to Control Silage, Slurry and Agricultural Fuel Oil Installation.

Scottish Development Department, 1990: Consultation Paper on Regulations to Control Silage, Slurry and Agricultural Fuel Oil Installation.

The Royal Society For The Protection Of Birds, 1984: Rivers and Wildlife Handbook: A Guide to Practices which further the conservation of wildlife on rivers.

The Forestry Commission, 1988: Forests and Water: Guidelines.

Department of Agriculture and Fisheries for Scotland Farm and Conservation Grant Scheme leaflet, 1989, No CS14: Arterial Drainage and River Works.

National Rivers Authority, 1990: Discharge consent and compliance policy: a blueprint for the future.

National Rivers Authority, 1990: Corporate Plan, 1990/91.

The Atlantic Salmon Trust (J. Solbe), 1988: Water Quality for Salmon and Trout.

The Nature Conservancy Council, 1990: Focus on Nature Conservation: The impact of afforestation and forestry practice on freshwater habitats.

House Of Commons Agriculture Committee, 1990: Fish Farming in the UK.

Institute of Aquaculture, 1990: Fish Farming and the Scottish Freshwater Environment.

Maitland, PS, 1989: The Genetic Impact of Farmed Atlantic Salmon on Wild Populations.

Ministry of Agriculture, Fisheries and Food: Series of leaflets on Environmentally Sensitive Areas.

SALMON ADVISORY COMMITTEE

January 1991

MEMBERSHIP OF THE SALMON ADVISORY COMMITTEE

Chairman: Professor G M Dunnet

Mr G H Bielby

Mr C G Carnie

Mr R M Clerk

The Hon Edward Davies

Mr S J Day (until 2 February 1990)

Mr E P Ecroyd (until 2 February 1990)

Mr J H Ferguson

Sir William Gordon-Cumming (until 2 February 1990)

Mr N W Graesser

Dr M M Halliday

Mr D Heselton

Mr A V Holden

Dr W R Howells (until 2 February 1990)

Dr P S Maitland

Mr I Mitchell

Mr M J Morgan

Mr M Owens (with effect from 3 February 1990)

Mr D R Paton

Dr J D Pirie

Dr D J Solomon

Mr W A C Thomson (until 15 February 1991)

WATER QUALITY STANDARDS FOR SALMONIDS

LIST I SUBSTANCES

The national standards (see source references below) listed for these substances are for general ecosystem conservation, not specifically for salmonid conservation. They do however apply to rivers containing salmon populations.

	Annual mean concentration in inland surface waters (µg/l)
HCH	0.10
HCB	0.03
HCBD	0.10
CHLOROFORM	12.0
CARBON TETRACHLORIDE	12.0
DDT	0.025
para para DDT	0.01
PCP	2.0
"DRINS" TOTAL	0.03
ALDRIN	0.01
DIELDRIN	0.01
ENDRIN	0.005
ISODRIN	0.005
MERCURY	1.0 (or 0.3 mg/kg in a sample of fish flesh)

CADMIUM	Total water hardness mg/l $CaCO_3$			
	10	50	100	500
95 percentile	0.6	0.9	1.0	1.5
50 percentile	0.3	0.4	0.5	0.75

LIST II SUBSTANCES

These standards are set for the maintenance of salmon fisheries. They are derived from EC directives and national standards (see source references below).

Annual average (aa), 95 percentiles (95P) and maximum (M) values of total (T) or dissolved (D) concentrations as µg/l

ARSENIC	50	aa,D
BORON	2000	aa,T
INORGANIC TIN	25	aa,T
ORGANOTIN TBT & TPT	0.02	M,T
IRON	1000	aa,D
PCSDs	0.05	95P,T
SULCOFURON	25	95P,T
FLUCOFURON	1	95P,T
PERMETHRIN	0.01	95P,T
CYFLUTHRIN	0.001	95P,T

The following standards are hardness related:

	Hardness (mg/l $CaCO_3$)						
	<50	50-100	100-150	150-200	200-250	>250	
CHROMIUM	5	10	20	20	50	50	aa,D
COPPER	1	6	10	10	10	28	aa,D
	5	22	40	40	40	112	95P,D
LEAD	4	10	10	20	20	20	aa,D
NICKEL	50	100	150	150	200	200	aa,D
ZINC	8	50	75	75	75	125	aa,T
	30	200	300	300	300	500	95P,T
VANADIUM	20	20	20	20	60	60	aa,T

pH 6.0-9.0 95P

OTHER DETERMINANDS

These standards are applicable to salmon fishery conservation, and are derived from EC directives and national standards (see source references below).

AMMONIA (µg/l)	21 (unionised), 780 (total)	95P
DISSOLVED OXYGEN	50% of values >9 (mg/l), all values >7 (mg/l)	
BOD	= <3 (mg/l)	95P
RESIDUAL CHLORINE	= <5 (µg/l) at pH 6	95P
PHOSPHORUS	0.2 (mg/l)	T
HYDROGEN SULPHIDE	0.5 at <15°C and <5mg/l O_2 aa (24hr max = 5.0)	
	1.0 at <15°C and >5mg/l O_2 (24hr max = 5.0)	
	0.25 at >15°C and <5mg/l O_2 (24hr max = 5.0)	
	0.5 at >15°C and >5mg/l O_2 (24hr max = 5.0)	
TEMPERATURE °C	<1.5 increase in affected water	98P
	<21.5	98P
	<10 for breeding of cold water species	98P

SOURCE REFERENCES

1. Council directive (78/659/EEC) on the quality of fresh waters needing protection or improvement in order to support fish life.
   Official Journal of the EC No. L222/1 1978.

2. Water Environment. The implementation of EC directives on pollution caused by dangerous substances discharged into the aquatic environment.
   DoE circular 7/89 1989
   Welsh Office circular 16/89

MAFF Publications, London SE99 7TP
 PB 0535 £3.95
Reprinted November 1994
Printed on an environmentally friendly ECO-CHECK® ★★★★★ paper.