Management advice for trout, grayling and Arctic char fisheries

Fisheries Technical Manual No. 7

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Statement of Use
This manual contains management advice for trout, grayling and arctic char fishery managers. The information in this document is for use by EA staff and others involved in the management of fisheries in England and Wales. All fisheries are different and require individual consideration for the application of principles described in this Manual.

Keywords
Trout, grayling, Arctic char, management, fisheries, conservation.

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EXECUTIVE SUMMARY

This manual provides good practice management advice for still water and riverine trout, grayling and Arctic char fisheries. The material produced in this manual is derived from extensive reviews of the relevant literature, and incorporates relevant Environment Agency policies. The manual is written to be relevant to both Environment Agency staff and external fishery owners and managers. Topics chosen for inclusion in this manual were derived from questionnaire surveys of Agency Fisheries staff and external fisheries managers and owners. Each chapter includes technical and practical advice and a summary of management options. The content has been quality-assured by Environment Agency staff. Readers are reminded that all fishery management decisions must be related to local circumstances and that this manual should not be read as a 'recipe book' offering generic solutions but should, rather, be used as a guide to good practice.

Chapters included in this manual have been grouped under four headings and include:

Fisheries Ecology	Trout Ecology; Grayling Ecology; Arctic Char Ecology; Feeding Ecology;
Water Quality & Quantity	Water Quality; Water Quantity;
Fisheries Management	Habitat Quality and Improvement; Aquatic Plant Management; Conservation; Fishery Development; Land Drainage Consents; Screens and Obstructions to Fish Migration; Fisheries Socio-Economics;
Fish Stock Management	Stocking; Interactions between fish species; Interactions with other species; Fish Diseases and Parasites; Poaching and Theft; Catch and Release Angling

Each chapter starts with a brief introduction that outlines the key principles of the topic. The questions that respondents wished to see covered in the manual are then answered as a series of topics within the detailed advice sections of each chapter. At the end of each chapter is a table providing concise information on good management practice. References cited in the text plus additional valuable sources of information are provided in the list at the end of each chapter. References marked with an asterisk are considered particularly useful reviews on a given subject.

This manual has been produced in support of the Agency’s National Trout and Grayling Fisheries Strategy which was published in 2003. The aim of the Strategy is, "to conserve and improve wild stocks of trout, sea trout, char and grayling, whilst enhancing the environment for, and the social and economic benefits from, all types of fisheries for these species in England and Wales". The Strategy policies that are of direct relevance to the manual are quoted in full, in the relevant chapters within this manual.

The Trout Ecology chapter introduces the ecology of the species and under Technical and Practical Advice, goes on to provide detailed advice on topics including determining stock densities, reviewing factors limiting trout production, examples and advice on increasing wild trout populations, fishery management objectives. Main topics included in the Grayling Ecology chapter include, competition with brown trout, sustainable exploitation of grayling, stocking grayling, water quality for grayling and river habitat improvements.

Important current issues on Char Ecology include eutrophication of lakes, degradation of char spawning streams, the impacts of introductions of other fish species and the regulation of exploitation of Arctic char in England and Wales. The Feeding Ecology chapter reviews important aspects of trout feeding ecology in both rivers and stillwaters, of grayling and also of Arctic char, including valuable information on dietary studies.

In the Water Quality chapter, the important water quality parameters for salmonid fish are reviewed and appropriate limits are defined. The chapter then goes on to provide advice on key pollution threats, including advice on assessing water quality, and to review the effects of catchment land use on water quality. Other key areas covered in the Technical and Practical Advice include the effects and causes of excessive plant and algal growth, the issue of acidification, and causes and remedies for low dissolved oxygen levels. The Water Quantity chapter deals predominantly with river flows, reviewing the importance of natural flow regimes, and providing advice on protection of flows against over-abstraction.

Habitat Quality and Improvement covers aspects of project planning, an overview of the pros and cons of a variety of habitat improvement methods and possible sources of project funding. Aquatic Plant Management provides valuable advice on the legislation regarding herbicides, including guidance on the use of approved products and decision frameworks for mechanical weed control and for herbicide use. The Conservation chapter provides an overview of important conservation designations such as Sites of Special Scientific Interest (SSSIs) and the UK Biodiversity Action Plan (UK BAP) that are of particular relevance to fisheries. Also included is advice on integrating conservation objectives into fisheries management plans.

Options for the development of a stillwater fishery are reviewed in the chapter on Fishery Development which also includes advice on stillwater habitat requirements and water quality considerations for stillwaters. The important process of obtaining Environment Agency consent for any structural work on river or stillwater fisheries, is described in the chapter on Land Drainage Consents.

Important legislative requirements are described in the chapter on Screens and Obstructions to Fish Migration. Practical considerations for the installation and maintenance of screens and of fish passes are described. Issues dealt with in the Fishery Socio-economics chapter include aspects of setting up a new fishery and commercial netting for sea trout.

The Stocking chapter provides advice on a wide range of popular issues and includes relevant policies from the National Trout and Grayling Fisheries Strategy. The chapter includes a good practice decision tree for trout stocking and covers important advice on permissions to introduce fish, fish health checks, minimising the impacts of hatchery trout on wild trout, trout genetics, grayling introductions and several other issues. Some practical examples of stillwater stocking practices are also detailed. The two chapters dealing with Interactions cover main issues on eels, cyprinids, pike, fish-eating birds, mink and otters.

The chapter on Diseases of Trout, Char and Grayling introduces the important links between fish diseases and factors like fish health, stress and environmental quality. The Technical and Practical Advice section reviews the legislative controls of fish disease and the method of disease categorisation in the UK. Advice on recognising the symptoms of disease is presented and the diseases that may affect trout, grayling and char are described, along with methods of control, and what to do in the event of a disease outbreak.

The Poaching and Theft chapter describes the main Acts relating to fisheries and lists the main fisheries offences, providing advice on security and bailiffing. The chapter on Catch and Release Angling presents valuable results from many catch and release experiences in both the USA, where the technique was pioneered, and the UK.

KEYWORDS
Trout, grayling, Arctic char, management, fisheries.

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1 INTRODUCTION

1.1 Manual Content and Use

The National Trout and Grayling Fisheries Strategy (Environment Agency, 2003) develops new policy for the conservation, regulation and management of sea trout and other trout, arctic char and grayling fisheries in England and Wales. This manual was produced to assist in the delivery of the Strategy by providing management information and advice on good fishery management practice for both Environment Agency staff and fishery managers and owners external to the Agency. A range of outputs including leaflets and electronic versions derived from this manual will be produced for use by fishery managers and available from the Environment Agency.

Subject areas for the detailed content of this manual were determined by circulating questionnaires to Regional and Area Environment Agency Fisheries staff, to key organisations involved in game fisheries management and to a large number of fisheries in England and Wales. Fisheries contacted were chosen by Environment Agency Fisheries staff to reflect the types and numbers of trout, grayling and arctic char waters present in given Agency Areas. The questionnaires required respondents to list the key fisheries management topics that they regarded as important. A complete account of the questionnaire process is given in the Project Record (Giles et. al., 2003).

The topics included in this manual have been split into a series of chapters, cross-referenced to facilitate linkage between related areas. Repetition has been minimised in this way, and it will be necessary for the reader to move between chapters to obtain a range of information on certain subjects. For instance, information on the biology of wild brown trout is mainly in chapter 2 but may also be found in virtually all of the other chapters whilst grayling (chapter 3) and char (chapter 4) have specific information in their own short chapters. Some key topics are mentioned in more than one chapter to reflect the need to consider a given topic from various perspectives.

Each chapter starts with a brief introduction that outlines the key principles of the topic. The questions that respondents wished to see covered in the manual are then answered as a series of topics within the detailed advice sections of each chapter. At the end of this section is a table providing concise information on good management practice. References cited in the text plus additional valuable sources of information are provided in the list at the end of each chapter. References marked with an asterisk are considered particularly useful reviews on a given subject.

Variations in Regional byelaws

It is important to note that byelaws often vary regionally throughout England and Wales. These variations can include, for instance, consenting procedures, angling and netting seasons, times and methods of fishing, etc. Also, it is important to note that fisheries legislation is currently under review and potentially subject to change. It is always best to check current legislative positions, Agency policy and practice with relevant Area, Regional or Head Office staff. Up to date information for staff is available on the Agency Easinet, Internet or from Head Office.

1.2 The National Trout and Grayling Fisheries Strategy

The Environment Agency has separate Strategies for Salmon, Coarse Fish and for Eel fisheries; the latest Strategy (EA 2003) addresses all trout, sea trout, grayling and Arctic char fisheries, completing the coverage of key fish species exploited in England and Wales. Sea trout are an important angling and commercial netting species; the Agency regulates fisheries in England and Wales, parts of the Scottish border and in relevant coastal waters out to 'the six mile limit'. Brown trout, both wild or stocked, are found in streams, rivers, natural lakes, reservoirs and man-made pools throughout England and Wales, rainbow trout are stocked into most still water trout fisheries and are present in some rivers. American brook trout are stocked into some enclosed still waters, particularly in upland moorland areas. Virtually all grayling fisheries are for wild fish and these fisheries extend through many rivers and some lakes, extending the game fishing season through the winter. There are a small number of traditional Arctic char rod fisheries on Cumbrian lakes and this species is of particularly high conservation value.

Each year around one million anglers buy an Environment Agency rod licence and, of these, some 43% fish for trout (Spurgeon et al, 2001). In 1999 licence holders spent an estimated £300 million on game fishing. Trout fishing rights in England and Wales have recently been valued at an estimated £500 million - five times that of salmon fisheries (Radford et al, 2001) and there appears to be further demand, particularly for wild brown trout and high quality grayling fishing. Tourism based on angling supports significant numbers of jobs in rural locations and the development of new fisheries represents an opportunity for farmers to diversify land use in environmentally-friendly, sustainable ways.

Around 3% of rod licence sales come from salmon and sea trout anglers; the relative importance of sea trout has increased in recent years with the widespread declines in salmon catches. The economy supported by game fishing is substantial. Commercial netting for sea trout also provides employment, particularly in North East England. In the West Country and parts of rural Wales traditional methods are used on some rivers. Following Review Group recommendations, it is appropriate to reconsider the exploitation and apportionment of sea trout catches between nets and rods on a wide range of fisheries where local conditions vary widely. There are small fisheries for Arctic char in Cumbria, based on traditional deep trolling methods.

Bearing in mind the value of this wide range of fisheries, it is evident that socio-economic considerations are important components of the Environment Agency's National Trout and Grayling Fisheries Strategy (Environment Agency, 2003). The Environment Agency has a duty to maintain, improve and develop fisheries within the important context of contributing to sustainable development. The Government's independent Review of Salmon and Freshwater Fisheries (MAFF, 2000) and the Government Response to the Review Group's recommendations (MAFF, 2001) have provided important guiding principles to help shape future fisheries policy in England and Wales.

The development of the National Trout and Grayling Fisheries Strategy was delayed so as to include due regard for these recommendations. Its aim is "To conserve and improve wild stocks of trout, sea trout, char and grayling, whilst enhancing the environment for, and the social and economic benefits from, all types of fisheries for these species in England and Wales".

The types of fishery involved include sea trout in estuaries, rivers and lakes, wild brown trout in rivers and lakes, grayling in rivers and lakes, Arctic char in lakes and the wide variety of waters stocked with brown, rainbow and brook trout. Key areas covered by the Strategy include:

- Enhancing social values and economic benefits of fisheries.
- Helping the allocation of sea trout catches between rods and nets.
- The setting of conservation targets, protecting and improving wild stocks and regulating exploitation.
- New policies on stocking and introductions.
- Support for and collaboration in landscape and fish habitat improvement projects.
- Provision of advice on predation by cormorants, improving weed growth and fly diversity and abundance, supporting successful fisheries.
- Initiatives to overcome obstructions to migratory fish movements.
- The classification of trout fisheries into 'native trout waters' (producing wild fish) and 'other' (no natural production) categories and the development of 'wild fish protection zones', agreed at local level with fishery owners and managers through Fishery Action Plans.
- Outcomes of the Strategy - assessing the success of the policies, background research and development work and consequent recommended fisheries management practice.

Further information on the Strategy and other Agency activities is available via the web site: www.environment-agency.gov.uk

1.3 Species

The fish species covered in this manual together with some key facts on their biology are presented in the following section.

Salmo trutta - the brown / sea trout

Figure 1 Brown trout

Table 1 Brown trout

Fish	Habitat	Biology
Brown trout Rod caught record 14.43kg, Loch Awe, Argyll, 2002.	Freshwater/estuary Upland or lowland streams, rivers, pools, lakes. Physical cover from habitat important - most brown trout live in smaller streams close to banks. Needs cool, clean water with relatively silt-free gravels for spawning usually from mid-October to December in small streams or lake shallows.	Eats invertebrates, particularly insects, and fish. Fast-growing, lake-dwelling *ferox* form eats fish from relatively early age. Can attain weights of 10kg+ and live for perhaps 20 years. Usually matures at 2 or 3 years, repeat spawning common. Body form and colouring and life cycle details very variable. Species very widely distributed. Brown and sea trout are same species and commonly interbreed.
Sea trout / Sewin Rod caught record 12.85kg, River Test estuary, 1992.	As for brown trout except for migratory marine phase of life cycle. May spawn in main river sections in same microhabitats as salmon. Often migrates far upstream to spawn in tiny moorland streams. Sea trout may be largely female in some rivers, males remaining in freshwater, maturing as brown trout.	Eats invertebrates, particularly crustaceans and fish. Can attain weights of 10kg+ and live for 10+ years. May smolt at 1-5 years. Returns to spawn after one or more winters at sea. Repeat spawning common, may not spawn every year. Hybridisation with salmon can occur.
Sea trout - Finnock / Peal / Whitling	Estuaries / inshore waters / rivers, lakes.	Eats invertebrates and fish. Usually weighs ~300g and has spent only a few weeks/months at sea. Young sea trout which may or may not attempt to breed.

Thymallus thymallus - the European grayling

© Nick Giles

Figure 2 Grayling

Table 2 Grayling

Fish	**Habitat**	**Biology**
Grayling Rod caught record 1.9kg, River Frome, Dorset.	Freshwater upland and lowland rivers some pools and lakes. Needs cool, clean water with relatively silt-free gravels for spawning usually from March - April. Sensitive to pollution.	Eats invertebrates, particularly insects and crustaceans, probes stream bed for food. Average adult fish 30cm and 350g, can attain weights of 2kgs+ and live for perhaps 8 years (longer in Scotland). Usually matures at 2 or 3 years. Active in winter when 'game' angling season can be extended after the salmonid season. This adds to the economic value of this species. The Grayling Society is a good source of information.

Salvelinus alpinus - the Arctic char

Figure 3 Arctic char

Table 3 Arctic char

Fish	Habitat	Biology
Arctic char Rod caught record 4.3kg, 1995, Loch Arkaig, Inverness.	Quite widespread in Ireland and northern Scotland, very localised in Cumbria and north Wales. Usually co-exits with brown trout and is principal food of ferox. Lives in large deep glacial lakes (Cumbria / Wales) or in more fertile lowland lakes (Ireland). Cool, clean water is a key habitat requirement. Char are very sensitive to pollution. Spawns (September to March) either on gravely lake beds or in gravel-bedded inflowing streams.	Eats invertebrates, particularly insects, and fish. Typically 100-200g, can attain weights of 4kg+ where feeding is exceptional (e.g. under fish cages) and live for perhaps 10+ years. Usually matures at 2 or 3 years, repeat spawning common. Body form and colouring and life cycle details very variable. Sub-stocks (races) with differing biology often occur in large lakes.
Sea-going form	Arctic char are usually anadromous but all known UK stocks are land-locked.	

Oncorhynchus mykiss - the rainbow trout

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Figure 4 'Blue' strain of rainbow trout

Table 4 Rainbow trout

Fish	**Habitat**	**Biology**
Rainbow trout	Introduced to British Isles over a Century ago. Native to Pacific coast of North America from Alaska to Mexico. Almost always stocked as hatchery-produced fish in UK. Lives in freshwater / estuary, upland or lowland streams, rivers, pools, lakes. Needs cool, clean water with relatively silt-free gravels for spawning usually from mid-October to December in small streams. Rarely establishes self-sustaining stocks in UK. In 1971 5 British / Irish locations were reported where spawning is regular enough to sustain a population, these were Derbyshire Wye, River Lathkill, Leigh Brook and Loughs Shure and La Liebe, Ireland (Frost, 1974).	Eats invertebrates, particularly insects, and fish. Can attain weights of 10kg+ in fish farms and lives for perhaps 5-8 years. Usually matures at 2 or 3 years, often recovers after spawning. Selective breeding has given rise to 'blue' and 'golden' trout varieties – these are occasionally stocked to add variety to still water rainbow trout fisheries.
Steelhead	As for Rainbow trout except for migratory marine phase of life cycle. May spawn in main river sections in same microhabitats as salmon. Spawning rarely appears to be successful in the British Isles. Occasional sea-run steelhead are recorded from various UK rivers.	Eats invertebrates, particularly crustaceans, and fish. Can attain weights of 10kg+. Repeat spawning very uncommon.

Salvelinus fontinalis - the brook 'trout' (char)

Figure 5 Brook trout (male above)

Table 5 Brook trout

Fish	Habitat	Biology
Brook trout Rod caught record 3.7kg, Fontburn Reservoir, Northumberland	Introduced to British Isles over a Century ago. Native to east coast Canada & North America. Usually stocked in the UK although some self-sustaining populations occur. Tolerates silty spawning gravels and relatively acid and turbid waters. Survives well in moorland still waters.	Diet invertebrates, fish and frogs. Mature at around 3 years, lives for up to 5+ years and attains weights of 3kg+. In common with other salmonids, life cycle and body form/colouring can be highly variable.

1.4 The Holistic Approach to Fisheries Management

Fisheries are best managed in the widest sense - including consideration for the river or lake catchment and ecology as a whole. Holistic approaches to fishery management often seek to:

- Maintain catches adequate to attract anglers at financially sustainable levels.
- Maintain self-sustaining fish stocks within the capacity of the available habitat.
- Manage actively to achieve an appropriate balance of biodiversity and recreational values. This may involve increasing the carrying capacity of habitats for fish and other species to benefit both fisheries and conservation.
- Consider carefully any impacts as well as benefits of fishery management practices on habitats and species.

A useful definition of a fishery includes not only the exploited fish species but also the habitats found there and the other species sharing those habitats.

A fishery with high environmental quality will tend to be resilient, productive and attractive to anglers. Most of the chapters in this manual include useful information for fishery managers who seek to improve the ecological quality of their rivers and lakes, whether supporting wild or stocked fisheries.

1.5 References and Bibliography

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Note references marked with an * are key information sources.

2 TROUT ECOLOGY

2.1 Introduction

Ecology is the study of the distribution and abundance of animals and plants and their communities and ecosystems. The ecological health of any population and the restoration of wild trout stocks, depend critically on the environmental quality of the habitat (see chapter 8 - Habitats). A good broad definition of a fishery should place it in the context of its ecosystem (Salmon & Freshwater Fisheries Review, MAFF, 2000). Population ecology seeks to understand the factors that determine distribution and abundance during the life cycle - factors such as spawning success, fry survival, predation, competition, diseases, parasites, weather conditions, exploitation, etc. Clearly, this is a complex subject and key factors affecting populations are likely to vary greatly between species, types of habitat, geographical location and even from year to year. Natural fluctuations in salmonid fish stock abundance make the identification and quantification of problems very difficult on many fisheries.

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Figure 6 A *ferox* brown trout from Loch Garry, Scotland (3.6kg)

Brown trout sometimes live in very large natural lakes where more than one sub-species may have evolved, for instance *gillaroo*, *sonaghan* and the fast-growing predatory *ferox* form (Figure 6 above). In productive rivers, brown trout may often complete their life cycle in freshwater. In unproductive (e.g. hard rock and peaty) catchments the poor food supply tends to produce migratory sea trout that grow rapidly at sea, returning to natal rivers to spawn. On such rivers some male brown trout usually remain in freshwater for the whole life cycle, fertilising the ova of returning female sea trout. Clearly, the population genetics, dynamics and ecology of these trout stocks are very complex and difficult to understand and, therefore, to manage. This is especially the case on large lake and river systems with mixed brown and sea trout stocks. Self-sustaining trout stocks, a key objective for many fishery managers, require good stock and habitat management - a challenging objective (see, for instance, Elliott, 1989, NRA, 1993).

Figure 7 shows a simplified *Salmo trutta* life cycle diagram - many variations on this basic pattern are seen in the wild.

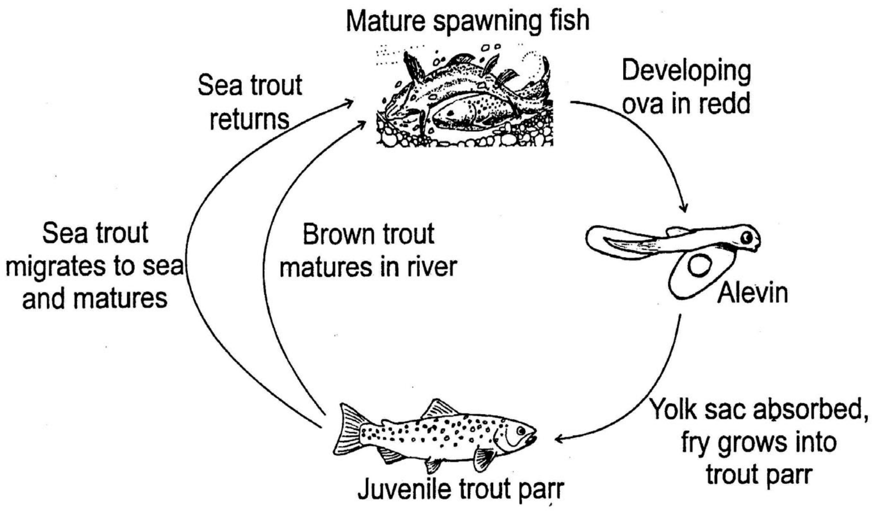

Figure 7 The trout's life cycle (from EA, 1996; not to scale)

Whilst grayling complete their life cycles in freshwater, as do char in the UK (although many char populations migrate to sea to mature further north), our native trout*, Salmo trutta* has a complex, variable life cycle that can include estuarine and marine phases (see Elliott, 1994 and references therein). Brown trout can live their lives in freshwater, migrating to greater or lesser extents to breed. They can drop down into estuaries for a period of time ('slob' trout) or migrate fully to sea, returning after only a few weeks as finnock (also termed peal, herling, whitling) or after one or more winters at sea as sea trout (or “sewin” in Wales). In some systems nursery streams produce trout that migrate downstream to large lakes, spending their adult lives there, before returning to spawn, perhaps on several occasions over a number of years (for instance, the *dollaghan* of Lough Neagh).

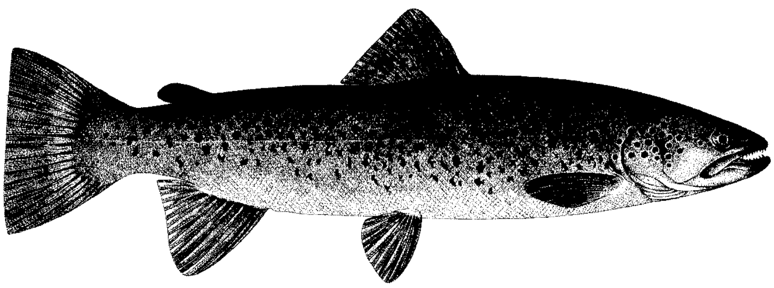

Figure 8 The brown / sea trout

Female trout from some stocks produce relatively few large eggs whilst others produce many more, smaller eggs. Such differences may be related to incubation conditions and food availability for young fry. Small trout are incapable of excavating redds in large gravel and shingle whilst large hen sea trout are able to do this, extending the breeding habitat of the migratory stock component in some rivers. The mixture of genetic and environmental influences that determines what form of life cycle individual trout adopt is unknown but population density and the productivity of the 'home' stream are thought to be important. In cold, unproductive waters trout grow very slowly, mature at small sizes and produce few eggs. Upland lakes with extensive spawning and nursery habitat often have very abundant stocks of small trout whilst similar waters with restricted spawning may contain fewer, larger fish. In contrast, warmer, more productive waters produce fast-growing, early maturing, highly fecund fish. Most sea trout stocks seem to come from relatively unproductive rivers where juvenile survival is high but growth limited by environmental conditions, especially water temperature and food supply. The need to access rich marine feeding areas to reach maturity in reasonable time, particularly by females, may have been the primary evolutionary drive favouring migration. Conversely, male trout need not achieve large body sizes to produce sufficient viable milt and so often remain in freshwater, maturing there. These males may inter-breed either with mature hen brown trout or sea trout that have returned from their marine fast-growth phase (see Fahy, 1985, Elliott et al, 1992, NRA, 1992, Solomon, 1994 and Harris, 2002 for reviews). Where stocking with hatchery-derived fish has taken place, inter-breeding between wild and stocked fish may adversely affect the overall genetic constitution of the population (see chapter 15 - Stocking).

The numbers of trout in a population are primarily determined soon after emergence from the gravel as fry, at this time they fight for territories and weaker individuals are pushed out into poor habitat areas where they may die. A stream bed will contain a fairly fixed number of suitable territories - the 'carrying capacity' for fry. The actual number of territories will vary with flows, food supply, shifts in bed shape and competition from other species - only fish that hold a territory can survive.

Each life cycle stage will have limits of abundance in a given habitat. If the stock is below carrying capacity at any life stage, individual survival will tend to be good (catastrophic factors excepted). If the stock ranges above carrying capacity a bottleneck is produced and competition causes poorly adapted individuals to die. This process is termed density-dependent mortality; the proportion of fish dying depending upon the numbers present. Trout and salmon stocks in many rivers are, therefore, to a degree self-limiting, natural checks and balances keeping densities around the carrying capacity as long as overall environmental conditions are similar.

Severe droughts, floods, sudden inputs of silt or other pollutants can, of course, wipe out most or all of a stock irrespective of population density. Such factors are termed density-independent and can cause major fluctuations in stock abundance. Elliott (1992) produced analyses of sea trout catch statistics for English and Welsh rivers, concluding that abundant stocks tend to have relatively low catch (and stock) variability and are, therefore, probably regulated primarily by density-dependent factors. Conversely, low abundance sea trout stocks often have highly variable catches, indicating that, probably, density-independent factors are of key importance in determining the dynamics of the population. Management strategies for these two fundamentally different types of sea trout stock should, of course, be tailored to local circumstances.

2.2 Technical and Practical Advice

2.2.1 Determining brown trout and sea trout stock densities

Still waters
On large still waters trout stocks can be estimated by SONAR or gill-netting mark-recapture experiments (O'Grady, 1983). Measures of relative abundance can be gained from angling catch-per-unit-effort (CPUE) data - see below.

Rivers
Resident adult brown trout in small stream fisheries are easily estimated by electric-fishing surveys. It is quite likely that there will be existing data for a given river, local Agency staff can advise. Environment Agency permission must be received in writing before any electric-fishing operation is undertaken. Larger rivers are much more difficult to survey as adult trout select deeper water and are usually close to dense cover. Surveys on small and medium-sized streams can give accurate population estimates if representative stretches are stop-netted and then fished three times. Fish from each catch are kept separate, measured and counted in size categories corresponding to year classes. The successive declines in catch allow the calculation, with statistical confidence intervals, of the population density for fish of differing sizes (Seber & Le Cren, 1967, Carle & Strub, 1978). Where large numbers of quantitative surveys have been done it is possible to calculate least squares regression lines allowing the estimation of actual fish populations from a single electric fishing sweep of a stretch.

Electric fishing is a skilled and hazardous operation - you must have Environment Agency consent before carrying out any work. Also, poor practice can lead to fish damage (broken backbones) and even to mortalities - it is essential to know what you are doing, the Environment Agency (1996) have published a code of practice for safety in electric fishing operations. Electric-fishing should only be carried out by suitably qualified and experienced operators using appropriate equipment.

Sea trout abundance is much more difficult to establish as fish will often be stopping in a fishery temporarily on their way upstream. Some may stay for weeks, some may move straight through without stopping. A very few rivers have fish counters that allow the estimation of sea trout runs. Usually, the best available (retrospective) data come from sea trout net catch returns and from angling catch records. Both sources of data can be prone to a number of errors. Whilst it is possible to incorporate estimated correction factors to obtain more accurate catch records, these data still need to be treated with care. Encouragingly, however, when catches from differing rivers are related to effort (Catch per unit effort, CPUE) and are plotted on the same time axis they tend to fluctuate together indicating that catches really do provide a reasonable index of actual sea trout stock abundance (Elliott, 1992). Care needs to be taken with sea trout net catch data for recent years owing to reduced netting effort in the spring imposed to conserve spring salmon. This will cause early-running fish to be missed. Also, in general, nets may tend to select larger sea trout, leading to over-estimates of average size and artificially skewed population structures for a given river. Some rivers have late-running sea trout stock components that are missed by anglers, netsmen and by routine scientific surveys - such populations have, therefore, very poorly understood biology.

Perhaps the easiest way to assess sea trout presence on a fishery is to ensure that anglers provide accurate catch returns and that these are monitored through the season and from year to year. The sooner records are kept, the sooner a picture of the performance of a given fishery can be built up. Bear in mind, however, the renowned fickleness of sea trout - there may often be many more fish present than you would imagine from studying catch records alone. Bouts of pollution, for instance, can reveal large-scale mortalities on fisheries that were thought only to have few sea trout present; an example was on the River Ogmore in south Wales. Upstream migration of sea trout in summer can occur even under low-flow conditions. Sea trout stocks show fascinating variations in run-timing, size at return as maiden fish, frequency of multiple spawning, growth rates and other factors. Much remains to be studied and elucidated in sea trout ecology; Solomon (1994) and Harris (2002) provide well analysed and referenced reviews for English and Welsh stocks.

2.2.2 The Environment Agency Fisheries Monitoring Programme

The Agency reviewed fisheries monitoring practice in England and Wales from 1998-2000, producing a new consistent, statistically robust programme designed to serve its business needs in Fisheries and to support Conservation - the National Fisheries Monitoring Programme (NFMP). The NFMP is currently being implemented and developed, its main components are:

- Index monitoring; detailed fish population dynamics studies on a small number of type-specific rivers.
- Core monitoring; long-term sampling strategies to identify trends in exploited fish populations by sites (spatial) and through time (temporal). This includes annual quantitative and 5-yearly semi-quantitative surveys. Salmonid surveys will concentrate on spatial aspects of population biology. Fish counter, netting return and anglers log book information will also be used to augment the core survey data. Information is stored in the National Fish Population Database (NFPD). The NFPD includes information on physical details of sampling sites, habitat measures, sampling methods, details of fish caught, recorded as individual fish or grouped by species and size/age. Analyses will routinely produce information on population estimates, biomass, age/growth, and species composition.

At the time of writing the Salmonid Core Monitoring Programme incorporates monitoring on 340 river sub-catchments, representing 29,000 km of river. Four categories are included:

- Salmon Action Plan (SAP) rivers (with or without sea trout).
- Major sea trout rivers (with no SAP).
- Principal brown trout fisheries (minimum 80% of catch wild fish)
- Sentinel rivers, where salmonids are present but do not fall into above categories.

Outputs from the monitoring programme will be very valuable for reviewing the status and performance of brown trout, sea trout and grayling fisheries. Area fishery staff are able to provide information at the local level.

2.2.3 Factors limiting trout production through the life cycle

Fish population abundance can be limited largely by single factors or by combinations of lesser impacts. Population bottlenecks can occur at any stage of the life cycle, as the diagram below shows:

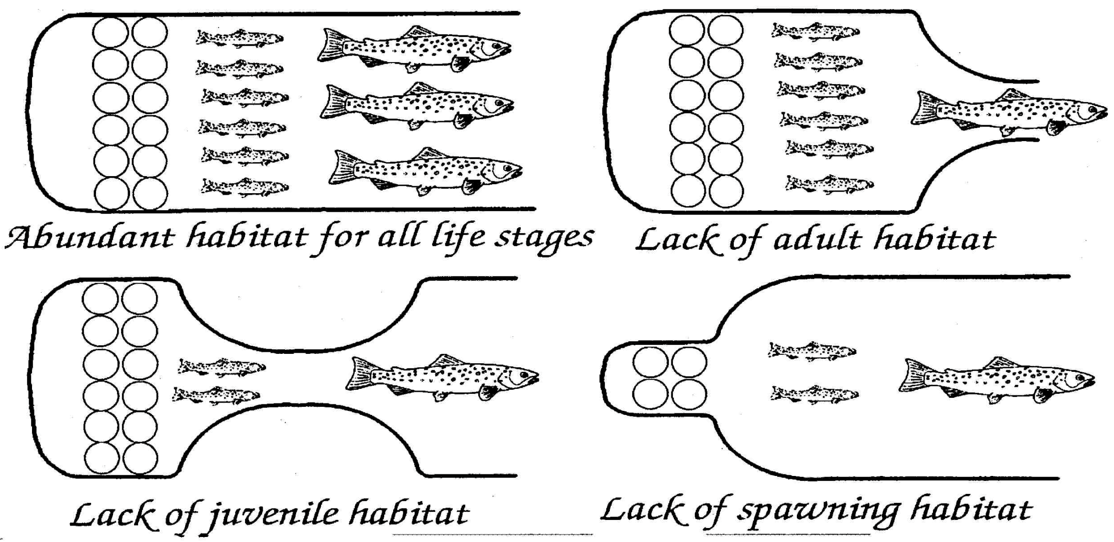

Figure 9 Examples of trout population 'bottlenecks' (EA, 1996)

Factors that may limit trout populations at differing life cycle stages include:

- For eggs: numbers of spawning adults, access to spawning gravels, silt levels in gravel, predation, wash-out of eggs in spates, water quality (e.g. acidification effects).
- For fry and parr: low current velocity microhabitats with abundant invertebrate food supply and good physical cover, habitat loss, predation, water quality, flow regimes.
- For sub-adults and adults: adequate amounts of well covered pool and glide habitats, water quality, flow regimes, predation, exploitation, abundant invertebrate food supply.

Management options (see also chapter 8 - Habitats)
Trout rivers need managing holistically in the context of catchment land use, water supply and quality and fish stock status. One way to assess the need for trout habitat management is to split up the river into areas relating to the life cycle of the fish:

Spawning areas

- Targeting and buffering diffuse silt inputs (ploughing, ditching, erosion by stock) to improve conditions for egg incubation.
- Assessing the area of gravel suitable for spawning accessible to fish. Where necessary, adding clean gravel to build new spawning riffles, de-silting existing gravels with high-powered water jets to ameliorate high levels of fine sediments (obtain agreement of Agency and downstream fisheries before mobilising large amounts of silt).
- Using stream-side egg incubator boxes (check first that spawning success is very low), these can help overcome chronic gravel siltation problems. Care is needed on Native trout waters to maintain genetic diversity via wild broodstock management -

use eggs and milt from a broad cross-section of the wild stock, rather than hatchery-derived eggs (see chapter 15 - Stocking).
- Removing obstructions to upstream migration (see chapter 13 - Screens and Obstructions).
- Assessing habitat quality and, where appropriate, instigating better habitat management of spawning streams and nursery areas to increase carrying capacity (see chapter 8 - Habitats).
- Note that rain-fed rivers tend to have their principal trout spawning and nursery areas in headwaters and tributaries whilst chalk streams may have spawning areas on gravel riffles almost anywhere in the system. The separation of breeding and adult salmonid habitats for chalk stream fisheries management is, therefore, not easy. This is an important consideration in the designation of Wild fisheries protection zones (see chapters 1 and 15).

Fry and parr habitats
- Habitat management to promote fry and parr survival (e.g. plentiful complex cover), increasing carrying capacity through stream restoration projects.
- Conserving stream flows (see chapter 7 - Water Quantity).
- Targeting point and diffuse pollution sources other than silt (e.g. silage liquor, cattle / pig slurry, sheep dip, see chapter 6 - Water Quality).

Adult habitats
- Habitat management for maturing and adult trout (e.g. deeper pools, more cover), to increase carrying capacity. Consider setting aside un-fished refuge areas.
- Conserving flows and water quality,
- Managing exploitation (methods, size / bag limits, catch-and-release (chapter 20)) and, where necessary, predation (see chapters 16 and 17 - Interactions).

Habitats for differing trout life stages are, very often, spread widely along a river catchment - spawning, migration and adult habitats; these need to be linked as a continuum for successful self-sustaining stocks. See Fahy, 1985, Hunter, 1991, Elliott, 1994, Solomon, 1994, Environment Agency, 1996, Environment Agency, 1998, Salmon & Freshwater Fisheries Review, 2000, Harris, 2002 and Environment Agency 2001 for further details and references on trout population ecology. Giles and Summers (1996) and Environment Agency (1996) provide advice on simple techniques to assess habitat quality and overcome wild trout population bottlenecks.

2.2.4 Trout recruitment

Juvenile wild trout surveys are routinely carried out by electric fishing operations. On small streams fry habitat areas are typically found downstream of gravel riffles on the tails of pools where spawning usually occurs. On larger river systems small tributaries typically act as spawning and nursery areas, with trout parr and sub-adults dropping downstream as they grow. This fact underlines the vital importance of good management of tributaries and headwaters as these areas are often the juvenile production centres for many miles of main river. An example of this is given in the figure below:

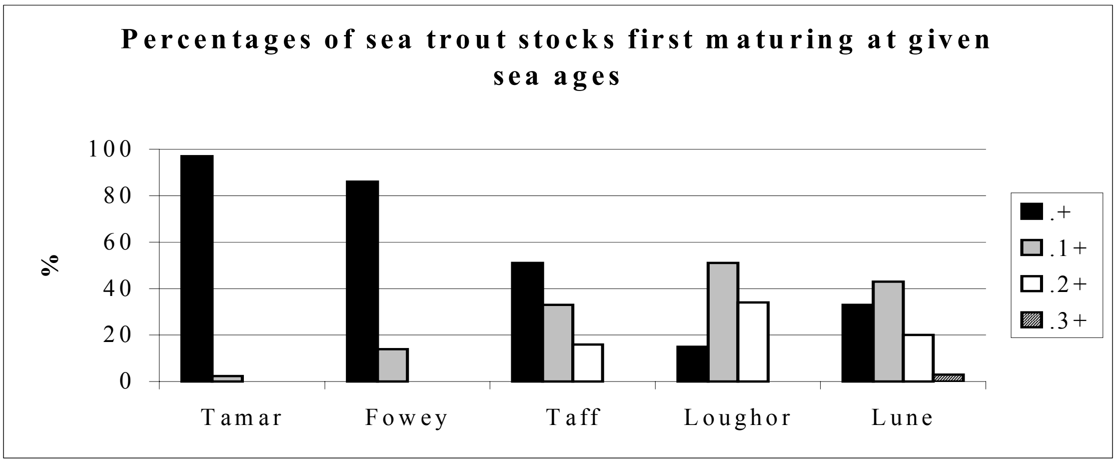

Figure 10 River Scorff, France, brown trout age distributions (after Maisse & Baglinierre 1999)

Key points to note are:

- The Kernac stream population is dominated by 0+ (over 60%) and 1+ (over 25%) brown trout.
- The upper River Scorff has fewer 0+ and more older trout.
- The lower river is dominated by adult trout older than 2+.
- The lower river stock migrates upstream in autumn to spawn in streams such as the Kernac.

Allen's (1935) major study of the Windermere wild brown trout population found the following:

- The majority of young trout enter the lake from streams at an age of 2 years although some 1 year- and 3 year-old fish migrate to the lake. Fast-growers migrate early.
- Most trout show most rapid growth in summer, gaining around 7cm in length each year.
- Trout of 40cm or larger feed mostly on small fish.
- The littoral-dwelling Windermere brown trout stock was estimated at around 12,000 fish - 50% in their third year and 25% in their fourth year of life.

Juvenile trout abundance

Environment Agency juvenile salmonid survey data are stored in the National Fisheries Population Database and are scored and assessed using the Fisheries Classification Scheme. The HABSCORE database holds a great deal of information on juvenile salmonid abundance related to habitat features for a range of river types. HABSCORE Manuals are available from the Agency's Salmonid Fisheries Science Group, Cardiff.

Whilst all rivers flow through varying countryside, it is possible to group them broadly according to predominant character. The table below provides some average trout fry and parr abundance data per 100 square metres from a variety of English and Welsh rivers. The field surveys were carried out in 1992 and 1993 and varying numbers of surveys were conducted on the various rivers mentioned. Note that wild trout densities vary greatly with the exact timing of surveys and local conditions; these data are, therefore, presented for illustrative, rather than predictive purposes.

Table 6 Juvenile trout abundance data for some English and Welsh rivers (provided by National Fisheries Technical Team, Cardiff)

River	River Type	Fry per 100m^2	Parr per 100m^2
Coquet	Moorland	151.5	90.8
Tees	Moorland	23.5	9.2
Tyne (North)	Moorland	68.9	16
Wear	Moorland	92.7	37.5
Ure	Moorland	28.7	1.9
Swale	Moorland	22.8	11.1
Wharfe	Moorland	73.7	10.2
Ure (Eller Beck)	Moorland	125	16.2
Stock Ghyll	Moorland	96.2	19.3
Troutbeck	Moorland	93.2	17.2
Dart	Moorland	15.5	14.6
Plym	Moorland	81.2	22.3
Lyd	Moorland	38.3	16.8
Dovey	Moorland	52.5	8.8
Yeo	Lowland	51.8	23.6
Tone	Lowland	36.1	9.9
Wyre	Lowland	49.8	5.9
Ribble	Lowland	0.89	0.74
Leven	Lowland	29.3	4
Lune	Lowland	26.6	10.1
Hodder	Lowland	2.8	1.2
Wey	Lowland	19.1	20.6
Tywi	Lowland	10.1	4.5
Tawe	Lowland	21.7	5.2
Hampshire Avon	Chalk stream	0	2.1
Piddle	Chalk stream	5.7	2.5
Bere stream	Chalk stream	7.6	1.5
Lambourn	Chalk stream	2.3	5.4
Frome (Dorset)	Chalk stream	9.3	1.3
Tadnoll Brook	Chalk stream	4.4	1.3
Bourne	Chalk stream	4.4	3.8
Coln	Chalk stream	1.57	3.5

Some key points to note from these data are:

- Trout fry densities on upland rivers can be over 100/100m^2 in high quality habitats and average 69/100m^2 in the above sample of 'moorland' rivers. Parr densities here can approach 100/100m^2 but average 20.8/100m^2 in the above sample.
- Lowland rivers (usually headwaters or side streams) tend to have lower trout fry and parr densities than moorland rivers, averaging 24.4/100m^2 habitat for fry and 8.6/100m^2 for parr in the above sample.
- Chalk streams, despite their reputation as premier trout waters tend, with their low gradients, small gravel and stable flows, to have relatively poor trout recruitment - 4.4/100m^2 for fry and 2.7/100m^2 for parr.

Juvenile salmonid densities tend to be a good guide to overall habitat quality as wild trout stocks are very vulnerable to habitat degradation processes. Serious declines in recruitment success soon knock-on to affect trout fishery performance - this is the point when fishery managers may suspect problems.

Abundance of 'takeable' trout

Judging whether sub-adult and adult wild trout recruitment to a fishery is adequate is best approached via the collection and analysis of detailed catch records. The usefulness of long-term catch records is illustrated by the study of Milner and Varallo (1988) on Llyn Conwy, Gwynedd - see Figure 11 below:

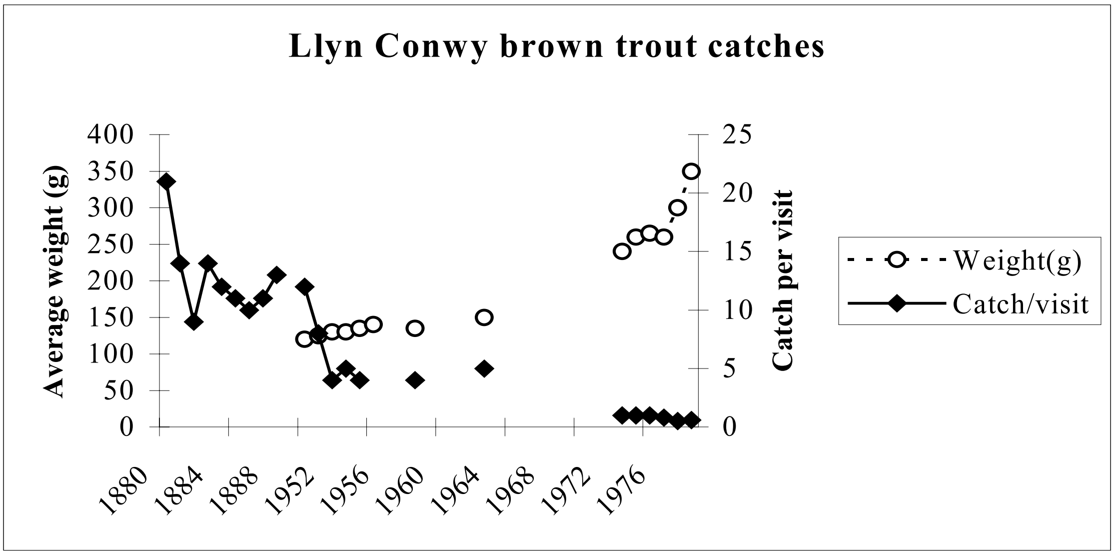

Figure 11 Long-term trout catch data from Llyn Conwy (after Milner & Varallo, 1988)

Several interesting points emerge from this analysis:

- In the late 19th Century anglers often caught 10-20 small wild brown trout per visit.
- By the early 1960s around 5 trout of 120g (4oz) was usual.
- By the late 1970s 1-2 trout was a typical bag, but the average size had risen to around 250g (8 oz).
- Stocking began in 1979 and average bags of 5 fish of around 8-12 oz were then maintained artificially.

Chronic long-term acidification (see chapter 6 - Water Quality) progressively suppressed recruitment; the few surviving wild fish in the late 1970s probably increasing in weight due to reduced competition for food. Stocking allowed a continued brown trout fishery but, of course, failed to address the root cause of the trout population problems.

Management options

- The Environment Agency Monitoring Review has produced a new system of core juvenile survey sites, fish counters, targeted investigation projects and angler log book schemes. Consult your Area Office for available information.
- Rod catch data for sea trout in England and Wales are recorded annually via the Rod Licence system. Licence holders are required to make catch returns at the end of each season. Annual analyses of catch statistics are published by CEFAS/EA.

- Individual fisheries can require members to make additional daily, monthly or annual catch returns - encouragement of catch returns is good management.
- The longer the run of data, the more interesting and valuable catch returns become.
- Establish a sound catch recording system and then don't change it, otherwise the ability to compare fishery performance between years may be lost.

Catch return information

When designing a catch return form consider including the following information:

- Date, river (lake), stretch, hours fished, time started.
- Number, sizes, species of fish caught, whether killed or released.
- Method of angling, water conditions (height, colour).
- Box for comments - useful for picking up important local information.

For season rods it is best to provide forms within water-proof covers and it is always worth following-up books that have not been returned. A prize draw for a rod or reel can prompt better return rates. An example of an Agency catch return book is given on the next page:

ENVIRONMENT AGENCY

NORTH EAST REGION

BROWN TROUT & GRAYLING ANGLERS LOG BOOK

EXAMPLE

RIVER: URE

LOCATION: Downstream of Kilgram bridge, upstream of Squirrel Bank.

DATE — PLEASE CIRCLE APPROPRIATE BOXES

DATE	1	2	3	4	5	6	7	(8)	9	10	11	12
	13	14	15	16	17	18	19	20	21	22	23	24
	25	26	27	28	29	30	31					
MONTH	JAN	FEB	MAR	APR	MAY	(JUN)	JUL	AUG	SEP	OCT	NOV	DEC

LENGTH OF TIME SPENT FISHING: 2 HOURS

CATCH — IF NIL TICK BOX ⟶ ☐

FISH No.	SPECIES (TICK BOX✓) BROWN TROUT	GRAYLING	OTHER PLEASE STATE	WEIGHT	LENGTH	METHOD	RETAINED IF YES TICK ✓
1	✓			12oz	11inches	DRY FLY	
2		✓		6oz	8inches	NYMPH	
3		✓		1lb 2oz	12inches	NYMPH	
4	✓			8oz	8inches	DRY FLY	
5	✓			1lb	12inches	WET FLY	✓
6			CHUB	2lb 4oz	14inches	DRY FLY	
7							
8							
9							
10							
11							
12							

WEATHER CONDITIONS: Warm, occasional sunny spells, slight SW breeze

RIVER CONDITIONS: Normal summer level, some algae in margins

FISHING CONDITIONS: Good

COMMENTS/OBSERVATIONS: Some mayfly and hawthorn flies. Two kingfishers seen

Figure 12 Angler's log book cover and example page

2.2.5 Increasing wild trout populations

The example of the Game Conservancy Trust project on the River Piddle, Dorset (see chapter 8 - Habitats) shows how directly wild trout fishery performance is linked to improved habitat quality. At the start of the study the upper Piddle was affected by chronic bank poaching by cattle, silt-inputs from ploughed land, a lack on many sections of diverse in-stream microhabitats, low flows affected partly by over-abstraction, pike predation, over-shading, impoundments and other factors. A broad-based wild trout fishery restoration project addressed many of these factors and has resulted in greatly increased wild trout densities (see Giles & Summers, 2000 and chapter 8 - Habitats). On the Dorset Piddle wild trout stock increases seem mostly to have been related to:

- Long sections of cattle fencing on previously badly eroded stream sections,
- Subsequent re-growth of marginal vegetation, narrowing the stream, increasing depths and current velocities, scouring gravels and providing cover for trout.
- Pool creation by building in-stream current deflectors and by excavating corner pools,
- Better *Ranunculus* growth in areas where riffle-pool sequences were re-established and/or where over-shading by mature trees was reduced,
- Increasing in-stream cover with timber structures,
- Coppicing willows to sky-light tunnelled stream sections,
- Control of pike populations by electric-fishing operations,
- De-silting spawning gravels with water-jetting apparatus.

Latest analysis of data from The Game Conservancy Trust (D. Roberts pers. comm.) has provided the results presented in chapter 8. Habitat improvement projects on many trout rivers are now becoming more commonplace. Successful projects by independent consultants, The Environment Agency, The Tweed Foundation, The River Restoration Centre, West Country Rivers Trust, Eden Rivers Trust, Northumbrian Rivers Trust, Wye Foundation, Wild Trout Trust, Grayling Research Trust, Game Conservancy Trust, Irish Fisheries Research Boards and others are establishing good practice. The River Restoration Centre maintains a database of river restoration projects and also provides a comprehensive manual of river restoration techniques that is available from its website.
http://www.therrc.co.uk/manual.php

Note that, on many salmonid rivers, spawning and juvenile habitats may often be situated largely in headwaters and tributaries, well upstream from significant rod fisheries. Adequate conservation of these nursery habitats can be a major challenge and funding often needs to be linked to the conservation and socio-economic fisheries benefits that are enjoyed lower down the catchment. This is a key reason why catchment-wide habitat appraisal and management is the ideal.

Management options
Promoting successful recruitment of wild fish involves:

- Knowing the stock size, age composition and potential bottlenecks in production.
- Analysing the need for habitat improvement,
- Producing a fishery management plan (see below),
- Implementing better habitat management,
- Regulating fishing pressure to well within the fishery exploitation potential,
- Releasing wild trout to conserve stocks, if necessary (see chapter 20 – Catch & Release).

Sustainable cropping
There are no simple 'rules of thumb' allowing the easy estimation of wild trout productivity. Everything depends upon the size and type of water body / river, its overall habitat quality, the health of the trout stock and the level and types of exploitation and natural mortality. In England and Wales so many rivers and still waters are routinely stocked, and have been for many years, that truly wild brown trout populations (those relying on natural spawning) are rare. Estimates of the population densities and population biology parameters of the wild stocks that we do have are rarer still. Consequently, direct calculation of likely sustainable yields will be a largely fruitless exercise. Indirect methods do, however, provide a partial answer to this problem.

Catch-per-unit-effort (CPUE)
By carefully monitoring catches it is possible to judge, over a period of time, whether CPUE is staying relatively steady, rising or falling. Clearly, a consistent falling average catch per unit effort is a danger sign.

If catch and effort data are unavailable, it is impossible to know how a fishery is performing. Despite this simple truth, few wild brown or sea trout fisheries keep accurate catch and effort records. In the event of a fishery having dissatisfied anglers, it is very difficult to provide any form of explanation or overview of the quality of the angling opportunities provided without hard data. A long and comprehensive set of catch records allows the analysis of typical seasonal trends, annual catches and trends in annual catches. In the absence of accurate information on actual fish stock abundance - and this is the usual situation for sea trout - all indirect information from catches is invaluable in appraising the status and performance of a fishery.

The example below for a real, un-named Welsh sea trout fishery (after Harris & Morgan 1989) shows classic declining catch, declining CPUE and increasing effort to try and maintain catches from a stock in decline.

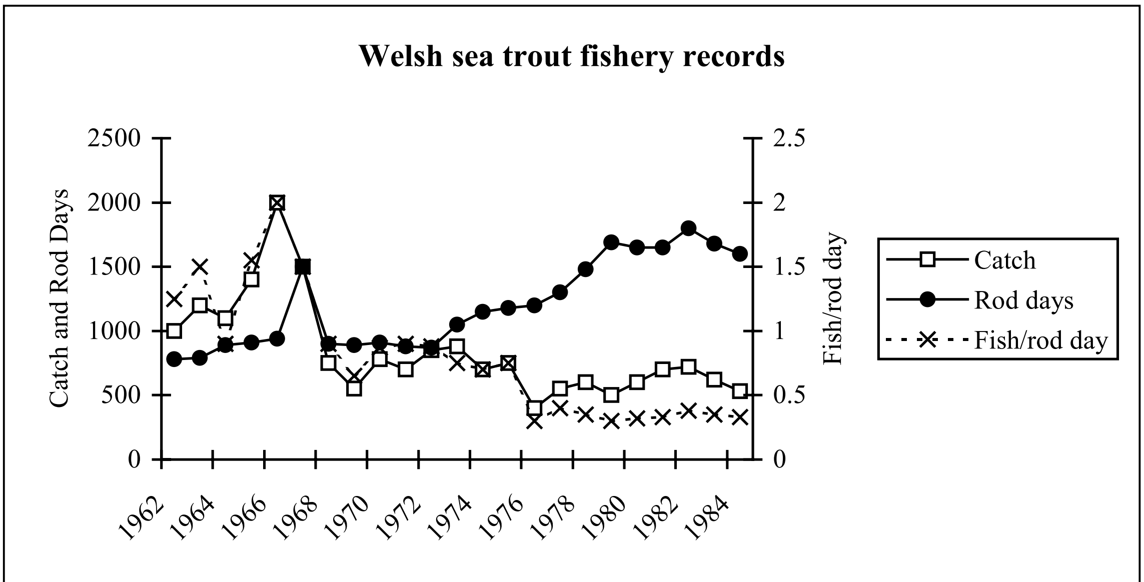

Figure 13 Welsh sea trout fishery - long-term rod catch data (after Harris & Morgan, 1989)

Population size structure
The size-frequency distribution of fish in a wild trout stock can reveal much about the health of the population. In a natural stock you would expect to find a 'pyramid of numbers' with many juveniles, intermediate numbers of sub-adults and low numbers of adults.

By requiring anglers to record the sizes of all trout caught (including any released), the fishery manager can soon compile a population profile of the catchable stock. If this is done annually it is possible to track the wild trout population structure. Clearly, danger signals for over-exploitation would include substantial reductions in adult numbers or size.

The Inver fishery (Connemara, Ireland) keeps long-term sea trout catch records that have shown fluctuations in catch number and average size, see Figure 14 on the next page and Fahy, 1985).

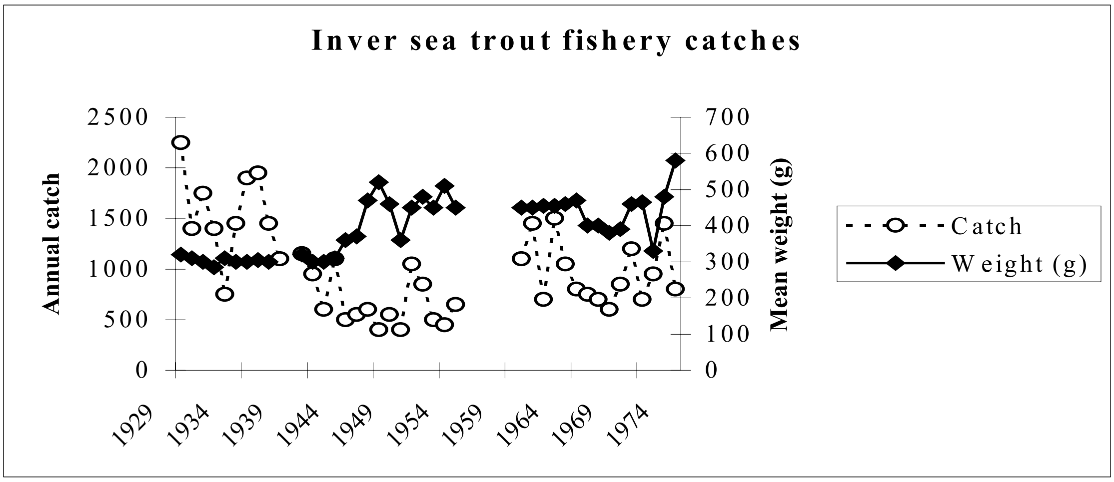

Figure 14 Inver fishery, Connemara, catch statistics

Fahy (1985) interpreted this data set as probably representing an increase in average size of sea trout (after 1945) in response to reduced harvest in previous seasons.

Population age structure

Scale samples, collected from live or dead fish can be very informative. Environment Agency Area staff may be able to get scales 'read' under a low-power microscope, providing estimates of the age and growth of the fish. Also, it is generally possible to judge how many times a fish has spawned from the presence of eroded 'spawning marks' (see Fahy, 1985, Solomon, 1994, Harris, 2002).

Scale Collection (see Environment Agency 'Guidelines for scale collection, storage & submission', National Fisheries Laboratory)

The collection of scales is a delicate procedure and care should be taken to minimise damage and stress to live fish.

- The fish should be placed on its right flank on a non-abrasive, wet surface to allow access to the scales on the left flank.
- A pair of forceps should be used to remove salmonid scales from the recommended area - above the lateral line just back from the dorsal fin. 5-10 scales are usually adequate.
- Hold the forceps parallel to the surface of the body, pointing to the snout of the fish. Slide one side of the tip of the forceps carefully between the scale and the body wall. Grip the scale with the forceps and gently pull backwards away from the head at a slight angle to remove from the socket. Do not pull the scale off at a sharp angle to the body as this may cause unnecessary damage to the fish. For the removal of small salmonid scales, it may be preferable to gently scrape off the scales with a blunt scalpel, in a snout to tail direction.
- In populations that are sampled frequently, some variation in the site of scale removal may be necessary to avoid replacement scales.

Regenerated scales, known as replacement scales, are characterised by the central area of the scale having a cloudy ‘crazy paving’ appearance. As the early growth history of the fish is absent from these scales, they are useless for ageing purposes. To ensure scales are not replacements, they can be held up to the light to check that centres are not 'cloudy'.

In order to be able to make detailed comments on population growth characteristics, it is recommended that scales should taken from at least 3 individual fish at 0.5cm length intervals across the length range captured. In larger size classes, it is recommended that scales be taken from all individuals. Scales from older fish can be more difficult to interpret and so a larger sample size should ensure greater accuracy in interpretation.

Scale Storage

- Once removed, scales should be placed into a small, paper envelope. The paper envelopes enable the scales to dry quickly, ensuring no deterioration in their quality. Wet scales should never be placed in plastic envelopes/ bags under any circumstance, as they will deteriorate in the damp environment, making ageing both difficult and unpleasant.
- The practice of placing scales in white paper inserts inside scale packets is discouraged as this makes their removal very difficult. It usually results in a paper residue being left on the scales, making reading very difficult.
- Any relevant details to the fish and the survey should be written on the scale packet. The following information should accompany each scale:-

Table 7 Fish scale envelope data

Essential Information	Useful Information
River/Lake	River stretch/location
Species	Weight of fish
Fork length	Sex of fish
Date of capture	Method of capture

© Nick Giles

Figure 15 ***Salmo trutta*** **smolt (above) and parr**

Age at smolting for sea trout in England and Wales
Solomon (1994) provides a wealth of information on sea trout biology in English and Welsh Rivers. Figure 16, below (after Solomon, 1994, Table 2.1) shows typical age distributions for sea trout smolts from a range of rivers:

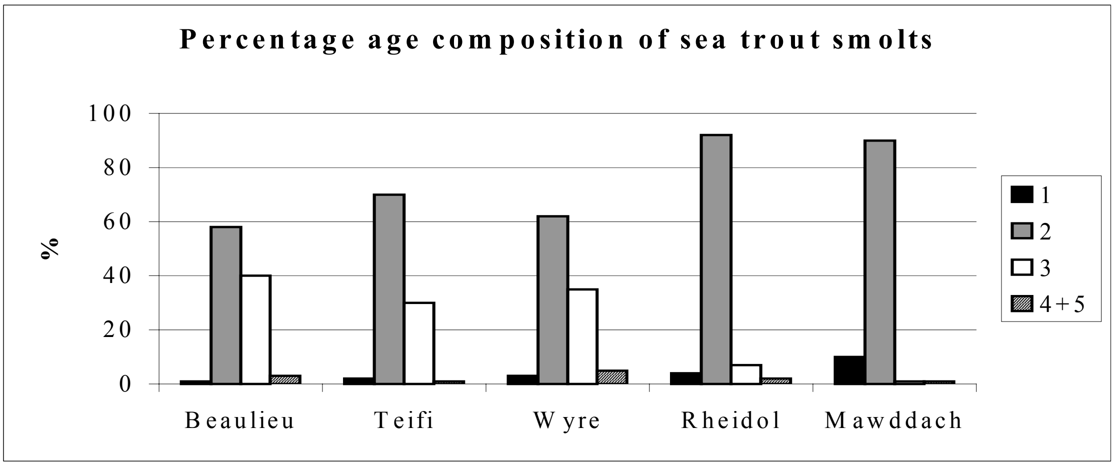

Figure 16 **Smolt age composition for some English and Welsh sea trout rivers**

Key points to note are:

- All five sea trout stocks produce mostly 2 year-old smolts.
- The Beaulieu River in the New Forest is a shaded, acidic stream with low trout growth potential and smolt ages tend to have a high proportion of 3 year-old and 4 year-olds.
- The Welsh Mawddach produces fast-growing smolts, many of which run to sea at 1 year of age and all others running the following year. Chalk stream smolts tend also to run at 1 or 2 years of age.

The following figure (after Solomon 1994, table 2.3) shows how sea trout growth and maturation at sea is revealed from scale reading studies:

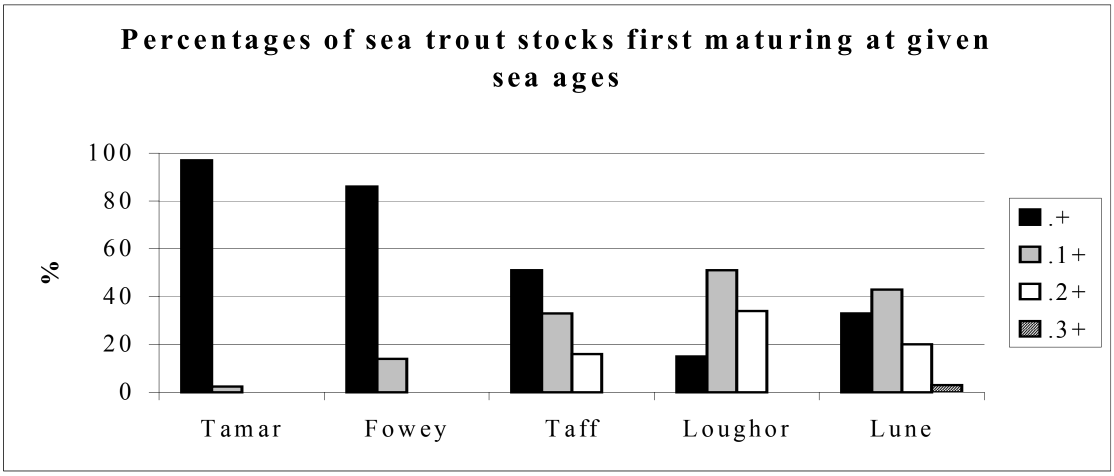

Figure 17 Percentages of maiden sea trout first maturing at given sea ages

Note that the Tamar stock has a high proportion of maturing finnock (whitling, peal), whilst, at the opposite extreme, the Lune stock has many more 2+ and 3+ sea age sea trout returning to spawn for the first time ('maiden fish'). Marine growth conditions are thought primarily to determine this life history characteristic. These are good examples of how ageing of fish can reveal important life history and fishery management data.

Sea trout scale reading conventions (see Nall, 1930, Fahy, 1985 and Solomon, 1994)

- Freshwater life is given as a number of years, with or without plus growth before a decimal point e.g. 3+.
- Post-smolt history is given after the decimal point, a finnock would be .+, a one-sea-winter maiden fish .1+, and so on.
- Spawning marks are designated SM, two spawning marks in successive years as 2SM, etc.
- A fish recorded as 3+.1+3SM+ has the following history:

Migrated to sea after three years freshwater growth with some plus growth after the last parr winter (3+). First matured after one winter at sea (1+) and spawned in each of the next three years (3SM). The + at the end denotes some plus growth after the last spawning mark and, if caught in a river, the fish was probably migrating upstream to spawn again. The total age of the fish at time of scale sampling is 7+ years (Solomon, 1994).

Trout scales

9+ year old sea trout scale with 2 years parr life and 6 spawning marks.

7+ year old lake brown trout scale with no clear spawning marks.

Figure 18 Examples of trout scales (from Fahy, 1985)

Clearly, the key objective in managing any wild game fishery is for long-term sustainability. With current angling pressures, only large rivers and lakes are likely to be able to sustain any significant degree of cropping of wild trout stocks. For the majority of smaller-scale wild fisheries, catch-and-release is likely to be the best option (see chapter 20 – Catch & Release)

2.2.6 Trout fishery management objectives

Trout fishery managers will generally be attempting to achieve the following:

- To make an adequate living and return on capital invested in the fishery.
- To provide a recreational resource to local and visiting anglers.
- To manage the fishery so as to conserve any wild fish stocks and to conserve wildlife generally.
- To develop a fishery management plan that encompasses financial, environmental and social aspects of the fishery and to implement that plan.

Agency fisheries staff are willing and able to help with many aspects of this planning process.

Fishery management plans

All fisheries benefit from a written management plan, that includes a large scale map, annotated with habitat and other work needing to be done, the locations of species/habitats of special conservation interest, stock assessment information, catch records related to effort, trends in performance, feed-back from anglers and a time-tabled development plan. The fishery manager may need specialist advice in compiling the plan but will then be responsible for implementing it and regularly checking the outcomes of the various actions.

2.3 Summary of Management Options

Table 8 Game fish management options and good practice

Issue	Management options	Good practice notes
Determining brown and sea trout stock densities	Record and analyse rod and net catch returns. Assess whether some stock components may not be being sampled owing to early or late running fish or restricted methods, etc. Conduct electric fishing surveys and visual observations if suitable staff / equipment are available.	Electric fishing needs Environment Agency consent and must be carried out by skilled experienced staff using correctly set-up equipment. Annual reports of sea trout catches, counter and trap data for key English and Welsh rivers are published annually by Agency.
Population production bottlenecks	Assess degree of gravel siltation Assess fry, parr, sub-adult and adult trout habitat quality.	Target and deal with point pollution sources. Buffer strips for diffuse inputs. Stream-side incubators to overcome serious gravel impaction and siltation – use wild parented fertile ova. Optimise habitat through carefully implemented management plan. Remove any obstructions to fish migration. Manage predation e.g. pike. Manage exploitation e.g. Size/slot/bag limits, method restrictions, catch-and-release.
Trout recruitment	Best monitored via observation of spawning, fry and parr plus catch returns and any available electric-fishing data and reports.	Design and administer catch record scheme. Note Agency electric-fishing surveys, reports, catch analyses.
Increasing wild trout stock	Assessment of fishery performance. Consider 'Wild fishery protection zone' status.	Take advice on need for physical habitat, water quality, river flow management projects. Implement recommendations. Monitor results with electric-fishing surveys, CPUE analysis, population size-frequency and age-frequency charts. Read scales to assess growth and spawning frequency / age at maturity.
Switching from 'other' to Native trout water status.	Reduce stocking whilst optimising conditions for wild fish and monitoring fishery performance to sustain adequate catches.	Slowly reduce stocking densities. Monitor catches to maintain adequate CPUE. Talk to anglers to assess their satisfaction with fishery. Maximise wild trout carrying capacity of fishery and stock management.
Management objectives	To make an adequate living and return on capital invested in the fishery. To provide a recreational resource to local and visiting anglers. To manage the fishery so as to conserve any wild fish stocks and to conserve wildlife generally. To develop a fishery management plan that encompasses financial, environmental and social aspects of the fishery and to implement that plan.	Take all available free advice and consult experts where necessary. Implement plans carefully and monitor results assiduously. Maintain frequent dialogue with anglers to monitor satisfaction with fishery performance. Consider their suggestions for improvements to fishery management.

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3 GRAYLING ECOLOGY

3.1 Introduction

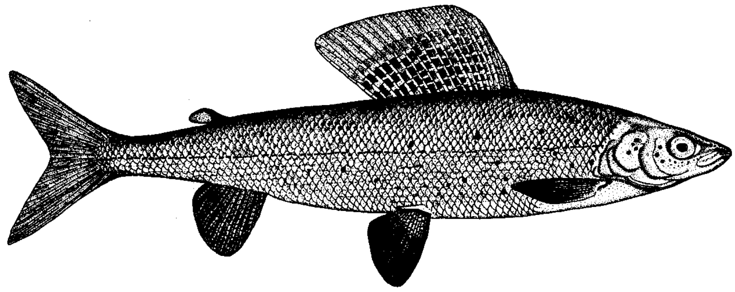

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Figure 19 Grayling

Grayling sustain valuable wild fisheries, thrive in good quality habitats and can be angled for by fly or bait. The season for grayling extends saleable game fishing opportunities through the winter months - an important economic consideration. Whilst virtually all stocks are riverine, in England and Wales there are two well known still water grayling populations - in Gouthwaite Reservoir, Yorkshire and in Llyn Tegid (Bala Lake) north Wales. Various other smaller still waters contain grayling.

Grayling are gaining in popularity with British anglers; membership of the Grayling Society is increasing at 10 to 15 percent annually (Grayling Society pers comm). Many anglers fish them routinely by catch and release and specialist fly-fishermen from Europe often visit the UK to enjoy its high quality grayling fishing. Large grayling are a key attraction, most specimens being killed for food in other European waters. UK grayling are, therefore, a locally important economic resource. Grayling also offer the opportunity of angling during the close season for trout and salmon although the current adopted "coarse fish" close season applied to grayling may not include the typical spawning time of grayling in all of England or Wales (Ibbotson et al., 2001).

Information on which English and Welsh grayling stocks are truly indigenous is currently lacking. Until this information is available Ibbotson et al (2001) recommend that grayling in rivers thought to contain indigenous stock, i.e. Ouse, Trent, Hampshire Avon, Severn, Wye, Thames, Ribble and Welsh Dee and their tributaries should be afforded high conservation status. They provide maps of current grayling distribution and notes on the provenance of stocks.

3.2 Technical and Practical Advice

Ibbotson et al (2001, and references therein) is the key literature source for the following sections.

3.2.1 Grayling competition with brown trout

- Where grayling and trout occur together they often occupy subtly different habitats (grayling in deeper areas with finer sediments, trout over the shallower gravely areas). But, when apart, each species will spread out to occupy both areas to some extent.
- The two species may have subtly different temperature preferences.
- Brown trout and grayling overlap, to a degree, in their preferred foods although grayling are more opportunistic feeders. The two species often forage in differing areas of river (grayling often in shoals, probing the substrate, trout taking invertebrates drifting in the current).
- Trout have seizing jaws with large teeth, grayling have smaller sucking jaws with tiny teeth.

Overall, given a diverse river system, it seems likely that the two species are adapted to live together, having evolved to avoid strong competition under most circumstances.

The National Trout and Grayling Fisheries Strategy (NTS, 2003) states that the historical practice of grayling removal to improve trout fishing is unfounded on scientific fact. Indeed, it is likely to result in a population imbalance with an increased abundance of smaller, earlier maturing grayling that are likely to detract from the quality of trout fishing.

The National Trout and Grayling Fisheries Strategy establishes the following policy:

Policy 11:
We will discourage the practice of removing grayling to improve trout fishing by providing relevant fishery owners with information about the effects of removing a large proportion of a grayling population.
We will not undertake any large-scale removal of grayling, except when the fish removed are required to re-establish a grayling fishery elsewhere.

3.2.2 Sustainable exploitation of grayling

Clearly, in some rivers, at least, grayling stocks are abundant and are harvested to some degree for human consumption. Care with exploitation is needed, however, as annual recruitment of grayling appears quite variable in some rivers, e.g. the Wiltshire Wylye (Ibbotson et al, 2001). Sustainable yields need careful judgement via analysis of fishery survey and catch data. This will be facilitated through the Agency Core Fisheries Monitoring Programme via the anglers log book scheme.

Longevity of grayling, in common with most fish, tends to be greater in higher latitude / altitude fisheries where temperatures and growth rates tend to be lower.

Grayling are readily aged from scale samples and their populations are, therefore, readily open to monitoring and analysis by this method:

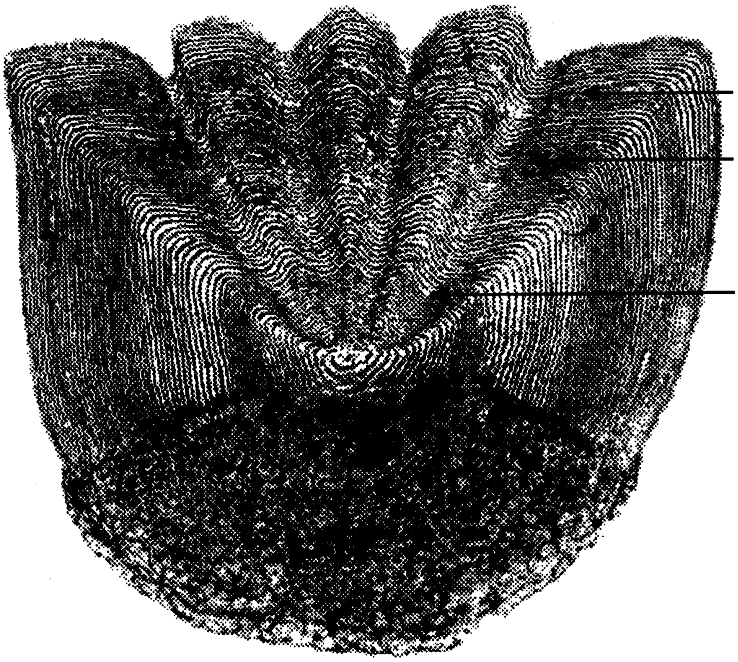

Figure 20 A scale from a 3+ year-old grayling (River Wylye, Wiltshire)

Sexual maturity in grayling is attained at ages 2-5 years. Maximum ages of 3-4 years occur on the Rivers Medway, Dove and Teise (Medway), perhaps 5 years on the Nidd, Severn and Test, 6-7 years on the Welsh Dee and Llyn Tegid and 10 years or over further north. Care in the interpretation of scales read from old fish is required as such individuals often show annual growth rings very close together towards the edge of the scale as growth in length slows markedly with sexual maturity and longevity.

Management options

As to how many grayling can sustainably be killed - this figure will vary widely between fisheries and years. To enable grayling to spawn at least once, Ibbotson et al (2001) regard a minimum angling size limit of 28cm as being suitable for English and Welsh grayling fisheries. The National Trout and Grayling Fisheries Strategy (EA, 2003) establishes:

Policy 9:

We will review the size limits, set by Agency byelaws, for non-migratory trout, char and grayling so that these limits will exceed the length at which fish mature. Only where it is apparent that wild stocks are depleted and that over-exploitation may be contributing, will we consider imposing additional mandatory restrictions.

Table 9 Environment Agency byelaws - grayling angling restrictions (after Ibbotson et al, 2001)

Region	Areas	Size limit (cm)	Bag limit / day	Closed season
South West	All Areas	25	2	15/3 - 15/6
Southern	All Areas	None	None	15/3 - 15/6
Thames	South East, North East, North West	25	2	15/3 - 15/6
Midlands	All Areas	20 all rivers except 15 on Severn, Vyrnwy, Banwy, and Tanat.	None	15/3 - 15/6
Wales	All Areas	None	None	15/3 - 15/6
North West	All Areas	23	None	15/3 - 15/6
North East	Dales / Ridings Northumbria	18 23	6 6	15/3 - 15/6 15/3 - 15/6

Catch and release

It is worth reiterating the attraction for anglers of specimen fish and the worth of returning grayling on a routine catch-and-release basis, as advocated by The Grayling Society Angling Code. Agency Policy developed in the National Trout and Grayling Fisheries Strategy (EA, 2003) is:

Policy 10:
To improve the quality of fishing for wild trout and grayling, and to reduce the risk of excessive exploitation, we will encourage anglers to release a greater proportion of their catch of wild fish. We will provide readily accessible advice to anglers on ways to improve fish survival after release, and to fishery owners on the benefits of 'slot' limits.

Local decisions based on the best available catch and population survey information are the way forward for sound grayling fishery management. CPUE (e.g. catch per hour or angler day) should be managed so that stock levels and structures remain stable in the medium to long-term. As with all fisheries, this requires a good catch recording and collation scheme. The Agency Core Monitoring and logbook schemes will provide size frequency and other grayling population information to help identify and rectify declines in abundance.

3.2.3 Stocking grayling fisheries

The National Trout and Grayling Fisheries Strategy (EA, 2003) notes that stocking with grayling is comparatively uncommon but has been undertaken in the past to generate new fisheries or in mitigation for pollution incidents. The Salmon and Freshwater Fisheries Review (MAFF, 2000) recommended that grayling should not be spread beyond its natural range. Agency Policy developed in the National Trout and Grayling Fisheries Strategy (EA, 2003) is:

Policy 21:
We will only permit stocking into rivers, streams or other un-enclosed waters in catchments where the grayling is already present, except possibly:
- **to re-establish a previous population (even if introduced); or**
- **for rivers recovering from long-term gross pollution where wider consideration will be given to the species stocked and the type of fisheries that might be developed.**

Stocked grayling must have a suitable, generally local, provenance.

3.2.4 Grayling water quality requirements

Table 10 below provides information on known grayling water quality requirements:

Table 10 Grayling and water quality

Parameter	Value	Notes
Water temperature	Optimum 18°C. Upper critical >18°C. Lower critical 0-4°C.	(Ref Crisp, 1996). Grayling stocks seem vulnerable to low-flows and very hot weather.
Acidity - pH	Optimum 7	(Baars, 1999)
Aluminium toxicity under acidified conditions	More sensitive than brown trout.	(Poleo et al, 1997)
Dissolved oxygen (DO)	Minimum 5-7 mg/l @ 18-20°C. Larvae may tolerate lower DO levels.	(Duvernay, 1975)
Organic pollutants	More sensitive than trout.	Grayling have smaller livers and thus lower detoxifying enzyme concentrations than trout (Jervis, 1999)

Despite few analytical studies it does appear that grayling may well be less tolerant of many commonly encountered pollutants than brown trout. This merits further investigation to underpin efforts to conserve grayling.

3.2.5 Physical habitat improvements for grayling

Grayling occupy a cool, well-oxygenated, medium-paced zone in many rivers with sequences of runs, riffles and pools (Huet, 1959). The 'grayling zone' is typically downstream of the more turbulent, faster 'trout zone' and upstream of the more placid and warmer 'barbel zone'. Self-sustaining grayling stocks usually require the following habitats (after Ibbotson et al, 2001 and M. Sidebottom pers. comm.):
- Relatively silt-free spawning gravels / fine chalk nodules.
- Sheltered margins with draping vegetation cover where young fry can gain strength out of the current.
- Gravely weedy shallows for juveniles.
- Sheltered glides for shoals of sub-adult fish.
- Sheltered deeper pools for adult fish.

It is worth noting that grayling can also do well in lakes and in relatively uniform, engineered river channels, such as in the upper reaches of the River Tern (Midlands Region) and in the lower River Test, indicating considerable adaptability in the species. Information on habitat improvement is given in chapter 8 - Habitats. Projects to improve grayling habitats will often be combined with trout habitat projects and may be collaborative efforts between angling interests, riparian owners, sponsors, relevant Trusts and the Environment Agency. The National Trout and Grayling Fisheries Strategy (EA, 2003) includes the following policies:

Policy 2:
We will work with others to promote angling for trout and grayling within the context of environmental protection and integration with other forms of recreation.

Policy 8:
We will work to develop conservation targets for the abundance and structure of wild trout and grayling stocks against which the status of these stocks can be assessed. Once set, failure to comply with conservation targets will trigger management action, including investigation of the likely causes.

The Environment Agency intends to use the following criteria of success for its National Trout and Grayling Fisheries Strategy:

Table 11 Criteria for success with grayling, trout and char fisheries

Outcome	**Measures**
Thriving populations of wild trout and grayling	Compliance with agreed conservation targets
Genetic diversity of wild populations protected	Compliance with stocking policy
Good and improved trout and grayling habitat	To be developed for water quality, quantity & physical habitat
Improved opportunities for trout, sea trout and grayling angling for different sectors of the population.	Distance to nearest available site offering a given type of angling. To be developed for sites with facilities for disabled anglers.
Increased participation, overall and for disadvantaged sectors of the population.	No. of trout/coarse licences sold in different categories (Full/Junior/Disabled/Senior). Proportions of licence holders fishing for 1. Trout, 2. Sea trout, 3. Grayling. No. of days spent fishing at different types of trout and grayling fishery.
Increased tourist expenditure associated with trout and grayling angling.	No. of trout and grayling fishing trips involving an overnight stay.
Increased environmental awareness	Preference for fishing for wild fish. Proportion of anglers practising voluntary catch-and-release.

3.3 Summary of Management Options

Table 12 Grayling fishery management options and good practice

Issue	Management options	Good practice notes
Competition with trout	Remove grayling regularly or leave relatively natural population.	There is little evidence of significant competition between grayling and trout. Therefore it is better to allow grayling stocks to self-regulate in good habitat.
Harvesting	Grayling are often a prolific species. Care is needed to watch for poor recruitment years and to manage accordingly.	Record catches, analyse and monitor CPUE, maintain fishery performance via regulations. Recommend 28cm lower size limit. Consider upper size limit to conserve specimens (a 'slot limit'). Fish catch-and-release if CPUE drops significantly - Core Monitoring and angler log book scheme.
Water Quality	There is evidence of sensitivity of grayling to a number of WQ variables. It is especially worth pursuing all opportunities to protect Water Quality on grayling fisheries.	Take care to protect fishery Water Quality by all available means. Liaise with Agency staff to ensure that potential problems are appreciated and monitored.
Physical habitat	Self-sustaining grayling stocks need good quality habitat.	Approaches to habitat improvement as recommended for wild trout should generally be applicable to grayling. Note the importance of low current velocity areas ('dead zones') for grayling larvae and small fry.

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4 ARCTIC CHAR ECOLOGY

4.1 Introduction

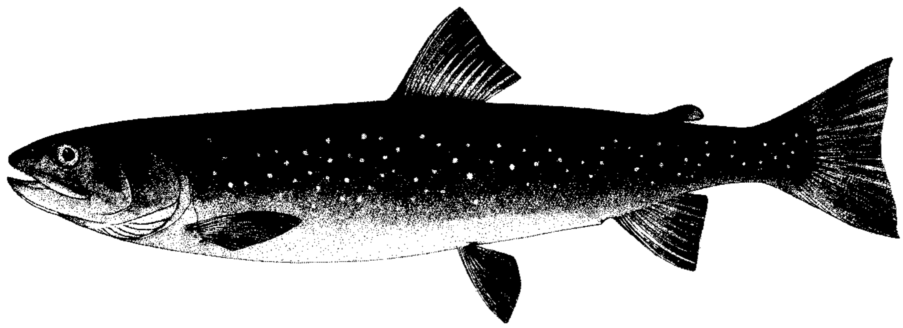

Figure 21 Arctic char

The arctic char, *Salvelinus alpinus* is of considerable fisheries and conservation importance in arctic, alpine and temperate lakes of the northern hemisphere, where they have the most northerly distribution of any freshwater fish. Many lakes have char alone, in others they may live with lake trout, brook trout, brown trout, whitefish (Coregonids), ciscoes, burbot, pike and sticklebacks. Whilst many thousands of char stocks remain world-wide, many have been lost through various forms of habitat damage (Maitland, 1995). Perhaps the severest damage has occurred in southern Norway where acidification has led directly to the extinction of 200-300 stocks with many more in decline (Hesthagen & Sandlund, 1995). Climate change may also threaten some southerly char stocks.

Langeland (1995) recognises four different sized forms of arctic char:

- dwarf (typically adult at 10-100g),
- normal (100-500g),
- anadromous (300-3000g) and
- fish-eating (500-3000g).

The fish-eating form of char is a parallel of the *ferox* form of wild brown trout. *Ferox* also normally co-exist with and eat char. Cannibalism may be an important factor determining char population characteristics (Svenning & Borgstrom, 1995).
Char populations often exhibit two or more morphological types linked to differing lake habitats (e.g. benthic and pelagic). These types may differ in timing and site selection of spawning, body shape, size and colour, micro-habitat use and diet, amongst other characters. Whilst studies are relatively few, these differences appear to have differing degrees of heritability and reproductive isolation. Char stocks have developed plastic morphologies and life histories in response to prevailing environmental conditions. It may be that Arctic char are currently undergoing the early stages of evolutionary adaptive radiation throughout their range (Savvaitova, 1995).

In the UK, Windermere char have distinct separate spawning stocks, with at least four races of fish (see below). Loch Rannoch in the Scottish Highlands has two morphologically and genetically distinct forms of char - a large mouthed benthic form and a smaller-mouthed pelagic form, each with its own typical diet (Gardner et al., 1988).

Arctic char have been exploited by man for thousands of years - often being a key natural resource for subsistence-dwelling human populations of the north. Exploitation commonly leads to dwarfing of char as large specimens are fished selectively from the population and earlier age at maturity is naturally selected for. As char usually grow slowly and mature late they can be very vulnerable to over-exploitation. Further north than the UK many char stocks behave essentially like sea trout with a migratory life cycle, land-locked stocks also commonly occur. Sea-going char spend the summer months in marine habitats returning to over-winter in their home lakes. All known UK char stocks are landlocked.

This manual, based on internationally published literature, provides management advice for char fisheries in England and Wales. The Cumbrian lakes have traditional char fisheries, for instance on Windermere, England's largest lake, where fish are caught on deeply-fished silver spoons. Windermere char include a high proportion of old individuals (aged from otoliths), indicating that the stock is currently not heavily exploited by either the rod or (research) net fisheries.

Elliott & Baroudy (1995) review the ecology of Windermere char that are split into separate spring- and autumn-spawning stocks in both the north and south basins;

Table 13 Windermere char stock characteristics

Autumn- spawning	Spring-spawning
Around 95% of adult char population.	Only 4-6% of Windermere population
Spawn November/December in lake shallows or River Brathay. Note Brathay spawning stock not detected in recent years (L. Black, pers com.)	Spawn February/March in deep areas of lake.
Large eggs, alevins and fry with relatively high survival (32%) to independence.	Small eggs, alevins and fry, low survival (3%) to independent fry stage.
Live mostly in pelagic (open water) zone.	Live mostly in pelagic zone.
Slow-growing, late maturing (7-8 years)	Slow-growing, late maturing (7-9 years)

British Arctic char could be protected, recognising their rare status or, given adequate management, (Langeland, 1995), there is no reason why char fishing should not take place on more UK lakes, reinforcing the recreational and economic values of the species. Note, of course, that stocks considered to be in danger should not be fished. Well-managed exploitation may confer greater conservation protection for the species than attempted preservation. This is the principle of 'wise use' of natural resources.

4.2 Technical and Practical Advice

4.2.1 Lake eutrophication

Eutrophication (nutrient enrichment with nitrate and phosphate) is a potent damaging impact on still water char habitats. The plant fertilisers, in themselves, are not toxic but the anoxia that can follow the decomposition of algal blooms that they fuel can severely limit habitat for char. On Windermere such algal bloom collapses have, in the past, deoxygenated large areas of the deep zones of the lake, forcing the char to move up into water that can be uncomfortably warm for them (Elliott & Baroudy, 1995). Water quality has improved in recent years but phosphorus stored in lake sediments may re-circulate for many years, fuelling periodic strong algal and cyanobacterial (blue-green algal) growth. Eutrophication effects are covered further in chapter 6 - Water Quality.

On the French-Swiss Lake Leman the endemic char population declined markedly in response to eutrophication but this commercial net fishery has been resurrected from a yield of 3-5 tonnes to 50-65 tonnes per year with a hatchery-based ranching programme. Wild char brood stock are used to produce the very large numbers of fingerlings stocked. This char population is fast-growing and early maturing (2+ years), as may be expected in this relatively productive lake (Champigneule & Gerdeaux, 1995). Whether stocking programmes might be appropriate for endangered English and Welsh char fisheries would require careful consideration by The Environment Agency and EN/CCW. Habitat enhancement of spawning areas may be a better way forward, where appropriate.

4.2.2 Spawning stream degradation

Whilst some char stocks spawn in winter on well oxygenated gravely lake shallows, others migrate to inflowing streams to breed. This is the case, for instance, for the Lake Ennerdale stock in Cumbria. These streams may be relatively small and vulnerable to a range of threats including:

- Changing peripheral land use such as intensive agriculture or forestry with consequent inputs of soil, silt, polluting chemicals (e.g. Synthetic Pyrethroid ,SP sheep dip), over-shading, reduced flows, over-grazed banks, etc. damaging spawning and nursery habitats.
- Pollution from mining operations or 'acid rain' with increased toxic metal concentrations and flushes of low pH water that can eradicate char eggs, alevins or fry.
- Dredging or gravel removal for land drainage or local aggregate use (e.g. for farm tracks) removing spawning and juvenile habitat.
- Ditching that can liberate large quantities of silt and sand that blanket stream beds.
- Water abstraction reducing flows and char nursery habitat area and quality in streams.

In Haweswater (Cumbria) water abstraction operations pumped large numbers of Arctic char (and schelly) out of the lake resulting in their death as part of the water supply for Manchester (Maitland, 1985). Whether this still occurs and, if so, whether abstraction causes overall stock depletion of either the char or whitefish appears to be unknown.

Many of these problems are amenable to better management, spawning stream restoration methods, for instance, are covered in chapter 8 – Habitat Quality and Improvement.

4.2.3 Species introductions

Fish communities in large natural lakes where char occur can be vulnerable to change through the introduction of other fish species.

Ecological interactions may include:

- Predation
- Competition for food and space
- Introduction of diseases and parasites
- Increased exploitation as a by-catch from new commercial fisheries

The best way to avoid these problems is to stringently apply legislation outlawing the release of non-endemic species into char lakes (see MAFF, 2000). To strengthen protection of Cumbrian char stocks The Environment Agency, North West Region has enacted byelaw (18) that prevents the use of live or dead freshwater fish as bait and prevents the possession of live freshwater fish with the intention of using them as bait in 14 named waters. Full details of this byelaw can be obtained from the Environment Agency website, www.environment-agency.gov.uk or by contacting your local Area office.

4.2.4 Catch regulation and exploitation

The example below shows how long-term CPUE angling data can help track the population abundance of wild game fish in large ecosystems - char in Windermere. The consistent technique of deep trolling with silver spoon lures allows comparison of catch data that indicate around a six-fold increase in char stock abundance in the south basin of Lake Windermere between the 1930s/40s and the 1970s/80s, (see Figure 20 below, after Mills & Hurley, 1990).

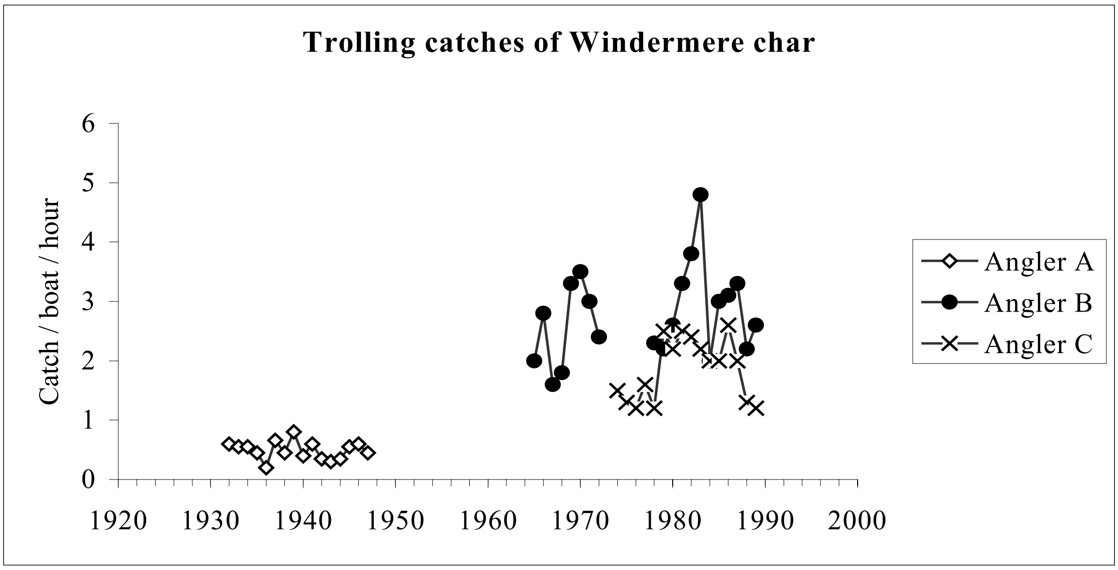

Figure 22 Long-term Windermere char rod catches

Char have a very restricted UK distribution, occur in important natural lake habitats and are vulnerable to over-exploitation. Since little research on sustainable char management has been carried out in the UK, long-term management of char stocks requires consideration of international experience. In the UK, in the absence of directly applicable applied scientific research, the precautionary principle will often need to be invoked to protect char stocks from a range of potential risks.

Management experience

Langeland (1995), who has performed long-term field experiments on exploitation of char in Norwegian lakes reached the following conclusions relevant to Norway.

Two approaches emerge; sustainable harvest or a sport fishery for large predatory fish:

1. Sustainable harvest: needs an upper size limit protecting the largest predatory char (and trout) from extinction. Both immature and mature char are harvested at maximum sustainable yield. Competing fish such as Coregonids need heavy exploitation to maximise resources for char management. This is acceptable in Norway where Coregonids are common but would be unacceptable in UK waters where Coregonids have a very restricted distribution.
2. Sport fishing for large predatory char (and trout): is low-yield as the top ecosystem production-tier is being cropped. The fishing areas should be rotated on the lake and a bag limit of 1-2 large fish per person per day imposed. No gill net fishery should be allowed on smaller lakes due to the vulnerability of the stocks of large

trout and char. In England and Wales, any exploitative net fishery for char is very unlikely to be acceptable to fishery managers and conservationists.

In the UK, Windermere char fishermen can take more than 2 fish per day and appear not to represent a threat to stocks. The small-scale scientific research net fishery on the lake also appears to cause no problems and yields important management information (see below). Clearly, all available information on the fished Windermere and Coniston char stocks is used with the objective of long-term sustainable management.

Langeland (1995) discusses the likely consequences of differing forms of predation/exploitation on a cohort (year class) within a hypothetical standard char stock first maturing at 3-5 years of age with a maximum age of 14 years:

- Predation on small char could reduce the population size by 50% and widen the first age at maturity but not affect maximum longevity.
- A well-managed sustainable harvest should leave the population structure largely unaffected save for the effective removal of the oldest fish - maximum longevity falling from 14 to 10 years.
- A selective fishery on large (predatory) char could increase the overall population size from the original to around double but, of course, reduce the population of the oldest/largest char.

In the Canadian Arctic undisturbed char populations tend to be characterised by stable structures with large and quite uniform adult size, high standing stock and high mean age (Johnson, 1987). After experimental fishing these stocks tend to return to their stable state. This may be due to the ecological nature of the habitat, naturally stunted stocks occurring in differing lake types or due to management conditions favouring differing stable states of char population. Langeland has shown that small-mesh gill netting can substantially increase numbers of larger fish in both char and brown trout populations whilst large-mesh gill-netting can soon wipe out larger individuals leading to classic 'dwarfing' of the stock.

These types of interventionist management of Coregonid and char stocks are acceptable in Scandinavia and Canada where there are many lakes holding these fish but, in the UK, because of their relative scarcity, both char and Coregonid stocks are very unlikely to be netted on an exploitative basis.

Yields

Annual yields from char lakes vary with ecological conditions from 0.5 - 2kg/ha in large deep Arctic lakes to 2-3 kg/ha in smaller oligotrophic lakes. Icelandic char lakes often yield 10-15 kg/ha and sometimes much more in particularly productive lakes. The long-term sustainability of these higher yields remains unknown, fishing may stimulate density-dependent survival and growth and stock turnover time can be halved, e.g. from 3 years to around 15 months through intensive fishing (Langeland, 1995). Char productivity may not, however, be as high as it first appears - natural char populations often seem to live at high standing stocks but with low turnover rates.

Brown trout yields in northern lakes seem to be in the same range as those for char, with char dominating clear water lakes and trout more productive waters.
To regulate catches effectively on any game fishery measures of both catches and stock or an effective index of stock are required. Indices of char stock abundance available to

fishery managers are usually catch-per-unit-effort (CPUE) data either from gill netting or angling or, unusually, SONAR stock assessments, carried out for research / monitoring. The examples for Windermere below; Figures 23 and 24 after Elliott & Baroudy, 1995 show the pattern of catches from research gill netting operations and angling activities from 1940 to 1994, a long and valuable data set:

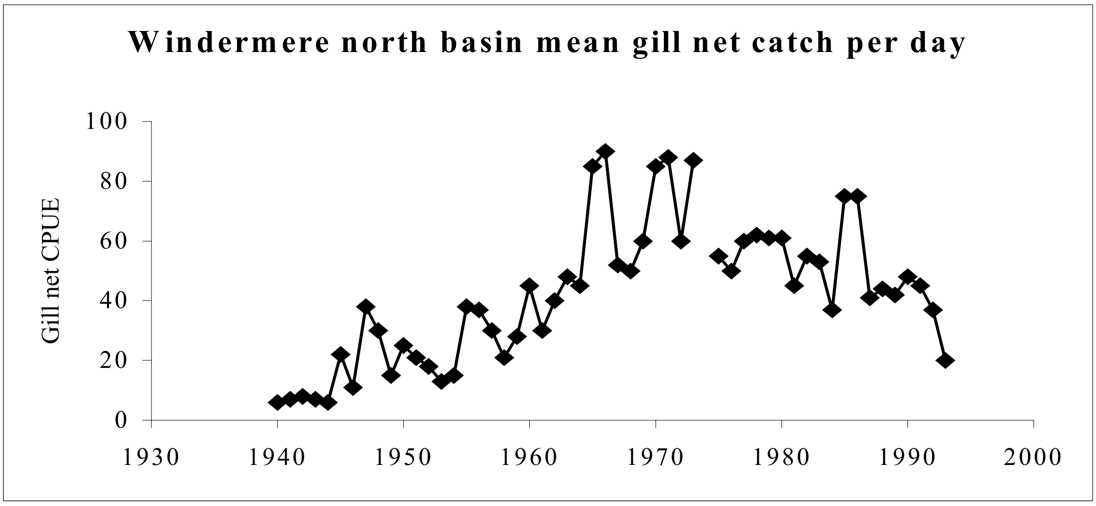

Figure 23 Long term gill net CPUE for Windermere char (after Elliott & Baroudy, 1995)

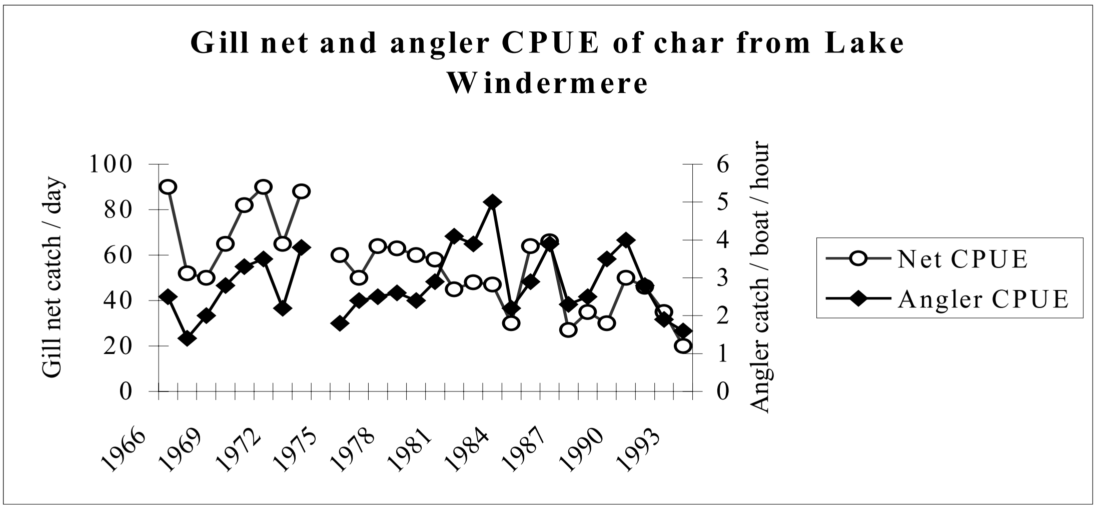

Figure 24 Long term gill net and angler CPUE for Windermere char (after Elliott & Baroudy, 1995)

These results allow the following observations:

- The upper graph shows how net catches in the North Basin peaked in the 1960s and 1970s.
- The lower graph shows how research gill net catches from spawning grounds and angler catches show generally similar fluctuations indicating that catches are probably shadowing actual char stock levels.
- Around 1980 angling catches increased whilst net catches declined.
- In more recent years both measures of char stock abundance declined.

Interestingly, the historic commercial net fishery for pike, perch, brown trout and char was halted in 1921 as it appeared, from catches, that overexploitation of the valuable char stocks was occurring. The classic signs of over-fishing were (Le Cren et al., 1972):

- Reduced fish size.
- Increased effort with smaller-meshed nets to try and maintain catches.
- Declining overall catches.

Regulation of char fisheries

Long term regulation of catches should seek to maintain viable stocks of all races of char. CPUE data help fishery managers to monitor relative stock levels and so are invaluable. On Windermere these data are augmented by regular echo-sounding surveys that assess pelagic fish stock (brown trout + char) abundance. Echo-sounder results generally correspond with angler catch data underlining the value of keeping long-term angling catch and effort information (Elliott & Baroudy, 1995). Note, however, that caution is required in interpretation of CPUE data alone. In Windermere char recruitment problems were revealed by echo-sounding surveys - these would have taken several years to show up in angler catch returns, by which time the stocks could have fallen to unacceptably low levels (M. Aprahamian, pers comm.).

4.3 Summary of Management Options

Table 14 Char management options - good practice

Issue	Management options	Good practice notes
Eutrophication	Great care is needed to conserve char habitat - good water quality being a key variable. Reduced Phosphorus inputs to Windermere have led to improvements there.	Char fishery managers should involve themselves with land use and development change in lake catchments to ensure maintenance of high water quality.
Spawning stream degradation	Small spawning streams are often highly vulnerable to land-use change, pollution, intensive agriculture, etc.	Char spawning streams should be buffered and carefully managed to optimise habitat quantity and quality.
Species introductions	Fish communities that include char are potentially vulnerable to a wide range of both direct and indirect ecological interactions with novel species.	Char fishery managers should do everything they can to ensure that new species are not introduced .
Exploitation	Char are potentially vulnerable to over-exploitation. Care is needed to regulate char fisheries, using CPUE and other survey data (ideally SONAR) to monitor stock abundance.	Char fishery managers should instigate catch return systems and, where affordable, routine population monitoring to ensure adequate long-term stock abundance.

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Note: references marked with an * are key sources of information.

5 FEEDING ECOLOGY

5.1 Introduction

Fly fishing

Central to trout and grayling fisheries is the production of fly hatches and the imitative fly fishing that this allows. Most river and still water trout fisheries rely primarily on hatches of 'upwinged' mayflies, stoneflies, 'sedges' - caddis flies and 'buzzers' - chironomid midges. On some waters, especially in unproductive systems, terrestrial invertebrates such as crane flies, caterpillars, beetles and grasshoppers falling onto the water surface are often eaten by trout.

On productive systems, the 'Anglers Mayfly', *Ephemera danica*, often provides excellent fishing in late May and early June. The key stages of the life cycle are shown in Figure 25 below: the aquatic nymph (a) matures into the emerging 'dun' (b) and then, subsequently transposes into the adult mayfly 'spinner', (c).

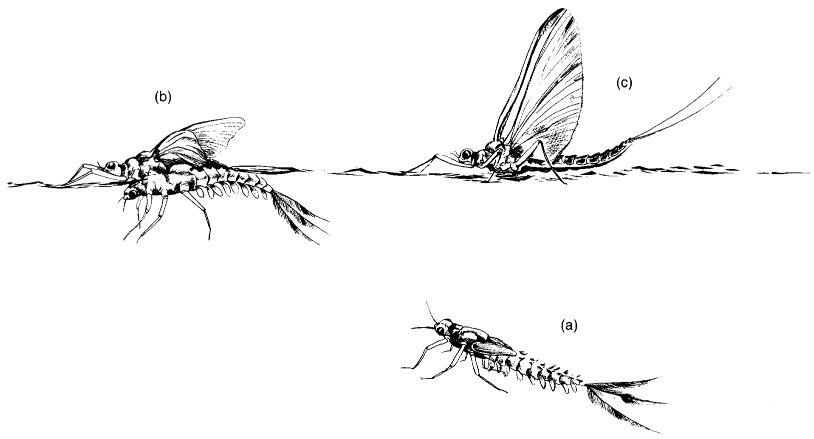


Figure 25 Key stages of Mayfly life cycle

Mayfly nymphs may be of several species, each adapted to specific habitat types:

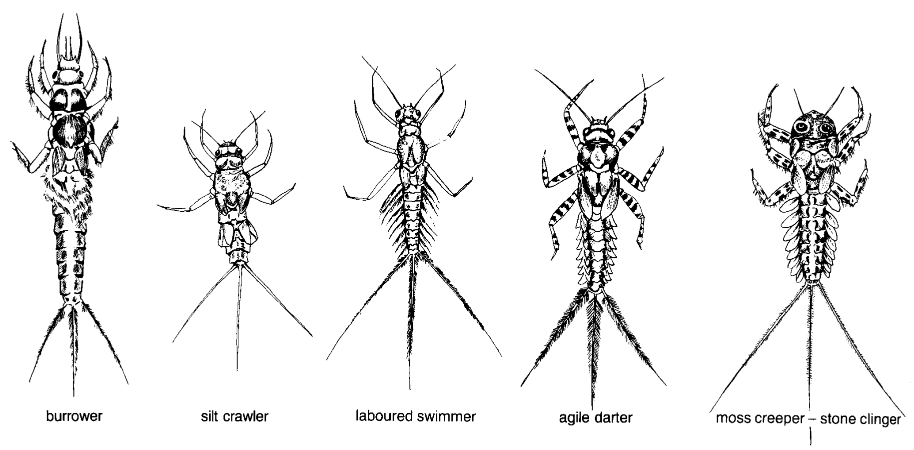
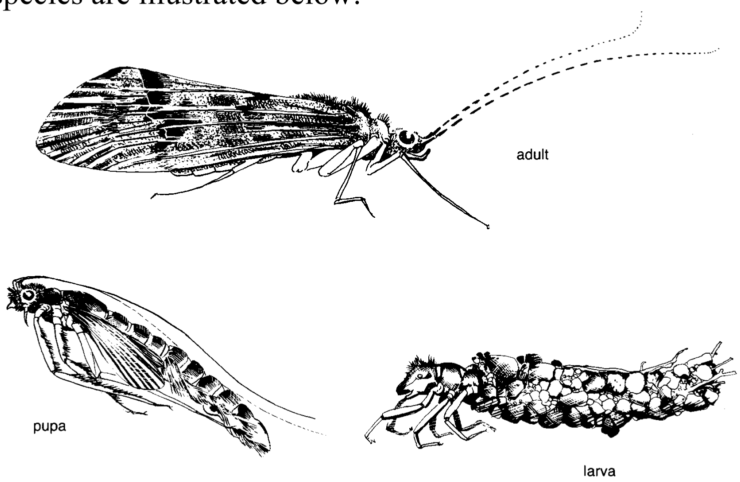


Figure 26 Mayfly nymphs

Caddis flies (Sedges), too belong to one of a wide range of species, some occurring only in clean streams, others being found in a wide range of fisheries. Caddis larvae are split into two major groups; filter-feeding caseless species that spin silk nets to catch drifting food particles and cased species that are mobile foragers. Key life cycle stages of a cased caddis species are illustrated below:



© Charles Jardine

Figure 27 Key stages of caddis fly life cycle

Chironomid midges (Buzzers, Duck fly) are, as a group, virtually ubiquitous in freshwaters and are important trout food on both rivers and still waters. Stoneflies tend to occur in more upland and less productive waters where their nymphs can be important trout dietary items. On still water trout fisheries flies tend to be dominated by buzzers, olives, mayfly, damsel flies, sedges and terrestrials such as craneflies, grasshoppers and heather beetles (Clarke, 1975). On rivers trout and grayling commonly eat upwinged flies, stoneflies, sedges, midges and terrestrials (craneflies, hawthorn flies, flying ants, beetles, grasshoppers, etc, see O'Reilly, 1997).

The groups mentioned above are the mainstay of insect trout diet although trout and grayling also often eat shrimps, snails, worms and many other groups of aquatic invertebrate as well as various small fish. On reservoir fisheries, in particular, coarse fish fry can be an important prey item for both brown and rainbow trout in the late summer and early autumn. Floating fry and submerged lure patterns are used by anglers at this time. Arctic char may specialise on planktonic or benthic food items. In some lakes stocks have differentiated into distinct morphological types with either small plankton-feeding mouths or larger mouths able to take macroinvertebrates and small fish (Walker, et al 1988, see also chapter 4).

5.2 Technical and Practical Advice

5.2.1 Trout feeding ecology on rivers

Figure 28 An upland trout stream

Anglers often wish to know what trout are currently likely to be feeding on and what flies best imitate these food items. Simple keys and illustrations to help anglers 'match the hatch' are given in Goddard (1988), O'Reilly (1997) and Greenhalgh and Ovenden (1998). Comprehensive scientific keys to identify various aquatic invertebrate groups to species are given in FBA keys (see reference list). A dead trout can be marrow-spooned to reveal its stomach contents - this is a very useful way of revealing recent diet and choosing an appropriate fly but it does necessitate catching a trout first! Failing this, observations of flies on the wing, flies floating on the water surface and trout activity can all give helpful clues to current trout feeding behaviour.

Table 15 on the next page gives an overview of the kinds of flies expected to hatch on still water trout fisheries through a typical season.

Table 15 Some key insect hatches on stillwater trout fisheries (after Goddard, 1988 and Church & Jardine, 1989)

Common name	Latin name	Timing and location
Duck fly, blae & black midge, buzzer	*Chironomus and other chironomid midges*	March-April and throughout season, during day and especially evenings.
Sepia dun	*Leptophlebia marginata*	April-May during day.
Hawthorn fly	*Bibio marki*	April-May during day often near hedge rows and trees.
'Mayfly'	*Ephemera danica*	May - June during day over silty lake beds.
Olive midge	*Chironomus plumosus group*	May-July, morning and evening over muddy lake beds.
Blue-winged olive	*Ephemerella ignita*	June-August, mostly evening hatches over weedy shallows
Angler's curse	*Caenis species*	June-August, mostly evenings, over silty beds.
Great red sedge, Murrough	*Phryganea grandis*	June-July late afternoon / evening near weedy shallows.
Pond olive	*Cloeon dipterum*	Throughout summer over weedy bays.
Lake olive	*Cloeon simile*	Throughout summer over weedy bays
Longhorn sedges	*Oecetis ochracea*	June-September, late evening in sandy/weedy bays.
Grousewing sedge	*Mystacides longicornis*	June-September, late evening in sandy/weedy bays.
Welshman's button	*Limnephilus lunatus*	June, late day in weedy shallows.
Coch-y-bonddu beetle	*Phyllopertha horticola*	Swarms on warm June days close to moorland.
Damsel fly nymphs and adults	*Various species*	Adults through day June-July, nymphs throughout season, especially in weedy shallows.
Large green midge	*Chironomus plumosus group*	July-August, morning and evening.
Large summer dun	*Siphlonurus lacustris*	August, during the day.
Crane fly	*Tipulid species*	August-September, during day close to grass fields.

Greenhalgh and Ovenden (1998) provide a beautifully illustrated and comprehensive table of the flies most likely to be hatching on all types of trout fishery through the year - it occupies 32 pages of text. Anglers who wish to learn how to choose and tie flies to imitate the insects that trout and grayling are eating are referred to the excellent books by Goddard, 1966, O'Reilly, 1997 and Gathercole, 1989.

An example of the key upwinged flies (Ephemeroptera) found in a Welsh river (after Pat O'Reilly & Melvin Grey, 1996) is outlined below. The keen trout / grayling angler would benefit from being able to identify at least some of these species. What may, at first, seem daunting soon becomes more familiar with practice and the help of knowledgeable fellow anglers.

Table 16 Fly hatches on the River Teifi

Common name	*Latin name*	Abundance
Mayfly	*Ephemera danica*	Moderately abundant in spring
March brown	*Rhithrogena germanica*	Moderately abundant in spring
Olive upright	*Rhithrogena semicolorata*	Abundant in spring
Autumn dun	*Ecdyonurus dispar*	Moderately abundant in autumn.
Large brook dun	*Ecdyonurus torrentis*	Moderately abundant in spring
Large green dun	*Ecdyonurus insignis*	Low abundance in summer
Yellow may fly	*Heptagenia sulphurea*	High abundance in spring
Dusky yellowstreak	*Heptagenia lateralis*	Moderately abundant in spring
Purple dun	*Paraleptophlebia cincta*	Low abundance in summer
Turkey brown	*Paraleptophlebia submarginata*	Very low abundance in spring
Blue-winged olive	*Ephemerella ignita*	Highly abundant in summer
Large dark olive	*Baetis rhodani*	Moderately abundant in spring
Medium olive	*Baetis vernus, Baetis tenax*	Highly abundant in summer
Small dark olive	*Baetis scambus*	Highly abundant in summer
Iron blue	*Baetis muticus*	Highly abundant in summer
Pale watery	*Baetis fuscatus*	Highly abundant in summer
Pale evening dun	*Procloeon bifidum*	Moderately abundant in summer
Small spurwing	*Centroptilum luteolum*	Highly abundant in summer
Large spurwing	*Centroptilum pennulatum*	Moderately abundant in summer
Angler's curse	*Caenis & Brachycercus species*	Highly abundant in summer

Finally, of course, it is worth remembering the importance of other invertebrate groups such as crustaceans (shrimps, water lice, planktonic species), molluscs (snails), worms, water beetles, water bugs (e.g. corixids) and others that feature widely in the diet of trout, grayling and arctic char.

Declines in chalk stream fly hatches

The Environment Agency routinely samples aquatic invertebrates from a wide range of rivers to monitor water quality. Samples are only taken from very small areas but Biology staff may have up-to-date information on how clean given rivers are likely to be and what sort of fly hatches to expect through the season.

Frake and Hayes (2001) report on a recent study of trends of aquatic fly abundance on chalk streams, finding that:

- Questionnaire responses from 365 fishermen, owners, club secretaries and keepers indicated a marked decline in fly numbers from before1939 to 1999.
- The major perceived phase of reduced fly abundance has been over the last 20 years and especially over the last ten years 1989 - 1999.

- The overall declining trend in numbers of flies occurs for Mayfly (*Ephemera danica*), Iron blue (*Baetis muticus*), Large dark olive (*Baetis rhodani*), Medium olive (*Baetis vernus*), Blue-winged olive (*Ephemerella ignita*) and various caddis flies.
- Midge numbers have remained high - possibly owing to their tolerance of reduced river habitat quality such as increased siltation and nutrient concentrations.

The National Trout and Grayling Fisheries Strategy (EA, 2003) includes the following policy:

Policy 25:
On appropriate fisheries, we will work with fisheries interests to identify key insect and plant species associated with fishing throughout the season, and where practical, adapt existing monitoring programmes to assess their abundance.

Figure 29 Chalk stream trout habitat

5.2.2 Trout feeding ecology on still waters

Lucas (1993) studied the diet of stocked brown and rainbow trout on a small stillwater fishery in Surrey. He found the following results:

- Brown trout tended to feed on small fish (sticklebacks) and lake bed-living invertebrates (Hog lice (*Asellus*), caddis larvae, Alder fly larvae, water beetles) whilst rainbows tended to feed more in open water, especially on water fleas (*Daphnia*) and midge pupae (buzzers).
- Chironomid midge pupae and adults (flies on the surface) were often eaten by both species.
- These results imply dietary separation of the two trout species except early in the season in April when both species fed on the lake bed on caddis and alder fly (*Sialis*) larvae.

Figure 30 below (after Lucas, 1993, Table 2) shows the overall (April to September) energy inputs from key food items for both brown and rainbow trout.

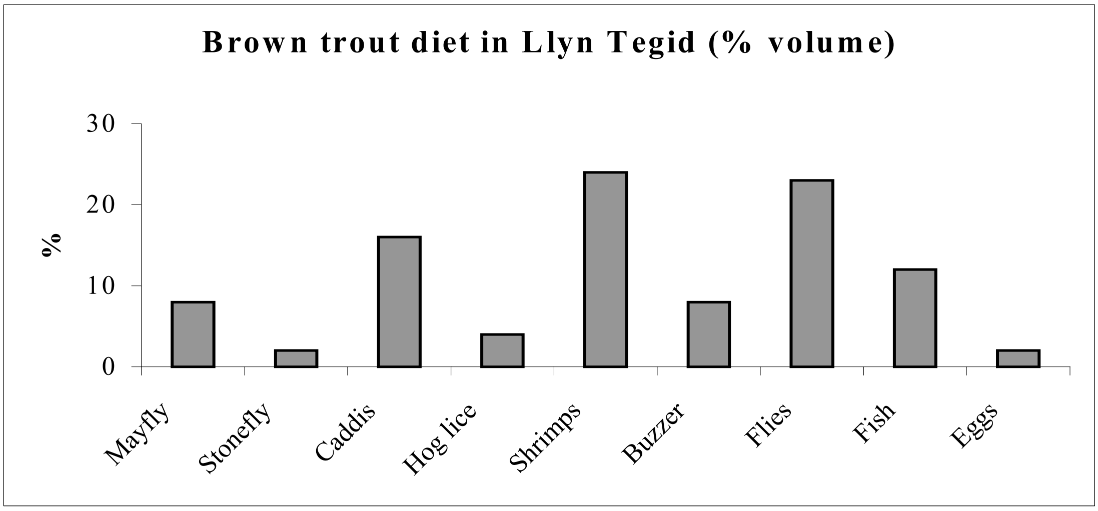


Figure 30 Percentage of total energy intake for brown and rainbow trout from a small still water fishery represented by key food items

Fitzmaurice (1979) showed that brown trout in lakes (Lough Sheelin, Ireland) will take large numbers of open-water planktonic crustaceans, in this case selecting the larger species, *Bythotrephes longimanus* over *Daphnia*. His data for trout from pelagic (open water) and littoral (shallow water) samples are summarised in Figures 31 and 32 on the next page:

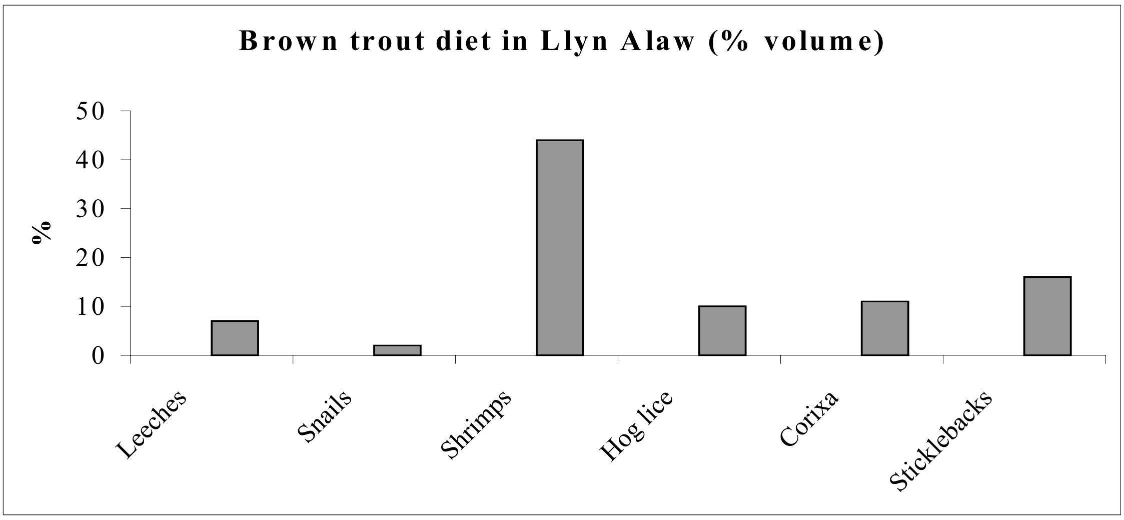


Figure 31 Lough Sheelin, Ireland - Pelagic trout diet (after Fitzmaurice, 1979)

It is instructive to compare these results with those below from trout sampled in shallow littoral habitats of Lough Sheelin (Fitzmaurice, loc cit):

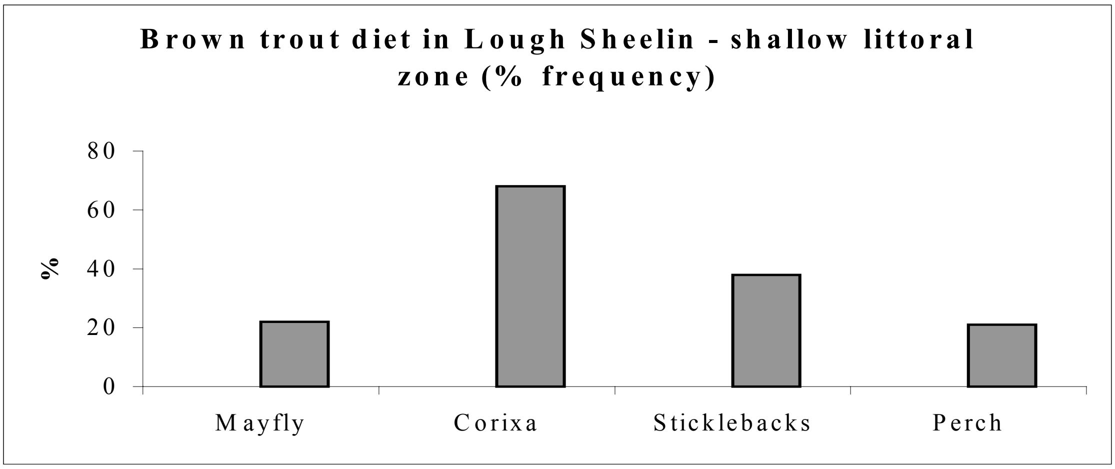


Figure 32 Lough Sheelin, Ireland - littoral trout diet (after Fitzmaurice, 1979)

Here, the open water crustaceans are absent and the diet is dominated by small fish and insects. Clearly, wild brown trout diet in large lakes varies markedly between habitat types and care is needed when interpreting stomach contents from restricted samples.

Figure 33 Upland trout lake

Ball (1961) studied the diet of brown trout and grayling in Llyn Tegid, Wales finding:

- Shrimps, caddis larvae, mayflies, midges, and hog lice (*Asellus*) were the key prey items.
- Brown trout foraged mainly on the lake bed from October to April and from the lake surface from May to September. Gwyniad (*Coregonus clupeoides*) eggs and fish (bullheads) were quite commonly eaten.
- The peak mean volume of food consumed in summer was eight times the winter level.
- Trout tended to browse more superficially on benthic invertebrates than grayling that often took caddis larvae and molluscs from between and beneath stones. This trophic separation probably serves to minimise competition between the two species in this unusual lake fish community.

Figure 34 on the next page summarises Ball's findings.

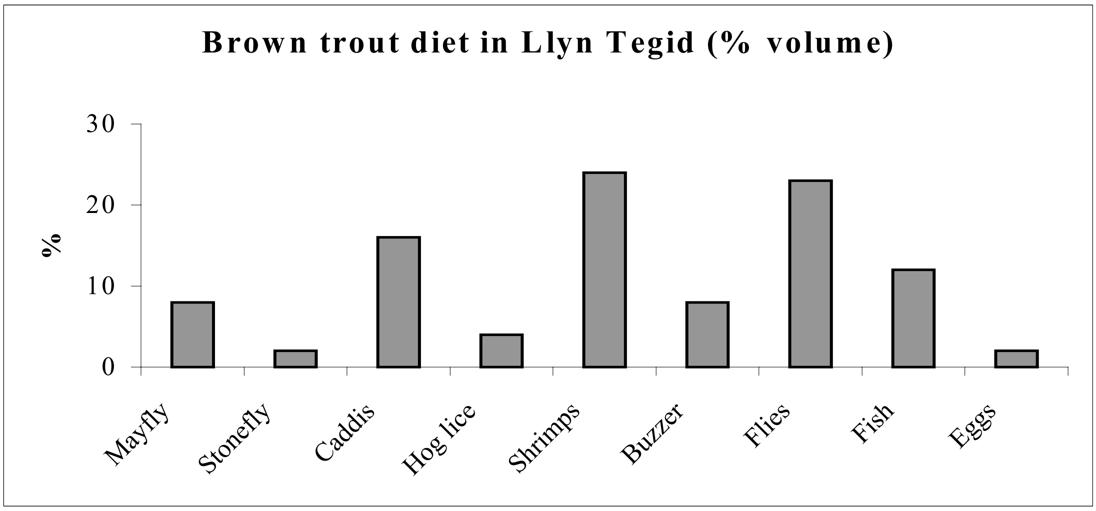


Figure 34 Llyn Tegid brown trout diet (After Ball, 1961)

Hunt & Jones (1972) studied the food of brown trout in Llyn Alaw, Anglesey, finding:

- Shrimps, hog lice, leeches, snails, corixids, caddis flies and sticklebacks formed the bulk of the prey.
- Shrimps, hog lice and corixids were actively selected by the trout.
- Trout ate most from May to September and also foraged actively during mild weather in January.
- Larger trout ate more sticklebacks, corixids, snails and leeches than smaller trout.

It is a common finding in brown trout dietary studies that larger trout eat more fish.

Figure 35 below shows the percentage by volume of key prey groups for all trout sampled from Llyn Alaw (after Hunt & Jones, 1972):

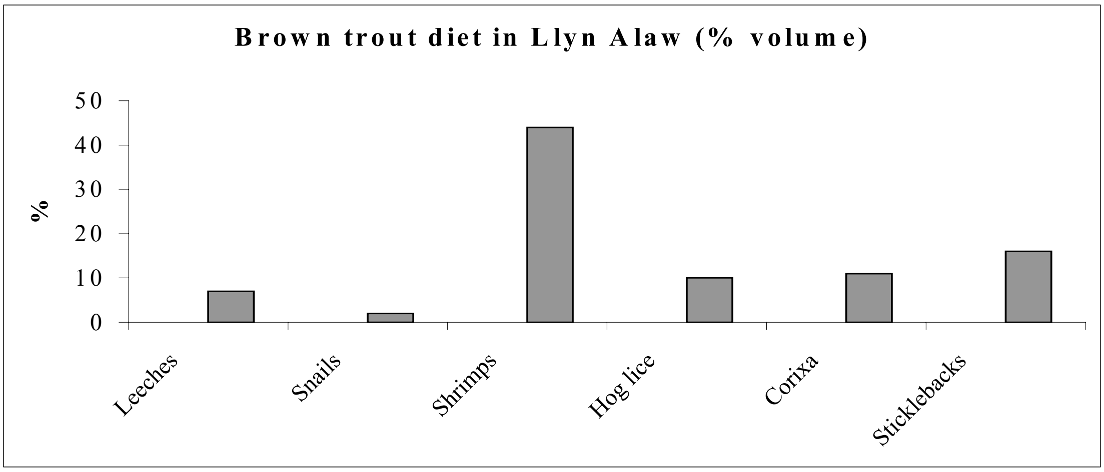


Figure 35 Percentage by volume Llyn Alaw brown trout diet (after Hunt & Jones, 1972)

Allen (1938) carried out a comprehensive study of brown trout in Windermere, Cumbria. The dietary component of the work showed:

- October to February - feeding on permanent bottom fauna (shrimps, hog lice, snails).
- March to July on temporary bottom fauna (emerging midges, stoneflies, caddisflies, Arctic Char eggs).
- May to September - surface food (adult insects).

Harper (1982) studied the diet of young brown and rainbow trout during the filling phase of Rutland Water:

- Earthworms forced to the surface and littoral crustaceans were important in the winter diet of trout.
- Shrimps, snails, midge larvae and pupae (buzzers) were key dietary items in spring, summer and autumn.

Warlow and Oldham (1982) reported on the diet of Rutland Water trout during the first two fishing seasons (1977 and 1978):

- In 1977 drowned terrestrial invertebrates dominated in spring and chironomid midge larvae and pupae in summer.
- In 1978 shrimps, hog lice and snails became more important than midges in trout diet.

Where trout are reared in cages some fish specialise in living beneath the cages foraging on pellets that fall through the mesh. Some anglers target these large trout and char. Clearly, trout diet varies considerably with season, habitat, species of trout and varying environmental factors. A skilled freshwater ecologist should be able to predict with reasonable accuracy the likely principal dietary components of fish in a given type of fishery. This can lead to useful recommendations on well-targeted habitat conservation and management to improve the fishery.

5.2.3 Grayling feeding ecology

Grayling are essentially river fish although some lake-dwelling populations (e.g. Llyn Tegid) do occur. Grayling have protrusible jaws that they use to probe the substrate for invertebrate food. Trout, with their terminal jaws have a more limited ability to pick up items from the stream bed and usually take food from mid-water or from the surface. The versatility that grayling have evolved enables this species to feed readily from the surface, mid-water and from the river bed. Grayling larvae feed on tiny drifting invertebrates such as chironomid larvae in the upper layers of sheltered, slow-flowing river margins. As they grow, grayling move out into the main flow and take up river bed feeding stations close to the bottom. Here they catch drifting invertebrates, search out benthic macroinvertebrates and rise to surface flies (see refs in Ibbotson et al, 2002, section 4.2). Prey groups include oligochaete worms, blackfly larvae, midge larvae, caddis larvae, mayfly nymphs, terrestrial flies, snails, shrimps, alder fly larvae and fish eggs (salmon, trout or cyprinid). Large grayling appear to rise less often and concentrate on benthic prey. Sometimes small cyprinid fish are eaten (Ibbotson et al, 2002).

Maitland and Campbell (1992, Table 25) compare published data for grayling feeding in the Rivers Tweed, Lugg and, for very young grayling, in the Dorset Frome. In the Tweed grayling diet was dominated by midge and mayfly larvae and beetles. In the

Herefordshire Lugg diet was predominantly shrimps, beetles, blackfly larvae and terrestrial insects. Young grayling on the Frome ate almost entirely midge larvae and tiny adult flies.

From the angler's perspective grayling extend the available fly-fishing season and offer sport even when water temperatures are low. At such times fishing with a weighted nymph or team of nymphs is often productive. Grayling shoals appear to organise themselves into dominance hierarchies where the most aggressive fish occupy the best feeding lies (Hughes, 1992).

5.2.4 Char feeding ecology

Maitland and Campbell (1992) provide a useful overview of Arctic char ecology. They suggest that where brown trout co-exist with char, char often specialise on feeding on open water plankton, leaving the trout to forage on invertebrates over the shallow littoral lake zones. Where char occur in isolation from trout the species feeds on both planktonic and littoral benthic prey. An example of this comes from the Outer Hebridean Island of North Uist (Campbell, 1982) where in Loch Fada trout and char are sympatric and char eat almost entirely plankton (77% diet) and open water and surface insects (18%). In the adjacent Loch Meallt where there are no brown trout, char eat mostly benthic invertebrates (72%), mid-water and surface insects (20%).

Maitland and Campbell (1992) present dietary data for seven Cumbrian char lakes (after Frost, 1977). In Windermere char ate mostly planktonic crustaceans (*Daphnia, Bythotrephes, Leptodora*), midge larvae and char eggs. Haweswater, Coniston and Crummock Water char had a similar diet. Char from Thirlmere, however, ate smaller crustaceans including *Bosmina, Cyclops* and other copepods. Midge larvae were also very important to this population.

Walker et al (1988) provide striking evidence for the existence of two morphologically separate trophic forms of char from Loch Rannoch, Scotland. Dietary data from this study (Maitland & Cambell 1992, Table 19) show how the small-mouthed pelagic form eats mostly planktonic crustaceans (95%) whilst the large-mouthed benthic form eats a wide range of bivalves, worms, mayfly nymphs, beetles, caddis larvae, midge larvae and small fish including juvenile char. This type of sub-speciation in large lakes does not seem uncommon in char populations and must have evolved over only the last 10,000 years or so, since the last Ice Age.

Management Options

Key game fishery management objectives to encourage aquatic invertebrate abundance include:

Streams

- Maintain a lush fringing river bank vegetation, minimise spraying with any pesticides.
- Buffer zone intensive agricultural use of riparian meadows.
- Protect water quality and flows.
- Cut weed sparingly and by hand, rather than via herbicide use.
- Promote as wide a diversity of physical habitats as possible (gravel riffles, bouldery or shingle runs, undercut banks bound with tree roots, fringed, silt-edged glides, deep pools with dead wood snags and silted margins).
- Promote a diversity of light levels from tree and shrub deep shade through dappled shade in coppices to open sky-lit water.

Still waters

- Protect water quality and inflows.
- Maintain varied weed beds and design new fisheries with varied depths and substrates.
- Avoid the use of pesticides.
- Crop coarse fish stocks (especially adult bream and carp) so as to minimise competition for invertebrate food and habitat damage by bottom-feeding fish.

5.3 Summary of Management Options

Table 17 Good management practice

Topic	**Good management notes**
Trout and grayling feeding ecology - rivers	Protect water quality, flows, in-stream and marginal habitats so as to promote invertebrate diversity and abundance.
Trout feeding ecology - man made lakes	Design lake to produce diverse features, weed beds and zones of varied marginal vegetation growth. Consider cropping coarse fish stocks to reduce potential competition with trout for invertebrate food supply.
Trout and char in natural lakes	Protect water quality so as to maintain invertebrate diversity and overall habitat quality. Ensure that adjacent land-use and development pressure does not impinge on lake water quality. Ensure that water abstraction does not impose unacceptable ecological pressure on lake habitats. Make sure that no new fish species are introduced to natural lakes where wild trout and char exist.

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Note: references marked with an * are key sources of information.

6 WATER QUALITY

6.1 Introduction

6.1.1 Natural water quality and E.U. Regulations

Natural streams, rivers and lakes are influenced by the water quality of rainfall, drainage from bedrock and soils, industrial and domestic effluents, drainage from developed areas and groundwater quality (NRA 1992, MAFF 1998, 2000). All of these sources of water also represent potential pathways for pollution to enter fisheries. Clearly, fishery managers should have an understanding of both pollution prevention and water quality management. Pollution can arise from a single location - a point source or can gather from a wider area - a diffuse source. Environment Agency (1998d) provides guidance on values of some typical water quality parameters for trout fisheries.

Table 18 Typical water quality characteristics of some fishery types

Parameter	Limestone / chalk river	Lowland river	Upland reservoir
Acid balance - pH	7.9-8.7	7.2-7.9	6.0-6.9
DO (ppm)	10-12.6	7.6-12.2	Saturated
Conductivity (micro-siemens per cm)	380-500	640-1090	99-119
BOD (ppm as O_2)	0.7-4.2	2.0-6.7	1.0-2.8
Chloride (ppm as Cl)	35-42	50-130	9-14
Nitrate (ppm as N)	8.5-9.8	5.2-10.3	0.5-1.2
Ammonia (ppm as N)	0.1-0.5	0.1-0.8	0.01-0.06
Hardness (ppm as $CaCO_3$)	165-210	233-445	32-41
Suspended solids (ppm)	0-5	7-94	2.8

Notes:
- Acidity / alkalinity is measured on the pH scale 1-14 where 7 is neutral.
- Dissolved oxygen concentrations (DO) are critical for salmonid fish survival. Biochemical Oxygen Demand (BOD) is a measure of oxygen-absorbing pollutants and bacterial load.
- Parts per million (ppm) are equivalent to milligrams per litre (mg/l) a measure of concentration of substances dissolved in water.
- Conductivity (a measure of electrical resistance) indicates overall ionic concentrations in water - low in 'soft' waters, high in 'hard' waters. Hardness of water is measured as Calcium Carbonate ($CaCO_3$) concentration.

The table below is a digest of information on European Union recommended water quality parameters for Salmonid rivers (EC Freshwater Fish Directive 78/659/EEC), given in Environment Agency (1998c).

Table 19 Water quality parameters for salmonid fish

Parameter	Recommended levels in samples	Comments
Temperature (Celsius) where there is a thermal discharge	Change from upstream at mixing zone should not exceed 1.5°C. Temperature should not exceed 21.5°C. at edge of mixing zone for more than 98% of the time.	Avoid sudden changes in water temperature. Cold water spawners may be protected by a 10°C. upper limit during the breeding season.
Dissolved Oxygen (DO, mg/l O_2)	*Guideline: 50% of samples should be greater than 9 mg/l and 100% greater than 7 mg/l. *Imperative: 50% of samples greater than 9 mg/l. If DO falls below 6m/l remedial action should be taken.	Samples should allow for daily fluctuations in DO. Single samples should be taken at lowest point.
Acidity/Alkalinity (pH units)	pH 6 to 9 Naturally acid or alkaline waters may fall outside these levels.	Man-made inputs should not cause natural pH values to change by more than 0.5 units.
Suspended solids (e.g. silt)	Less than 25 mg/l.	High values during floods can be excluded from average value calculations.
Biochemical oxygen demand (BOD, mg/l O_2)	Less than 3 mg/l.	Should be viewed in combination with the DO parameter.
Nitrites (mg/l NO_2)	Less than 0.01 mg/l	This standard may be too critical, nitrite toxicity to fish declines with increasing chloride concentration.
Phenols (mg/l C_6H_5OH)	Should not taint flesh	A standard to protect consumers, rather than fish.
Petroleum hydrocarbons	Should not form a film on water surface or banks and should not taint flesh or harm fish.	This is a difficult class of chemical compounds to set pollution standards for.
Non-ionised ammonia (mg/l NH_3)	Guideline less than 0.005 mg/l Imperative less than 0.025 mg/l	
Total ammonia (mg/l NH_4^+)	Guideline less than 0.04 mg/l Imperative less than 1 mg/l	

* E.U. Member States shall not set values less stringent than Imperative and shall endeavour to respect Guideline values.

The importance of key water quality parameters

Trout, grayling and Arctic char require relatively cool, clean water. Environmental influences that tend to decrease dissolved oxygen (DO) concentrations, raise water temperatures or increase pollutant concentrations all pose threats to successful salmonid fisheries.

6.1.2 Temperature

Water temperature is the key variable influencing trout growth rates and is critical to overall stream and lake ecology. Trout are ectotherms - their rate of metabolism is determined primarily by external water temperature. Low summer flows can lead to elevated temperatures, as can removal of shading. Conversely, habitat works that increase current speeds or increase shading from trees and shrubs will tend to lower stream temperatures. Warming upland streams and cooling lowland streams can potentially boost trout growth, depending on prevailing temperature regimes. It is worth noting that spate and clay vale rivers are much more prone to temperature variations than chalk streams that are moderated by the relatively constant temperature of aquifer spring inputs.

6.1.3 Low dissolved oxygen (DO) levels

These usually occur after excessive organic pollution (e.g. sewage effluent, farm wastes, food processing wastes) enters a fishery causing high Biochemical Oxygen Demand (BOD) and consequent de-oxygenation. BOD is measured by the milligrams of oxygen used by bacteria to oxidise organic matter in 1 litre of water over a 5 day period. Sometimes, excessive submerged plant growth or decay can impose high respiratory demands on a fishery. Decomposition of organic matter can often cause lethal low DO when still water fisheries are ice-covered for any length of time. Low DO increases the respiration rate of fish, making the uptake of pollutants more rapid and the onset of suffocation possible. Fish rapidly adapt to low DO by modifying their blood chemistry to increase the efficiency of oxygen uptake from water although rapid respiration tends to reduce the mechanical efficiency of the gills. If the oxygen supply cannot meet metabolic needs trout become increasingly stressed and are forced to the surface where they exhibit aquatic surface respiration (ASR) - gulping of air. In warmer water DO levels are reduced and fish metabolic rates increased - a doubled respiratory problem. Also, in warmer water, CO_2 levels from bacterial respiration are increased making it more difficult for the trout to lower its blood CO_2 via diffusion and take up oxygen at the gill surfaces - further respiratory problems. Fish kills often, therefore, occur in warm, eutrophic or polluted conditions or under ice ('winter kill').

6.1.4 Ammonia

Fish excrete nitrogenous waste products (from protein break-down) primarily as ammonia via the gills; increases in the concentration of this ion in water may, therefore, reduce the fishes' ability to rid the blood of toxic metabolites, leading to serious problems. Ammonia (NH_3) pollution usually enters fisheries with sewage effluent or other organically-rich inputs. It splits into two forms; non-ionised NH_3 and ionised NH_4^+. Both increased pH and temperature increase the proportion of non-ionised ammonia - the form that is toxic to fish. The proportion of toxic ammonia present in any water sample can only be estimated from pH and temperature readings and so toxicity is not readily measurable at the waterside. Alkaline waters will be more prone to ammonia pollutions than acid waters. The pH of water is determined primarily by bicarbonate and carbonate concentrations. DO is also affected by ammonia as NH_3

oxidises to nitrite, NO_2 and then nitrate, NO_3 reducing DO levels as oxidation occurs. Lloyd (1992, table 5.1 page 75) reviews factors affecting ammonia toxicity to fish.

6.1.5 Sediment

Point source pollution tends to be readily identifiable. Pollution emanating from diffuse sources, on the other hand, can be insidious and cumulative. Sediment washed from ploughed land or from fresh ditching work is one example of the latter type of pollutant; excessive silt and sand inputs to rivers can clog the bed and ruin plant, invertebrate and salmonid spawning habitats (Theurer et al 1998). Silted spawning shallows can be cleaned but causing silt to be mobilised and to drift downstream can sometimes be interpreted as a form of pollution (SaFFA, 1975), particularly if the silt is from an off-river source, such as a lake. In some Agency Regions water-jetting gear may be available on free loan to fisheries wishing to de-silt spawning gravels. Care is needed to liaise with downstream neighbours to agree that silt can be mobilised and allowed to drift downstream. Take advice from Area Environment Agency staff before disturbing large volumes of sediment.

6.1.6 Heavy metals

Toxic mine discharges depress DO, elevate metal ion concentrations such as aluminium, cadmium, chromium, copper, iron, lead, mercury, nickel and zinc and lower pH (Solbe 1980, 1997, Haslam 1990, Lloyd 1992). Elements effectively do not break down and disappear from the environment, they are simply transported from habitat to habitat, many building up in 'sediment sinks', particularly in marine environments (Lloyd, 1992). The toxicity of both copper and zinc are reduced by increasing water hardness. Acid waters are, therefore, more dangerous to trout where heavy metal pollution occurs. Many mines are, of course, situated in acid moorland areas such as Cornwall, west Wales and Cumbria. Flushes of zinc-polluted water seem to irritate trout gill membranes and may damage respiratory efficiency. Trout ova and alevins are sensitive to excessive concentrations of heavy metals such as aluminium in solution. Copper is often effectively reduced in toxicity in trout waters either via combination with carbonate or organic humic acids, both of which bind free copper ions. Lead tends to be very insoluble in all but the softest of natural waters and so may be less problematic for game fisheries.

6.1.7 Acidity and water hardness

Acidity is the concentration of hydrogen ions, H^+ present in water, usually expressed as pH (the negative logarithm to the base10 of the H^+ concentration). A pH of 1 is, therefore, ten times more acidic than a pH of 2, etc. pH 7 is neutral on the scale and 14 is the highest alkaline state (very few free hydrogen ions in solution). Hydrogen ions in solution are neutralised by combination with bicarbonate and carbonate ions - 'hard' (chalky) water has higher concentrations of these basic ions and so is more alkaline. Naturally acid moorland waters that are often peaty tend to have quite high concentrations of H^+. Normally, dissolved CO_2 is in equilibrium with the air above the water producing a concentration of about 1.5 mg/l. Productive still waters have lower dissolved CO_2 levels and increased pH values (become more alkaline) when photosynthesis removes dissolved CO_2 from solution, reducing carbonic acid (HCO_3^-) concentrations. Ammonia toxicity increases with increased temperature and pH so warm alkaline productive trout lakes are potentially vulnerable to organic pollution. However, under these conditions, reduced CO_2 levels due to photosynthesis may reduce the actual toxicity of un-ionised ammonia to fish - Lloyd, 1992, pages 70-72 explains this complex phenomenon.

6.1.8 Plant nutrients and eutrophication

Still- and flowing waters contain plant nutrients such as nitrogen, phosphorus, carbon and sulphur. When in balance, algal and higher plant growth produces enough vegetable matter to fuel normal animal growth and productivity. If dissolved nutrient concentrations increase so as to fuel excessive algal or weed growth then undesirable ecological consequences can ensue. These include large-scale swings in pH and dissolved oxygen concentration due to intense photosynthetic activity and decay processes of dead plants. Excessive nutrient inputs, fuelling intense plant growth, can occur via various industrial processes, Sewage Treatment Work (STW) effluents, intensively farmed riparian fields and meadows. The process of over-enrichment of freshwater habitats is termed eutrophication.

Where a still water fishery lies well within a landowner's boundary it may often be possible to modify local land use and drainage patterns to improve water quality. Rivers, streams and large lakes tend to be influenced by polluting inputs from further afield and making significant improvements may often involve the co-operation of water company, farming, industrial concerns and riparian owners (Royal Commission on Environmental Pollution, 1992). Fishery managers may wish to note that The Environment Agency is well placed, both as a regulator of water quality and as an 'honest broker' in the case of disputes to help achieve improvements in environmental quality of their fisheries.

Still waters are often suffering from eutrophication - improving their water quality can be critical to the success of game fisheries (English Nature, 1997, 2001). River quality in England and Wales has generally improved in recent years (Environment Agency, 1998c), although the example below highlights the continuing widespread potential for river eutrophication.

Impact of a nutrient-rich source of river pollution

A point source ('end of pipe') polluting discharge of organically-rich matter (e.g. sewage or food processing effluent) will impact the water quality of a river as follows (see Figure 36 on the next page from Solbe, 1997):

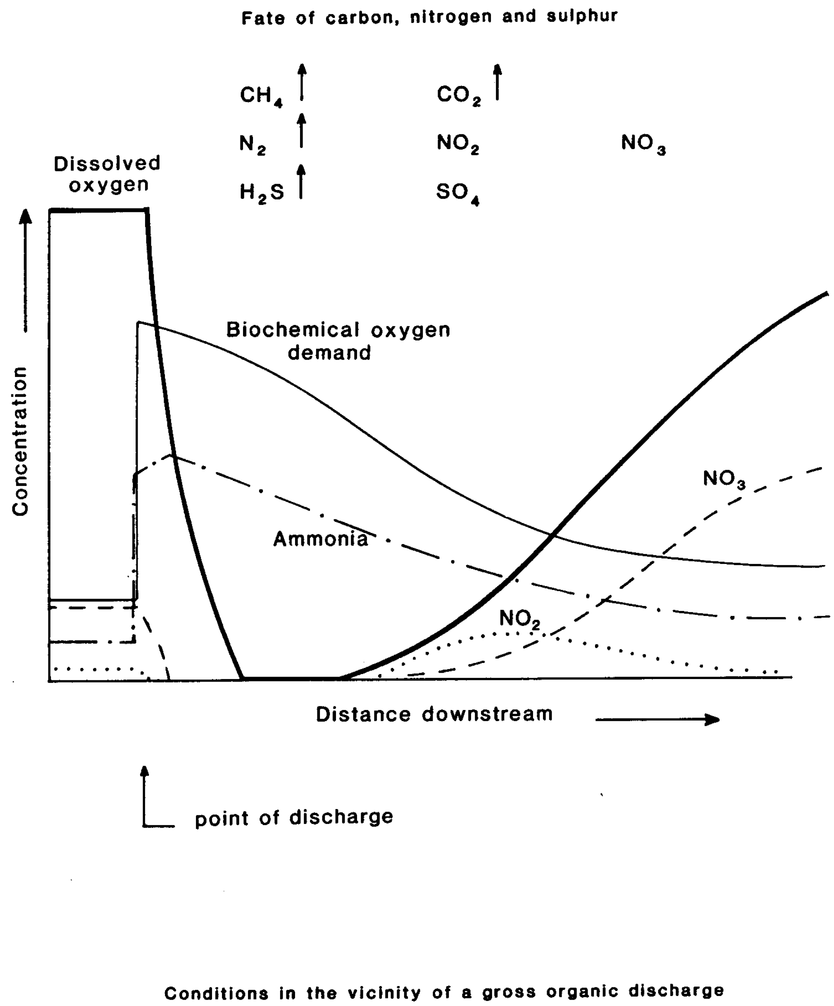

Figure 36 Effects of pollution on downstream water quality

Organic pollution sharply lowers local dissolved oxygen (DO) and raises biochemical oxygen demand (BOD) and ammonia levels. As the effluent moves downstream microbial action and re-oxygenation lowers BOD and ammonia and raises DO, nitrite (NO_2) and nitrate (NO_3). This natural ability of freshwaters to break down organic matter is an important buffer against this form of pollution but streams, rivers and lakes can easily be over-loaded. The chemical influences on water quality shown above are also reflected in the distribution of animals downstream of a pollution source.

Figure 37 on the next page (from Solbe, 1997) indicates what can happen where a polluting input (the dotted line) enters a river; the biological impacts being seen for 5-10km downstream. Closest to the pollution source only tubificid worms, midge and blackfly larvae, some snails and water lice, three-spined sticklebacks, roach and tench survive. As the pollution is diluted downstream diverse caddis larvae return and gudgeon, eels, stone loach, bullheads, dace, chub, minnows and trout are able to tolerate the environmental conditions.

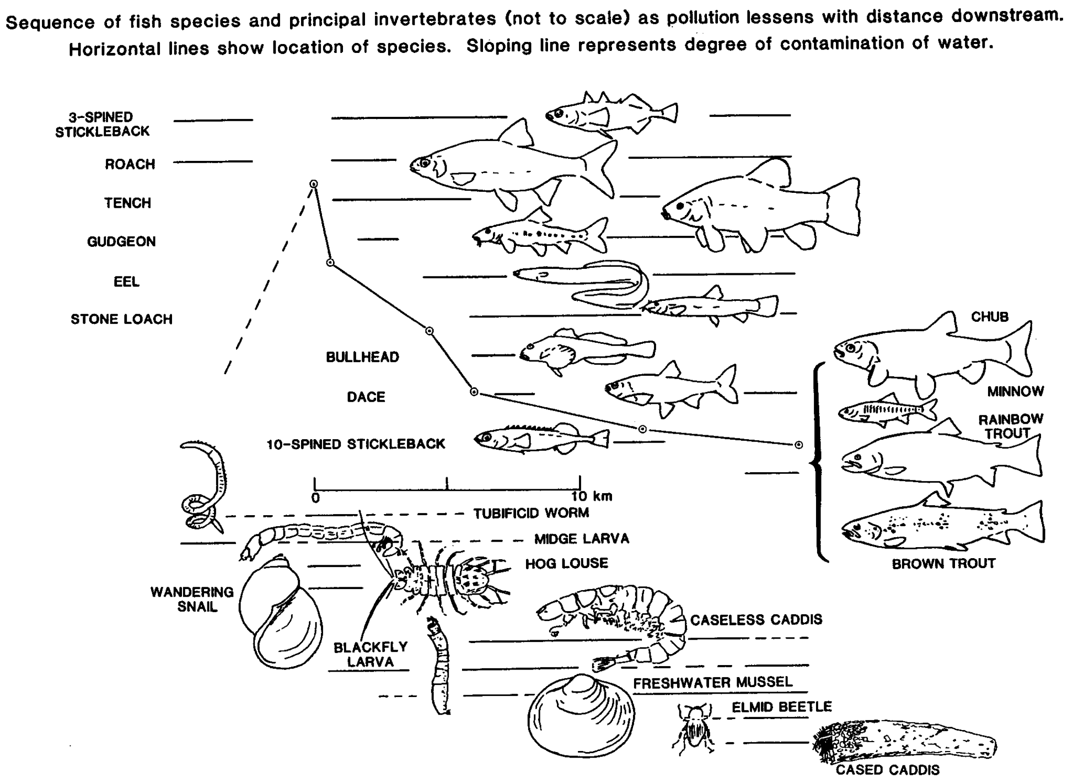

Figure 37 Effects of pollution on distribution of animal species

As Figure 37 indicates, rainbow and brown trout do not tolerate contaminated water. The fact that differing invertebrate species tolerate pollution to greater or lesser extents is used through regular invertebrate sampling programmes to monitor water quality in rivers.

Agency Area staff are often able to mount rapid-response fish rescues and to assess what is causing a particular pollution and how to stop it. Aeration equipment may be available to help overcome low DO conditions. Information and advice on river and lake water quality and likely local adverse influences on water quality are available from Environment Agency Area staff. Routine water quality and biological monitoring provides much of this baseline information. Remember the Agency Freephone pollution number: 0800 807060.

Solbe (1988) discusses water quality standards with respect to salmonid farming, rivers and lakes. Alabaster and Lloyd (1980), Lloyd (1992), NRA (1992) and The Royal Commission on Environmental Pollution (1992) provide examples and supporting references on all key aspects of pollution impacting game fisheries.

The Environment Agency uses a scheme of River Quality Objectives (RQOs) set for 45,000 km of river in 1997 in England and Wales to regulate water quality. Information on influences on river water quality is available on the Environment Agency website: www.environment-agency.gov.uk.

6.2 Technical and Practical Advice

6.2.1 Key pollution threats to rivers and still waters

River pollution threats depend primarily on where the fishery is and how the surrounding catchment is managed, still waters are similarly affected (The Royal Commission on Environmental Pollution, 1992, NRA, 1992 and Environment Agency, 1998c). Rivers, streams and still waters are vulnerable to many kinds of contamination.

In urban and industrial areas polluting influences can include:
- Sewage Treatment Works (STW) effluents (detergents, suspended solids, BOD, ammonia, oestrogenic endocrine disrupting chemicals),
- Combined sewer / storm drain overflows (raw sewage and other contaminants),
- Industrial effluents (organic wastes, heavy metals, petroleum hydrocarbons, phenolic compounds, dyes, moth-proofing and dry-cleaning agents),
- Run-off from roads, car parks, garage fore courts, etc all of which contain oils and metals,
- Contaminated land seepage (e.g. phenols, cyanates, tars, acids, oils, organic solvents),
- Mine workings discharges (acids, iron compounds, arsenic, cadmium, lead, zinc, aluminium),
- Construction sites and rubbish tips (e.g. silt, soil, oils).
- Atmospheric pollution from acidic emissions.

In rural areas pollution sources include:
- Toxic agri-chemicals (insecticides e.g. synthetic pyrethroid (SP) sheep dip, herbicides, fungicides), pollution from disused coal and metal ore mines,
- Enriching agri-chemicals (inorganic and organic fertilisers, sewage sludge)
- Farm organic wastes (cattle/pig slurry, chicken manure, silage liquor, dairy washings),
- STW effluents and cess pit / septic tank seepage (detergents, organic pollution),
- Land use (arable/ grazing/ forestry: chemical, soil and silt inputs),
- Fish farms (organic pollution, suspended solids, ammonia, pharmaceutical compounds),
- Water cress farms (silt, chemical treatments).
- Acidic inputs from the atmosphere.

Any of these sources of pollution can have adverse impacts on game fisheries. A recently highlighted case has been that of synthetic pyrethroid (SP) sheep dips that are extremely toxic to aquatic invertebrates and use is widespread in upland river and stream catchments, for instance in Wales (Evans, 1997). Disposal of sheep dip is also a serious potential hazard to river ecosystems. Invertebrate populations can be wiped-out over kilometres of river, seriously affecting food supplies for trout and salmon parr (Salmon & Freshwater Fisheries Review, 2000). The Environment Agency Area office will provide information on the water quality of your river and its compliance with designated water quality objectives (WQOs). Environment Agency (2001) provides excellent advice on Best Farming Practice.

Assessing water quality on a fishery

A very useful indirect method of gaining an overview of river water quality is to sample the large aquatic invertebrates (macroinvertebrates) living there. The Environment Agency's routine biological monitoring of river invertebrates is a good starting point. Aquatic insects, crustaceans, molluscs, annelids and other groups have varying tolerances to polluting substances. Since these animals must live in the river all year-round, any bout of pollution (even a short-lived one) will affect their distribution and abundance. A fine-meshed pond net swished through weeds, under banks or downstream of a boot shuffled in the gravel (a 'kick sample') will catch a variety of animals that can then be inspected in a white plastic tray. A scheme of scoring the pollution tolerance of invertebrate species has been developed - The Biological Monitoring Working Party (BMWP) scores. High scores from standardised samples mean clean water species, low scores indicate pollution-tolerant groups or just a very few animals present (e.g. in a mountain beck).

Good signs for water quality include the presence of native crayfish (in hard water areas), diverse stonefly, mayfly and caddis fly species, dragonflies, freshwater limpets, pea mussels and freshwater shrimps. A stream supporting only a few species of snail, leech, water louse, midge larvae and oligochaete worms is less encouraging. The example below (from Solbe, 1997) shows samples from a relatively clean stream on the left and a polluted river on the right. Scores for all invertebrates are totalled and then divided by the number of scores. This gives an Average Score Per Taxon (ASPT), that helps to even out sampling effects, see Solbe (1997) for a full discussion.

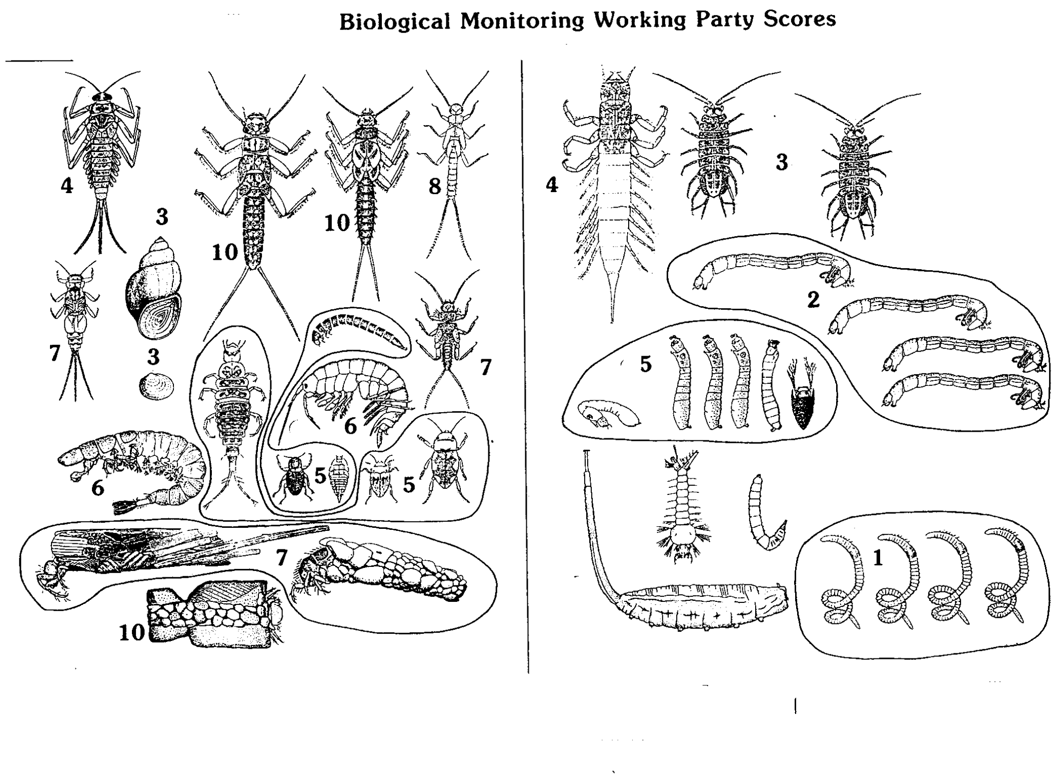

Figure 38 Invertebrate samples from differing rivers (cleaner on left)

The numbers in Figure 38 refer to BMWP scores, the invertebrate groups with their relevant scores are:

Clean stream: Snail (*Bithynia*) and River limpet (*Ancylus fluviatilis*) (score 3), Mayfly (*Baetis*) (score 4), Adult and larval water beetles (*Elmis*) (score 5), Caseless caddis (*Hydropsyche*) and Shrimp (*Gammarus*) (score 6), Cased caddis larvae (*Stenophylax and Anabolia*), Stonefly (*Nemoura*) and Mayfly (*Caenis*) (score 7), Stonefly nymph (*Leuctra*) (score 8) and Cased caddis larva (*Silo*) and Stonefly (*Perla*) (score 10).

Polluted stream: Tubifex worms (score 1), Chironomid larvae (score 2), Water louse (*Asellus*) (score 3), Alder fly larva (*Sialis*) (score 4) and Black fly larvae (*Simulium*) (score 5).

The Environment Agency booklet 'Identifying Freshwater Invertebrate Life' (1997) helps with interpreting macroinvertebrate samples netted from a river or stream. For the more advanced reader Wright, et al. (2000) provide a detailed and comprehensive review of the assessment of biological quality of freshwaters.

There have been some recent major improvements in game fishing rivers following long-term rehabilitation of water quality in formerly grossly polluted waters. For instance, Mawle et al (1985) reported the increase in salmon running the lower reaches of the River Taff, Cardiff, formerly impacted by the iron, coal, steel industries and gross organic pollution. Improvements in water quality have allowed the re-establishment of a migratory game fishery on the river (Mawle, 1991).

Champion (1991) relates a similar story for the Northumbrian River Tyne where salmon and sea trout stocks have made a strong recovery after reductions in lower river pollution levels following industrial change and improvements to the Tyneside STW. The building of Kielder Reservoir led to the establishment of a salmon hatchery and release of around 160,000 salmon parr each year in mitigation of damage to several miles of inundated headwater salmonid nursery habitats. Recent increases in rod catches have shown a parallel recovery for salmon and sea trout. Of particular significance is the fact that, despite having no recent support via stocking, the sea trout population has shown a rapid and sustained recovery (Environment Agency, 1998a). Tyne sea trout are often multiple spawners and this may have helped build up numbers in recent years. Interestingly, sea trout numbers in the nearby River Wear have also risen in recent years (J. Shelley, pers. comm.).

Other rivers in England and Wales with recovering migratory salmonid runs include the Tyne, Tees, Taff, Rhymney, Ogmore, Neath and Tawe. Hopes are high for the Mersey, Ouse, Thames and Trent (Environment Agency, 1998).

Management options for dealing with river pollution

The following points are useful to bear in mind:

- Report any pollution incidents immediately to the Environment Agency (freephone 0800 807060)
- Be aware of likely sources of pollution and develop contingency plans to combat pollution (blocking lake intakes, having oxygenation kit to hand or, perhaps, alternative fish holding facilities.

- Reduce or eliminate all polluting inputs under your control on your fishery.
- Collaborate with other riparian owners/managers to encourage better land use in the catchment.
- On larger rivers, consider forming a River Trust to focus efforts on fund-raising and fishery improvement projects.

6.2.2 Effects of catchment land use

This chapter concentrates on the most significant water quality issues that involve land use, this topic is also broadly covered in chapter 8 (Habitats) and under rural polluting influences in the section above.

A key topic of current concern for game fisheries is the siltation of spawning gravels for trout, grayling and stream-spawning char. In a recent review of sediment inputs to UK rivers Theurer et al. (1998) concluded that high levels of fine silt are present in many gravel riffles used for spawning by trout, salmon and other fish. In the USA sediments clogging riffle heads are a recognised major factor limiting salmonid production. More detailed research is needed in the UK to establish the degree to which sediments are responsible for poor egg incubation success in England and Wales. Indications from chalk streams (Environment Agency 1993, Beaumont, et al. 1994) and moorland rivers such as the Taw and Torridge already indicate, however, that local impacts can be severe. Environment Agency (2001) provides excellent advice on Best Farming Practice and on ditching procedures, reducing the risk of fine sediment pollution.

Management options for catchment land use

Silting of river gravels can be reduced by (refer to Theurer et al, 1998):

- More careful catchment land use patterns to limit soil erosion - keeping fine sediments out of rivers is the best sustainable solution. Environment Agency LANDCARE projects, River Trust initiatives and DEFRA Agri-environment grant aid schemes for buffer-zoning can all help to address this very widespread problem.
- Stabilising serious bank erosion with natural materials such as hazel faggots, conifer tree tops or live willow stakes that grow into living revetments / habitats.
- Promoting the growth of bank side vegetation to help trap silt and consolidate banks - fencing out livestock and providing alternative drinking places via pasture pumps or stone-bedded marginal shallows is often very successful.
- Digging and emptying 'sumps' (deepened areas) in drain beds that act as silt traps.
- High-pressure water jetting of gravels to de-silt them to a depth of 30-40cm so as to produce a 'sump' below redds for the collection of newly-infiltrating fine sediments.
- Raking or harrowing cemented gravels to allow hen fish to dig their redds.
- Still water siltation can be reduced via the construction of silt traps or reed beds on inflows and / or buffer-zoning adjacent arable agriculture.

Clearly, the first action treats the problem whilst the latter ones merely treat the symptoms. Remember to check with Environment Agency staff before carrying out de-silting work. Mobilising large amounts of silt could be interpreted as causing pollution downstream and may need formal Consent.

6.2.3 Excessive algal/weed growth (see also chapter 9 – Aquatic Plants)

Stillwaters
Nutrient levels in natural lakes limit plant growth to produce a diverse community of submerged weeds, lilies, etc (macrophytes) and a moderate planktonic or lake bed algal community. In naturally nutrient-rich (eutrophic) still waters algal blooms may occur in the spring (usually diatoms), summer (often green algae and cyanobacteria) or autumn. Dense submerged weed beds and marginal reed/rush/sedge beds will also often be present. Fluctuating pH and DO values and high temperatures can make these lakes marginal for trout.

In nutrient-poor still waters algal populations are less dominant and a diverse variety of submerged weed species generally thrives in the clear water. This type of weedy, clear-watered ecosystem that is generally biodiverse and of high conservation value makes a good trout fishery.

Excessive algal and/or weed growth can be produced in any of these types of lake if sufficient nutrients are made available for plant growth. Two principal causes often tip the balance from a clear watered to an algal-dominated lake (Giles, 1992, Smith & Moss, 1994). These are:

- Nutrient enrichment from treated sewage effluent or agricultural drainage / fertilisers, or,
- The presence of high densities of bottom-feeding fish such as common bream or common carp. These fish populations may have gained access during floods or have been stocked when a lake was created. Coarse fish stocks are often far denser in still water fisheries than may be apparent just from casual observations. See chapter 9 - Aquatic Plants, for a full discussion of this topic.

Management options for stillwaters

Reducing nutrient inputs
Excessive algal growth (floating mats or filamentous blanket weed on the bed) can be countered by reducing all sources of incoming plant nutrients. This can involve blocking or diverting land drains, ditches, run-off from arable land or planting filtering reed beds around inflows. Nutrients present in the sediments on the lake bed are often re-circulated at differing times of the year, fuelling new plant growth. The solution may necessitate some dredging to alleviate problems in the long-term. Take advice from Environment Agency Area office staff - there is little point in going to the expense of dredging out sediments if most nutrients are entering your fishery via different routes or if the sediments are largely inorganic (clay, sand) and contain few stored nutrients.

Reducing nutrient availability

Dense populations of bottom-feeding coarse fish can be netted out and, if satisfactorily health-checked, sold to other fishing associations for stocking. Large-scale reductions in coarse fish populations on still water trout fisheries can have a range of benefits including:

- Reducing nutrient recycling rates - cutting off the nutrient supply fuelling algal blooms and dangers of de-oxygenation during die-backs,

- Reducing or eliminating toxic cyanobacterial ('blue green algae') blooms.
- Reducing extreme daily pH and DO fluctuations owing to algal respiration and photosynthesis,
- Reducing competition for invertebrate food resources between coarse fish and trout,
- Stimulating oxygenating weed growth,
- Reducing the number of fish hosts for parasitic lice (*Argulus*) and other parasite species (see chapter 18 – Diseases & Parasites).

Under certain circumstances, the use of rotting barley straw at pond inlets may reduce algal growth by having an algicidal effect (see chapter 9 – Aquatic Plants). The precise mechanism involved is obscure and the effectiveness unpredictable. Nevertheless it can be worth trying. Check with Area Environment Agency staff for the applicability of this technique.

Even very large lakes can be subject to significant nutrient enrichment (eutrophication) and algal bloom problems. The south basin of Lake Windermere, Cumbria, for instance, has become enriched from the inputs of soluble phosphorus from lakeside STWs (Talling & Heaney, 1988). Resulting algal blooms and dissolved oxygen slumps when they die off have caused serious problems for and declines of arctic char stocks in the lake (Elliott & Baroudy, 1995). Fortunately, after nutrient-stripping treatment plants were installed at the offending STWs, phosphate levels have declined and there has been a strong recovery of densities of young char (Annual Reports by CEH Windermere to EA North West Region). This is a large-scale example of both the potential for damage that eutrophication represents and the potential for economic game fish habitat restoration.

Lough Sheelin, in Eire, provides an example of a wild brown trout fishery of considerable reputation that was severely impacted by water pollution problems. In this case the source of the excess nutrients was via intensive livestock (pig) production and other intensive agriculture within the lake catchment area. Improved farming practices have subsequently ameliorated the situation and the fishery is performing well once more and attracting large numbers of anglers (Dodd & Champ, 1983).

Rivers

Excessive filamentous algal growth on trout stream beds with the clogging of gravels and smothering of macrophyte beds can have a number of root causes, the key ones being (see Giles et al, 1991, English Nature, 1997, and chapters 7 and 9):

- Nutrient enrichment with elevated soluble phosphorus levels from STWs and farmland.
- Over-abstraction of water and consequent low stream flows (increasing nutrient concentrations and favouring slow-flow plant species).
- Over-widening of river channels through bank erosion by livestock and consequent low water levels, reduced current speeds and silted river beds.

Management options for rivers

Potential solutions to enrichment problems include:

- investment by Water Companies through the Asset Management Plan (AMP) process to reduce polluting inputs from STWs,

- buffer-zoning rivers to filter out polluting influences before they reach fisheries,
- fencing livestock away from eroding river banks,
- supporting the Environment Agency in its work to restore flows to over-abstracted rivers; higher flows dilute pollutants.

Environment Agency (2001) provides excellent advice on best farming practice.

6.2.4 Acidification and catchment liming

Acidification of still water and riverine trout fisheries has happened extensively in Wales (Edwards et al, 1990), Northern England (Turnpenny et al, 1987) and south-west Scotland (Maitland et al, 1987). Twelve thousand kilometres of small streams have brown trout stocks impacted by acidification in Wales (Weatherley, 1993). The root causes are industrial and transport sources of air pollution sending plumes of acidic fumes into the atmosphere where they are blown on prevailing winds to vulnerable areas. It is likely, even with foreseen reductions in sulphur emissions, that improvements will only be gradual, over the next few decades. Vulnerable areas are those with low soil buffering capacities for acid precipitation. Whilst limestone-based catchments easily neutralise acid rain, granite catchments do not. Blanket coniferous forests increase the uptake of acid mists and translocation to soils and may absorb buffering cations (calcium, magnesium) during growth and acid/metal ion release to ground waters after clear-felling (Reynolds et al, cited in Weatherley, 1993).

Some peat and hard rock-based catchments are naturally acidic and game fish stocks may have adapted to local conditions. Such populations, for instance of wild brown trout, can have considerable conservation and potential management values owing to their ability to withstand acid waters. Also, naturally-acid grasslands and bogs tend to have high conservation values in their own right. Liming programmes in sensitive catchments therefore require very careful consideration of risks and benefits.

When 'acid rain' falls on vulnerable catchments or is absorbed and translocated to soils by trees and other vegetation, various toxic metal ions such as monomeric aluminium and zinc are dissolved in the ground waters and washed into streams and lakes. Acidic snow melt can have similar effects. These metal-rich acid flushes of water can kill salmonid eggs, alevins and fry, progressively wiping out wild trout stocks in vulnerable catchments (Weatherley, 1993). Toxic flushes of water either directly kill young fish or lead to excessive mucus production by gill membranes, impaired respiration and progressive debilitation or death. Classic signs of acid damaged habitats are relatively clear lakes with few surviving fish and impoverished acid-tolerant invertebrate communities. These ecological impacts knock-on to affect dipper and otter populations, amongst other species (Weatherley & Ormerod, 1991).

Maitland et al (1987) review the effects of acidification on Scottish trout populations in Galloway where several granite-based lochs are now fishless and others have declining trout stocks. Lochs with peaty coloured waters may convey some form of protection to fish by rendering inorganic aluminium less toxic, perhaps through combination with humic substances. A further finding of the study is that brown trout with tail deformities often occur in acidified lochs. Characteristic rounding of the caudal fin may be a useful early indicator of acidification in some wild trout stocks (see R.N.B. Campbell, Appendix 5 in Maitland et al, 1987).

Management options for acidified fisheries

The long-term solution to acidification is, of course, to cut air pollution from fossil fuel-burning activities such as coal-fired power stations and internal combustion engines. In the short- to medium-term acidification can be mitigated for, to a degree, by neutralising acid waters and catchments with liming programmes. This approach can, however, have a number of adverse impacts as well as potential benefits (Weatherley, 1993):

- Finely powdered limestone ($CaCO_3$) is spread over soils or waters to raise pH and alkalinity and to reduce concentrations of soluble iron, manganese and aluminium.
- On Llyn Brianne at the headwaters of the River Tywi, liming the reservoir has neutralised acid waters, acid-sensitive invertebrates have returned to the upper river and salmon and trout nursery habitats have been restored. Not all schemes are likely to be this successful, however, and all potential liming projects should be fully appraised for risks, costs and benefits to the overall ecosystem.
- Deaths of salmonid eggs, alevins and fry can be reduced by liming but natural water chemistries in soft water catchments are changed, making them relatively calcium-rich. This can adversely affect peat bog plants adapted to low-calcium soils (calcifuges, e.g. *Sphagnum* mosses and some liverworts), invertebrates and small mammals.

6.2.5 Low Dissolved Oxygen levels

Dissolved oxygen concentration in water can be measured by using a correctly set up meter. Oxygen meters are inexpensive, portable and very useful for fishery managers. Note that they need regular calibration to achieve accurate results - the membrane changes in permeability to gases as it ages. Oxygen meters may give values in mg/l (milligrams per litre) or as percentage saturation. Compared with air, water holds comparatively little oxygen; a litre of air contains around 300mg of oxygen whilst a litre of water at 15 Celsius holds only10mg. The concentration of dissolved oxygen in fully air-saturated fresh water is directly proportional to temperature - see Solbe, (1988), it equals:

468 (31.6 + T) mg oxygen per litre. Where T is the temperature in degrees C.

Because fish tend to become more active in warmer water (up to a limit), they need more dissolved oxygen at times when the water actually holds less. This can cause problems.

Low dissolved oxygen concentrations occur when respiration demands by living organisms exceed photosynthetic oxygen production plus diffusion rates through the water surface. DO typically fluctuates through the day, being relatively high at higher light levels and at its lowest at the end of the night. Classic causes of low dissolved oxygen levels in fisheries include:

- Pollution of streams, rivers, ponds with high Biochemical Oxygen Demand (BOD) pollutants such as sewage, livestock slurry, dairy or food processing wastes.
- Low flows in streams with little shading

- Dying algal blooms in lakes or slow-flowing rivers.
- Dense weed bed growth in lakes or slow-flowing rivers.
- Decaying weed beds in lakes or slow-flowing rivers.
- Excessive fish stocks in lakes (usually of coarse fish + trout).
- Warm thundery weather coinciding with any of the above, especially in still waters.

It is worth noting that trout need more oxygen after feeding and also when swimming actively as opposed to finning slowly. Large fish need less oxygen per kg body weight than smaller fish. An actively swimming rainbow trout uses about five times more oxygen than when it is resting. At 15 degrees Celsius a 1 kilo rainbow trout requires about 220mg of oxygen per hour whilst 10, 100g fish need 300mg per hour. This is worth remembering when stocking fisheries that are prone to low dissolved oxygen levels - fewer large trout have a lower oxygen requirement than the same weight of smaller fish.

Water absorbs oxygen from air by simple diffusion - the rate being proportional to the concentration gradient. Rates of re-aeration of water depend upon how low the level has fallen below saturation, the roughness of the water surface (rough = greater surface area) and how pure the water is. Polluted water recovers its dissolved oxygen level more slowly than clean water. Water with very low DO absorbs oxygen from air very much faster than water that is only marginally deoxygenated. Agitated water presents a larger surface area for diffusion to occur across. These facts are fortunate, giving the fishery manager a chance of rectifying a potentially disastrous situation through the application of some simple principles.

Management options for low dissolved oxygen concentrations

See Environment Agency (2000) for a practical booklet on dealing with de-oxygenation, Figure 39 on the next page is taken from that source.

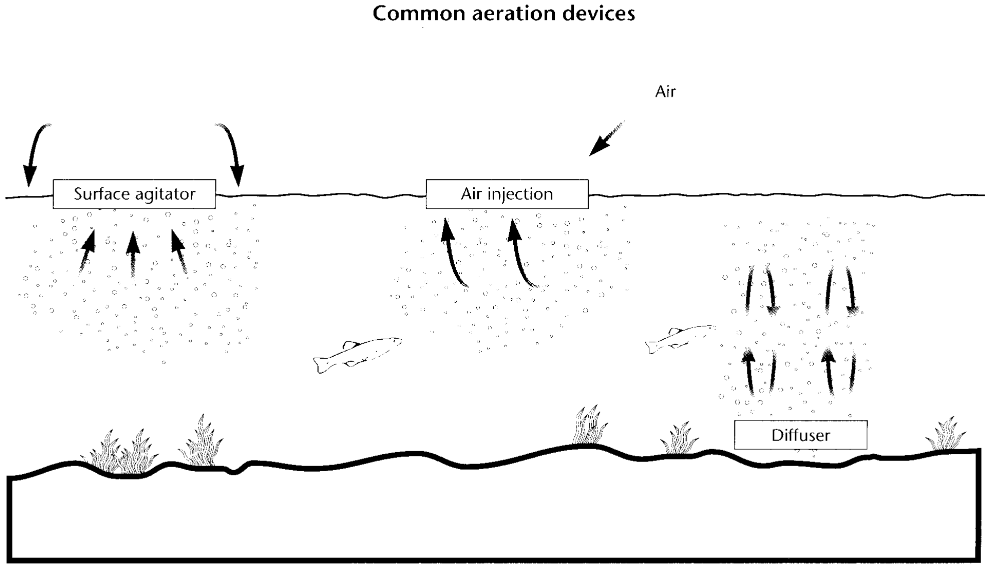

Figure 39 Aeration methods

Practical actions when faced with fish in distress - usually swimming slowly, close to the surface and gulping air include:

Lakes

- Running a water pump to jet water up into the air as a fountain and allow it to splash back down into the fishery. Fine sprays are better for re-oxygenation than solid jets of water.
- Fitting a venturi device that entrains air bubbles in the pumped water flow, increasing dissolved oxygen levels.
- Surface agitators - paddle wheel or mushroom fountain designs both work; the former is better for long thin lakes and the latter for square or round ponds.
- Running an air pump with set of diffuser stones in the lake - this, too, instantly helps to raise dissolved oxygen levels. Small bubbles have a greater overall surface area than fewer larger ones and are better for re-oxygenation. Greater air pressure is needed, however, to force them through the diffuser block.
- Breaking ice cover and keeping water on the move over a manageable area to prevent re-freezing.
- Consider purchasing in-lake water circulators, these run on an electricity supply and, whilst expensive to run, may allow the keeping of trout in marginal lakes that are warm and rich. Such solutions are not, however, truly long-term sustainable options from an environmental stand-point and such lakes may be better managed as coarse fisheries.

Longer-term actions on lakes suffering regular low DO levels include:

- Building structures (e.g. low weirs, boulder shallows) in streams or lake inflows to aerate water (see chapter 8 - Habitats)
- Reducing nutrient inputs (e.g. reed beds filters on lake inlets, see chapter 6 - Water Quality).
- Reducing the chance of algal blooms (see chapter 9 - Aquatic Plants).
- De-silting lake to remove decaying organic matter and provide cooler, deeper water in summer. Anaerobic silt is black and often smells of hydrogen sulphide ('rotten eggs').
- De-stocking excess fish (and selling them if health-certified).

Rivers and streams

- Building small waterfalls, low weirs, boulder shallows to increase surface agitation.
- Pumping air or even oxygen via a diffuser system into river water close to the bed.

Note that weir building and other works in rivers or on river banks may need Environment Agency consent (see chapter 12 - Consents).

6.3 Summary of Management Options

Table 20 Water quality management options and best practice

Issue	Management options	Best practice notes
Water quality adequate?	Consult Agency, get water chemically tested, inspect invertebrate community.	Take all opportunities to maintain or improve water quality.
Threats to rivers	Consult LEAP / Salmon Action Plan (SAP)/ Fishery Action Plan (FAP). Join River Trust / Anglers Conservation Association (ACA - legal help).	Locate source of problems, work with landowners, industry, Agencies to put problems right. Consult ACA on legal rights over pollution incidents.
Excessive plant growth	Reduce nutrient inputs and stores in sediments where possible. Increase shading if appropriate.	Identify root causes and, where possible, deal with them. This may include routine weed-cutting and removal or suitable herbicide treatment.
Acidification	If naturally acid lake/stream accept limitations of habitat. If acidified by pollution consider liming to neutralise waters.	Take Environment Agency / EN / CCW advice on conservation status of water and suitability for liming programme. Discuss better practices with forestry interests if appropriate.
Low DO	Monitor with DO meter. When necessary, re-circulate and spray water into air OR pump air into system.	Identify root causes and eliminate, consider changing to coarse fishery in extreme cases.

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Note: references marked with an * are key information sources.

7. Water Quantity

7.1 Introduction

Three key aspects of habitat quality sustain salmonid river fisheries - water quantity (flows), chemical quality (see chapter 6 - Water Quality) and physical habitat quality (see Harper & Ferguson, 1995 and chapter 8 - Habitats). Flows depend fundamentally on rainfall patterns, followed by run-off or percolation and storage in soils and rocks. The flow patterns in some English and Welsh rivers are regulated by large dams that are used for public water supply. Many of our rivers are affected with smaller weirs and sluices that fundamentally affect the water levels and bed gradients. Most of our rivers, particularly those on impervious rocks, tend to be directly rain-fed so experience very variable flows. Rivers on pervious rocks (e.g. chalkstreams) experience more stable flow regimes, being supplied with water from wetland and aquifer (underground) sources. Links between surface and groundwaters are often complex and usually poorly understood in detail for a given river or lake catchment. Consequently, the principal causes of low-flows on a given river - for instance whether they are primarily climate or abstraction-driven, are usually arguable, e.g. on the River Kennet at Axford, Wiltshire (Arnell, et al, 1997, Giles, 1996).

Cunningham (2002) provides a valuable overview of the legal control of water resource licensing in England and Wales, key points include:

- Common law riparian rights ensure that relevant landowners (with watercourses flowing through or at the boundary of their property) have the right to receive water without significant diminution in quantity or quality. This doctrine allows reasonable use of water.
- Regulative legislation was established by the Water Resources Act, 1963, amended by the Water Resources Act 1991 and the Environment Act 1995, key features are:
    1. With a few exceptions it is illegal to abstract water without a licence, the licence protects against third party claims for damages but does not guarantee water quality or quantity.
    2. Holding a licence protects against subsequent claims on a water resource - new licences must not derogate from existing rights.
    3. Prior to 1963 abstraction licences were based on historic volumes of use and were issued without restrictions, these are termed 'Licences of Right'.

The abstraction licensing system is currently under review with the Government proposals for reform published in 'Taking Water Responsibly' and the consultative 'draft Water Bill', see Cunningham (2002) for a very useful discussion of this topic.

Regulation of water abstraction in England and Wales rests with the Environment Agency, which has a set of low-flow rivers of concern. Catchment Abstraction Management Strategies (CAMs), currently under development, will allow a balanced allocation of water resources within river catchments. England and Wales are now split up into CAM units (Environment Agency, 2001). Water level management plans (WLMPs) are intimately linked to abstraction regimes and the forthcoming European Water Framework Directive will ensure that river flows are viewed in an ecological context, with habitats to be maintained in acceptable condition.

CAMS are to be the new Agency planning framework for integrated sustainable catchment abstraction management. The former ALF (Alleviation of Low Flows) programme that helped identify low flow rivers has now been replaced with the RSAP (Restoring Sustainable Abstraction Programme); information on particular rivers is available from Agency Water Resources staff. In October 2001 The Environment Agency launched its Resource Availability Methodology (RAM) that will be used to determine water resource availability in England and Wales.

Water Company 5-yearly Asset Management Planning (AMP) rounds provide opportunities for periodic review of abstraction practice and environmental impacts. Under the EU Habitats Directive, Special Area for Conservation (SAC) rivers have particular importance owing to the need to protect designated species such as water crowfoot, salmon and bullhead by ensuring adequate flows, temperatures and water quality.

Natural variations in river flow are of fundamental importance in determining river shape and behaviour; fish life cycles are adapted to seasonal flow patterns and are liable to serious disruption if flow characteristics of a given river are forced to change too much (see review chapters in Harper & Ferguson, 1995).

Fish stocks need flow protection for many reasons including:

- Differing species have differing flow requirements at different life cycle stages and through the year. River flow management must be holistic - catering for all needs.
- Maintaining winter spates powerful enough to re-distribute and de-silt spawning gravels.
- Maintaining summer and autumn spates to induce upstream migrations.
- Maintaining adequate spring, summer and autumn flows to facilitate downstream smolt migrations and parr re-distributions.
- Maintaining baseline summer flows to maintain adequate quality and area of juvenile, sub-adult and adult habitats.
- Maintaining adequate flows to dilute pollutants and maintain preferred temperatures and current velocities for target species.

Flows are measured in terms of their timing, frequency, magnitude and duration. Each of these factors can be of key ecological importance to species. River flows need to be allocated between competing interests - public water supply, hydro-electric power, agriculture, industry, conservation and recreational uses including fishing. The extent and timing of abstractions or releases from reservoirs can affect ecological and angling conditions quite profoundly at critical times of year (e.g. when sea trout are running).

To determine flow allocation, river objectives need to be set and defined. For key species and habitat conservation these are developed through the UK Biodiversity Action Plan or through protective site legislation relating to SSSIs, SACs and SPAs (see chapter 10 - Conservation). River Flow Objectives RFOs and Minimum Acceptable Flows, MAFs (see Acreman & Adams, 1998) can also be set for abstraction points. For migratory fish requirements see Solomon et al (1999) and for fishery management purposes see Swales & Harris (1995).

The Environment Agency uses a range of methods to determine acceptable flow regimes (Harper & Ferguson, 1995). These include:

- Hydrograph analysis - in many cases the 95 percentile has been used as a crude river low-flow threshold value whilst, for groundwaters, typical recharge times are used to estimate sustainable volumes for abstraction (Petts et al, 1995 and Cunningham, 2002). Solomon et al (1999) have recently related radio-tracking salmon migration data to river flow regimes.
- The views of expert panels of anglers (EPAM, see Swales & Harris, 1995) who fish the river under varying flow conditions, recording their independent assessments of suitability for recreation.
- Favourable habitat conditions, e.g. for salmon and/or bullheads determined as part of SAC notifications (Boon, 1995).
- Research projects developing new models of flow requirement based on energetic and behavioural needs of fish (Ibbotson et al, 2001).
- The use of macroinvertebrate distribution and abundance in relation to flow regimes. The LIFE (Lotic-invertebrate Index for Flow Evaluation) method is currently under development (see Extence et al, 1999).
- PHABSIM - Physical Habitat Simulation Modelling; this often involves field and desk work and is relatively expensive but can be very useful for detailed analysis.

In the context of this Fisheries Technical Manual the most relevant technique used by the Agency to assess acceptable river flow conditions is PHABSIM. PHABSIM is part of a larger suite of computer programmes called the Instream Flow Incremental Methodology (IFIM). The Agency uses the PHABSIM approach as a negotiation tool with abstractors, rather than as a purely prescriptive technique. The habitat components (e.g. depth, current speed, substrate type) that are preferred by key life stages of a given species (water crowfoot or brown trout, for instance) are determined (habitat indices). These are then modelled with IFIM to estimate their availability under changing flow regimes (e.g. on the River Allen, Dorset, Johnson et al, 1995, see also Dunbar et al, 1996 and Ibbotson et al, 2001). PHABSIM is a very useful method for assisting discussion of acceptable flow regimes that are required to support target species and habitats. Limitations of PHABSIM include:

- That it generates theoretical habitat changes that may not actually correspond with real population changes of animals or plants in the river.
- Habitat preference curves for a given species may not transfer at all accurately between rivers (preferences of species may need to be measured for each river or, at least, type of river).
- Aquatic plant communities and growth patterns have profound effects on in-stream hydraulics and predicted outcomes from modelling work.

Ibbotson et al (2001) mention the development of more sophisticated flow requirement models for fish species, for instance, based on energy budgeting. Extence et al (1999) have produced a very interesting set of macroinvertebrate species groups that tend to correlate with particular sets of flow conditions - this LIFE methodology is under development within the CAMs project. Work undertaken so far indicates that invertebrate community structures react most to summer flow variations in chalk and limestone streams and to short-term flow events in spate rivers (see Extence et al, 1999 for full discussion). The Agency water Resource Availability Methodology (RAM) uses the following classification methods to aid the setting of river flow objectives for river reaches by scoring the following variables:

- Physical character.
- Fisheries classification.
- Macrophyte scoring.
- Macroinvertebrate scoring (LIFE).

7.2 Technical and Practical Advice

7.2.1 Protecting river flows from over-abstraction

Anglers can help protect river flows by alerting Agency officers to drying wetlands, low-flow stretches of river and to dwindling fish stocks, reduced habitat quality and poor angling conditions on their fisheries. It is worth noting that low-flow conditions on rivers are often exacerbated by past river engineering (e.g. deep-dredging) schemes and intensive land use (e.g. silt inputs and channel over-widening through bank erosion by livestock). Such impacts can often be addressed through cost-effective habitat improvement schemes, maximising the ecological value of the available flows (Giles & Summers, 1996, Summers, et al, 1996, Environment Agency, 1996 and chapter 8 - Habitats). A habitat improvement project on the River Piddle in Dorset - a low-flow river where the Agency successfully reduced abstraction within the catchment - has enhanced wild trout fisheries, making best use of the increased flows (Environment Agency, 1996, Environment Agency, 1996, Giles & Summers, 2001 and chapter 8).

Participation in Agency statutory committees is a good way to communicate grass roots concerns over low-flow impacts on angling opportunities. The Regional Fisheries, Ecology and Recreation Advisory Committee, RFERAC, Regional Environment Protection Advisory Committee, REPAC and Regional Flood Defence Committee , RFDC are all potential pathways for advice to the Agency on changing river flow patterns. Angling consultative groups, Fishery Action Plan (FAP) groups and Area Environment Groups (AEGs) are also directly relevant. Agency officers do act on the advice of their Regional Committees - inputs to this advisory system are worthwhile.

The references given below provide a good starting point for understanding the technical background on how flows can be linked to fishery quality and to the need to campaign to retain water in rivers and wetlands. The political impact of fisheries opinion can be substantial and can help to generate support for research work on particular river catchments (e.g. Game Conservancy Trust, 1996). Fishery associations and riparian owner groups also wield substantial influence on important river fisheries. River Trusts are increasingly being set up with the express intent of campaigning for better river conditions and habitat restoration programmes (examples include The Tweed Foundation, The West Country Rivers Trust, The Hampshire Rivers Trust, The Wye Foundation, The Eden Trust, The Northumbrian Rivers Trust and many others).

Management options

Improving fishability under low-flows
The Agency has used the 'expert panel' approach (Swales & Harris, 1995) on some low flow rivers (e.g. upper Bristol Avon) to help determine acceptable flow regimes through the angling season. Where habitats have been degraded, leading to enlarged river channels and exacerbated low-flow conditions, habitat restoration projects can make a big difference to the quality of angling and of sustainable fisheries (e.g. Giles & Summers, 1996, Summers et al, 1996, Giles & Summers, 2001. Techniques for concentrating available flows include (also see chapter 8 - Habitats):

- Fencing to promote marginal vegetation growth - natural stream narrowing.
- Channel narrowing with bioengineering techniques and current deflectors.
- Bed-raising by importing clean gravel to build new gravel riffles.

- Encouraging *Ranunculus* growth to channel and hold back flows.
- Creating new scour pools to provide fish with deeper low-flow habitat.
- Enlarging corner pools and planting alder/willow to reinforce undercut banks.

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Figure 40 Series of low profile, upstream 'V' current-deflectors, scouring pools and stimulating *Ranunculus* growth on faster-flowing intervening riffles, Devil's Brook, Dorset

(See Figure 57, page 122, for a photograph of this same stretch, one year after fencing)

7.3 Summary of Management Options

Table 21 Flow management options and best practice

Issue	Management options	Best practice notes
Flow protection	Assess whether fishery has adequate year-round flows. Get involved in local discussions and advisory committees.	Take expert advice on whether low-flows are likely to be affecting a given fishery unacceptably and what are the best solutions.
Habitat improvement to optimise use of available flows	River channels are often over-wide owing to excessive bank erosion and dredging operations. Channel re-profiling can help to make the best use of available flows year-round.	Don't compensate for over-abstraction by simply making a smaller river. Gauge the likely original width of channels and restore back to those dimensions. Use 'greenest' approach possible.

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Note: references marked with an * are key information sources.

8. HABITAT QUALITY AND IMPROVEMENT

8.1 Introduction

Habitat includes physical, chemical and biological components. This chapter concentrates on aspects of physical aquatic habitat quality whilst chapter 6 covers Water Quality, 7 Water Quantity, 9 Aquatic Plants, 10 Conservation and 16 and17 Species Interactions. All of these chapters are directly relevant to understanding key aspects of overall game fish habitat quality. Reviews of salmonid habitat requirements are given in Environment Agency, (1996), APEM Ltd (1997), Environment Agency (1998b) and Ibbotson et al, (2001). The National Rivers Authority and Environment Agency pioneered between 1994 and 1996 the RHS (River Habitat Survey), the first systematic survey of river physical habitat quality in the UK (NRA, 1996, EA 1996, 1998a). The RHS method (EA, 1996) provides a simple standardised approach to assessing overall river physical habitat quality. An example of the application of RHS to characterise the habitats of the River Lune is given by Naura and Blackburn (1999). Trout habitat quality can be assessed by reference to texts such as Hunter (1991), Hunt (1993), Barnard and Wyatt (HABSCORE, 1995) and Giles and Summers (1996). Grayling habitat requirements are reviewed by Ibbotson et al (2001).

The Environment Agency has considerable existing physical habitat information bases in the River Habitat Survey (RHS) and HABSCORE. Biodiversity and Ecological Appraisal staff are essential links with Fisheries staff when consideration of potential habitat improvement works is contemplated. Flood Defence staff are able to advise on any increased flood risks associated with in-channel works and Development Control officers on the overall advisability of proposed projects (see chapter 12 - Consents).

Habitat creation for new still water trout fisheries is covered in chapter 11 - Fishery Development, and conditions for promoting an abundant invertebrate food supply in chapter 5. Chapter 4 on Arctic Char, covers specific points of particular reference to upland lake ecology. This chapter covers river habitats and their management.

A natural trout or grayling river typically has gravel shallows (riffles), steady glides, deep corner pools and, sometimes, waterfalls and cascades. These are the principal physical habitat features of streams and rivers. Rivers confined within hard banks tend to run deep, those running through softer rocks and soils are wider with lower banks and meandering loops. Long rivers may have stretches of varying physical quality, depending upon local geomorphological and geological conditions.

Many habitats, both river and lake, have been degraded in past centuries. Key impacts have been caused by land drainage and flood defence schemes, intensive agriculture, construction and development (Salmon and Freshwater Fisheries Review, 2000). In the British Isles habitat damage has severely impacted on wild brown and sea trout distribution and abundance (Giles, 1992). Fish habitat management and restoration is now an active research area by European and North American fisheries biologists and hydrological engineers (e.g. Brookes & Shields, 1996, FAO, 1998). On fluvial (river and stream) systems an understanding of geomorphology, hydrology and hydraulics needs to be blended with an equal understanding of ecological considerations in order for long-term sustainable solutions to be developed. Many problems experienced downstream are triggered by land use or river channel morphology change upstream.

The Environment Agency National Trout and Grayling Strategy (EA, 2003) includes the following policy:

Policy 22:
We will work with others to monitor, protect and improve the physical, chemical and biological quality of trout, char and grayling habitat, including work with Government to ensure that impacts on fisheries are fully considered in the development of new policies and grant schemes relating to land use.

The Agency uses its over-arching powers for fisheries, conservation and sustainable development to protect and improve habitats. Because of the need for formal Agency consent to work in and around rivers (chapter 12), this approach applies both to Agency projects and to the work of others. Often, large projects involve the collaboration of several partner individuals and organisations. As mentioned above, any individual in England and Wales contemplating in-stream or river bank works must obtain prior written consent from the Environment Agency. It is best to discuss plans at an early stage to smooth the pathway for successful applications. Note that, on some streams that are not designated as 'Main river', some activities may not need consent - always take advice from your local Area office before starting any work. This could prevent the situation of being instructed to remove un-consented works.

All self-sustaining fish stocks must have adequate habitat to complete their life cycles. Any significant under-representation or depletion of a key habitat for a life cycle stage will produce a 'bottle-neck', restricting the productivity of a fishery (see chapter 2 – Trout Ecology). Consequently, habitat management, restoration and creation are very important activities for trout, grayling and char fishery managers.

Wildlife other than game fish, including rare and endangered species (otters, water vole, lampreys, shads, bullheads) shares salmonid habitats and any habitat manipulation must include due regard for overall conservation objectives on a given river or lake (Giles 1998a & b, see also chapter 10 - Conservation). Ideally, habitat restoration initiatives should be assessed and planned on an holistic catchment basis, working where the need is greatest, rather than in an *ad hoc* manner. In this way a comprehensive overview of habitat problems and their solutions can be collated and implemented. Wherever possible, projects should be monitored for their success or failure - this is essential for both practical and scientific progress to be made. As mentioned above, river habitat projects are often collaborative and may involve riparian owners, fishing associations, Government Agencies, consultants, River Trusts, Wildlife Trusts, The Wild Trout Trust, Grayling Research Trust and others. The River Restoration Centre holds a database of river habitat improvement projects (RRC, 1999) that is interpretable and available for consultation at a cost.

Whenever a river habitat improvement project is envisaged it is recommended that specialist advice is sought from the outset. It is easy to do more harm than good to your river fishery by mis-applying techniques. Recommendations for good lake habitat management are given in chapters 11 (Fishery Development), 9 (Aquatic Plant Management), 16 (Interactions Between Fish Species) and 6 (Water Quality).

8.2 Technical and Practical Advice

8.2.1 Project planning

Habitat restoration projects need careful planning, the key steps being:

- Obtain advice on the habitat status of the catchment from the Agency and discuss your initial ideas with them well in advance of the date when you envisage starting work. Identify problems with both a 'desk top' and 'walk-over' survey.
- Develop ideas either with the Agency or in collaboration with an experienced and successful independent expert. Define the overall objectives of the project.
- Conduct a pre-scheme assessment to identify, as far as possible, factors limiting trout, grayling or char production. Develop specific objectives for the scheme.
- Ensure that your objectives do not compromise biodiversity objectives within the catchment.
- Design habitat restoration scheme, including cost-benefit analysis and obtain written Agency (Land Drainage) consent before starting any work.
- Monitor the stretch before work begins to obtain baseline data for future comparisons.
- Do the work.
- Maintain any structures over the long-term.
- Monitor the results to see whether objectives have been met.
- Report and disseminate results so that all can benefit from your experience.

Note that this is an idealised model, many projects have insufficient funds for scientific monitoring of results and are, in any case, using tried and tested techniques. The Agency consenting system involves Fisheries, Biodiversity, Flood Defence and Development Control staff (as well as others, if the need arises) - this ensures that all proposals get a rounded and well-considered airing. A fuller description is given in Environment Agency (1996) and APEM Ltd (1997). All Environment Agency works, and consents for the work of others, have had to be reviewed to ensure that they comply with the requirements of the E.U. Conservation of Natural Habitats and of wild flora and fauna - 'The Habitats Directive' and the network of the key 'Natura 2000' sites. This major task is a collaborative effort between the Agency, EN, CCW and landowners; it is due for completion in Spring 2004 (Environment Agency, 2001).

8.2.2 Habitat restoration methods - what, where and why?

Restoration implies a return to an original pristine state - this is usually impossible. Perhaps, rehabilitation - a partial return to an undisturbed state or enhancement (any improvement in environmental quality) are terms more usually applicable to fisheries projects. Habitat creation is, by definition, the establishment of a new habitat area within a given river reach. Many workers use the above terms interchangeably, all seek to improve habitat quality and quantity - the basis of biodiversity. The Environment Agency has a very useful RHS survey methodology and associated database that may be a useful starting point for habitat analysis on a given river catchment. Also, the Agency uses the HABSCORE system that correlates salmonid survey data with various habitat variables allowing assessments of the condition of given stretches of river (contact the Environment Agency, National Fisheries Technical Team, Salmon Fisheries Science Group, Cardiff).

Remember that, for much habitat work, prior consent is needed, the following table provides some examples:

Table 22 Some habitat works requiring formal consents

Activity	Authority
In-stream structures e.g. weirs, groynes, gravel riffles, cover structures.	Environment Agency.
River channel re-profiling, two-stage channels, river bank work.	Environment Agency.
Tree planting on river banks, fencing river banks.	Environment Agency.
Using herbicides or pesticides near water.	Environment Agency (see chapter 9).
Weed cutting in rivers and weed disposal.	Environment Agency (see chapter 9).
Stocking of fish.	Environment Agency (see chapter 15).
Construction of new still water fisheries	Environment Agency (see chapter 11, may also need Local Authority planning permission).
Any work on SSSIs, SACs, SPAs, etc.	Take advice from EN / CCW.

Salmonid habitat requirements

Stream-living trout, grayling and migrating or spawning char need relatively silt-free gravel for egg deposition, sheltered stream margins and shallows for young fish to develop in and deeper runs and pools for sub-adult and adult fish to seek sanctuary. Sometimes, for trout and grayling and always for UK char, deep water adult habitat is provided by a lake with in-flowing spawning streams forming nursery habitats. These spawning streams are often of critical importance to the abundance of the lake fish stock whilst adequate water quality and temperature regimes in the lake are vital for adult survival (see also chapters 6 - Water Quality, and 2 - Trout Ecology).

Assessing the quality of fish habitats is not easy - you have to visualise what is not there as well as what is. These observations then have to be compared with the ecological requirements of the species in question. Knowledge, skill and experience are needed to judge what is likely to be wrong with a river and which methods should deliver cost-effective solutions. Note that private projects by riparian owners, syndicates or angling clubs may often be embarked upon with the full realisation that they may not be fully cost-effective. Many habitat benefits cannot be quantified in economic terms.

There is a large general and specialist habitat improvement literature, much of it originating in pioneering North American trout stream restoration projects that started almost seventy years ago (Tarzwell, 1936). For technical reviews the reader is referred to Mann and Winfield, (1992), Central Fisheries Board (1995a, b), Environment Agency (1996), APEM Ltd (1997), Gordon et al (1992), Petts and Calow (1996) and Brookes and Shields (1996). For broader interest texts; Carter Platts (1930), Lewis and Williams (1994), Purseglove (1989), Giles and Summers (1996, 2001), Haslam, (1997) and Brooks and Agate (1997) are all recommended.

8.2.3 Coarse woody debris / trash dams - best practice

Large woody debris - tree root wads, trunks and branches are natural stream features. The protective cover that marginal deadwood and tree roots provide is a vital feature of trout streams. Wherever possible it is best to leave natural cover in place. Where dead trees cause unacceptable increased flood risk then they have to be removed but routine removal of virtually all in-stream cover is very damaging for fisheries. Sometimes, deadwood partially blocks channels to produce timber 'trash dams' of varying scale and density. These natural features produce several useful effects as well as having some down sides:

Table 23 Pros and cons of 'trash dams'

Positive attributes of 'trash dams'	Negative attributes of 'trash dams'
The scouring of deep pools and the deposition of de-silted spawning gravels on the pool tail. Stream fish and invertebrate productivity is thus increased through habitat diversity.	Possible obstructions to the upstream migration of trout and salmon.
The provision of dense overhead cover - highly preferred habitat by adult trout.	Possible increases in flood risk to farmland or waterside property.
Trapped decaying organic matter and silt, often colonised by high conservation value lamprey larvae (ammocoetes) and many aquatic invertebrates (shrimps, caddis larvae). In heavily shaded catchments this is an important source of nutrients within the stream system.	None.

Best practice is to carefully weigh pros and cons of individual accumulations of woody debris, rather than routinely removing them all. Partial removal may often be a possibility, especially in remote forested stream catchments. Gaps cut in trash dams will lower the upstream water levels, reduce flood risk during spates and allow free passage to migratory fish. Note: If cutting slots in woody dams be very careful - de-stabilising a trash dam may cause it to fail suddenly, potentially washing any in-stream worker away, amid churning logs and fast water, with a risk of injury and/or drowning. Some measure of protection may be derived from working along the upstream edge and staking parts of the structure that are to be retained.

8.2.4 Managing bank side trees

Bank side trees play an important role in the ecology of streams and rivers. Shade can be important to reduce water temperatures and provide safe cover for sea trout, brown trout and other fish. Old trees with a degree of decay such as willow pollards tend to have diverse wildlife communities associated with them. These can include roosting bats, nesting ducks and woodpeckers and a wide range of invertebrates. Good tree management on river catchments involves cyclical management to produce a mosaic of light and shade and a wide variety of habitat types. Leave 'standard' trees as landscape features. Alder, willows, black poplar and hazel were traditionally harvested every few years to provide wood for charcoal, clog-making, fence posts, hurdles, faggots, basket making, thatching ties, fuel, etc. Such harvesting is seldom cost-effective today and routine river side tree maintenance, if done at all, generally falls within the remit of a fishery manager's winter schedule. In Hampshire, Wiltshire and Dorset hazel coppice is still used for hurdle and faggot making - useful natural materials for wetland and stream restoration projects. Pollarded or coppiced willow and alder provide the following benefits for fisheries:

- A natural strong form of bank revetment, through the roots, preventing large-scale erosion. Support via the roots for undercut banks and corner pools.
- Habitat for otters, nesting birds and invertebrates above ground and cover for fish in exposed roots below the water surface.
- Shading to prevent excessive weed growth, for instance on spawning riffles.

A lack of tree maintenance can lead to the following fisheries problems:

- Tunnelling of small streams - keeping out too much light for aquatic plant growth, reducing subsequent invertebrate and fish production.
- Shading out bank side grasses, leading to bank erosion and trees 'stranded' out in the river. Over-shading also removes feeding and cover habitats for water voles and other river bank species.
- Top-heavy trees blow over in gales, ripping scour holes out of the banks.

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Figure 41 A mosaic of shade and sky-lighting on the River Piddle, Dorset

O'Grady (1993) compared salmon and brown trout densities on paired, shaded and open stretches on a wide range of Irish rivers. He found that:

- Over-shaded river sections held far lower stocks of juvenile salmon (0.25-60% of open sections) and juvenile and adult brown trout (0.6-62% of open areas) than open river sections. Out of 20 paired sites, every one held significantly lower fish stocks in the shaded section.

- The average trout stock density for 27 shaded areas was only 28.5% of the figure for open zones.
- Both salmon and trout numbers are correlated to the degree of shading.
- The phenomenon of over-shading reducing stream salmonid densities is thought to occur nation-wide in Ireland.

There is no doubt that, with the general demise of widespread riparian tree coppicing and pollarding, many English and Welsh salmonid stream fisheries are now over-shaded. Figure 41 below shows best practice in coppicing a stream side bush:

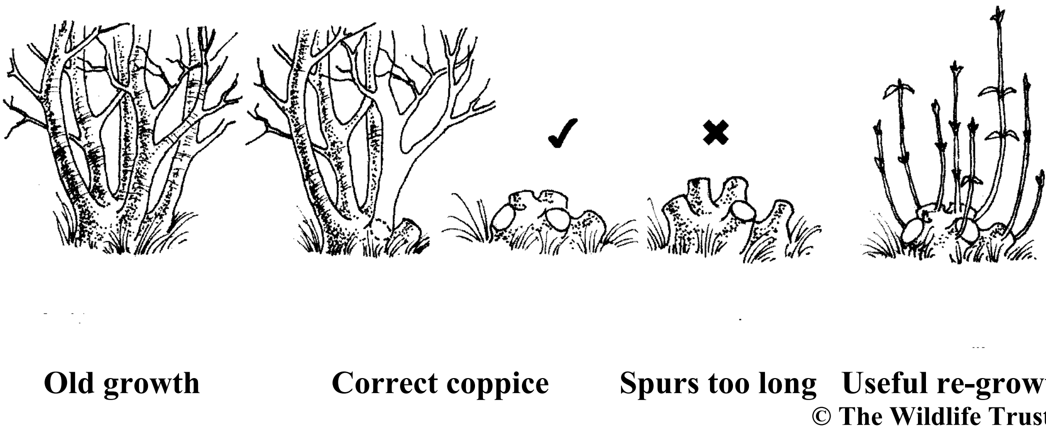

Figure 42 Correct coppicing practice

When coppicing willow, alder, ash or hazel, cut stems at an angle to shed water; cuts at the stool surface maximise re-growth. The resulting new, straight growth provides useful timber for bank maintenance and other habitat work. Coppicing extends the life span of trees. A tree planting and management plan is a useful exercise on all fisheries - think how to maximise habitat variety whilst providing the best conditions for target species.

8.2.5 Silt pollution and buffer zones

Natural river catchments are comprised of extensive grassland, moorland, wetland or woodland. Modern land use has largely modified natural plant communities for high density sheep, pig or cattle rearing / dairying or for arable cultivation or forestry. High density stock rearing removes much or all vegetation from stream banks exposing the soil to trampling and erosion. Over-grazed river banks tend therefore, to be broken down and the river channels widened and shallowed. Ditching operations, especially on sandy moorland soils can lead to serious silt and sand inputs to headwaters. Ploughing of river corridor fields, for instance for potato, maize or cereal production, often exposes soil to erosion during heavy autumnal rain and may also increase agri-chemical pollution of watercourses. The photographs below show an extreme form of arable field erosion (Figure 43) and silt entering a chalk stream fishery (Figure 44):

Figure 43 Erosion gulley in maize field - a source of extensive sediment inputs

Figure 44 A clear-watered, buffer-zoned tributary entering the main River Piddle that is silty with run-off from recently ploughed fields

Excessive quantities of soil and silt particles washed into watercourses will clog the stream bed, causing many problems including:

- Bare eroding banks that provide no cover for water voles, water shrews, otters and shy birds such as water rails. Also, by definition, lush vegetation is absent and this means that silt-rich water can wash straight into the river, rather than being filtered.
- Silted and sand-clogged river beds that have a low invertebrate diversity and low abundance of certain insect groups. Interstices (spaces between gravel), vital niches for invertebrates such as shrimps and caseless caddis larvae, are filled-in.
- Silted gravels that provide very poor conditions for fish egg survival (salmon, trout, grayling, dace, barbel, chub, bullhead, lampreys). Free intra-gravel water flow, vital to provide buried incubating fish eggs with dissolved oxygen and to remove waste

products, is blocked. Poorly irrigated eggs are prone to fungal infections and suffocation.

- Silted stream sections that tend to provide low current speeds and poor conditions for water crowfoot (*Ranunculus*) growth - a high conservation value aquatic plant.

Silt pollution is, therefore, a major threat to UK salmonid fisheries (Theurer et al, 1998). Note that land use resulting in excessive sediment inputs to rivers can lead to potential prosecution under the Salmon and Freshwater Fisheries Act, 1975.

The setting-aside of 'buffer zones' - roughly vegetated strips of 5-25m width along river banks provides a natural silt-filter and can have a number of other benefits for water quality such as reducing nutrient and pesticide inputs. Grant-aid for farmers to encourage buffer zoning may be available and best practice is to seek local advice from the Environment Agency, Wildlife Trust, FWAG (Farming and Wildlife Advisory Group) or FRCA (Farming and Rural Conservation Agency).

8.2.6 Bank erosion by livestock - fencing pros and cons

As noted above, over-grazing by sheep or cattle and ditching unstable sandy soils is a very widespread problem in both upland and lowland river catchments. Localised damage by horses and outdoor pig production on riparian meadows is also important in some areas. A tried and tested solution is to erect either temporary (electric) or permanent (post and wire) fencing. Set well back from the river or ditch edge, this will also produce a buffer zone.

Figure 45 Sheep-grazing bank erosion and fenced opposite bank with dense riparian vegetation

On the River Piddle, Dorset, The Game Conservancy Trust fenced long sections of cattle-poached river bank in order to improve riparian and in-stream habitats (Giles & Summers, 2000). The figures below (D. Roberts, pers. comm. © Game Conservancy Trust) show 1995 and 1996 results for wild brown trout and salmon parr comparing average fish densities (+/- 1 SE) for six fenced sections and six un-fenced, “control” sections. Densities are numbers of fish per 100 square metres of stream bed and are higher in fenced sections:

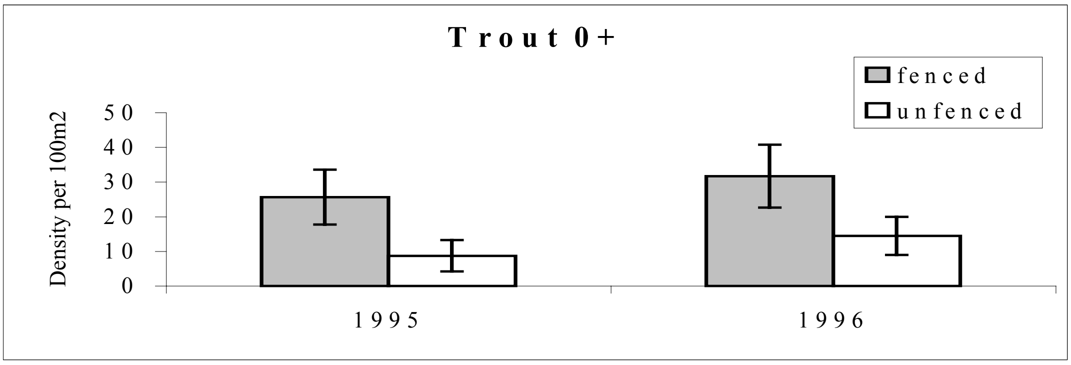

Figure 46 Wild trout fry densities on fenced and unfenced sections of the Dorset Piddle

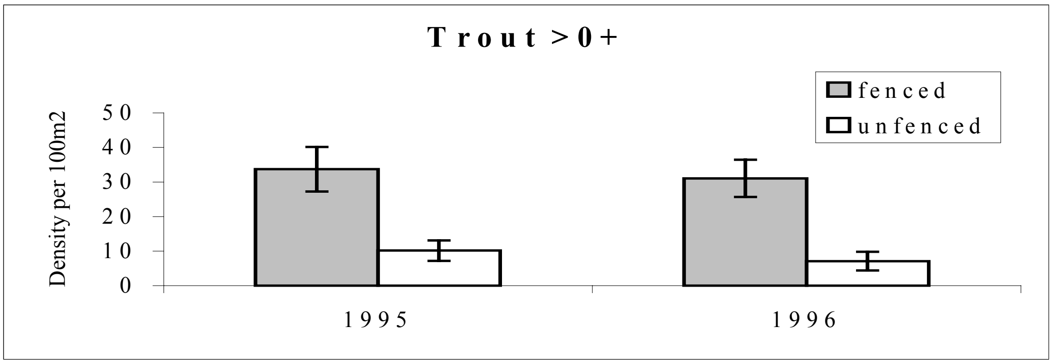

Figure 47 Wild trout parr and adult densities on fenced and unfenced sections of the Dorset Piddle

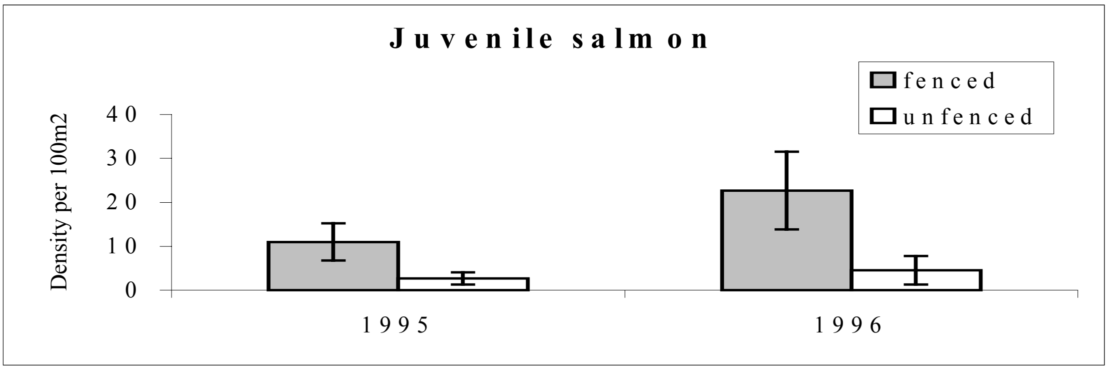

Figure 48 Salmon parr densities on fenced and unfenced sections of the Dorset Piddle

The benefits and potential pitfalls of fencing schemes include:

Table 24 Pros and cons of fencing stream banks

Positive attributes of well designed fencing schemes.	Potential negative attributes of fences
A rapid re-growth of riparian vegetation providing habitat for invertebrates, water voles, nesting water birds, etc.	Set-up and maintenance costs of the fencing and lost grazing or crop production areas.
Binding of the bank by grass roots, reducing further erosion.	A relatively rapid growth of woody shrubs and trees that need maintenance.
Trapping of silt amongst the plant stems reducing silt inputs and narrowing over-wide channels. Higher banks allow native crayfish to shelter amongst underwater vegetation and to build burrows in consolidated soils.	The over-shading of weakly competitive plants with reduced floral diversity and habitat removal for some rare invertebrates adapted to live on muddy stream margins.
Channel narrowing speeds the flow, de-silting gravels and deepening the water.	
Water table levels in riparian meadows are raised (with raised stream level), often improving grazing conditions.	
Marginal vegetation provides cover for fish (especially very young ones that cannot survive in fast currents) and an invertebrate food supply.	

As always, variety is the key to success; it is best to have fenced areas interspersed with areas where livestock have access to the river but, ideally, at relatively low stock densities. Habitat diversity leads to high biodiversity - a highly desirable management objective.

Clearly, the potential for better fishery management through a carefully planned fencing and subsequent buffer zone management plan, can be high. Once again, aim to leave sections of all habitat types on the fishery. It is good to have areas of dense vegetation where anglers cannot fish - these serve as sanctuaries for trout, grayling and other wildlife. Very large trout, for instance, may live there during the day and venture out in the late evening to feed.

8.2.7 Bank erosion - further control methods

Natural vegetation and durable natural rock/soil banks, along a meandering river valley flanked by marshes and wetlands are the best protection against excessive erosion. A degree of erosion is necessary on any river to liberate new supplies of gravel from upstream and to allow the natural gradual geomorphological adjustment of the channel with time. New gravel bars come and go and pools change shape over the years.

Unfortunately, however, large-scale human impacts have been imposed upon this natural gradual regime, causing changes in run-off after rain, in river channel shape and gradient and in peripheral land use. The key culprits have been large-scale land drainage and flood defence schemes, intensive agriculture and development, including reservoir building. Some of the combined effects of these activities have been to:

- Straighten, widen and deepen river channels, speeding flood flows and reducing habitat diversity.
- Speed run-off into rivers from field drains and impermeable surfaces (roads, car parks, pavements, roofs, etc) causing more rapid peaks in flood flows.
- Remove bank side vegetation that would otherwise slow flood flows and provide erosion protection and sheltering habitats.
- Remove marginal wetlands that would naturally store storm waters, attenuate flood peaks and support summer base flows.

Rapidly rising powerful spates hitting banks that have often been stripped bare of much of their protective vegetation cover leads, not surprisingly, to accelerated bank erosion. Bank erosion is at its maximum when rivers are running a full capacity. Couple this to the fact that naturally meandering river channels with low gradients have often been engineered to lead to straighter, steeper channels and the potential for rapid development of spates becomes apparent. Rapidly moving flood waters from headwater catchments are bound to meet constrictions such as bridges, culverts and townships downstream. This is often where flooding problems occur.

Methods of combating erosion are as follows - starting with low energy 'green' solutions and increasing in engineering robustness; note that green solutions may not always prove durable under high flows on spatier systems:

- Allowing natural grass and reed growth to bind banks together.
- Using live willow spiling (woven grids), staked hazel hurdles or faggots or conifer tree top revetments to protect banks and encourage silt trapping, re-vegetation and the stabilisation of new sections of bank. See Figure 49 below.
- Planting and managing dense, low-growing woody shrub and tree (willow, alder) growth at key erosion points.
- Re-engineering the channel to form meanders and a two-stage profile with a central summer low-flow channel and a bunded winter high-flow channel (see Figure 50 below).
- Add timber staking or logs to protect the toe of the bank at erosion hot spots.
- Add geotextile barriers behind natural materials to protect and contain bank materials.
- Add rock 'rip-rap' (tumbled boulders) along a carefully angled bank to slow current.
- Build jointed rock revetted banks or use pre-fabricated concrete cellular products. These must be based on firm surfaces to prevent undercutting and failure.
- Steel-pile ('sheet-pile') eroding banks or concrete or brick face eroding banks - the worst solution ecologically but often seen in urban circumstances.

Techniques early in this list qualify for so-called bio-engineering or soft-engineering solutions whilst the latter ones are termed hard engineering solutions. Sustainable game fisheries and biodiversity objectives are more likely to be supported using soft-engineering techniques. Note that active water vole burrows or otter holts must not be destroyed during bank maintenance works (WACA, 1981). If the presence of otters or water voles is suspected a suitably qualified surveyor should assess the site before any bank work is attempted. The Wildlife Trusts are a good contact for river bank mammal surveys.

Figure 49 Staked woven willow panels used to reinstated bank on this badly eroded river bend. The fencing will prevent livestock incursion

Figure 50 below shows a more ambitious project where a two stage channel has been created by The Environment Agency on an over-widened section of the River Alt, Liverpool. Note the excellent growth of riparian vegetation.

Figure 50 Channel narrowing creating a two-stage channel

High gradient, high energy streams need a more robust approach to erosion protection than gentler, low-gradient systems. Technical details of all these approaches are given in the reference list appended.

8.2.8 In-stream structures

In-stream work usually needs Environment Agency Land Drainage consent before any work proceeds (see chapter 12 - Consents). All in-stream habitat improvement work must be designed for specific river stretches - a 'recipe book' approach is likely to lead to failure to achieve the desired objectives. The use of locally-produced sustainable materials is recommended, where possible. Take professional advice when considering river habitat restoration projects. Before you dig, especially with powerful hydraulic equipment, check carefully with relevant companies that there are no gas mains, water mains, sewerage pipes, electrical cables or other important underground structures that may be damaged during habitat work. These checks are available at no charge via a fax-back or e-mail service, fax numbers for Utilities Companies are available from Agency Area Offices.

Building shallows

On deep-dredged river channels where gravel shoals have been removed it is relatively easy to re-instate riffles by adding suitable clean gravel (see Figure 51 below). Better salmonid fish spawning success, invertebrate communities and improved *Ranunculus* growth can often be promoted using this simple technique. The table below provides some guidance on useful gravel sizes:

Table 25 Examples of characteristics of brown trout spawning habitats from field studies (after Environment Agency 1996a, see Box 3.1 for references to studies)

Velocities	Depths	Substrate sizes
Mean 39.4 cm/s	Mean 31 cm	Mean 14 mm
Generally > 30 cm/s	Mean 25.5 cm	Mean 6.9 mm
20-60 cm/s	20-50 cm	-
33-95 cm/s	18-46 cm	-
24-37 cm/s	12-18 cm	26 - 75 mm
30-40 cm/s	-	Commonly 80 mm
20-70 cm/s	Over 20 cm	7.5-75 mm

Clearly, when choosing gravels for riffle creation, careful examination of the study reach is required to check the local spawning conditions for trout or other species targeted in the study. The substrate and current speed needs of differing fish species vary (see, for instance, Environment Agency, 1996, Ibbotson et al, 2001). Only clean washed gravel should be introduced to river channels. Remember that, on high energy (steep gradient) systems, added gravel may often be washed away by spates. This may not be a catastrophe as it will be trapped in pockets downstream and available there as new spawning substrate. Trout will often use relatively small pockets of gravel for spawning.

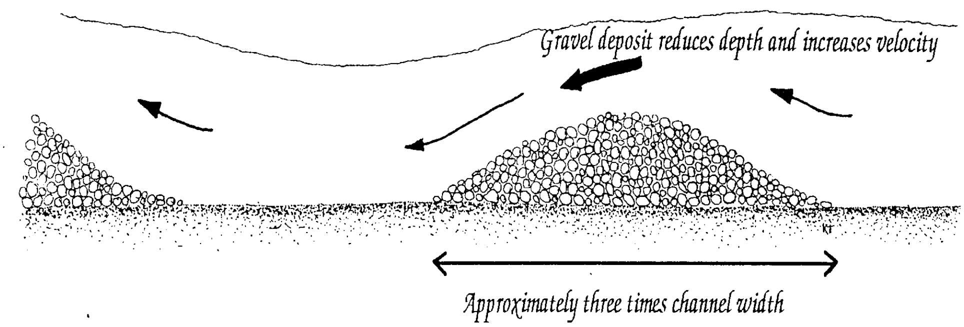

Figure 51 Riffle placement (Environment Agency, 1996)

Building pools

The simplest way to build a pool is to excavate the river bed in an area where the force of the current will keep the pool relatively silt-free. In the example below a uniform dredged channel is improved by digging occasional pools. The pool spacing of six channel widths is a useful 'rule of thumb' that suits many river systems. If pools are created in the right places they will remain stable for long periods. If they are made in the wrong places they will often fill back in with sediment after only one winter. This is especially true on high gradient (high energy) streams such as many spate rivers.

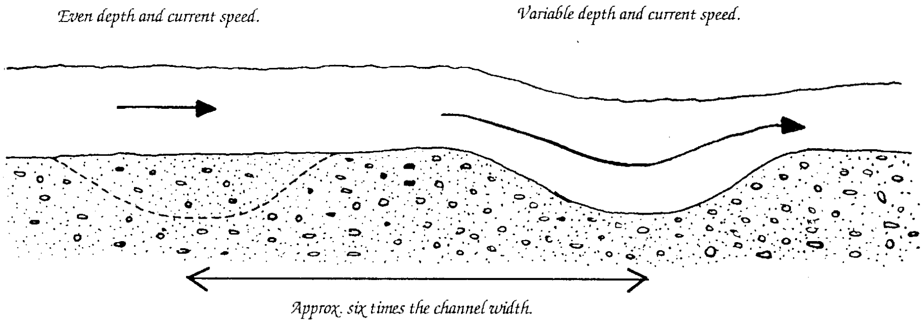

Figure 52 Excavating pools in a straight section stream

A second approach to pool-building is to use a series of timber current-deflectors to create a meandering channel, cutting new pools, depositing riffles and providing ample physical cover through the addition of securely-staked timber marginal cover.

Such projects can also be a useful opportunity to incorporate substantial amounts of marginal deadwood cover for fish and other wildlife.

The photograph on the next page (Figure 53) shows such a scheme under construction during low summer flows on the River Till, Wiltshire. Lush vegetation rapidly re-established after ground works were completed.

© Nick Giles

Figure 53 Habitat improvement project using timber deflectors and marginal cover

New pools often benefit from bank side coarse draping grasses or bushes that provide lateral cover for trout. The pool on the Dorset Piddle in the photograph below (Figure 54) has suitable depth, cover and current velocities to provide excellent adult brown trout habitat.

© Nick Giles

Figure 54 Bush providing cover over pool

On steeper-gradient streams, up-stream 'V' weirs are useful for creating new pools and riffles. The point of the 'V' faces upstream so that the arms of the 'V' direct water centrally into the channel, scouring a pool and depositing de-silted gravel on the tail of the pool. This gravel riffle is a new potential spawning site. Siting of such weirs should generally be on relatively straight river sections with an appreciable gradient. Ensure that the weir is very low profile so as not to impound a significant stretch immediately upstream. Note the importance of keying logs into banks and making an apron upstream of the weir to prevent undercutting. As with all in-stream work, weir-building should be viewed as part of a carefully planned sequence of habitat improvements designed to provide important new habitat for defined species.

© Nick Giles

Figure 55 Upstream V weir creating a scour pool and spawning riffle next to tree root cover. River Piddle, Dorset

The Devil's Brook, Dorset - a monitored example of habitat improvement.
On the Devil's Brook, River Piddle, Dorset (Giles & Summers, 2001) the Game Conservancy Trust used a water meadow system with four consecutive sections of heavily grazed chalk stream separated by hatch pools to set up a habitat improvement field experiment. Two of the sections were developed with pairs of low-profile upstream 'V' timber groynes that scoured pools and deposited new gravel riffles and two intervening sections were left as controls. These two experimental sections were also fenced to keep dairy cattle out of the stream. The remaining two sections were left un-modified from the original grazed condition that they were in. The wild trout stocks in all four sections have been surveyed by electric-fishing each year since the completion of the work; the consistent difference in adult wild trout stocks between the habitat improved and unmodified, control sections is quite clear:

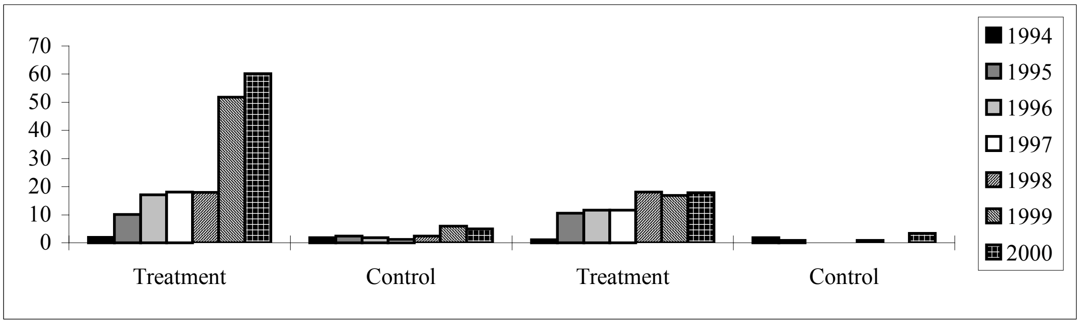

Figure 56 2+ years and older wild trout numbers in each of four sections of the Devil's Brook 1994-2000 (Publication in prep, Game Conservancy Trust)

The photograph below (Figure 57) shows this Devil's Brook study site only one year after the work was carried out (c.f. Figure 40 in chapter 7 page 100, taken soon after construction):

© Nick Giles

Figure 57 Devil's Brook, Dorset, experimental section 2

Further information on building in-stream structures can be found in Environment Agency (1996a). When planning such work it is usual for an expert to walk the fishery sketching a restoration plan that is subsequently agreed and worked-up into a formal set of drawings that are submitted to the Environment Agency as part of a Land Drainage Consent application (see chapter 12 - Consents).

8.2.9 Sources of project funding

Sources of funding for habitat restoration change with time, your Agency Area Office has staff who can help. Some current potential sources of funding and partnership projects include:

- EU grant aid for rural development.
- Water Companies through the 5-yearly Asset Management Planning (AMP) process.
- Heritage Lottery Fund (HLF).
- DEFRA Rural Development Regulations - agri-environment schemes such as Countryside Stewardship (England) and Tir Gofal (Wales).
- Environment Agency internal project funds and/or collaborative partnership bids.
- English Nature and Countryside Council for Wales, especially on SSSI and SAC rivers.
- Riparian owners and fishing associations, River Trusts, Wild Trout Trust.
- Sponsorship from commercial companies.

8.3 Summary of Management Options

Table 26 Habitat improvement management options and best practice

Issue	Management options	Best practice notes
Project planning	Take advice, obtain consents, check for infrastructure that could be damaged by hydraulic machinery, carry out a pre-scheme survey, implement, plan then monitor and publish results.	Go through the check list opposite so as to ensure a cost-effective and successful project.
Coarse woody debris / Dead wood	Remove dead wood to leave a clean open channel. Conserve deadwood where it adds to fish habitat quality and provides habitats for other wildlife.	Where dead wood constitutes a genuine raised flood risk, it is best removed. Where flooding impacts are absent or negligible it is best to leave deadwood snags, root wads, etc as important year-round fish cover.
Trees	Trees can be left as 'standards' to complete their natural growth or cyclically cut back to a carefully designed plan.	It is best to avoid too much open water and too much shade. Good practice is to manage trees and bushes by pollarding and coppicing so as to produce a diverse range of light levels along the stream banks and bed. Excessive weed growth can be deliberately shaded out by allowing trees to grow on appropriate banks.
Buffer zones	Encouraging land managers to buffer catchments subject to intensive arable or livestock production.	Check potential sources of silt and agricultural pesticides and fertilisers and then work out best approach to stopping them reaching the river. Note that under-field drains can by-pass buffer zones.
Fencing	Consider fencing out livestock with electric or permanent fencing where over-grazing and or bank damage is evident.	Fencing a whole river catchment is expensive, unnecessary and can reduce floral and faunal diversity. As usual, variety is the best outcome, with few areas of serious silt inputs but some bare banks and light grazing of riparian meadows.
Bank erosion	Some bank erosion is natural on fisheries and often liberates gravel that is essential for fish spawning. Too much erosion, however, causes excessive channel shifts and siltation of gravel shallows.	Best practice is to use the softest engineering approach that the site will allow. It is unwise to use lightweight materials that will be swept away during the first flood but, equally, an over-use of rock structures is deemed unsightly by many conservationists. Take Agency advice to reach a sensible, cost-effective compromise.

Table 26 cont'd.

Issue	Management options	Best practice notes
In-stream structures	Make sure that you take expert advice, check for underground pipes, cables, etc and obtain necessary Agency consents. Seek early advice on consents.	Plan any habitat improvements so as to diversify the physical channel form (riffles, glides, pools, physical cover) to benefit fish and other wildlife.
Funding sources	These can include: European Union, Water Companies, Heritage Lottery Fund, EN/CCW, DEFRA, collaborative EA projects, Riparian owners, Angling Associations, River Trusts, Wild Trout Trust, Commercial sponsorship.	Produce a well structured, costed, appropriate restoration plan. Agree with project partners the best potential sources of funding and approach these first.

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Environment Agency / NRA leaflets (available from area offices):

Farm waste management plans.
Farm waste minimisation.
Understanding buffer strips.
Managing maize.
Agriculture, pesticides and water.
Silage pollution and how to avoid it.
Desilting stillwaters.
Fisheries habitat improvement.
Protecting our habitats; The Habitats Directive.
Phytophthora disease of alder.
Aquatic weed control operation.
De-oxygenation - Practical self-help for fishery owners and managers.
Environments for fish.

Water plants their function and management.
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Note: references marked with an * are key sources of information.

9. AQUATIC PLANT MANAGEMENT

9.1 Introduction

Aquatic plants are the vital first photosynthetic step of the fishery food chain, combining carbon dioxide and water to form sugars and thereafter, the synthesis of plant tissues and production of oxygen. Aquatic plants provide the following essential ecosystem functions:

- Primary (plant) production to be consumed by herbivore invertebrates which, in turn, are consumed by fish.
- Dead and decaying plant matter (detritus); an essential source of food for many bacteria, fungi and invertebrates.
- Aquatic macrophytes (large plants) take up nutrients (nitrogen, phosphorus, potassium and other elements) dissolved in the water and lake bed sediments - this reduces the nutrients available to algae, reducing the potential for problematic algal blooms.
- Oxygenation of still and running waters. During the day, plants release oxygen (O_2) in excess of their respiratory requirements. At night, however, plants continue to respire and absorb, rather than produce O_2. This can lead to very low dissolved oxygen (DO) concentrations in weedy fisheries. In still waters during algal blooms and on warm summer nights followed by overcast mornings, low DO can kill trout (see chapter 6 - Water Quality).
- Underwater weed beds form a three-dimensional structure which becomes coated with algae, bacteria and fungi ('aufwuchs') - a coating grazed by many invertebrates and some fish species. Few freshwater invertebrates eat aquatic macrophytes, most browse aufwuchs.
- Weed beds thus provide important feeding habitats, cover for fish from predators and spawning substrates for many fish (coarse) and invertebrate species.
- Good fly hatches on rivers and lakes depend critically on having the right plant species present (see chapter 5 - Feeding Ecology). Many insects of importance for trout food live preferentially on particular weed species - for instance, olive mayfly nymphs on river water crowfoot and so a good diversity of plant species is beneficial to a fishery (see chapter 11 - Fishery Development).

A well-balanced trout river or lake tends towards relatively clear water with a diverse plant community. When the balance of the system is disturbed, submerged plant diversity may often decline, to be replaced by rampant growths of just a few dominant macrophyte or algal species. Such disruptions often arise from:

- Excessive nutrient inputs (eutrophication) from point or diffuse sources including STWs, agricultural fertiliser and silt inputs (see Wade, 1995).
- The presence of dense shoals of bottom-feeding cyprinid fish. Algal blooms become commonplace in summer, water becomes turbid, submerged plants decline. Insect and other food availability for trout changes and angling performance is reduced owing, for instance, to poor visibility of artificial flies (see chapter 6 - Water Quality).
- Introductions of 'exotic' plant species. For instance, floating-leaved pennywort, water fern, parrots feather, Australian stonecrop and Canadian pondweed in the water or Japanese knot weed, Himalayan balsam and giant hogweed on river and lake banks. These invasive species can all out-compete and smother native

vegetation. Loss of native plants can severely limit trout food production and physical cover for fish from predators. Damage to conservation and fishery values can be extreme through elimination of native flora and associated fauna (see Waal et al, 1995).

- Die backs of overgrowths of submerged macrophytes, phytoplankton and cyanobacteria ('blue green algae') often lead to very low DO concentrations and fish mortalities.
- Blanketing plant growths clogging river and lake surfaces stop normal diffusion processes and can lead to die off of submerged plants, stagnation, low DOs and fish deaths (see Ridge et al. 1995). They can also make angling impossible.
- Excessive algal or macrophyte growth may often disrupt water chemistry by causing major diurnal fluctuations in pH (the acid-alkali balance) and DO - these can sometimes prove fatal to trout or at least, affect their feeding behaviour.

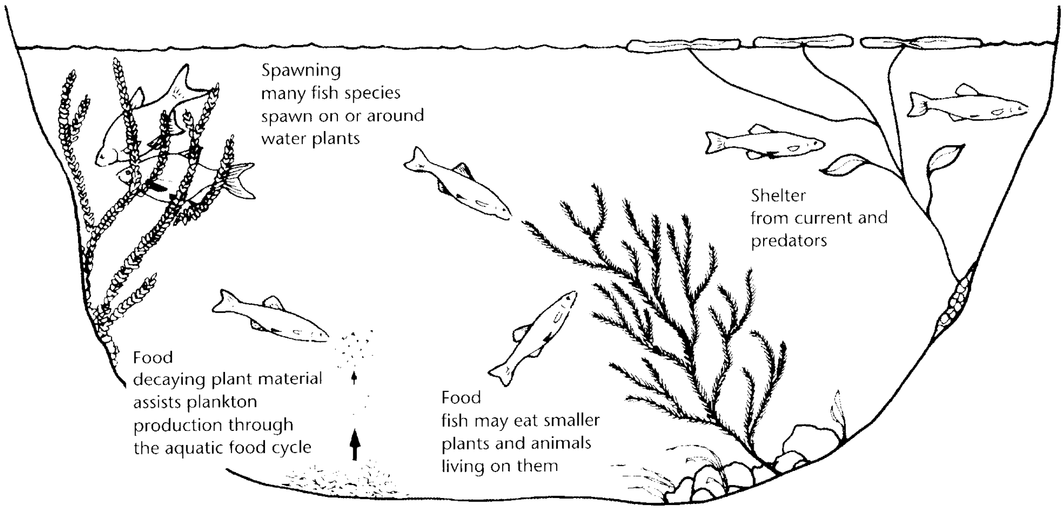

Figure 58 Functions of aquatic plants in fisheries (Environment Agency, 1998)

Aquatic plants are vital to healthy fisheries (see Figure 58 above) but can also:

- Raise river water levels at times of low flow, by partially blocking channels,
- Block navigations and impede fishing on both rivers and lakes,
- Block weirs and sluices, reducing amenity values,
- Both cause erosion and protect banks from erosion on rivers and lakes,
- Oxygenate and deoxygenate water on rivers and lakes,
- Create and destroy wildlife habitats on all fishery types.
- Create safety hazards.

Fishery managers would do well to risk assess their waters both for aquatic plants and other factors. Consideration of potential problems in advance of their occurrence allows for better planning and reductions in accidents.

Plant communities

Aquatic plants range from microscopic cyanobacteria, through planktonic green algae, diatoms and other groups, to filamentous bottom-dwelling or floating algal mats ('blanket weed'), stoneworts (charophytes; *Chara* & *Nitella*), submerged weed beds, lilies and marginal reeds, rushes and sedges. All waters have dissolved plant nutrients and sunlight available for green plants to photosynthesise. The balance of algal production in open water and macrophyte (submerged weed) growth is determined by which species are most competitive over any given period. Good management provides the right balance through the angling season.

Still waters
Lakes can be classified according to their overall ecology, for instance, five major trout lake types are widely recognisable:

Table 27 Lake types

Lake type	Characteristics
Peat-stained bog lakes	Poor light transmission, low nutrient status and low plant productivity. Often occurring in upland moorland areas, these often have brown trout and may be suitable for brook trout.
Clear watered upland lakes	Sparse diverse macrophyte growth, cold water, high dissolved oxygen concentrations and sparse phytoplankton. Often occurring in mountainous or glacial valley areas. Usually have brown trout, Arctic char may be present.
Clear-watered lowland lakes	Abundant diverse macrophyte growth, warmer water, variable dissolved oxygen concentration and occasional planktonic 'blooms' (dense phytoplankton growth). Often occurring as lowland estate lakes, flooded gravel pits, reservoirs. Often ideal for stocked rainbow and brown trout fisheries.
Turbid nutrient-rich lakes	Regular algal blooms and low diversity and abundance of macrophytes. Often occurring as enriched natural or man-made lakes. May be suitable as trout fisheries, especially with good management to improve conditions. May be better developed as coarse fisheries.
On-line lakes	Characteristics determined primarily by the nature of the river running through them. Limestone and chalk aquifer sources provide excellent potential trout waters.

Successful still water trout fisheries tend to need relatively deep, cool, clear, well-oxygenated waters with plenty of open water for fly-fishing. Limestone-based (hard water) systems are more productive for plants and insects than hard rock (soft water) catchments and tend, therefore, to have better trout fishing potential. Naturally turbid waters or enriched lakes prone to algal blooms can often have problems as trout fisheries owing to poor visibility of flies and periodic low DO levels.

Where high concentrations of plant nutrients such as phosphorus and nitrogen reach rivers and lakes from point sources such as STWs or large fish farms, or diffuse sources such as agricultural land run-off, natural low levels of phosphate are elevated, fuelling extra plant growth. Problems caused by elevated phosphate levels can be added to by higher nitrate levels - both nutrients may limit plant growth when the other is present in excess. Clear -watered lowland lakes are therefore, becoming less common owing to widespread nutrient enrichment (eutrophication). Once a clear-water fishery becomes turbid because of over-enrichment, it is very difficult to return it to its former state.

Dense shoals of adult common carp or common bream dig over lake beds whilst feeding, uprooting macrophytes, disturbing sediments, eating seedlings and re-cycling nutrients. This fuels algal blooms and blanket weed and suppresses submerged large plants (macrophytes). Management to recover water clarity is, however, possible; these lakes can sometimes be transformed to a weedier, clearer-watered state through careful management and reduction of coarse fish stocks (Giles, 1993). This topic is covered in more detail later in this chapter, see also Moss et al (1996).

Rivers

River plant communities are determined primarily by gradient, bedrock and water chemistry characteristics of the river in question (Holmes 1978, 1983). This basic pattern is further influenced by degrees of eutrophication (Haslam, 1990, English Nature, 1997). Enriched rivers are often dominated by dense growths of competitive algal species with a reduced diversity of macrophyte species. Dense algal growths can blanket the river bed and cause DO and pH shifts due to intense photosynthetic activity. Algae may also blanket weed beds, e.g. water crowfoot, causing them to die back. This form of habitat damage can be serious; trout, grayling and particularly char stocks all suffer when their habitats become over-enriched.

Where unacceptable plant growth occurs, legal and cost-effective control with best environmental practice is required. Methods for the control of and legislation relating to the control of submerged and emergent aquatic plants are given in Seagrave (1988), MAFF (1995) and Environment Agency (2001). Useful identification keys for aquatic plants are given in Haslam et al (1982) and Seagrave (1988). Where physical methods are inappropriate, herbicidal control of plant growth may be the best management solution but great care is needed in pesticide choice and usage. In particular, ensure that no rare plants, habitats or other species will be damaged by the application of herbicides - consult Environment Agency Biodiversity staff and where appropriate, EN or CCW staff.

9.2 Technical and Practical Advice

9.2.1 Pesticide and herbicide use

A written application to the Environment Agency's designated Area Officer is required from fisheries managers before a herbicide can be used in or near water (Environment Agency, 2001). Applications should be screened by all relevant functional staff. If consent is granted, it is up to the user to make sure that all operations are carried out satisfactorily. The user must understand and carry out herbicide applications safely and responsibly and ensure that downstream owners and abstractors are aware of the work being undertaken. The Agency may include the following disclaimer with each herbicide consent: "Herbicide approval is issued on the condition that the applicant has the agreement of the landowner to carry out the treatment".

The following law governs pesticide use (see Environment Agency 2001 for full details):

- Control of Pesticides Regulations 1986 (as amended) (COPR)
- The Plant Protection Products Directive (91/414/EEC)
- Water Resources Act 1991
- Control of Pollution Act 1974
- Dangerous Substances Directive (76/464/EEC)
- The Water Industry Act 1991 and Water Supply (water quality) Regulations 1989
- Surface Water Directive (75/440/EEC)
- Groundwater Directive (80/68/EEC)
- Wildlife and Countryside Act 1981
- The Habitats Directive (92/43/EEC)
- Health and Safety at Work Act 1974
- Control of Substances Hazardous to Health Regulations 1988 (COSHH)
- Fire Precautions Act 1971
- Health and Safety (safety signs and signals) Regulations 1996
- Carriage of Dangerous Goods by Road Regulations 1996.
- The Countryside and Rights of Way Act 2000 (CROW).

In general, given this wealth of complex protective law and the potential to break it through ignorance, it is essential only to use herbicides in or near water where really necessary. 80% of all Environment Agency weed control operations are effected by mechanical methods (Environment Agency 1998). Correctly selected and correctly applied herbicidal products can provide acceptable management solutions but remember, - pesticides are designed to kill target living organisms - they are dangerous. Impacts include both direct toxicity and indirect effects such as potential de-oxygenation owing to weed decay. It is vital to take expert advice before any application is contemplated. Recent changes in European legislation mean that some herbicides presently in circulation are either banned or under review.

9.2.2 Controlling plant growth - general advice

It is essential to both identify correctly the plant species that you seek to control and to define your management objectives. BASIS-trained Environment Agency staff can help with species identification. Mechanical or physical methods may be better than herbicide use for your particular situation. Remember, if mechanically controlling a problem species, it is illegal to spread exotics such as giant hogweed. A full assessment of costs, risks and benefits should be carried out before attempting a control programme. Specialist advice is available under contract to the Environment Agency and to private fishery managers at cost from the Centre for Aquatic Plant Management (CAPM), Broadmoor Lane, Sonning, Reading, Berks, RG4 6TH, Tel 0118 9690072. CAPM produce a very useful set of aquatic plant Information Sheets. Their website is www.capm.org.uk .

For thorough reviews of appropriate methods of control, herbicide choice, pesticide legislation and safety of use, types of aquatic weeds and plants of conservation concern, the reader is referred to Environment Agency (1998, 2001), MAFF (1995a, & b) and TAPS (1994, 1995).

Mechanical control - emergent and riparian plants

Bank side plants can be mown, flailed or strimmed - be careful not to let cuttings enter the watercourse. Note that it is very desirable to leave a broad (at least 1 metre wide) fringe of rushes and/or reeds along the edge of a trout fishery to provide cover for fish, food organisms for fish and habitat for other wildlife such as water voles. Anglers also use this screen as cover to reduce the chance of scaring trout and grayling.

Mechanical control - submerged plants

Submerged aquatic plants can be cut (mechanical digger bucket, weed-cutting boat), dredged, hand-pulled or raked from your fishery. Hand scything of weed beds (particularly crowfoot) is a skilled task of the river keeper and patterns such as chequer boards and cross channel cuts are often employed. The keeper maintains adequate cover for fish whilst trimming back growth to allow room for successful fly fishing. A well-keepered trout stream is a challenge to fish and has carefully channelled flows, plentiful lies for trout and retains high biodiversity value. Hand or chain scythes permit small-scale local control of weeds whilst diggers with weed buckets and weed-cutting boats can be used on larger-scale jobs. Cut weed should, wherever possible, be removed from water bodies - otherwise it can cause pollution, fish kills, disruption to angling and flooding around blocked sluices and culverts. Removal of weed cut on chalk streams is often facilitated by weed racks, catching floating material that can then be removed mechanically. Some rivers have weed lagoons where cut weed is diverted and allowed to degrade out of the main flow or from which the weed is removed by hydraulic machinery. Removing weed strips nutrients from the fishery - in view of widespread eutrophication effects, this is generally beneficial.

Biological control
Biological control is the use of animals or plants to deliberately impact target problem species. River banks can be successfully grazed by low densities of livestock - this promotes a diversity of plants but must not be allowed to cause excessive bank erosion and soil/silt pollution of the watercourse. Electric fencing allows for fine control of grazing pressure at relatively low cost. Countryside Stewardship (DEFRA) agreements can provide financial support for low stock density riparian meadow grazing regimes.

Stocking grass carp
In relatively warm still waters and canals, the stocking of Chinese grass carp (*Ctenopharyngodon idella*), with suitable consents from the Agency, DEFRA and EN/CCW, can be effective in the control of certain water plants (Foundation for Water Research, 1992, Seagrave, 1988). Grass carp do not breed in the UK, are hardy and relatively long-lived. When carefully used they do not appear to cause any serious environmental problems and can consume their own weight in water plants each day. Water temperatures of around 25 degrees C. are required for optimal feeding although they will feed above 16 degrees C. Clearly, warm summers are needed for prolonged feeding seasons.

Initial stocking densities of 100 - 200kg/ha are usually recommended but 500kg/ha of fish can exert rapid control over dense plant stands. Densities of grass carp must be kept in balance with a lake's plant communities. These fish tend to survive well, are long-lived and grow to large sizes (10kg plus); they can soon over-graze plants, creating a turbid, algal-dominated fishery. Once submerged plants are lost they may be very difficult to re-establish. The netting out of excess grass carp stocks may, therefore, be required to prevent severe over-grazing of plant communities. Excess stocks are saleable for stocking, given that the appropriate consents (S30, ILFA, WACA) have been obtained - see chapter 15 - Stocking.

Grass carp eat the softest, most succulent plant species first, their preference tending to be (Seagrave, 1988); duckweeds (*Lemna*), stoneworts (*Chara, Nitella*), Canadian pond weed (*Elodea canadensis*), starwort (*Callitriche*), small-leaved Potamogeton pond weeds.
Less palatable species include hornwort (*Ceratophyllum*), milfoils (*Myriophyllum*), larger-leaved *Potamogeton* pond weeds, filamentous algae and, if very hungry, water lilies (*Nuphar, Nymphaea*) and draping emergent rushes, reeds and grasses.

Fish removal
The reverse of stocking - fish removal can sometimes be effective in the control of algal blooms. Juveniles and adults of many cyprinid fish (bream, carp, roach) eat large numbers of planktonic crustaceans (*Daphnia* species and others) which, in turn, eat phytoplankton. Large-scale fish removals can lead directly to large increases in zooplankton populations and consequent declines in the algal populations that they graze. When the algae have been driven down to low levels by grazing zooplankton, these subsequently also decline and the two communities tend then to cycle in abundance throughout the year. When the right balance is achieved relatively clear water is promoted. Seedlings from the macrophyte seed bank may then re-establish submerged weed beds in the clearer water. Snails are important grazers of submerged weed beds, keeping down algal coatings and allowing efficient photosynthesis. Where coarse fish densities are deliberately reduced, snail abundance increases very markedly

and excellent submerged weed bed growth can be promoted (Giles, 1992). In some circumstances predation pressure by trout may exert sufficient impact on juvenile cyprinid fish abundance to allow increases in *Daphnia* abundance and so reduce the potential for algal blooms on some fisheries.

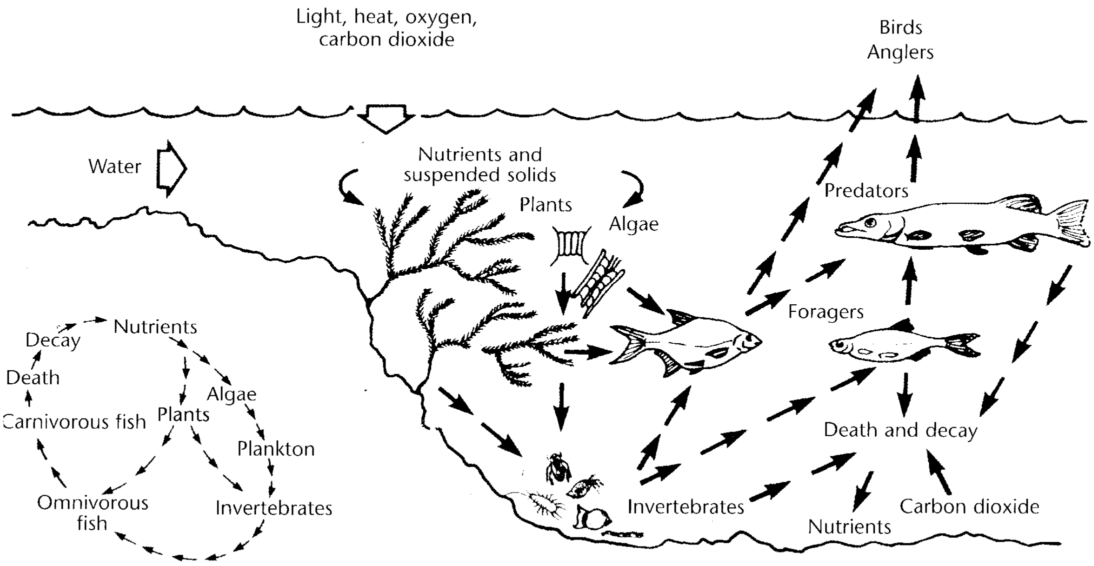

Figure 59 Nutrient cycles in fisheries (Environment Agency, 1998)

Coarse fish-removal to promote clearer water and better submerged weed bed growth does not work in all situations, much depends upon the exact nature of the lake concerned (see Giles, 1992 for successful gravel pit example of field experiment).

Lake states

Both turbid, phytoplankton-dominated and clear-watered weedy lake states tend to persist once established. Switches from clear to turbid states can be thrown by factors including serious reductions in submerged weed beds, increased nutrient inputs, fish stocking and reductions in crustacean populations (e.g. by pesticides).

Reverse switches from turbid back to clear waters may be triggered by reinstating crustacean grazer populations (reducing fish populations) and reintroducing plants under conditions where they can thrive (reduced nutrients, clearer water). Moss et al. (1996, chapter 2) provide a detailed explanation of switching between the two relatively stable lake states.

Some keys points to note are provided in Table 28 on the next page:

Table 28 Key factors supporting stable lake states (after Moss et al, 1996)

Submerged plant dominated	Phytoplankton algal dominance
Water clear with limited open water algal growth.	Water turbid with fine sediment and algal blooms.
Sediments peaty, anaerobic and bound by plant roots. Denitrification occurring in sediments.	Sediments very fine and unbound - easily disturbed. Sediments aerobic and turned over by foraging fish. Large amounts of available Phosphorus and Nitrogen stored in sediments.
Seedlings able to establish and grow in well-lit shallows.	Plant seedlings few, shaded out by algae, covered in periphyton, disturbed by feeding fish.
Diverse submerged plant community secreting algal-suppressing (allelopathic) chemicals.	Few or no submerged plants, perhaps some lilies, floating leaved pond weeds, marginal rushes and reeds.
Plentiful large planktonic crustaceans (e.g. water fleas) and cover protecting them from fish predation.	Few or no large crustaceans, many tiny crustaceans inefficient at grazing typical phytoplanktonic algae.
Well structured diverse fish community with tench, rudd, pike and perch.	Few predatory fish, many small planktivorous fish eating larger crustaceans, many larger carp or bream digging over lake bed sediments.
Phosphorus and Nitrogen largely captured by large plants via sediments.	Phosphorus and Nitrogen freely available to open water algae.

Removal of dense shoals of bream or carp can be an attractive management option on mixed fisheries for a number of reasons. Benefits can include (see also chapter 6 - Water Quality):

- Improvements in water clarity (and angling performance) and *Daphnia* populations (which trout will eat).
- Reductions in coarse fish hosts for *Argulus* fish lice and other parasite species, so a possible longer-term decline in parasite problems for stocked trout.
- Sale of (health-certified) coarse fish to other fisheries.

Note that consents both to net and transfer fish are required from the Environment Agency.

Barley straw use to control algae

The potential for decomposing barley straw to kill algae has been known for around 25 years. As part of aerobic decomposition the straw appears to release natural algicidal chemicals that seem to do no harm to macrophytes or invertebrate populations (Environment Agency 1997). It is critical to use the straw in a loose, teased-out form so as to ensure a well-oxygenated (aerobic) decay process. The use of bales just thrown into lake or riverside margins is ineffective partly because most decay is anaerobic. This reduces lake water DO and releases plant nutrients - a useless result for the fishery manager. Effective loose straw masses can be contained in mesh enclosures, either in inlet streams, along fishery margins or floating in various structures. Mesh tubing used to package Christmas trees works well. Individual units should not exceed 20kg, a minimum of 50kg/ha water surface (maximum 250kg/ha) should be applied in spring, before algal blooms develop. Treatments should be repeated before the straw has rotted completely, usually at around 6-monthly intervals (Environment Agency, 1997). Well-rotted straw should be removed. Note that barley straw does not work in all situations - smaller waters with low flushing rates, lower nutrient levels and adequate shading from trees are often the most successful fisheries to try.

Herbicidal control of weeds

The introduction to this chapter warns the reader of the need for careful consideration before applying herbicides to fisheries. Manual or mechanical methods coupled with cut weed removal will usually be a preferable approach. Important points to check before starting aquatic plant control programmes are:

- Are there better methods than herbicide use (manual, mechanical) available to me?
- Do I understand fully what I am doing and what the consequences of my actions may be?
- Have I taken advice from staff at my Environment Agency Area office and other experts?
- Do I require and have I obtained consent to use pesticides from the Environment Agency?
- Am I trained and qualified to use pesticides (NPTC or SSTS)?
- Have I taken care to protect public drinking water and agricultural supplies from pesticides? Inform abstractors of your plans in writing.
- Can I control lake inflows and/or outflows to facilitate treatment?
- Selection of a herbicide that is least environmentally damaging and most effective for your target nuisance plant species.
- Carry out assessments of risks under the Control of Substances Hazardous to Health (COSHH) Regulations (1994) (see MAFF, 1995 for details).
- Is my fishery on or upstream of a designated Wildlife Site - take advice from EN/CCW/Wildlife Trust on approved pesticides to avoid damage to rare species.
- If the fishery is part of, or near to an SSSI, permission must be sought from EN/CCW 4 months prior to use (Wildlife and Countryside Act, 1981).
- If the fishery is part of, or near to an SSSI, the Agency is required to give EN/CCW 28 days notice before permitting a third party to carry out an activity that is likely to damage the special features of an SSSI (i.e. the use of herbicides). Consent can be granted earlier with EN/CCW agreement (Countryside and Rights of Way Act).
- Have I told my neighbours and signed public pathways to avoid risks to animal and public health?
- Can I calculate dilutions correctly, use well-maintained equipment and correct protective clothing?
- Is the weather right, are the plants at the correct growth stage for treatment?
- Minimise spray drift and/or work in an upstream direction.
- Do not treat large areas of dense weed in warm (>12 degrees C.) water - treat widely spaced sections.
- Dispose of any unused pesticides according to the Code of Practice for the safe use of pesticides on farms and holdings (HMSO, 1990). Note, this publication is due for updating to include reference to the Ground Water Regulations.
- Have I obtained the appropriate Groundwater Regulations 1998 authorisation if pesticides are to be disposed of to land?

Herbicide choice
Remember that dying and dead weed uses up dissolved oxygen and can lead to DO concentrations low enough to kill trout. When applying herbicides only treat relatively small areas at a time.

Only substances approved under the Control of Pesticides Regulations 1986 (as amended, COPR) for use in or near water can be used. Herbicides must not be used where there is a risk of contaminating potable water supplies or groundwaters, each application should be assessed on its merits by BASIS-qualified Environment Agency staff. The Agency may offer an Area service on plant identification and associated correct herbicide choice. The storage, disposal and use of herbicides are all covered by relevant legislation that must also be observed. Note that herbicides have stipulated safety intervals and concentrations before they may be released into controlled waters.

Plants toxic to livestock such as hemlock water dropwort may become palatable during decomposition but retain their toxicity - be careful to remove safely all such growths (see table 4.4.3 Environment Agency, 2001). To prevent de-oxygenation and fish kills or unacceptable ecological change to a habitat, consider phasing herbicide applications so as to treat only relatively small areas at a time.

Table 29 Introductory guidance on approved products for use as herbicides in or near water

(see Environment Agency, 2001 for further detail but note subsequent changes in EU regulations):

Chemical **With updated EU status notes.**	**Interval before irrigation**	**Approved Product**	**DEFRA Number**	**For control of**
2,4-D **NOW ONLY FOR USE NEAR WATER.**	3 weeks	DORMONE, ATLAS 2,4-D, MSS 2,4-D AMINE.	05412 07699 01391	Many waterside broad-leaved weeds. No longer for use in water.
DICHLOBENIL **EU MAY BAN THIS CHEMICAL IN 2008**	2 weeks	CASORON G (Zeneca Crop) CASORON G (Miracle) CASORON G (Zeneca Prof) LUXAN DICHLOBENIL	08065 07926 06854	Rooted floating-leaved and submerged weeds
DIQUAT liquid **BANNED FROM 1st JULY 2002**	10 days	REGLONE (Zeneca Crop) REGLONE (Zeneca Crop)	06703 (expires June 2002) 09646	
DIQUAT alginate **BANNED FROM 1st JULY 2002**	10 days	MIDSTREAM (Miracle) MIDSTREAM (Scotts)	07739 09267	

Table 29 cont'd.

Chemical **With updated EU status notes.**	**Interval before irrigation**	**Approved Product**	**DEFRA Number**	**For control of**
GLYPHOSATE	Nil	ROUNDUP ROUNDUP PRO ROUNDUP BIACTIVE ROUNDUP BIACTIVE DRY ROUNDUP PRO BIACTIVE BARCLAY GALLUP AMENITY HELOSATE GLYFOS PROACTIVE GLYPER SPASOR SPASOR BIACTIVE	01828 04146 06941 06942 06954 06753 06499 07800 07968 07211 07651	Emergent and floating weeds, including reeds, water lilies and all weeds on banks.
TERBUTRYN <u>**WILL PROBABLY BE WITHDRAWN FROM SALE in 2004 or 2005.**</u>	7 days	CLAROSAN (Novartis) CLAROSAN (Scotts)	08396 09394	Floating and submerged weeds including algae.

<u>Note that the potential for the herbicidal control of submerged aquatic plants is currently being progressively reduced through EU review procedures.</u>

The following table provides examples of products that can be used near <u>but not in</u> water (Environment Agency, 2001).

Table 30 Herbicides for use near but <u>not in</u> water

Chemical	**Interval before irrigation**	**Approved product**	**DEFRA Number**	**For control of**
ASULAM	Nil	ASULOX	05235	Bracken and docks on banks beside water
FOSAMINE AMMONIUM	Nil	KRENITE	01165	Deciduous trees and shrubs on banks
MALEIC HYDRAZIDE	3 weeks	REGULOX K	05405	Weeds and grasses on river banks

The susceptibility of some commonly occurring aquatic weed species to herbicides is given in Tables 4.3 and 4.4.2 of Environment Agency (2001). See Seagrave (1988), MAFF (1995) and Environment Agency (1997, 2001) or contact CAPM for further specific advice on aquatic weed control operations and herbicide choices.

Consult qualified Environment Agency staff before making your application for herbicide use. A BASIS certificate of competence is required of all Environment

Agency staff giving internal and external advice on herbicides (see Environment Agency, 2001, chapter 8).

Timing of aquatic plant control operations
The following table (Environment Agency, 1998) indicates the typical optimum times to undertake common weed control operations; seasonal or geographical differences will affect timings and should be taken into account.

Table 31 Timing of weed control operations

Time	Target weeds	Technique
April - early May	Submerged weeds and algae	Dichlobenil* and Terbutryn*
May - July	Water crowfoot	First cut
Late May - June	Common Reed	Glyphosate
Late May - July	Free-floating weeds	Glyphosate
July - August	Emergent, floating, submerged weeds and algae	Cutting/raking
July - August	Water lilies	Glyphosate
August - early September	Emergent weeds	Glyphosate
September - October	Water Crowfoot	Autumn cut
September - December	Emergent weeds	Channel cleaning/cutting

Note * Dichlobenil may be banned by 2008. Terbutryn is being withdrawn from sale.

9.2.3 Liming trout fisheries (see also chapter 6 - Water Quality)

Some fishery managers attempt to increase the productivity of nurient-poor natural trout waters by liming them. This practice is not recommended - see below. Man made fisheries such as clay, sand and gravel pits or purpose-built excavated lakes can be fertilised to increase productivity. There is, however, a danger of unnecessary fertilisation leading to excessive algal activity, blanket weed and unstable DO levels leading to fish mortalities. Note, also that fisheries that are on-line with controlled waters must not be fertilised owing to potential adverse water quality impacts downstream. On suitable waters, the following methods may work but each fishery requires careful consideration (Environment Agency, 1998):

- Hydrated lime (@ 200-750 kg/ha) raises the pH, releases nutrients for plant growth and can help to reduce organic silt build-up. Treat areas of the lake sequentially at weekly intervals in winter so as not to produce too sudden a change in water chemistry.
- Crushed limestone added in winter to nutrient-poor ponds and lakes at 750-1000 kg/ha. Can be combined with basic slag treatment.
- Basic slag - a slow release phosphate-rich fertiliser added in winter @ 300 kg/ha.
- Triple super-phosphate - a soluble 'instant' booster for algal growth. Dosage rate 100 kg/ha. The algae are intended for consumption by zooplankton that are, in turn, eaten by the fish. Don't combine with hydrated lime as insoluble phosphate salts are produced, greatly reducing the effectiveness of the operation.

Note that excessive fertilisation can lead to dense algal blooms or heavy submerged weed bed growth, both may die back suddenly, deoxygenating the water. Great care is needed when trying to manage the nutrient balance in still water trout fisheries.

Outcomes are not always easily predictable. Fertilisation to boost fisheries to artificially high levels is therefore, generally not recommended in natural waters as it may well have detrimental effects on the fishery ecosystem as a whole and on rare species, such as *Sphagnum* mosses, in particular. Acid peaty catchments may often have high conservation value species that can be damaged by liming.

Liming of man-made waters can, however, sometimes be a useful management technique for increasing plant growth and/or helping to reduce accumulations of lake bed leaf litter. Where a lake has a 'sour' acid bed, organic matter of this type can be naturally broken down by bacterial and fungal decay promoted via the addition of finely powdered chalk. The decision on whether liming is appropriate for a fishery should always be made in consultation with your Environment Agency Area Fisheries and Biodiversity staff.

9.2.4 Improving river *Ranunculus* growth (see also chapter 7 - Water Quantity)

Water crowfoots are of key importance in the maintenance of chalk stream trout and grayling habitats, they are also important on many other river types. Crowfoot beds provide cover for fish, areas of insect production and hold back and channel flows - many of these benefits disappear where crowfoot growth is sparse and trout and grayling fisheries consequently suffer.

Dry phases of weather, over-abstraction and eutrophication can all affect crowfoot distribution and abundance (Giles et al 1991). The Environment Agency (2001) have reviewed the available science on *Ranunculus* growth and suggested a series of key factors and drivers:

<u>Factors:</u>
- Discharge - Seasonal/Annual changes in river flows,
- Stream velocity, depth, levels,
- Substrate composition and siltation,
- Physical channel characteristics,
- Competition - Interaction/Life Cycle/Colonisation,
- Water quality, enrichment, suspended solids,
- Grazing, light, shade, temperature.

<u>Drivers:</u>
- Natural climate cycles,
- Abstraction and catchment water use,
- Channel management,
- Vegetation management,
- Enrichment from point sources,
- Shading by algae,
- Land use and diffuse enrichment,
- Rehabilitation, augmentation, etc.

Under low-flow conditions, when *Ranunculus* beds are often sparse in any case, over-grazing by mute swans can have additional important localised impacts, especially on chalk stream trout fisheries. Examples include the Wiltshire Wylye and upper Hampshire Avon (MAFF 2000).

Crowfoot beds thrive in fast, clear, cool water. Different *Ranunculus* species are adapted to live in differing river types such as sandstone, clay-bedded, limestone, chalk rivers and winterbournes (seasonally-flowing streams). The best approaches to stimulating abundant *Ranunculus* growth are (see also chapters 8 - Habitats, 7 - Water Quantity and 6 - Water Quality):

- Conserving flows - campaigning to reduce over-abstraction,
- Managing land around the river to minimise silt and agri-chemical inputs,
- Check that, where necessary, STWs have phosphate-stripping equipment - water quality improvements are generally secured through the periodic water company Asset Management Plan (AMP) process,
- Manage in-stream habitats to maximise the use of available flows (make sure that channels are a reasonable width, etc),
- Cut back over-shading of channel by trees,
- Where significant channel over-widening (erosion by livestock or flood defence / land-drainage projects) has occurred, narrow channel to former dimensions using bed-raising with clean gravels and/or reductions in width with fencing, bio-engineering revetment or current-deflector techniques. Note that Environment Agency consents will be required for in-stream works and that any increased risk of flooding will be weighed against potential fisheries and conservation improvements during the consenting process (see chapter 12 - Consents).

9.2.5 Reducing 'blanket weed' growth in still waters

Blanket weed growth (buoyant masses of *Spirogyra, Cladophora, Rhizoclonium or Vaucheria* algae) can sometimes be reduced by barley straw treatment. Reductions in nutrient inputs to the fishery and increases in shading can also help.

9.2.6 Reducing submerged macrophyte growth

Submerged weed bed growth in a trout fishery can potentially be reduced by the following approaches:

- Shading from trees on the southern side of river or small lake fisheries.
- Using sunk, weighted, woven black nylon sheeting to shade out plants on small lakes or to open up angling positions on larger lakes.
- Use of grass carp (Note requirement for SaFFA Section 30, ILFA, WACA consents).
- Weed cutting with a hand or chain scythe (remember to remove cut weed).

Table 32 Management methods for mechanical removal of submerged weeds

Fishery type and weed type	Method of control	Notes
Rivers - water crowfoot	Hand-cutting: by standard or long-handled scythe Usually in a chequer board (regular patch) pattern or as a series of lateral bars and open sections across the channel. A skilled river keeper can cut weed @ around 200 metres per day on a medium-sized chalk stream	Carried out a little and often to prevent channel blockage, to allow space for angling, to channel flows and create lies for trout. Note, to minimise disruption to angling, some rivers have specified weed cutting days. Cut weed needs collection, removal from water and legal disposal.
Rivers or lakes - marginal reeds	Hand-digging: spades, rakes, cromes Usually tackled by a team of helpers that can cover perhaps 50 metres of bank in a day. Pulling: hand removal of individual plants. Small areas can be cleared on a regular basis.	Reed rhizomes are chopped out from the stream-side of the bed to a depth of around 20cm. Hand-pulling of plants allows the ultimate selectivity for small-scale fishery operations. Plant material needs careful disposal.
Rivers - various weed beds	Chain scythe: 2 man team This set of linked cutting bars is pulled saw-like through the base of weed beds. One man on each bank. A 2-man team can cover around 100metres of small river in a day.	Working the chain scythe carefully and slowly in a down stream direction allows for selective cutting and leaving gaps, etc. Cut weed needs removal and careful disposal.
Larger rivers and lake margins - dense submerged weed beds	Weed-cutting boats. These purpose-built boats have a reciprocating blades on a front-mounted cutter bar or a stern-mounted V blade. They plough through beds cutting down to 1.5m as they go. Amphibious machines can be used in shallows. Large areas (several hundred metres) can be cut in a day but removal and disposal of cut weed needs careful organisation. A JCB or 360 degree excavator bucket is often the best approach.	Weed cutting boats need very careful use as they can produce a severe cut with consequent habitat loss for many species. Also, on rivers, large-scale reductions in water depth and increases in current speed can abruptly result from a summer weed cut. This can sweep away fish fry and other delicate wildlife.
Rivers, lake margins, ditches	Hydraulic excavator bucket ('Bradshaw bucket') JCB, 360 degree sloughs, draglines can all be used to scoop excess weed growth and underlying sediments from fisheries. In skilled hands these machines can cover 2-300 metres per day, depositing the weed either in trailers or along the bank away from the water's edge. Care needed to dispose of weed in environmentally acceptable way.	The Bradshaw bucket (1-4m wide) is made with gaps between bars to allow weed to be collected and water to drain away. A reciprocating cutter bar works along the front edge of the bucket. Skilled contractors can be hired in on short-term contracts for this type of work.

Management options

Figure 60 below provides a decision framework for mechanical weed control.

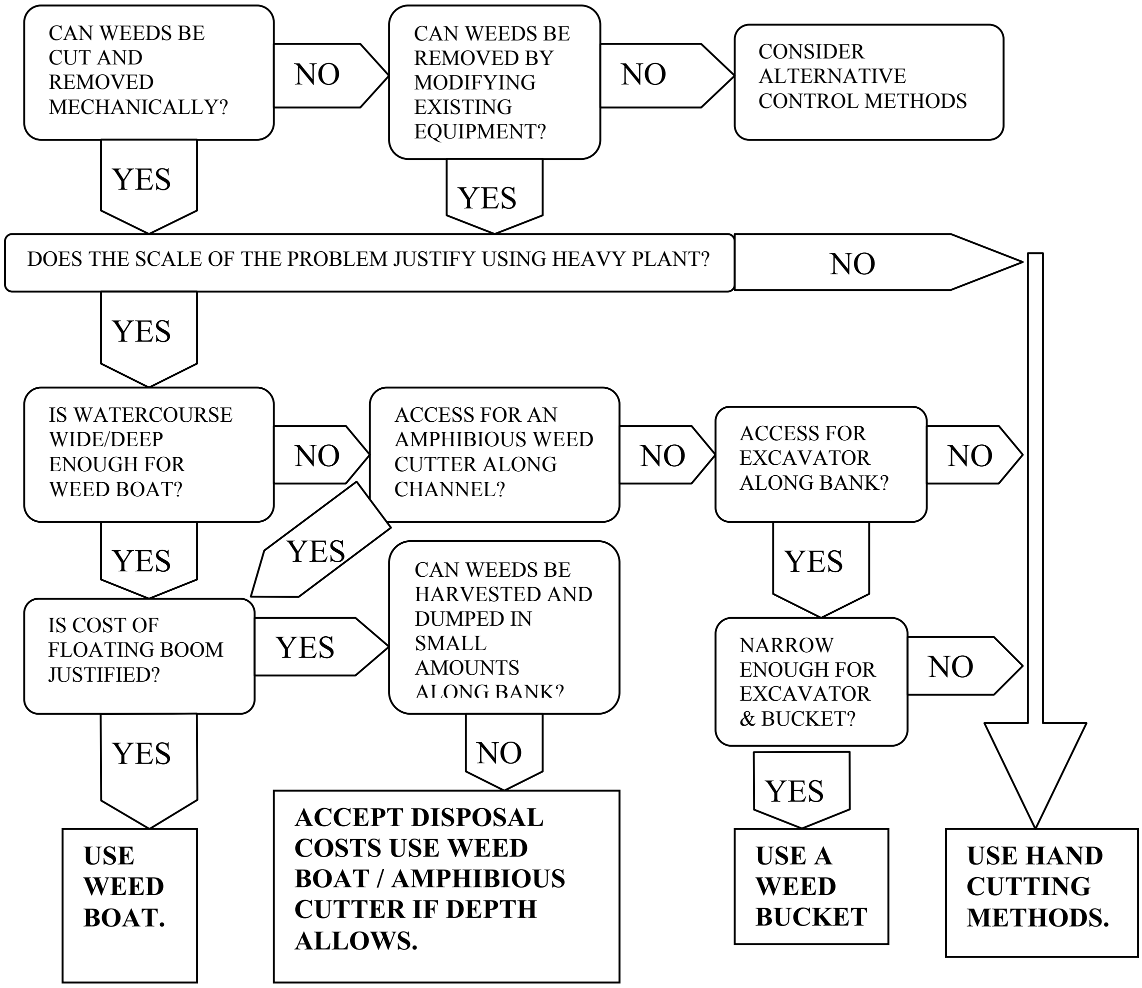

Figure 60 Mechanical weed control options (Environment Agency 1997)

9.2.7 Disposal of cut weed

Contact local Environment Agency Waste Regulation Unit to obtain an exemption under the Waste Management Licensing Regulations (1994) before undertaking weed-cutting and disposal operations. If very large amounts of cut weed and/or sediments are produced - in excess of 50 tonnes per linear bank metre or 5,000 tonnes per hectare of land overall, then disposal to a waste tip or other approved site may be necessary. Lesser quantities should be disposed of in the most appropriate of the following ways:

- Spreading thinly along or just behind bank tops (no plants poisonous to livestock)
- Spread as a soil conditioner, ideally shredded. Note: may contain viable weed seeds. Do not let liquor run back into water - it is polluting.
- Use for composting or mulching away from the waters' edge.

Figure 61 below provides a framework helping assessment of herbicide choices.

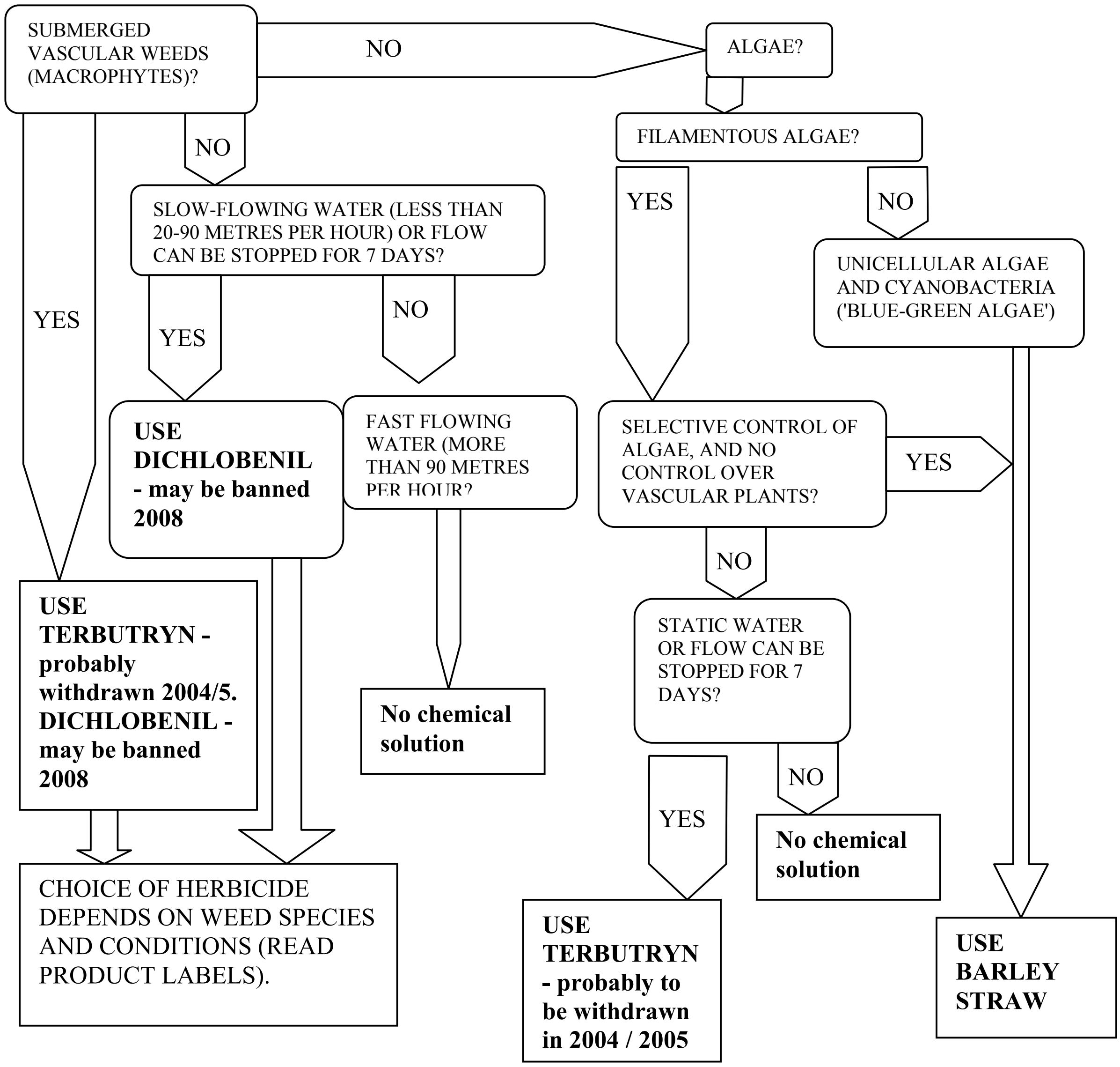

Figure 61 Herbicide options for submerged plants (modified from Environment Agency 1997 with updates on current (spring 2003) EU regulations)

9.3 Summary of Management Options

Overall considerations:

- Is there really a problem with plant growth on my fishery?
- Is my proposed weed control necessary, cost-effective and environmentally-friendly?
- Will my operations affect other people, water supplies, protected habitats or species?
- Am I encouraging a diversity of plant species, on my fishery whilst controlling excessive growth?

Table 33 Controlling aquatic plants

Issue	Management options	Best practice notes
River banks - invasion by exotic species , e.g. Japanese knotweed Himalyan balsam Giant hogweed	Physical cutting back retards invasion. Take advice on best options for herbicidal control.	Control invasive exotic species sooner, rather than later. They can totally out-compete native plants. Be careful of giant hogweed sap - it can cause serious skin irritation.
Lakes - invasion by exotic species, e.g. Swamp stonecrop Floating pennywort	Take advice on best herbicidal control	These plants can entirely cover the surface of ponds, lakes and drains. Control on a trout fishery is vital.
River banks - native species	Promote lush fringe of draping reeds, rushes, sedges, bushes. Mow to short sward up to river bank to facilitate angling.	A well fringed river edge is best as it provides fish cover, fish food, cover for anglers and a diversity of wildlife habitats. Avoid a short sward next to the river. Coppice trees and bushes to retain rootstocks but reduce any over-shading of stream bed. If weed growth is a problem retain shading by trees.
Algal blooms in lakes	Do nothing if trout catches remain acceptable. Reduce nutrient inputs. Reduce coarse fish stocks (carp, bream). Consider de-silting lake (take advice on cost-effectiveness).	Take expert advice on the species of algae causing blooms and the likely causes. Then act accordingly. Blooms may occur after submerged weed kills due to nutrient release.
Submerged weed growth rivers	Physical cuts by scythe or weed-cutting boat. Herbicide treatment but great care needed to avoid environmental damage.	Little and often is best with removal of cut weed. Retain diverse mixed open/cover habitat for fish. Use herbicides as last resort.
Submerged weed growth in lakes	As above Consider stocking grass carp. Remove all cut plant matter to avoid deoxygenation.	As above Consider shading with lilies, trees, temporary black sheeting on bottom.
Extensive reed and rush growth in rivers and lakes	Physical cutting Spray carefully with GLYPHOSATE.	Maintain reed and rush beds, only control areas where fishing is impeded. These plants help maintain good water quality, especially along inflows.
Blanket weed on lakes	Reduce nutrient inputs. Consider barley straw Consider herbicidal control	Best, where possible, to manage lake so as to shade out and reduce nutrient availability for algal growth.

Table 34 Fishery characteristics of key plant groups/species

Species / group	Management impact	Notes
Filamentous algae - 'blanket weed' - floating or on bed of fishery	Can cover water surface and clog bed of river or lake, seriously impacting the ecology.	Blanket weed is a major problem on fisheries. Control is difficult. High nutrient and light levels often lead to outbreaks. Floating species can be netted off but laborious and short-term benefit.
Reeds (Canary grass, *Phalaris* and Norfolk reed, *Phragmites*)	Very good for binding river banks to stop erosion. Can fill in lakes due to slow break-down of leaf litter.	Extensive reed beds are excellent wildlife habitat and larger still waters benefit from nutrients absorbed by their growth.
Reed mace (*Typha*)	Invasive - can fill in lake shallows.	Control with GLYPHOSATE to stop rapid loss of open water.
Bur-reed (*Sparganium*)	Non-invasive, useful shallow water cover.	Seeds important food for ducks.
True Bulrush (Club rush - *Schoenoplectus*)	Can be invasive in rivers, blocking shallow channels with tough growth.	Best controlled by regular cutting, retaining main beds to channel river currents where you want them to go.
Water cress (*Rorippa*)	Abundant in margins of clean chalk trout streams.	Excellent for natural narrowing of over-widened channels.
Arrowhead (*Sagittaria*)	No problem shallow silt dweller.	Nice addition to fishery.
Duck weed (*Lemna*)	Major problem clogging surface of slow rivers and ponds. Rapid grower cuts out light and oxygen.	Grass carp can potentially control this problem. Netting off floating mats gives temporary respite.
Broad-leaved Pond weed (*Potamogeton*)	Useful cover and invertebrate habitat. Can become invasive.	Cut back and drag out by hand or chain scythe. Maintain some beds - useful shading.
Curled and fennel-leaved Pondweeds (*Potamogetons*)	As broad-leaved Pond weed.	As above.
Hornwort (*Ceratophyllum*)	Good oxygenator, good for invertebrates.	Pull out excess floating growth, maintain beds under control.
Canadian pond weed (*Elodea*)	Excellent oxygenator but can fill in entire pond.	Best avoided
Milfoil (*Myriophyllum*)	Same characteristics as hornwort.	As hornwort.
Water lilies (*Nymphaea, Nuphar*)	Useful cover and shading in shallows. Can cover large areas.	Manage by making sure beds don't get too big - mechanical removal.
Fringed water lily (*Nymphoides*)	Attractive but invasive in shallows.	Best avoided in smaller shallow fisheries - can take over.
Starwort (*Callitriche*)	Good chalk stream oxygenator and good invertebrate habitat.	Winter spates rip out silty areas around roots. Leave alone.
River Water Crowfoots (*Ranunculus*)	Good water channeller, good cover, good for insects.	Cut moderately to maintain trout lies and some open water. Conserve beds.

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Note: references marked with an * are key sources of information.

10. CONSERVATION

10.1 Introduction

Game fisheries management cannot be carried out in isolation from the wider environment. Anglers enjoy fishing in a high quality environment and this fact is reflected in fishery incomes and values. Fish share their habitats with many other species, some of them rare and legally protected. The very places that some fisheries occupy are, themselves, protected by law in order to conserve their key environmental characteristics. Britain is obliged to conserve biodiversity, managing its wildlife resources sustainably. The relevant legislation includes the following international law and agreements (English Nature, 1997, Macdonald, 2000):

- Convention on Biological Diversity ('Rio Convention')
- European Birds, Habitats and Species Directives ('Habitats Directive')
- The Ramsar, Bonn and Bern Conventions
- Convention on International Trade in Endangered Species ('CITES')

And national law and site designations:

- The Wildlife and Countryside Act (WACA) including protection for Sites of Special Scientific Interest (SSSIs)
- The UK Biodiversity Action Plan (UK BAP)
- Countryside and Rights of Way Act (CROW Act)

Environment Agency policy and practice must take account of special conservation interest (Environment Act Section 7, see also chapter 15 - Stocking and 8 - Habitats). It is critical to understand that biodiversity and the quality of the environment cannot be fully protected by designating just a relatively few sites. SSSIs, for instance, occupy only about 8% of the total land area. Rivers and wetlands represent wildlife corridors communicating across the country and allowing animals and plants to travel from area to area. Fishery managers have an important role to play in valuing and managing sympathetically their land and water so as to promote both broad and specific conservation objectives (MAFF 2000).

If a fishery is a designated wildlife site, conservation objectives are likely to have been defined, if not, it is still worth managing for the best biodiversity potential. Aesthetically pleasing fisheries are popular with anglers, as well as wildlife and so tend also to be financially successful.

Table 35 on the next page provides some key advice on fishery management operations that require conservation inputs:

Note: on SSSIs and SACs any prospective management activity will need prior approval of English Nature or Countryside Council for Wales.

Table 35 Some fisheries activities requiring conservation inputs

Activity	Authority
In-stream structures e.g. weirs, groynes, gravel riffles, cover structures.	Environment Agency. EN/CCW on SSSIs and SACs.
River channel re-profiling, two-stage channels, river bank work.	Environment Agency. EN/CCW on SSSIs and SACs and Wildlife Trusts where water voles / otters occur.
Tree planting on river banks, fencing river banks.	Environment Agency. EN/CCW where rare riparian plants occur e.g. on SSSIs.
Using herbicides or pesticides near water.	Environment Agency and EN/CCW where plant species of conservation concern occur (see also chapter 9) and on SSSIs and SACs.
Weed cutting in rivers and weed disposal.	Environment Agency (see chapter 9) and EN / CCW on SSSIs and SACs.
Stocking of fish.	Environment Agency (see chapter 15). EN/CCW on SSSIs and SACs. DEFRA for disease risks from fish farms. EN/CCW where native crayfish are present on SSSIs.
Construction of new still water fisheries	Environment Agency (see chapter 11, may also need Local Authority planning permission). Consult EN / CCW on SSSIs or SACs.
Control of predation.	Environment Agency, DEFRA, NAW, EN/CCW for protected species (see chapter 17).
Any other work on SSSIs, SACs.	Take advice from EN / CCW.

10.2 Technical and Practical Advice

10.2.1 SSSIs

English Nature (EN) and The Countryside Council for Wales (CCW) notify owners and occupiers of special interest (flora, fauna, geological or physiographical features) on their land that justifies SSSI status and advise on management. Mutually agreed Site Management Statements and sometimes, Management Agreements are developed, often in concert with Countryside Stewardship in England and Tir Gofal in Wales and other agri-environment schemes.

Internationally important wetlands are all notified as SSSIs and, additionally, may be deemed important enough to qualify for International-level protection as:

<u>Special Areas of Conservation (SACs)</u>; government and 'competent authorities' must prevent deterioration or disturbance of these key sites designated under the EU Directive Conservation of Natural Habitats and Wild Fauna and Flora, 1992.

<u>Special Protection Areas for Birds (SPAs)</u>; these enjoy similar protection to SACs but under the EU Directive Conservation of Wild Birds, 1979.

<u>Ramsar sites</u>; arising from the convention agreed at Ramsar in Iran in 1971, (Convention on Wetlands of International Importance especially for waterfowl) - if any part of one of these sites is damaged, it must be replaced by designating equivalent habitat elsewhere.

10.2.2 The UK BAP

The Convention on Biological Diversity ('Rio Convention') was signed by the UK in June 1992. In January 1994 Biodiversity: The UK Action Plan was subsequently published and the UK Biodiversity Steering Group set up. The UK Biodiversity Action Plan (BAP) has led to the development of a long series of costed habitat and species action plans (HAPs and SAPs) with target actions. HAP and SAP target actions are excellent for monitoring progress and delivery of the overall UK BAP (Macdonald, 2000).

Whilst BAP projects have helped focus conservation efforts on key species and habitats, there has been little or no accompanying financial support from government to implement local projects. Each species or habitat has a lead organisation or individual responsible for progressing the SAP or BAP and many successful initiatives have been collaborative. For instance, the Environment Agency (2000) is a lead organisation for:

Species
- Water vole, otter,
- Marsh warbler,
- Allis and twaite shads, vendace, burbot,
- White-clawed crayfish,
- 11 plants, 11 species of beetle, 3 flies, 3 mussels and a bryozoan.

Habitats
- Turloughs / fluctuating meres (aquifer-fed fluctuating water bodies),

- Chalk rivers,
- Coastal saltmarsh,
- Eutrophic standing waters,
- Mudflats.

Developments and progress with each of these has been reviewed in Environment Agency (2000) - Focus on Biodiversity and subsequent updates. Further key Agency BAP publications have included:

- The mink and the water vole (with WildCRU, Oxford, 1999)
- Water vole conservation handbook (with EN and WildCRU, Oxford, 1998)
- Otters and river habitat management (1999)
- Freshwater crayfish in Britain and Ireland (1999)
- Lampreys, a conservation message (1998)
- Allis and twaite shad (1997)
- Freshwater fisheries and wildlife conservation (1998)
- Rivers and wetlands best practice guidelines (1997)
- Conservation Directory (1999).
- Species and habitats handbook (1999)

10.2.3 Conservation value of wild trout stocks

Salmo trutta is widely distributed, has a very important economic and recreational role in the countryside (see chapters 1 - Introduction and 14 - Fisheries Socio-economics) and shows considerable genetic variation and local adaptation to their environment (Allendorf et al, 1976). Not many UK wild trout stocks have been studied genetically but some that have, for instance Northern Ireland's Lough Melvin (ferox, gillaroo and sonaghan trout) and Lough Neagh's dollaghan trout, show distinctive adaptations to the local environment. Importantly, there may be many less obvious locally-adapted trout stocks that remain to be discovered, e.g. Jorde and Ryman (1996). These locally specialised forms of trout are important to conserve for current biodiversity and to maintain the future potential of the species to adapt to environmental change. Stocking, for instance, with relatively inbred farm strains of brown trout could impact adversely through hybridisation with local trout stocks (Laikre & Ryman 1996, Laikre, 1999 (Table 1), Ferguson, 2003 and chapter 15 - Stocking).

Laikre (1999) concludes (as editor) her important review of the conservation and genetic management of brown trout in Europe by proposing a strategic approach:

- Brown trout management must have due regard to the genetic constitution of the stock - brown trout are mentioned in the IUCN Red List of Threatened Animals.
- Brown trout in Europe have developed into several evolutionary groupings, each of which needs conservation; within these, local populations need careful conservation.
- Brown trout may often have subtle local genetic adaptations to their environment that are not obvious - a precautionary approach with regard to wild trout population management is therefore wise.

This topic is also covered in chapter 15 - Stocking.

10.2.4 Combining game fish management with broader conservation objectives

Brown trout, Arctic char and grayling all require high quality habitats for self-sustaining populations (see chapter 8 - Habitats). The cool, clean-watered streams, rivers and lakes that form their natural habitats are also home for many other species. Habitat protection, and where appropriate enhancement, that benefits these salmonid fish should also benefit species of conservation concern such as:

- Atlantic salmon that share sea trout and brown trout habitats.
- Otters - need abundant fish stocks, good physical cover, low disturbance.
- Water voles - need lush riparian vegetation, soft banks to burrow into, few mink.
- Native crayfish - need clean water, weed beds, soft banks for burrowing.
- Shads, bullhead and lampreys - need clean, cool, clear, gravel-bedded rivers and streams with no significant barriers to migration.
- Water crowfoot - needs strongly-flowing, cool, clean rivers and streams.

Careful management for self-sustaining game fisheries benefits conservation overall.

© Nick Giles

Figure 62 Spawning bullheads

10.2.5 Water voles

The water vole conservation handbook (Strachan, 1998) is a key reference. Water voles interact with game fishery management in several ways. Because water voles and their burrow systems are protected under WACA (1981), it is an offence to disturb them without a licence from EN/CCW. This can mean that damaged river banks have to be repaired in a water vole-friendly way. Water voles need soil to burrow in, easy access to water and abundant fringing vegetation. Vegetation is often cut back (sometimes severely) by fishery managers. Water voles, especially in relatively open habitats, are vulnerable to predation by mink that can potentially catch them on the ground, in their burrows or in the water (MacDonald & Strachan, 1999, see also chapter 17).

Fishery managers can help to protect water voles by doing the following:

- Before carrying out structural river bank work, establish whether water voles are present (holes, burrows, latrines/faeces, pathways, grazed vegetation). If unsure on

signs of water voles, obtain professional advice on whether they are present and, if so, how best to tackle the project without affecting the voles.
- Maintain a rich bank side vegetation cover and don't mow it too short.
- Control mink through a humane trapping programme (see chapter 17).

Mason (1995) reviews river management effects on mammal species in the UK.

10.2.6 Crayfish - minimising plague transmission

Crayfish plague, a devastating fungal infection, can entirely wipe out native crayfish stocks. This disease could potentially be transferred between rivers and lakes with stocked trout. Agency policy is to minimise the risk of this happening. This topic is dealt in detail with in chapter 15 - Stocking.

10.3 Summary of Management Options

Table 36 Conservation management options and best practice

Issue	Management options	Good practice notes
Conservation designations	Ensure that you know whether given fisheries have conservation designations associated with them.	Take advice from EN/CCW and Area Conservation staff on whether proposed fishery management programmes are likely to affect species or habitats of special conservation interest.
Wild trout	Wild trout genetic diversity is important to conserve. Good sustainable trout fishery management enhances habitats for many other species.	Incorporate good conservation principles into your Fishery Management Plan.
Water voles	Be very careful to survey for the presence of water voles. If present, design works to avoid conflict. Consider mink control.	Take advice from Area Conservation staff and from Wildlife Trusts Water for Wildlife officers.
Native crayfish	See chapter 15 - Stocking	

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Note: references marked with an * are key sources of information.

11. FISHERY DEVELOPMENT

11.1 Introduction

Still water trout fisheries range from natural lakes through large reservoirs and gravel pits to estate lakes, pools and ponds. This chapter relates to man-made lakes and those characteristics that best suit trout fisheries. New fisheries can either be developed in existing lakes or through the excavation or impoundment of new ones. The most fundamental questions to answer regarding the building of a new lake are:

- If a commercial venture, is there likely to be adequate demand for the new fishery?
- If so, do I have an adequate (quantity and quality) water supply?
- How big will it be and what shape and peripheral habitats do I want to include?
- How will spoil be disposed of in non-flood plain locations?
- Will the new fishery impede the passage of any migratory fish? If so provision for passes must be made.
- Will predatory species such as cormorants, sawbill ducks, otters, pike or others jeopardise the success of the venture?
- How much will it cost and will this be a good investment in the long-term?
- Am I likely to obtain consents from the Environment Agency and Local Authority?

Environment Agency Area office staff can provide some help with all of these important points, particularly the first three (see also chapter 14 - Fisheries Socio-Economics). The degree of help available will depend on local circumstances. Legalities regarding the source of water are very important. Ponds and lakes can be filled with water in a variety of ways, some needing legal consent and others not.

The following diagrams and notes are developed from those in IFM (1991):

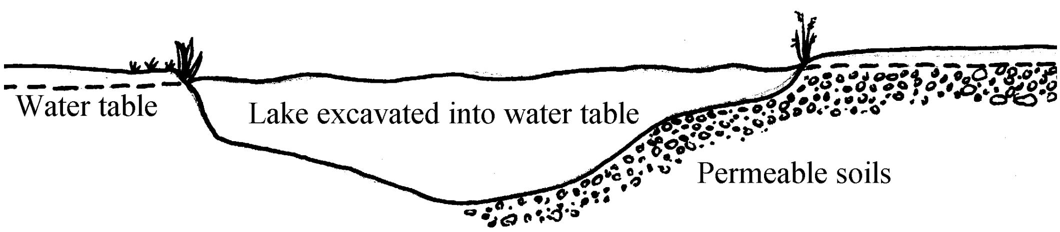


Figure 63 Excavated ponds – e.g. Worked out gravel/sand pit

The excavation of a natural depression into the water table does not require licensing under the Water Resources Act 1991 but care is needed to ensure that adequate water levels will be present year-round. Trial trenches dug to a depth of around 3m and monitored over summer are recommended.

A pond utilising drainage water can also be made on some sloping clay-bedded sites, a so-called 'cut and fill' pond:

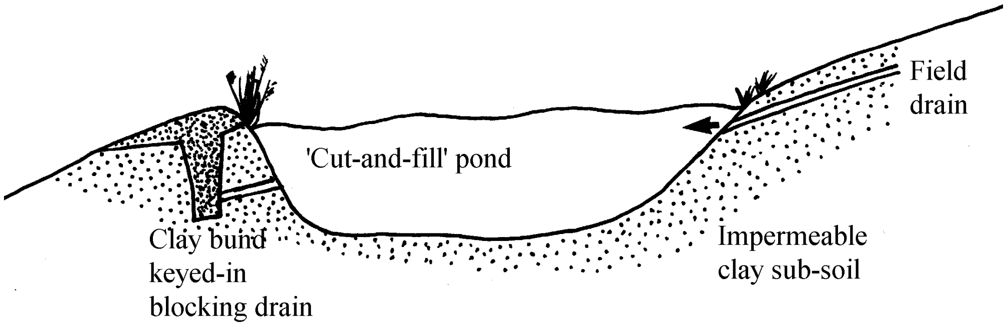


Figure 64 Excavated ponds - 'Cut-and-fill'

The widening of a stream to form a pool does not require an Abstraction Licence. However in-river works do require consent under the Land Drainage Act (1991). If fish are to be fed in an on-stream pond a Discharge Consent may also be required.

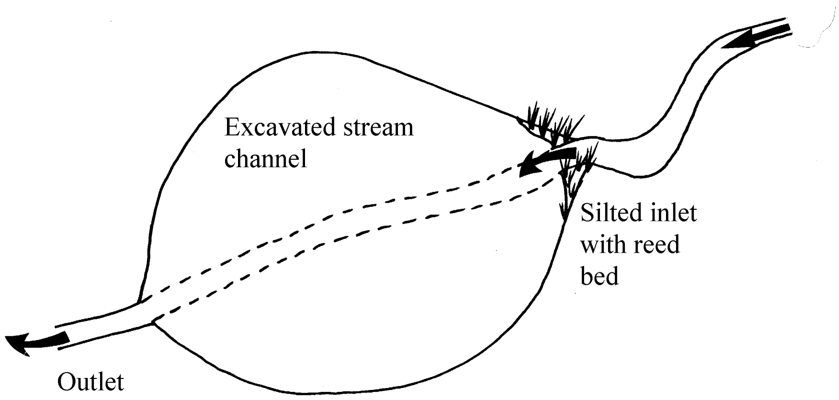


Figure 65 Excavated ponds - widened stream channel

If damming a water course as below, both Land Drainage Act consent and an Impounding Licence are required.

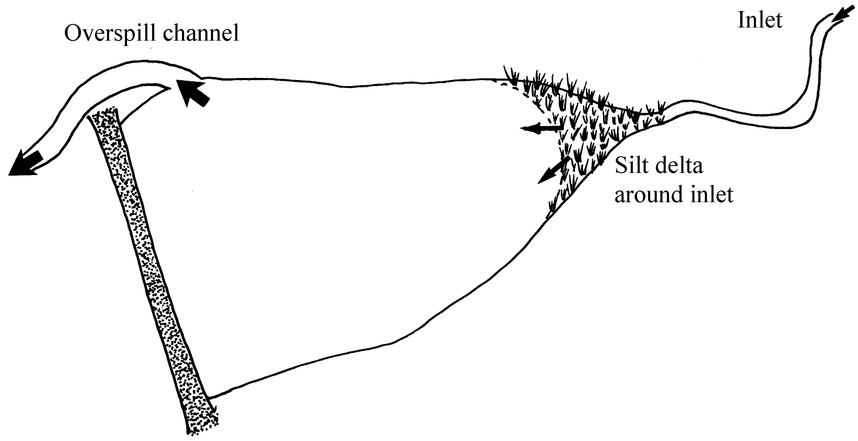


Figure 66 Single on-line pond

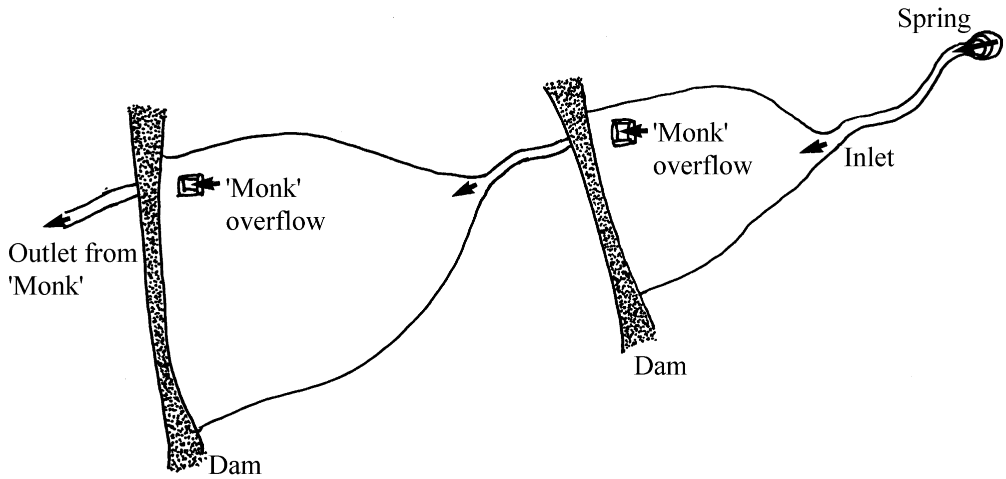


Figure 67 A series of on-line ponds

On-line ponds such as those in the diagrams above do not require abstraction licensing but may require Land Drainage Act consent. Note that the Agency does not regard the following situations as impoundments:

- Where the upstream water level is not raised outside the normal wetted perimeter of the inland water under non-flooding conditions; and,
- Where the flow regime is not temporarily or permanently modified to the extent that the effects are potentially detrimental to other protected rights, lawful users or the environment.

When in doubt, take advice from Environment Agency staff.

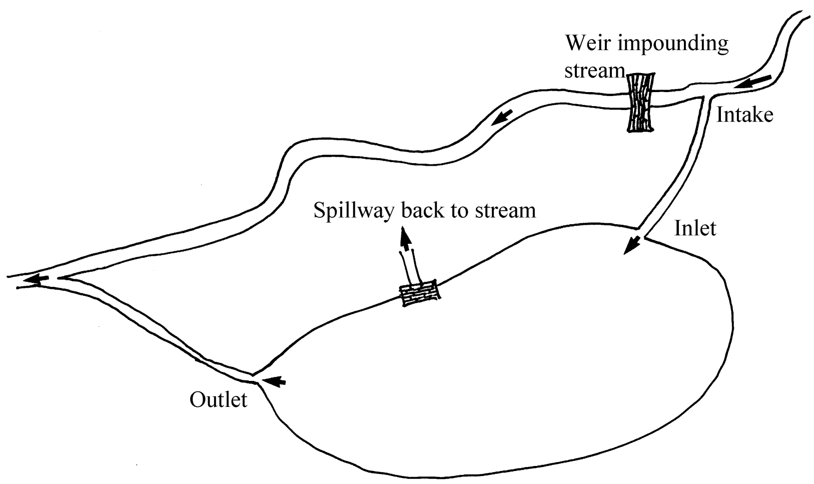


Figure 68 Off-stream gravity-fed pond

In the case of the off-stream gravity-fed pond above Impounding and Abstraction licences, plus consent under the Land Drainage Act are required. Abstraction Licences are likely to have restrictive conditions that ensure adequate flow is maintained in the original river channel to protect both river ecology and existing abstractors.

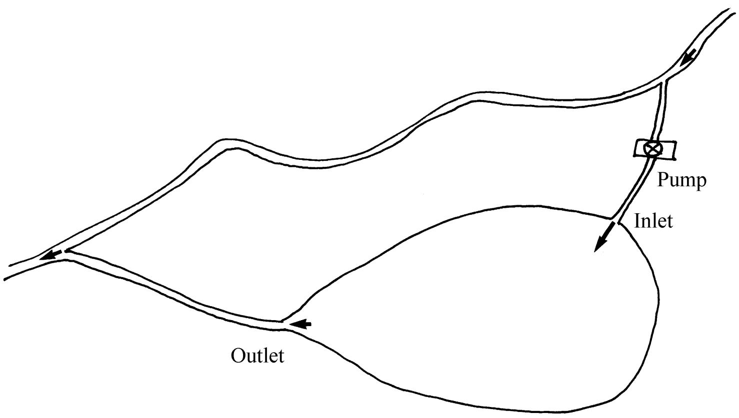


Figure 69 Pump-filled pond

The pump-filled pond above requires Land Drainage Consent and a Water Abstraction Licence. Again, the Abstraction Licence is likely to contain conditions that protect river flow and downstream abstractors.

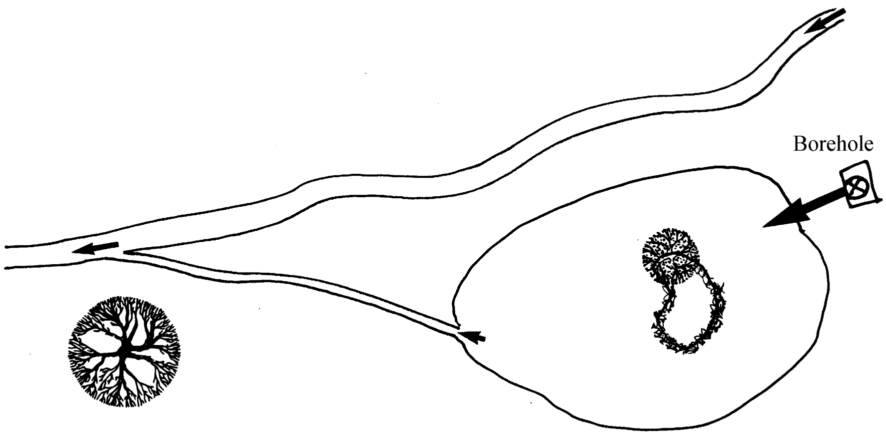


Figure 70 Borehole-filled and supplemented pond

In the case of a borehole-filled pond you will require a Section 32 Consent to drill and test pump the bore hole followed by an Abstraction Licence for the day-to-day operation. Exemptions from control do exist for agricultural or domestic abstractions for less than 20m^3 per day however the interpretation is complex, so early consultation with Area Environment Agency staff is essential. Land Drainage Act consent is needed where the outlet enters a stream.

New ponds and lakes may also require Planning Permission - take advice from the Local Authority. Normally, ponds for non-agricultural use, within 25m of a road or that require movements of excavated material off-site will need planning permission. Movements of material will also need to comply with waste disposal legislation - the Environment Agency will advise on this aspect of the project.

Windward shorelines and islands may need stabilising with vegetation, rock or other artificial materials to reduce erosion and muddying of the waters. Safely constructed fishing platforms can be installed in shallow or reedy areas to protect the banks and vegetation and provide safe and comfortable access points for anglers. A hut or lodge for shelter, toilet facilities, recording of catch returns, etc is a very useful facility.

11.2 Technical and Practical Advice

11.2.1 Still water habitat requirements and construction

Key site elements to the construction of a new fishery are outlined above. The subsequent development and management of still water trout fisheries are described in Behrendt (1977), Barrington (1983), Robbins (1988) and Templeton (1995).

Any new pond or lake has the potential to be of high environmental quality. Some key design aspects to include are as follows (see The Game Conservancy, 1993):

- Lakes and ponds need to hold enough water through the season to maintain angling performance: take professional advice on pond/lake design, siting and construction.
- Any dam must be constructed very carefully, either of earth with gently sloping sides or with a keyed-in clay core and steeper sides. The top of an earth dam should be at least 1m above overflow level. Any dam of more than 4.5m in height, must be designed by a Chartered Engineer. Permeable soils must have a thick clay core keyed-in laterally and vertically to ensure adequate water-holding.
- If a dam impounds a water volume greater than 22,500 cubic metres (5 million gallons) above surrounding ground level, it must be designed by a Panel 1 Engineer, Reservoir Inspectors Panel, appointed by the Secretary of State for the Environment (Reservoirs Act 1975).
- Before construction of a dam all vegetation, topsoil, porous sands or peat must be removed down to stable sub-soil level. The surface of this must then be disked or ploughed to ensure good keying-in with the dam materials.
- Water should not be able to over-top earth dams or they may wash away and fail.
- Ponds and lakes with appreciable water inputs need either under-dam overflow pipes linked to a vertical chamber within the pond (a 'monk') or spillway channels taking overflowing water around the dam to link up with an outflow stream well below the dam.
- No trees should be allowed to grow on earth dams - they may blow over in a gale and take the dam with them. Root growth can lead to leakage through dams and failure.
- The lake bed should be covered with irregular ridges, furrows and depressions.
- The inclusion of a flat-bottomed sump or draw-down facility such as a 'monk' will facilitate fish removal, if required.
- A variety of substrates, gravel, cobbles, rocks, fine silt, clay and sunken deadwood for cover will stimulate the production of a diverse fauna and flora and provide a degree of protection from predatory cormorants.
- An irregular shoreline and inclusion of islands improves the look and wildlife potential of a lake. Islands are also useful for using up excavated spoil.
- Trout lake shorelines should rapidly shelve to a depth of around 1 metre - this helps to reduce shallow water vegetation that can impede fishing.
- Plant a variety of native marginal plant species to ensure that very competitive colonists such as reed mace, reed sweet grass and reed canary grass do not over-dominate the shoreline.
- Lake margins can be left boggy in some areas and shallow pools and scrapes close by the main lake can be created to allow the development of marginal wetland habitats. These are inexpensive to make while machinery is on-site and add a great deal to the appeal of a fishery.

- For trout, that need relatively cool water, some sanctuary areas with depths of 4 -5 metres will be needed, especially in smaller (less than 1ha) pools with little or no through-flow of water or shade. Stillwaters shallower than 3 metres tend to become over-weeded and very difficult to fish. Marginal areas should be 0.5-1 metre deep (few shallows) and most of the lake should undulate around 1.5m - 4m. If possible when building a new stillwater trout fishery provide large areas of deep water - these should act as cool, relatively weed-free sanctuary areas in mid-summer.

The design below is suitable for many lowland coarse or trout fisheries. Depth contours are in metres; greater average depth may be needed in especially warm, sunny or exposed ice-prone locations.

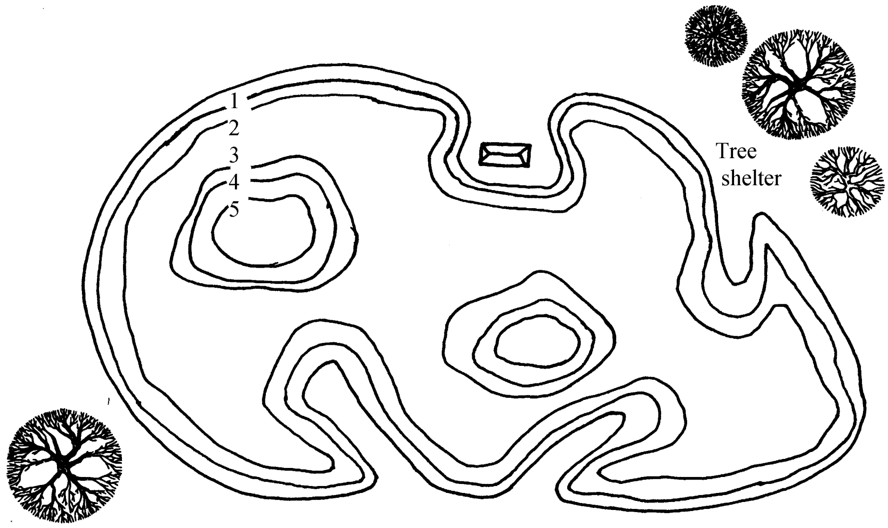


Figure 71 A good lowland lake design

The diagram below (Environment Agency, 1998) shows how aquatic plant communities are in part, determined by water depth:

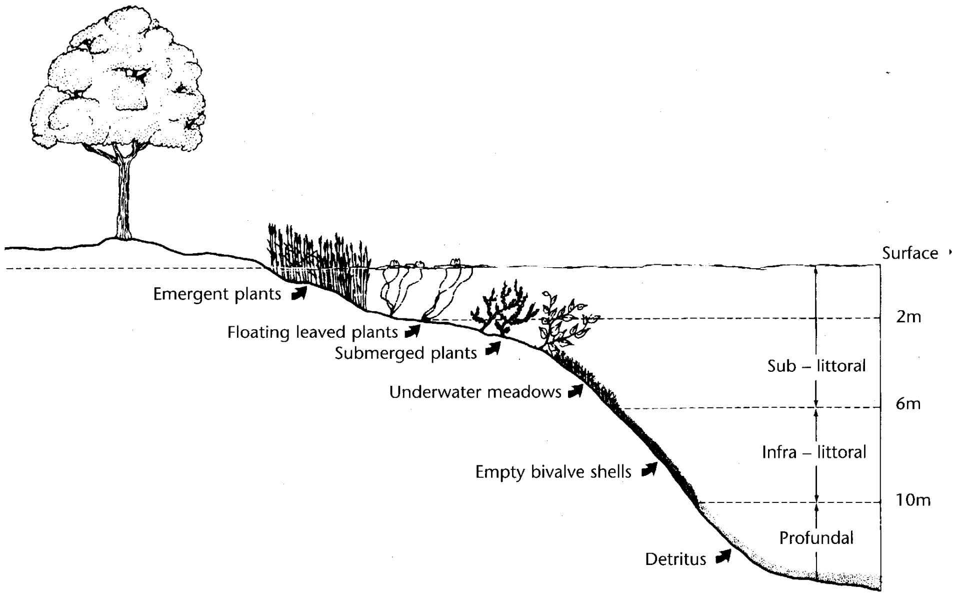


Figure 72 Plant communities and water depth

Most man-made trout lakes include only littoral and sub-littoral zones. Clear-watered, well-oxygenated, cool ponds and lakes with diverse weed beds and good physical cover for trout are the objective. The following points are worth considering:

- Think carefully about the chemical quality and chances of pollution of the water supply. Can the water supply to the lake be cut off in the event of an upstream pollution?
- Planting trees well back from the water's edge along a southern shoreline will help shade a small open pond whilst ensuring leaf inputs are not too abundant.
- Ponds made in deep, narrow wooded valleys are often well shaded.
- A healthy crop of submerged plants (not too many so as to hamper angling) will help produce good fly hatches and interesting dry fly and nymph fishing (see below).
- Fish refuges such as sunken dead wood snags, lily, bulrush and pond weed beds can help trout avoid too much danger from cormorant predation.
- Don't stock any fish other than health-certified trout. This will reduce the chances of the introduction of parasites and disease that can ruin a trout fishery (see chapter 18 – Diseases and Parasites).

11.2.2 Water quality

Fishery managers often wonder - why did my trout die? The answer often lies in the 24-hour maintenance of adequate water quality. This subject is dealt with in greater depth in chapter 6 - Water Quality, but the following information is useful when thinking over the potential of a water supply or existing pond for trout fishing. Consider the following points:

- What trout species do I want to stock?

- Are environmental conditions in the new lake likely to be suitable for trout year-round?
- If problems such as low DO, high temperature, prolonged ice cover occur, will it be possible to overcome them simply and economically or should I consider another site or a coarse fishery?

Templeton (1995) provides the following preferred water quality requirements for trout.

Table 37 Water quality criteria

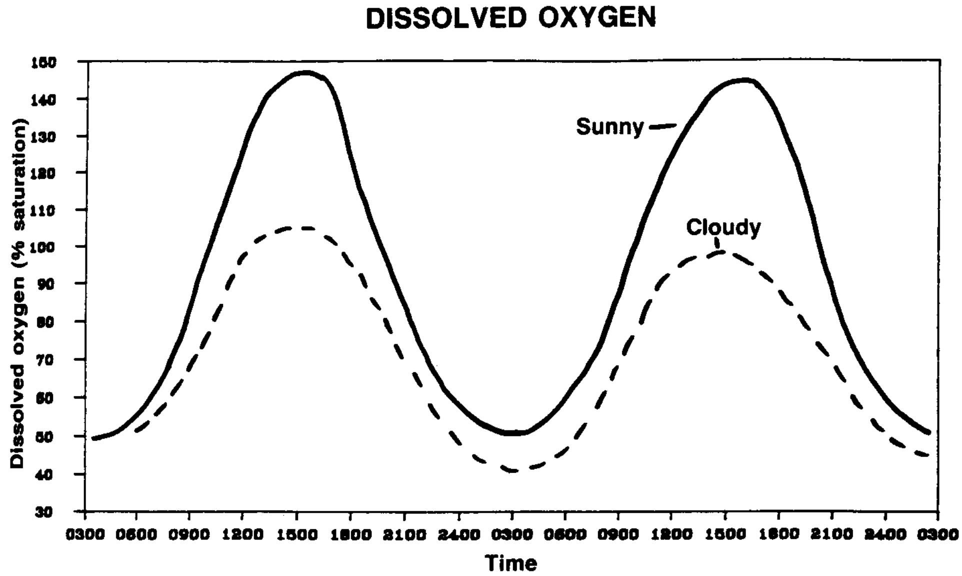
Requirement	Brown trout	Rainbow trout	Brook trout (char)
Temperature	Preferred 12°C. Max 19°C.	Preferred 14°C. Max 20-21°C.	Preferred 12-14°C. Max 19°C.
Range of pH	5-9	5-9	4.5-9.5
Dissolved oxygen (DO)	Preferred 9mg/l More than 5mg/l	Preferred 9mg/l Need at least 4-4.5mg/l	Preferred 9mg/l Need at least 4-4.5 mg/l

Recommended temperatures for optimum growth for farmed trout are often around 14°C for browns and 16°C for rainbow trout (D. Moore, pers. comm.).

The following points are worth noting:

- Brown trout prefer cool water and, in many waters, fish best in the spring and autumn.
- Rainbow trout remain active and catchable in warmer water.
- Rainbows and Brook trout (char) can cope with lower DO levels than browns.
- Brook trout can survive more acid and turbid waters and feed at lower temperatures than browns - they can do well in moorland lakes and upland reservoirs. Note requirement for ILFA licence for brook trout.

Note that, especially in relatively warm, weedy lakes both pH and DO show marked daily fluctuations, take DO, for instance in Figure 73 below (IFM, 1991):



Dissolved oxygen levels over 24hrs.

Figure73 Diurnal DO fluctuation

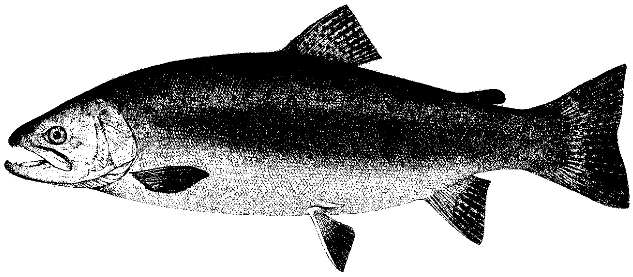
Clearly, when assessing the suitability of a lake for trout, due regard needs to be taken of the time of year and time of day when water quality samples are taken. A range of samples taken under varying conditions is a worthwhile investment.

When considering stocking programmes, it is worth remembering that browns stocked in the cool water of spring may show up better in angling returns than rainbows at that time (see chapter 15 - Stocking). During the 'dog days' of summer a typical still water trout fishery may well perform best if most of the surviving stock are rainbows.

In the unusual circumstance of a peaty, relatively acid, cool upland lake or reservoir where there is no danger of fish escaping to un-enclosed waters (rivers, streams, natural lake systems), it is worth considering stocking with American brook trout. This species of char can do well in these habitats and provide an unusual quarry species for the angler. ILFA and WACA licences will be required (see chapter 15 - Stocking). Brook trout can sometimes establish self-sustaining stocks in waters with no in- or out-flowing streams. Spawning probably occurs on gravely lake shallows - this species is able to tolerate muddier breeding conditions than most salmonids.

The liming of naturally acid waters in an attempt to increase fishery productivity or make a lake more suitable for rainbow or brown trout is not recommended (see chapter 6 - Water Quality).

11.2.3 "Commercial" trout fisheries



© FBA

Figure 74 Rainbow trout

The Environment Agency offers the following areas of advice for still water trout fisheries:

- Advice on the design and setting up of new fisheries,
- Advice on consenting requirements and practicalities,
- Advice on stocking, sources of fish, disease risks, species selection, recommended stock densities,
- Advice on the management of predatory fish, birds and mammals,
- Advice on the management of parasite and disease problems,
- Advice on water quality, hydrology and water supplies to still waters,
- Advice on conservation and ecological lake management including aquatic plants and fly life,
- Advice on angler's fishery preferences and on numbers and types of fishery operating in a given Agency Area,
- Advice on combating poaching and theft from fisheries,
- Help with fish rescues and de-oxygenation emergencies,
- Information from current R&D projects, for instance management of *Argulus* in still water fisheries and predation risks from fish-eating birds.

To benefit from these services, please contact Area Office staff.

11.3 Summary of Management Options

Table 38 Management options and good practice for new lake fisheries

Issue	Good practice notes
Design of new lake	Survey site to ensure adequate water supply and ground water-holding quality. Take advice on need for Local Authority planning permission and / or Environment Agency Water Resource, Land Drainage, Waste Regulation consents. Take professional advice on design - especially on dam construction and safe over-flow. Ensure that overall lake design will produce an environmentally high quality landscape feature that will perform well as a fishery.
Still water habitats for trout	Trout thrive in cool, clean, clear-watered, relatively weedy waters. Ensure that lake bank shapes, depth profiles and substrates / contours will suit trout and provide good angling conditions. Ensure that trout have year-round cover from predators such as cormorants.
Water quality	Ensure that water quality through the season is likely to suit the trout species of choice.
'Commercial' trout fisheries	Ensure that S30 and any WACA/ILFA consents are obtained before stocking. Remember that Agency Area staff are able to provide a wide range of valuable advice to trout fishery managers.

11.4 References and Bibliography

Allen, K.R. (1938) *Observations on the biology of trout in Windermere*. Journal of Animal Ecology, **7**, 333-349.

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Gale, J., Moore, D. & Gathercole, P. (1992) *Trout.* Boydell Press.

Giles, N. (1998) *Freshwater fisheries and wildlife conservation: a good practice guide*. Environment Agency.

IFM (1991) *The creation and management of pond fisheries*. Institute of Fisheries Management.

*The Game Conservancy Trust (1993) *Ponds and lakes for wildfowl*.

*Templeton, R. (1995) *Freshwater Fisheries Management* 2nd edition. Fishing News Books.

NRA (1990) *Stillwater fisheries, their creation, development and management*.

Note: references marked with an * are key information sources.

12. LAND DRAINAGE CONSENTS

12.1 Introduction

Consents for fishery-related activities are most usually required if building new still water fisheries (see chapter 11 - Fishery Development) or restoring/improving in-stream habitats (see chapter 8 - Habitats). Under The Environment Act (1995) The Environment Agency has responsibility in England and Wales for general supervision of flood defence. This includes land drainage activities and thus, any works in and adjacent to streams and rivers.

The supervision is intended to:

- Avoid damage to or impede efficient drainage in watercourses;
- Allow for any necessary future improvement or enhancement to the watercourse drainage system;
- Control the creation of obstructions limiting access both along watercourses and to associated drainage works;
- Preserve and protect essential floodplains and washland areas;
- Ensure that good engineering principles have been adopted for structures built in, or close to, the watercourse and that they have adequate hydraulic capacity;
- Protect and promote the interests of conservation in respect of landscape, flora, fauna, geology and sites of archaeological interest;
- Protect fisheries.

The supervision is carried out by:

- Consulting with Internal Drainage Boards (IDBs) and Local Authorities on planning matters (the Agency is a statutory consultee on all planning applications, with a primary responsibility to protect floodplains);
- Vetting of, and consenting to, proposals for work in, under, over or adjacent to watercourses and floodplains of statutory main rivers;
- Vetting of, and consenting to, certain activities affecting ordinary watercourses;
- Advising the general public;
- Carrying out maintenance and improvements;
- Strategic planning.

Common standards and methods of approach for Land Drainage Consenting and Development Control have been adopted by The Environment Agency. Main Rivers Maps and indicative maps of floodplain areas (IFP maps showing approximate limits of risk of flooding) are now available. Locations of land drainage problems are shown on Section 105 C30/92 Survey maps although not all areas have been surveyed. Area Flood Defence and Development Control staff can advise on specific locations.

Note also the need to 'Dial Before You Dig' - contact gas, water, electricity and other owners of subterranean and overhead infrastructure in an area where excavation, piling or other activity that may disturb the land is contemplated. It is critically important to locate and mark all cables, pipes and other potentially vulnerable structures before any heavy machinery is brought onto site.

12.2 Technical and Practical Advice

12.2.1 Land drainage consents

Main rivers
Each Environment Agency Region has statutory maps of 'main rivers' over which it has permissive powers to carry out maintenance, improvements and new works. South-west Region, for instance, has 4,092km of designated main river. Flood Defence maps are kept at all Area and Regional Offices, confirmation of main river status can be obtained from the Area Development Control Officer.

All other watercourses are termed 'Ordinary watercourses' and either Internal Drainage Boards or Local Authorities have permissive powers over them for Flood Defence work.

Section 109(1) of the Water Resources Act (1991) states that:

> No person shall erect any structure in, over or under a watercourse which is part of the main river or shall erect or alter any structure designed to contain or divert the floodwaters of any part of the main river except with the consent of and in accordance with plans and sections approved by The Environment Agency; carry out any work of alteration or repair any structure in, over or under such a watercourse if the work is likely to affect the flow of water in the watercourse or to impede any drainage work.

The Environment Agency, under Section 34 of the Land Drainage Act (1976) and the Water Resources Act (1991) also has land drainage byelaws, copies of these are available from Area and Regional Offices.

The three byelaws (applying to Main Rivers) most relevant to fisheries management require that:

- No person without the consent of the Environment Agency shall erect or construct any structure within 8 metres measured horizontally (this distance can vary between 5-10 metres in differing Agency Areas) from the brink of the river or within 4 metres from the foot of an embankment on the landward side (8 metres for tidal embankments). Check with Agency Area Office for exact local practice.
- No structure or deposit shall be permitted on floodplains (land adjacent to main river over which flood water may flow) and;
- No act endangering the stability of, or causing damage to, banks (including ploughing of floodbanks) shall be carried out without consent of the Agency.

Ordinary watercourses
The following activities require Land Drainage Consent under Section 23 of the Land Drainage Act (1991):

- The erection of any mill, dam, weir or other like obstruction to the flow of any watercourse or raise or otherwise alter any such obstruction;
- The erection of any culvert that would be likely to affect the flow of any watercourse or alter any culvert in such a manner that would be likely to affect any such flow;
- Under Section 17 of the Land Drainage Act 1991, any drainage works carried out by a District Council against flooding.

Penalties
Any person acting in contravention of any of the Byelaws or Section 23 of the Land Drainage Act (1991) shall be liable on summary conviction to a fine not exceeding level 5 on the standard scale and to a further fine not exceeding £40 for every day on which the contravention or failure is continued after conviction.

Obtaining Consents from The Environment Agency
Early consultation with the Environment Agency is advised to avoid unnecessary delays or misunderstandings. Applicants will receive an 'Application for works in rivers' form (FD1) that describes the minimum requirements to be submitted. The Agency then has 2 months from the submission of a valid application for consent to be determined. The Environment Agency can charge £50 for each application for Consent for each structure. These charges are to cover 'costs' for examining each proposal. Consents may be subject to requirements such as timing of works and or the manner in which works are carried out. Such requirements are stated on the consent.

The need to comply with any duties or responsibilities for the conservation or protection of the environment (including flora and fauna) will also be taken into consideration when issuing consents. Where a SSSI is involved, the formal consent of EN/CCW must be obtained and form part of the application. In some Areas the Environment Agency undertake this liaison, sometimes the Applicant may need to apply to EN/CCW for a separate consent.

With any impounding works (e.g. construction of a weir, channel narrowing or shallowing) the applicant must, in addition to obtaining Land Drainage Consent, request an Application for Works in Rivers form, and an Impounding Licence application form under Section 24 of the Water Resources Act, 1991. The applicant is responsible for identifying the extent of likely flooding and should demonstrate that he has the agreement of those who may be affected before a consent will be granted.

Where appropriate, an applicant shall submit hydraulic capacity calculations consistent with the Agency's current practice on the minimum standards of flood protection, expressed as the return period between floods as follows:
1 in 100 years: Urban areas, villages;
1 in 50 years: Agricultural land of high value i.e. arable or horticultural and isolated properties;
1 in 25 years: Agricultural land (mainly arable)
1 in 15 years: Agricultural land (mainly pasture)
1 in 5 years: Grass floodplain.

Except that in no case shall the level of protection of the proposed works be lower than the existing level of flood protection.

Requirements for additional consents and licences
The applicant shall note that other licences, consents, approvals or permissions may be required by law. Information sheets on Water Resource Licencing, Water Quality, Environmental Assessment and Protected Species are available from Area Offices.

12.3 Summary of Management Options

Table 39 Land drainage consent procedures

Issue	Management options	Best practice notes
Seeking consent	Never undertake repair or new construction works around any watercourse before first obtaining necessary consents and investigating the presence of any subterranean infrastructure that may be damaged during works.	Take advice from relevant Environment Agency staff before submitting a formal consent form.

12.4 References and Bibliography

*Environment Agency (2000) *Land drainage consent guide - Fact Sheet.*

13. SCREENS AND OBSTRUCTIONS TO FISH MIGRATION

13.1 Introduction

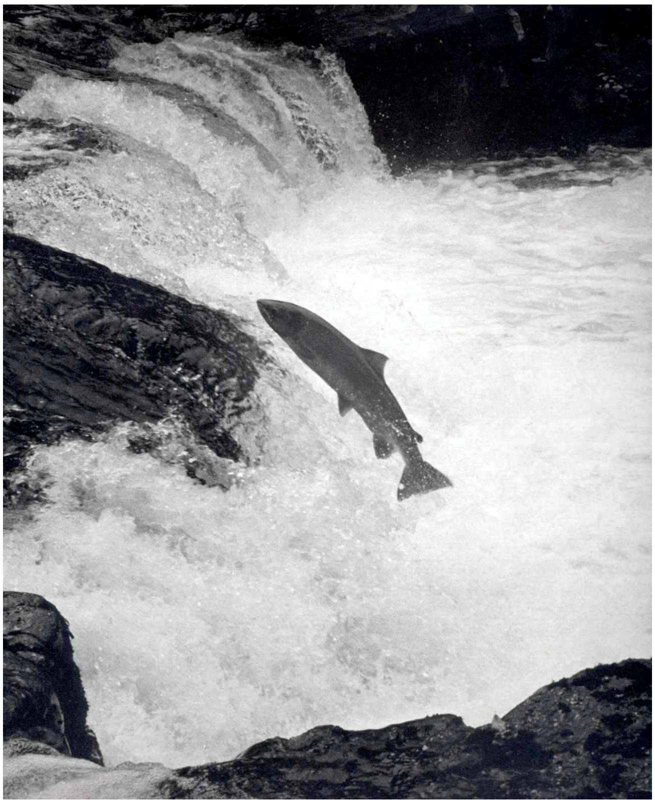

Figure 75 Upstream migration

The importance of barriers was recognised as long ago as the 13th century, when the Magna Carta required the removal of weirs on the Thames and Medway in order to allow the free passage of fish. More recently, Section II of the Salmon and Freshwater Fisheries Act, 1975 is dedicated to this subject. Current legislation was written to protect migratory salmonid species but not eels, shads, lampreys or any other freshwater species that typically migrate during their life cycles (e.g. barbel or dace).

Access to suitable spawning and nursery habitats is vital for all fish. Sea trout and brown trout commonly migrate through river catchments to reach headwater and tributary breeding areas. Grayling, however, are not thought generally to undergo such marked spawning migrations. All fish migrate to a degree however, and obstructions to migration can impose serious consequences for fish abundance and distribution. Also, migratory fish such as sea trout can be very vulnerable to over-exploitation, both legal and illegal when shoaled up in weir pools under low-flow conditions.

Most man-made river barriers have been constructed over the past 150 years - for abstraction, navigation, milling, power generation, river gauging, etc. Fish stocks have suffered as a consequence; Shad, for instance, disappeared from the River Mersey after the building of complete barriers to migration. In England and Wales an estimated 7-10,000 obstructions now need to be by-passed by fish passes suitable for both salmonid and other fish groups (Environment Agency, 1999).

In contrast, some wild trout stocks above natural impassable barriers such as high waterfalls may be genetically distinct and have high conservation value. Such natural barriers may be best left, rather than by-passed by fish ladders to allow access by sea trout. The Environment Agency National Trout and Grayling Strategy includes the following:

Policy 24:
Obstructions:

- **We will work with others to improve natural recruitment to trout fisheries by removing, or making passable, obstructions to migration, taking into account the costs and benefits. Such obstructions might be man-made or, if natural, not wholly restricting passage.**
- **Where natural obstructions are considered impassable, we will take a precautionary approach to the protection of stocks that may be genetically distinct and not remove the obstructions or ease fish passage past them.**
- **For any new structures, where Agency consent is required, these must be designed to enable fish migration.**

The Salmon and Freshwater Fisheries Act (1975), Section 9 requires anyone building a fish pass required by this section to maintain it in an 'efficient state' but this term is undefined. Under Section 10 of the Act The Environment Agency can, at its own expense, install a fish pass in any dam provided that the efficiency of the dam is not affected (see 13.2.2 below). The Salmon and Freshwater Fisheries Review Group Report (MAFF 2000, chapter 12) provides a good summary of this subject and made the following recommendations with respect to barriers to fish migration:

<u>Recommendation 126</u>: Anyone creating a new obstruction to the passage of any fish, or increasing or rebuilding an existing one, either in whole or in part, on any river should be required by law to install a fish pass to a design approved by the Environment Agency unless excused from doing so by the Environment Agency. In approving the design, the Environment Agency should determine the purpose of the fish pass, in terms of the species and sizes of fish that should be able to use it, and should require it to be suitable for this purpose.

<u>Recommendation 127</u>: It should be a requirement to install elver passes (if the fish pass is not suitable for this purpose) on all new or altered dams and other obstructions, and their installation should be encouraged on existing ones.

Further recommendations were to empower the Environment Agency to enter land and reduce or remove barriers to the passage of fish where ownership of the obstruction is unknown (Recommendation 128) and a presumption against any further estuarine barriers affecting rivers with anadromous (migratory) fish stocks (Recommendation 193). The Government agreed to accept, accept in principle or consider these various recommendations (MAFF 2001).

Sea trout, brown trout, grayling and char can all encounter water intakes and outfalls at differing stages of their life cycles. Entrapment in or diversion via intakes or outlets of hydro-electric plants, industrial complexes, public water supply installations, fish farms, irrigation systems, carrier and mill streams and other sites can all have serious potential impacts on salmonid fish stocks. Migrating smolts can be at great risk where abstractions coincide with migratory movements. Suitable grids placed across such intakes and outfalls can help to avoid such problems (Solomon, 1992, Salmon Advisory Committee, 1993, 1997).

Current legislation (Section 14 Salmon and Freshwater Fisheries Act, 1975 and extended by Schedule 15 of the Environment Act 1995) includes intakes and outfalls for fish farms and intakes for water or canal undertakings, or any mill. Intakes and outfalls constructed after 18th July, 1923 that take water from a river or stream frequented by salmon or migratory trout must be screened and maintained at the expense of the owner/occupier to prevent salmon or trout being drawn in. Char are also included in the definition of 'trout'.

In the case of fish farms, screens must stop the egress of farmed fish. Any screens placed across a channel or conduit must have, immediately upstream, a 'by-wash' (flowing passage) allowing fish to return directly to the river. Screens and by-wash structures should be located and constructed so as to minimise damage or injury to fish. Local byelaws are used to determine periods during the year when screens must be operable (e.g. kelt and smolt runs, parr re-distributions, upstream migratory runs).

The Agency can exempt an owner/occupier from these obligations, if it so wishes. The year 1923 is determined by the Salmon and Freshwater Fisheries Act 1923. Note that, under Section 15 of the Act, the Agency may, at its own expense and in consultation with the owner, construct and maintain screens on any watercourse, mill race, cut, leat, conduit or other channel for conveying water for any purpose, from any waters frequented by salmon or migratory trout. Under these circumstances the Agency may deepen or widen the watercourse (at its own expense) to maintain previously intended flows.

The Salmon Advisory Committee (1997) recommended that screening requirements be introduced for industrial and agricultural abstractions and for mill channels constructed prior to July 18th 1923. The Salmon and Freshwater Fisheries Review (2000) recommended that protection by screening be revised to include all outlets drawing water from rivers thus protecting coarse fish species too. The Government accepted this recommendation in principle and intends to consult on the proposal (MAFF, 2001). Section 38 (2) of the Water Resources Act (1991) allows the screening of intakes on non-migratory rivers and streams as a condition of an abstraction licence. An example being a river off-take point on the River Cober, Helston, Cornwall (S. Toms, pers. comm.).

13.2 Technical and Practical Advice

13.2.1 Screens

All fisheries should review the need for screening of water intakes and outlets to prevent unwanted fish movements. The design of screens depends upon the species and life stage of the fish to be contained and the nature of the flow characteristics of the site (see Anon, 1995 and Salmon Advisory Committee, 1997, Appendix F). Screens can be made of fixed meshes or bars. 1cm square holes exclude salmonid parr/smolts down to 8cm. In recent Scottish hydro-electric station screening a maximum gap between bars of 4.2cm for adult salmon and 3.2 - 3.8cm for adult sea trout has been adopted (Salmon Advisory Committee, 1997). Bubble and sound screens are also sometimes used to divert fish around water intakes.

Detailed discussions of screens and associated structures are given in Solomon, 1992, Anon., 1995 and Salmon Advisory Committee, 1997.

Key points to understand are:

- Intakes should be sited where fish are least likely to approach them.
- If practically possible, abstractions should be stopped during peak adult, smolt, kelt or parr migrations.
- Screens can be physical - wedge wire, drum or sub-gravel, behavioural - louvre, bubble, sound, electrical or ecological - deep water, for instance.
- Whilst slow-moving mill wheels with widely spaced paddles are unlikely to damage sea trout smolts, fast moving close-bladed hydro-electric turbines may kill most fish passing through them. Screening is therefore vital in some circumstances.
- Mortality of smolts drawn into fish farms, irrigation systems and similar systems may usually be 100% unless attempts are made to trap and transfer them back to the river downstream of the hazard.
- It is important not to constrict a channel where a screen is installed as this will increase current velocity and increase the risk of entrainment (being caught in the fast water and drawn against or through the screen). Also, partial blockage of a screen by debris will similarly increase current speeds; a facility to clear screens of debris is therefore necessary.
- Downstream-migrating kelts, smolts and parr in freshwater have differing behaviour from upstream-migrating sea trout - a fact that needs to be included in intake and outfall screen design.
- The siting and design of intakes greatly affects the likelihood of smolts being drawn in. Safe 'by-wash' channels must be provided.
- Screens must be designed for the species and size of fish to be excluded (mesh size) and the maximum acceptable current velocity for those fish (siting/design).
- Swimming speeds and endurance are determined by fish length and water temperature. Cold water decreases swimming performance. For salmon smolts, for instance, which can be as small as 10cm, current velocities passing through the screen should not exceed 25cm per second unless at sites where fish can easily evade the intake (Salmon Advisory Committee, 1997). Note that fish will usually rely on cruising (red aerobic muscle) swimming to evade screens, rather than burst (white anaerobic muscle) swimming which they seem to reserve generally for evasion of a frightening stimulus. Increased current speeds close to screens may not be perceived by fish as dangerous. They may often cruise for long periods upstream

of them before becoming exhausted and trapped against the screen. For this reason screen intake velocities should be calculated with respect to sustainable swimming speeds.
- Screens angled across the flow, leading fish straight into an adequately-flowing by-pass channel are often effective.
- Screen design should allow sufficient surface area to cope with the normal debris load in the given watercourse without blocking. Angled screens have a self-cleaning element. The efficiency required of a screen by the Agency will vary according to the status of the local migratory fish stocks. For example, a screen placed in a watercourse supporting an endangered salmon stock would be required to be 100% efficient.

Solomon (1992) provides a full discussion of screen types, designs and relative merits. Environment Agency officers with suitable training, assess water intake sites for compliance with SaFFA Section 14 and help owners to solve potential fisheries problems. Where intakes potentially take a significant proportion of a migratory smolt run, then solutions must be found and implemented rapidly.

13.2.2 Obstructions to migration

The Salmon Advisory Committee (1997) gave the following advice regarding obstructions to fish migration:
- There should be a fully effective fish pass on each existing or new man-made obstruction on a salmon river.
- Such passes will ensure safe downstream or upstream passage of salmon at relevant stages of their life cycle (parr, smolts, adults).
- Environmental assessments will generally be required for new fish passes. Factors such as likely delays in fish passage, spawning behaviour and success, whether the pass is selective and any increased predation risk to migrating fish should be included.
- A practical definition of fish pass efficiency would be helpful.
- All passes should be tested for their efficiency.
- All passes need regular inspection to ensure that they are working properly.

Part II of the Salmon and Freshwater Fisheries Act (1975) (SaFFA) is directed at protecting the free passage of migrating salmon and sea trout. Section 9 of SaFFA puts a legal obligation on anyone who, in waters frequented by salmon or sea trout:
- Constructs a new dam
- Raises or alters an existing dam so as to increase obstruction to the passage of salmon or sea trout or
- Creates, increases or causes any other obstruction to their passage

Such a person can be required, by the Environment Agency to install a fish pass to EA specifications (Beach, 1984, Solomon, 1992, Salmon Advisory Committee, 1997). Also, anyone rebuilding or reinstating an existing dam, providing that at least half its length has been destroyed or taken down, can also be required to install an adequate fish pass. The Agency must provide provisional consent before any work is started. Passes built in accordance with SaFFA Section 9 are required to be maintained in 'an efficient state' and to function to the satisfaction of the Agency. Provisional approval can be withdrawn for an inefficient fish pass and, if the owner does not make good the construction, the Agency is legally entitled to undertake the work and to recover costs.

Section 10 of SaFFA entitles the Agency to build at its own expense a fish pass in any existing dam, provided that the efficiency of the dam is not reduced. This Section really only refers to dams constructed before 1873 as legislation since then has required fish passes to be constructed in all new dams (in rivers where salmon and sea trout occur).

13.3 Summary of Management Options

The Environment Agency should know of significant barriers to fish migration and plan for fish passes of suitable design to be installed when funding is available. Partnership projects may be useful mechanisms for fund-raising and fish pass construction (e.g. The Thames Salmon Project).

Some types of fish pass

Pool and traverse type fish pass with notched traverses, after Beach (1984). The pass is a series of small stepped weirs and pools that fish sequentially leap. The pool and weir dimensions shown below offer correct proportions to dissipate water energy. The weir lip or notch should have a rounded profile to guide water down the face thus slowing it down. Long passes may have occasional larger resting pools

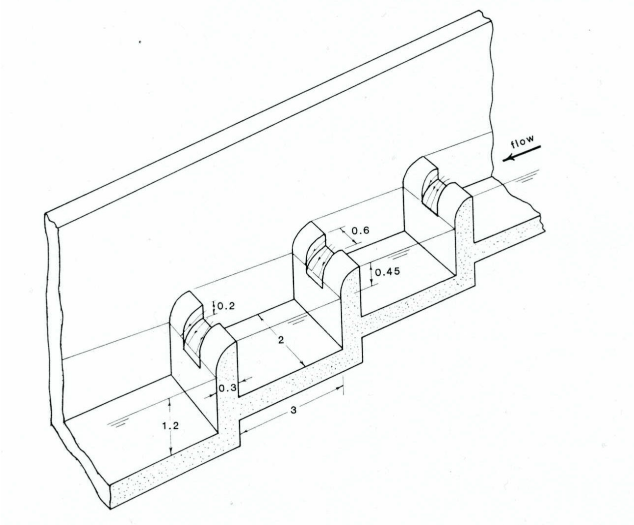

Figure 76 Pool and traverse fish pass

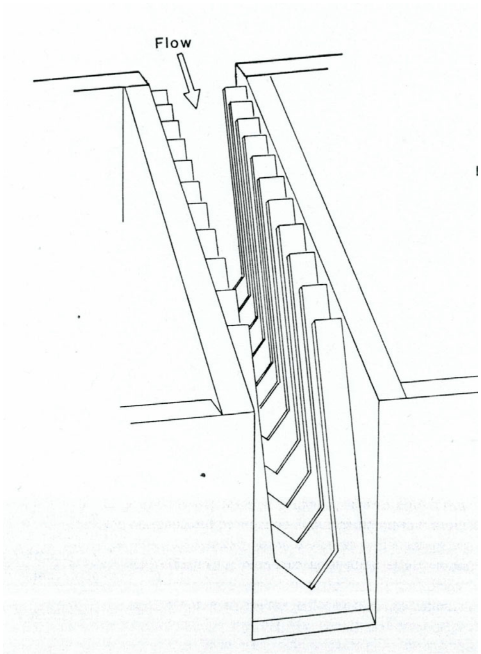

Figure 77 Denil type fish pass, after Bell (1986)

Table 40 Examples of fish pass types (see Salmon Advisory Committee, 1997, Appendix E)

Type	Notes
Cut or gap in weir, 6 inches deep, 4-6 feet wide.	Cobbles embedded in base of notch to break up flow help. These simple notches often work for salmon in weirs of up to a metre high.
Dished channel ("King's Gap") down slope of weir.	May work on shallowly sloping weirs and where bottom is submerged in pool at all water heights.
Diagonal baulk	The notch in the weir has a diagonal timber or concrete baulk leading down to the pool below. Water running down the surface of the baulk forms the channel for fish passage.
Uniform gradient pass	A shallowly sloping (e.g. 1:40) channel by-passing the weir in a loop with flow broken up by base cobbles or alternating side wall baffles.
Pool and Weir	Pool and traverse type fish pass with notched traverses. The pass is a series of small stepped weirs and pools that fish sequentially leap.
Submerged orifice pass	Holes in weir walls allowing water to pass into pool below. Holes are usually at least $0.68m^2$ cross sectional area and angled down to aim water into a depression in the pool floor. Size of orifice is designed with respect to pool size and flow conditions.
Denil	A rectangular chute with closely spaced baffles or vanes along the sides and bottom to break up the force of the flow. Baffle design is subtle.
Fish lifts and locks	These work in the same way as navigation locks - water levels in a chamber are equalised with upstream levels and then fish are released.
Note Take professional advice on fish pass design.	

13.4 References and Bibliography

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Note: references marked with an * provide key sources of information.

14. FISHERIES SOCIO-ECONOMICS

14.1 Introduction

Trout, grayling and char fisheries provide considerable cultural, recreational, economic and conservation values for society. The Salmon and Freshwater Fisheries Review Group Report (MAFF 2000) Recommendation 3 includes the following:
'… enhance the social value of fishing as a widely available and healthy form of recreation.'
'… enhance the contribution salmon and freshwater fisheries make to the economy, particularly in remote rural areas and in areas with low levels of income;'

In support of this philosophy, The Environment Agency National Trout and Grayling Strategy (2003) includes the following:

Policy 1:
We will offer concessionary rates on Agency rod licences to junior, senior and appropriate categories of disabled angler.
We will work with others to help provide low cost opportunities for fishing near centres of population both in urban and rural areas particularly for use by such anglers, and generally to increase the availability of trout and grayling fishing.

Fishing rights constitute significant capital assets throughout the British Isles - there is often local controversy over the allocation of sea trout catches between nets and rods (MAFF 2000). The Environment Agency National Trout and Grayling Strategy (2003) includes the following policy:

Policy 6:
Our aim is to optimise the economic and social value of sustainable exploitation of fish stocks. Where rod fishing interests are willing to compensate netsmen to stop netting, we will assist both parties to reach a mutually acceptable agreement.

However, current legislation limits the Agency's ability to reallocate the catch solely for social and economic reasons. The Agency supports Recommendation 114 of the Salmon and Freshwater Fisheries Review Group Report in relation to sea trout as well as salmon fisheries:
<u>Recommendation 114</u>: A power should be introduced to restrict salmon net licence numbers by byelaw for economic and social reasons. No netsman solely or mainly dependent on fishing for his livelihood should be deprived of his licence without his consent under this provision. Any netsmen deprived of their licences under this provision should be entitled to compensation. If agreement cannot be reached on the level of compensation, this should be determined by an independent arbitrator.

The Environment Agency National Trout and Grayling Strategy (2003) therefore includes:

Policy 7:
If the recommended power is introduced, we will assess each net fishery individually. Assuming that there is no conservation issue, net fisheries will continue to be supported unless there is a clear socio-economic benefit from doing otherwise.

Where there are well-substantiated concerns over sea trout conservation and following Review Group recommendations, the Environment Agency National Trout and Grayling Strategy (2003) includes:

Policy 12:
Where netting or angling is believed to be preventing stocks of sea trout achieving conservation targets, measures will be introduced to restrict catches so that stocks can recover, taking into account costs and benefits.
We will review the size limits, set by Agency byelaws, to safeguard the migration of smolts and survival of whitling (small sea trout).
We will support the introduction of a ban on the sale of rod-caught sea trout.

Mixed stock fisheries for salmon and sea trout can make stock conservation management difficult because of a lack of knowledge of which fish come from which river. Most, if not all mixed stock sea trout net fisheries are being phased out because they are also mixed stock salmon net fisheries. The National Trout and Grayling Strategy Policy 13 states:

Policy 13:
In line with the views of the Salmon and Freshwater Fisheries Review we will continue to phase out mixed stock net fisheries for sea trout except where stocks from a small number of rivers are exploited, in which case catches will be regulated to protect the weakest stock.

Such measures are important when considering both the conservation and economic value of game fisheries. Radford et al (2001) estimate the economic value of trout fishing rights in England and Wales to be around £400m for still waters and £200m for rivers; salmon and sea trout rivers add another £100m. Sea trout netsmen derive incomes from their catches and pay for their licences (1999/2000 income to Agency estimated at £150,000, MAFF, 2000). Anglers derive pleasure from their pastime and spend substantial amounts of money on licences, permits, tackle, accommodation, meals, fuel and other items. Often, game angling makes significant economic contributions, both direct and indirect to rural communities - places where jobs are often low-paid and scarce. Fisheries can also represent a valuable form of diversification for farmers who seek to widen their sources of income. The good management of fisheries in England and Wales underpins a substantial business sector and source of employment.

Prospective fishery owners/managers may consider setting up new trout fisheries to take advantage of this business opportunity. The setting up of a new still water or river trout fishery needs to take account of a wide variety of factors. Radford et al (2001) found that key variables of interest to anglers were:

- For still waters - the number of rods fishing and the average catch per day.
- For rivers - the size of the river, the average catch per day and the proportion of wild trout.

Angling 2000: Survey of licence holders

From a concurrent survey of around 2,600 rod licence holders in 2001, Simpson and Mawle (2002) found that, of around 200,000 licensed anglers, 50% fished for trout on rivers, 78% on still waters and 28% fished on both in the previous year. In 2000 an estimated 2.6 million rod days were spent on stillwater trout fisheries and around 1 million rod days on rivers. Trout (and grayling) angling is, therefore, a substantial recreational resource and potential business venture.

Trout anglers preferred to fish rivers (51%) or still waters (34%) or had no particular preference (15%). Still water trout fishing tends to be more readily available than river fishing. There was reasonably good statistical evidence from the survey that distance travelled to a fishery has a significant bearing on the likelihood of an angler visiting a river fishery. In the survey, the average distance to the nearest available still water fishery was 11 miles compared with 16 miles to a river fishery.

Rainbow trout are the most available fish and 66% of anglers caught rainbow trout most often while only 26% caught brown trout most often. However, 42% of anglers prefer to catch brown trout, particularly wild brown trout (67%). More than 75% of trout fishermen always or usually voluntarily release all wild brown trout caught. There were indications of some unsatisfied demand for wild brown trout river fishing and of trout fishing available relatively close to home. High fuel costs and time constraints are likely causal factors.

Just 5% of licence holders had fished for grayling in the previous year, probably a reflection of the limited availability of the species. Only 25% of anglers knew of somewhere they could go grayling fishing and the fishery averaged 27 miles away from their homes. Around 75% of trout anglers who hadn't fished for grayling were either very or fairly interested in going grayling fishing in future (Simpson & Mawle 2002).

In 1999 expenditure by game anglers (including salmon) was estimated at £300m a year (Gibb Ltd et al, 2002).

14.2 Technical and Practical Advice

14.2.1 Socio-economic factors when setting up a new fishery

From the studies of Radford et al (2001) and Simpson and Mawle (2002) important factors to be thoroughly investigated before setting up a new trout fishery include:

- The suitability of the site in ecological, planning and geographical location terms.
- The current availability of trout fisheries in the area.
- The recent economic success of those existing fisheries.
- The likely unsatisfied demand for trout fishing in a given area.
- The types of fishing that could be offered including species, sizes and numbers of fish, angling methods, bag limits, catch and release, mixed coarse and trout, amenities and facilities, fishing seasons, etc.

Area Environment Agency Fisheries staff will be able to advise aspiring trout fishery owner/managers on:

- The likely suitability of a given site for a trout fishery (water supply, water quality, etc).
- The requirements for Environment Agency Consents and likelihood for the need for Local Authority Planning Approval.
- The location of existing local trout fisheries relative to population centres and what those fisheries offer. The Agency has recently compiled an inventory of trout fisheries in England and Wales (contact National Fisheries Technical Team, Salmon Fisheries Science Group, Cardiff).
- Numbers of anglers buying coarse and trout or migratory salmonid licences in a given Region. Information on this is available from The National Rod Licence Centre, Warrington.
- The results of national studies on angler's preferences for different types of trout and grayling fishing in differing parts of England and Wales and types of fishing most frequently undertaken.

The National Trout and Grayling Fisheries Strategy includes the following:

Policy 4:
We will work with others to identify, develop and market angling opportunities that will contribute to the local economy, especially through tourism in rural areas.

And

Policy 5:
We will regularly assess anglers' preferences for different types of trout and grayling fishing in different areas of the country, and the types of fishing most frequently undertaken.

The Association of Stillwater Game Fishery Managers (ASGFM) and Salmon and Trout Association (S&TA) are both very good sources of information on the current availability and success of trout fishing waters in any given area.

14.2.2 Sea trout netting

The Environment Agency seeks to manage wild trout stocks on a sustainable basis and to help optimise the economic value of the resource whilst ensuring social equity considerations. The average economic value of a rod caught sea trout may be greater than that of one taken by nets. However, it cannot be assumed that closing net fisheries to benefit rod fisheries will always generate a greater economic benefit. As mentioned in the Introduction to this chapter, careful analysis is needed of local supply and demand for angling, social equity, netmen's attitudes to continuing fishing, etc. On some rivers, at least, sea trout stocks, for instance, late-running ones, may be little exploited by rods and could represent a 'wasted' resource if not exploited by other means. Even if netting is stopped altogether, by mutual agreement, on a popular sea trout rod fishery, would the projected increase in economic returns exceed the former combined incomes from angling- plus netting-related activities? This would need to be so for a socio-economic argument to reduce or remove netting to prevail.

Therefore, any decision to change the status quo with respect to netting on a given river should consider the following points:

- Is the sea trout stock at a safe conservation level?
- If so, need the anglers be concerned over the level of catches by netsmen?
- Would any reduction in the numbers of netted fish lead to increased angling catches and increased overall income to the local economy?
- If so, and if the netsmen are willing to enter negotiations on an agreed buy out, the Agency may be willing, on a local basis, to help broker a fair agreement between rods and nets.
- In this instance no netsman should be excluded from fishing against his/her will.

Following these principles, the aim would be to reach amicable long-term agreements on allocation of sea trout resources on a given river. Each case must, necessarily be considered in its own right as local economic, environmental and social circumstances vary greatly between river catchments.

14.3 Summary of Management Options

Table 41 Socio-economics of trout fisheries - good practice

Issue	Management options	Good practice notes
New fisheries	Seek and carefully consider all available advice on: the suitability of the site current availability of trout fishing likely unsatisfied demand for the type of fishing envisaged.	Talk to: Area Environment Agency staff, Local anglers, Tackle shops, Association of Still Water Game Fishery Managers (ASGFM). Local branch of Salmon and Trout Association (S&TA).
Sea trout netting	Assess levels of rod and net catches for river, historic trends and comparative performance of local rivers.	Environment Agency can act as 'honest broker' in discussions and assessments of socio-economic returns from fisheries. No netsmen will be bought out of licence use against their will.

14.4 References and Bibliography

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Note: references marked with an * provide key sources of information.

15. STOCKING

15.1 Introduction

Stocking is crucial to the success of many trout fisheries and is widely practised. Persons stocking fish require Section 30 consent from the Environment Agency.

Two principal reasons for stocking fish are (see Aprahamian et al, 2002):
1. To increase fish numbers within the carrying capacity of the fishery - trying to improve long-term self-sustainability of the stock or,
2. To deliberately increase the fish stock beyond the natural carrying capacity of the habitat to improve angling performance. This may impact upon the long-term sustainability of any wild stock present and affect other species too.

The Environment Agency (1998, see also 2001) defines the following types of stocking:

Table 42 Types of stocking

Stocking type	Definition
Mitigation	Conducted to mitigate lost production due to a scheme or activity that cannot be prevented or removed. Examples include construction of river headwater reservoirs, estuarine barrage schemes and power stations.
Restoration	Carried out after the removal or reduction of a factor that has been limiting or preventing natural production. This can involve a 'quick start' for fish populations after long term water quality or habitat quality improvements or after a serious bout of pollution.
Enhancement	To supplement an existing stock where the production is less than the water body could potentially sustain. Examples include compensating for poor water quality, low flows or damaged physical habitat quality (loss of gravel shallows, pools, in-stream cover, etc).

Note: It is the Environment Agency's policy not to carry out any enhancement or mitigation stockings for migratory salmonids unless paid for by a 3rd party.

Scientific investigations may require the stocking of fish (often tagged) to assess, for instance, migratory behaviour, aspects of population ecology, the success of stocking or habitat improvement projects, etc. There may be circumstances where attempts are made to establish or re-establish new populations of rare or endangered species. Also, conservation stocking may be used to support existing stocks of un-exploited rare fish species. This is confined to those species or populations that are considered, by the Environment Agency, to be rare or endangered.

15.1.1 Whether to stock a fishery - Policies in the National Trout and Grayling Fisheries Strategy

The decision to stock fish or not should always be weighed against the merits of improving other factors (water quality, flows, physical habitat) to improve wild fish stocks indirectly or perhaps, by reducing exploitation through adopting catch and release, lower bag limit or increased size limit rules.

Commercial stocking decisions may be based on maximising income from visiting anglers; many prefer to fish for wild trout whilst others prefer to catch stocked fish. When done appropriately and well, stocking can be an essential and cost-effective form of game fishery management. Whilst stocking often seems an instant solution to fishery problems, it can however, bring with it many negative environmental and commercial consequences. Poor stocking decisions can easily lead to financial loss, poor fishery performance and damage to wild fish stocks and other wildlife. Wild trout can be affected by stocked fish in several ways, for instance:

- Through competition for food and space.
- Through direct predation by stocked trout on smaller wild fish.
- By attracting more predators (e.g. cormorants) to the fishery.
- By stimulating increased fishing effort, therefore increasing the exploitation of both stocked and wild fish.
- Through introduction of diseases or parasites.
- Through interbreeding with wild fish and reducing the genetic quality of the offspring.

This final point merits expansion. Some authorities (e.g. Pawson 2003) argue that stocked trout introduce new combinations of genes that could enable locally-adapted trout stocks to further adapt to their environment. Others (e.g. Ferguson, 2003) argue very convincingly that there is no published evidence that this is the case. In fact, they argue that introducing relatively inbred, hatchery-produced trout into a wild population is likely to reduce the degree of adaptation in offspring by diluting the local gene pool. This is an important area of potential risk to wild stocks and is addressed further below.

Managing for wild fish stocks is important in the context of sustainable development, i.e. "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". (The Brundtland Report 1987).

In the context of trout fisheries this means that regulations on management must include safeguards for wild stocks. Care is needed to weigh up the costs, benefits and risks of stocking on a case by case basis (Aprahamian et al, 2002). Stocking is a complex topic, involving considerations of habitat suitability, ecological conditions within the water, existing fish stocks, species, size, number, health status of fish to be stocked and angling requirements (Salmon Advisory Committee, 1991, Salmon and Freshwater Fisheries Review, 2000, National Trout and Grayling Strategy, 2003).

Where precise effects, for instance of stocking, cannot be established but where there is a risk of damaging wild fish stocks, a precautionary approach becomes important.

The Precautionary Principle:

> Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation. (Rio Declaration 1992).

Bearing in mind these principles, The National Trout and Grayling Strategy established:

Policy 15:
In considering whether or not to consent a stocking, we will adopt the guiding principles that:

- **fish introductions should not be allowed to jeopardise the well-being of naturally established ecosystems; and**
- **there should be no overall detriment to the fisheries (stock, habitat, performance) of the donor water or the receiving water, or to the viability of the fish involved in transfer and introduction.**

Nursery areas, in particular, are vulnerable to stocking with relatively large and predatory trout, many of these areas may be protected from stocking in future, and their precise locations will be established with local consultation. Even outside nursery areas it may be important to restrict by regulation, numbers, sizes and provenance of stocked trout to reduce negative impacts on wild stocks. For this reason, Policies 16, 17 and 18 of the National Trout and Grayling Strategy were developed:

Policy 16:
We will work with others to identify limits on the number and size of trout which could be stocked into different types of water without undue risk of a deleterious impact on wild stocks.

Policy 17:
Where a proposed stocking of *Salmo trutta* differs from current practice, it will not be consented if it presents an additional risk of genetic damage that could either:

- **reduce the viability of any wild population; or**
- **change the characteristics of those wild populations that are considered to be distinct or evolutionarily important.**

(Policies 27, 28 and 29 provide more detail of how this will be achieved - see below).

Policy 18:
Non-native species

- **We will not grant consent to introduce any non-native species, other than rainbow trout, into rivers, streams and other un-enclosed waters.**
- **We will grant consent to stock into enclosed stillwaters outside the floodplain provided that all appropriate legal, environmental and disease conditions have been met.**

Rainbow trout are the mainstay of stocked still water trout fisheries and have, for a long period, been stocked into various rivers, very occasionally establishing breeding populations, for instance on the Derbyshire Wye. Because of the long established practice of stocking rainbow trout and the fact that they are distinguishable from brown trout and can be used to help conserve them, rainbows are treated differently from other non-native species:

Policy 19:
Rainbow trout into rivers, streams and other un-enclosed waters

- **Subject to other constraints, we will permit introductions where there is a history of stocking to sustain a fishery or where the introduction of non-breeding rainbow trout can be clearly demonstrated to be a preferred environmental option.**
- **In all other cases, we will not consent the introduction of rainbow trout into rivers, streams or other un-enclosed waters.**

On some rivers, however, escapes of rainbow trout from fish farms have proved to be a regular nuisance to downstream fisheries, particularly when large numbers of small fish are involved. Because of the widespread nature of these escapes and their potential to affect wild fish stocks and angling performance of fisheries, Policy 20 was developed:

Policy 20:
Escapes from fish farms

- **We will seek better ways of identifying the source of escapees.**
- **Where we have relevant evidence we will assist in legal action taken against those responsible for escapes.**
- **We will work with others to monitor the scale of the problem.**
- **We will seek stronger legislation and if needed additional resources, to reduce escapes from fish farms.**

15.1.2 Classification of trout fisheries

Wild fisheries for sea trout, brown trout, grayling and char can be managed so as to maximise natural production and hence, fishery potential. Well-managed wild fisheries require no stocking for their routine management. Abundant, self-sustaining fish stocks require high quality habitats that also support a diverse wildlife community - a key objective for sustainable fisheries management.

To help conserve wild stocks and to enhance economic benefits derived from them, trout waters will be divided initially into:

- **‘native trout’ waters**: those that have significant natural production of trout (*Salmo trutta),* whether migratory or non-migratory, or from which there is ready access to other waters with such production; and
- **other waters**: those that do not have such production or access.

The designations of ‘native trout’ waters will initially be by Environment Agency Area staff but subject to local consultation.

Consent to stock these waters will be subject to certain constraints to limit the risk of damaging the viability of the wild population - Policy 27 (see also Policy 29; 'Wild fisheries protection zones'):

Policy 27:
In general, we will continue to consent stocking into 'native trout' waters if:
- **consistent with practice over the last five years (the objective is to avoid increasing stocking levels of fertile, farm strain trout); or**
- **stock fish are triploid females; or**
- **stock fish are derived from local, naturally produced, broodstock under a suitable rearing regime.**

In all waters stocking will still need to be consistent with Policy 15, particularly with regard to the number, size and species of trout stocked (see Policies 16, 18 and 19).

15.1.3 Female triploid brown trout

All female triploid (triple chromosome compliment) rainbow trout have been used to stock trout fisheries for some time and have proved very successful. Commercial production of all female triploid brown trout is also now well established in parts of England and Wales and these fish have performed well in a number of fisheries. If triploid browns were more widely available and could be shown to perform satisfactorily in all types of trout fishery, they would potentially be an excellent fish with which to stock. Benefits would include the fact that they are sterile and therefore, pose no genetic threat to wild trout stocks. Further benefits may also accrue from a policy of stocking these fish (see Solomon, 2001 and Dillon et al, 2000).

Female triploid trout look similar to diploid (normal, double chromosome complement) trout, but do not develop characteristics linked to sexual maturity:
- are infertile;
- do not develop eggs or 'colour up' during the spawning season;
- exhibit no spawning behaviour;
- may show better growth rates than ordinary trout because they are not putting their energy into egg production;
- survive better over winter than ordinary trout of mixed sexes;
- maintain their condition and flesh pigmentation over winter;
- provide similar returns to the rod as ordinary stocked trout; and
- may fight more spectacularly than ordinary trout.

Female triploid brown trout have successfully been used in recent seasons on rivers including the Test, Itchen, Kennet, Wylye and Allen. More information is needed to see whether their applicability is widespread in England and Wales and, to this end, the Agency will be commissioning further Research & Development work in accordance with Policy 28 of the National Trout and Grayling Fisheries Strategy (EA 2003):

Policy 28:
Further research will be commissioned into:
- **triploids: production, performance, and interaction with wild fish;**
- **stocking with ordinary farm-reared trout including performance and interaction with wild fish; and**
- **improved assessment of the risks to wild trout via genetic changes resulting from stocking fertile trout of farmed strains.**

Where possible and appropriate the research will seek to involve fish-farming and angling interests.
In 2006, following completion of the research, policy will be reviewed to assess whether further constraints should be placed from 2007 on stocking fertile, farm strain trout in waters with significant natural trout production. The review will include further consultation with fisheries interests.

15.1.4 Wild fisheries protection zones

Some stretches of river and stream that are important salmonid nursery areas, or are recognised as wild trout waters, or which owners wish to develop into wild fisheries will be given greater protection and designated as Wild Fisheries Protection Zones. These zones will only be designated after local consultation with interested parties and, in the event of disagreement, there will be a simple and inexpensive appeals procedure. Policy 29 represents an exception to Policy 27 (page 291 and they should be read in conjunction):

Policy 29:
The only exceptions to Policy 27 will be fisheries within 'Wild Fisheries Protection Zones' where stocking will not be consented for one or more of the following reasons:
- **local fisheries interests wish to avoid their 'wild' fisheries being contaminated with stock fish;**
- **the wild trout are considered to be genetically 'distinct or evolutionarily important';**
- **the zone contains important nursery or spawning areas for trout and/or salmon, at unacceptable risk from predation/competition by stock fish.**

The classification and associated constraints on stocking will help achieve a number of desirable outcomes:
- fisheries managers wishing to attract anglers to 'wild' fishing could ask for their fisheries to be designated as Wild Fisheries Protection Zones;
- preventing an increased risk of genetic damage to wild stocks;
- increased protection of key nursery areas for wild stocks of trout and salmon; and
- anglers will be able to identify whether they are fishing in waters containing wild trout or whether they may be stocked.

15.1.5 Stocked fisheries

Stocked trout fisheries are those where natural production is clearly insufficient to sustain exploitation pressures and where routine stocking is therefore, required to maintain or enhance natural fishery performance. Consideration as to the best provenance, species, size and number of trout to stock should be related to the type of river or lake, the state of the wild stock and other ecological and commercial factors. At one extreme, stocked fish may never be seen again, at the other they can represent all of the fish caught on a fishery. Where the balance lies on a particular fishery will depend upon the analysis of catch returns, assessment of any wild stock and a good understanding of fishery ecology and management. Catch-and-release rules can help both to conserve wild stocks and to reduce numbers of stocked fish required on stocked fisheries.

Put-and-take fisheries have no natural recruitment potential and rely, therefore, completely on stocking to sustain performance. Under these circumstances a closed season for brown trout is inappropriate and The National Trout and Grayling Fisheries Strategy therefore establishes:

Policy 3:
We will support a change in the law so that the statutory close season for brown trout can, at the owner's discretion, be dispensed with on enclosed still water fisheries with no natural recruitment.

Figure 78 below summarises some of the information given above:

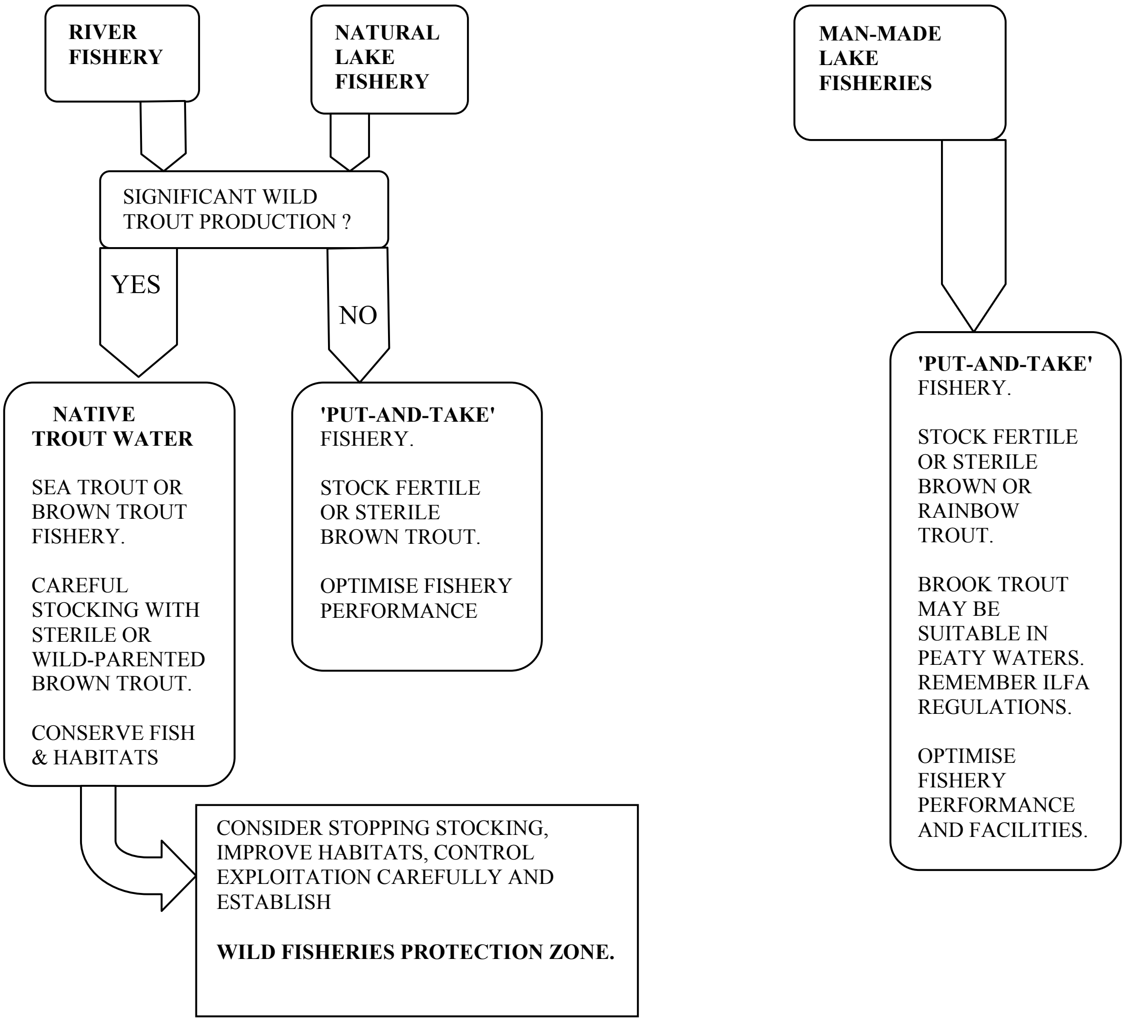

Figure 78 Good practice when stocking trout fisheries

15.2 Technical and Practical Advice

15.2.1 Permissions to stock fish

Fish introductions are included in a range of legislation overseen by DEFRA, EN/CCW and the Environment Agency:

- The Diseases of Fish Act 1937 (controls imports from non-EU countries, defines fish farms for registration, fish farms are screened for 'notifiable' diseases),
- Salmon and Freshwater Fisheries Act, 1975, (SaFFA)
- Import of Live Fish (England and Wales)Act 1980, (ILFA)
- The Wildlife and Countryside Act 1981 (Section 14 requires licensing of introductions to the wild of non-native and naturalised species in consultation with EN/CCW/EA), (WACA)
- The EC Directive 91/67/EEC (fish movements within and between EU countries, ensuring free trade whilst preventing the spread of 'notifiable' diseases),
- Conservation (Natural Habitats etc) Regulations 1994
- Environment Act 1995
- The Prohibition of Keeping of Live Fish (Crayfish) Order 1996
- The Prohibition of Keeping of Live Fish (Crayfish) (Amendment) Order 1996
- The Prohibition of Keeping or Release of Live Fish (Specified Species) Order (1998), created under the Importation of Live Fish Act (1980, ILFA) to combat increased illegal importation of species such as wels catfish or to increase the effectiveness of existing legislation, e.g. for wels catfish and grass carp. DEFRA and the Environment Agency share enforcement of this Order.

Prior written consent from the Environment Agency under the Salmon and Freshwater Fisheries Act 1975 - Section 30 is required before any fish, or their spawn, are stocked into inland waters (other than fish farms). Section 30 (including an amendment via Section 34 of the 1986 Salmon Act) is stated in full below:

> A person shall be guilty of an offence if he introduces any fish or spawn of fish into an inland water, or has in his possession any fish or spawn of fish intending to introduce it to an inland water, unless he first obtains the written consent of The Environment Agency within whose area any part of the water is situated, or the inland water is one which consists exclusively of, or of part of, a fish farm and which, if it discharges into another inland water, does so only through a conduit constructed or adapted for the purpose.

Inland waters include rivers, streams, drains, canals, lakes and ponds but exclude fish farms (see Salmon Act 1986) and garden ponds.

The Environment Agency's objective, via Section 30 of the Salmon and Freshwater Fisheries Act 1975 is to provide:

> Nationally consistent protection of native fish stocks and the environment from risks associated with fish introductions, without compromising the socio-economic benefits of legitimate fisheries management.

15.2.2 Health checks (see chapter 18 - Diseases and Parasites)

The Environment Agency currently tiers Section 30 applications with respect to the need for health checks on fish to be stocked:

Open or Mandatory waters
Stocking into rivers, streams, drains, canals or other waters into or from which fish may escape, require a mandatory health check. This includes isolated stillwaters that are in a flood plain or are liable to flooding. Many health checks are undertaken by the Environment Agency National Fisheries Laboratory at Brampton or by other laboratories. DEFRA cover most health checks on fish farms producing trout for stocking.

Enclosed or Non-Mandatory waters
On enclosed waters i.e. from which there is no risk of fish escaping, a 'Buyer Beware' policy is applied where health checks are recommended but not mandatory. The onus is on the fishery owner/manager to protect the fishery by stocking only healthy fish. It is very wise to check the health status of fish to be used for stocking; unhealthy fish may soon die and any introduction of disease or parasites can be an irreversible catastrophe for the existing stock in a fishery.

DEFRA is responsible for regulating and administering the importation of live fish and their eggs/sperm into England and Wales. DEFRA consents generally relate to fish farms and ornamental fish outlets whilst the Environment Agency consents fish introductions to trout and other fisheries in the wild.

An ILFA Order 1998 licence from DEFRA/Welsh Office is required for introduction and/or keeping of certain non-native fish. The salmonid species are listed below; note that DEFRA are consulting on the addition of several more salmonid species:

Table 43 ILFA - regulated Salmonid species

Common name	Species name
<u>Salmonids</u>	
American brook trout	*Salvelinus fontinalis*
Landlocked Atlantic salmon	*Salmo salar*
Pacific salmon	*Oncorhynchus* species
Pacific trout (excluding rainbow trout)	*Oncorhynchus* species
Steelhead (excluding rainbow trout)	*Oncorhynchus mykiss*

Where ILFA applies
ILFA licence requirements cover fisheries, fish farms, garden ponds, fish suppliers premises and aquaria. A general licence may apply to some species kept in gardens ponds and aquaria (other than on retail or wholesale premises). A WACA 1981 licence is also required for the introduction of non-native fish into the “wild”.

A licence from DEFRA/NAWAD under the ILFA Order 1998 is required to keep or release those non-native fish listed in the Schedule to the order. The ILFA licence requirements covers all fisheries, the wild, fish farms, garden ponds and dealer's premises.

While DEFRA/NAWAD are responsible for granting ILFA licences, the Environment Agency has an important role to play. The introduction of non-native fish into fisheries, or the wild requires a Section 30 consent in addition to the ILFA licence. DEFRA/NAWAD will not grant an ILFA licence for fisheries or the wild without Environment Agency agreement that S30 consent will be granted.

Where WACA applies
The introduction of any non-native species (not ordinarily resident) requires a WACA licence from EN/CCW. The ILFA licence application form covers WACA licence requirements and, where appropriate, a single licence will be issued to cover both ILFA and WACA.

Table 44 Consenting requirements for fish introductions

Site	ILFA licence	WACA licence	Section 30 consent
Aquarium	Yes		
Wholesale/retail	Yes		
Garden pond	Yes		
Fish farm	Yes	Yes (if in wild)	
The wild	Yes	Yes	Yes
Fishery	Yes	Yes	Yes

15.2.3 Wildlife conservation and fish stocking

In considering whether to stock or remove fish, the Environment Agency has a duty under Section 7 of the Environment Act 1995 to:

- Further the conservation of flora and fauna of special interest (so far as it is consistent with the fisheries duties).
- Take into account any effect on flora and fauna.

The Environment Agency also has a duty under section 6(1) of the Environment Act 1995 to promote, to such an extent as is considered desirable, the conservation of flora and fauna which are dependent on an aquatic environment. Therefore, in making the decision on whether to stock or remove fish, a precautionary approach should be adopted where the site is a Site of Special Scientific Interest (SSSI), and take into account the effects on flora and fauna at all other sites. Rare fish are just one group which require consideration. Rare and Endangered Fish Species in England and Wales include the following (Salmon and Freshwater Fisheries Review, MAFF 2000):

Table 45 Rare and endangered fish species in England and Wales

COMMON NAME	SCIENTIFIC NAME
Spined loach	*Cobitis taenia*
Vendace	*Coregonus albula*
Whitefish (powan/ schelly/ gwyniad)	*Coregonus lavaretus*
Houting *	*Coregonus oxyrinchus*
Allis shad	*Alosa alosa*
Twaite shad	*Alosa fallax*
Smelt	*Osmerus eperlanus*
Sturgeon	*Acipenser sturio*
Arctic char	*Salvelinus alpinus*
Burbot *	*Lota lota*
River lamprey	*Lampetra fluviatilis*
Brook lamprey	*Lampetra planeri*
Sea lamprey	*Petromyzon marinus*

* Probably extinct.

The Countryside and Rights Of Way Act 2000 (CROW Act) strengthens the law on SSSIs and on species protection, putting biodiversity on a statutory basis (Marsh & Heaton, 2000). The Environment Agency is required to give EN/CCW 28 days notice before determining an authorisation for a third party for an activity which might damage an SSSI. The Environment Agency must take account of advice given by EN/CCW and, if intending to grant an authorisation against their advice, must give EN/CCW notice as to how their advice has been considered. The authorised activity cannot proceed within 21 days of this notice (Marsh & Heaton, 2000).

Where a European or Ramsar site may be affected, the Environment Agency has an obligation under the Conservation (Natural Habitats etc.) Regulations 1994 to ensure that there is no adverse effect on the integrity of the site from the introduction or removal of fish. The restoration of stocks following pollution or other habitat degradation may have direct benefits for conservation/biodiversity in addition to fisheries. Finally, in determining a Section 30 consent, the approving officer must also consider the welfare of the stocked fish and those already in the receiving water.

15.2.4 Avoiding the introduction of non-native crayfish and crayfish plague

Non-native crayfish are known to degrade macrophyte communities, macroinvertebrate diversity, fish populations and native crayfish populations (Environment Agency, 2002). The introduction of non-native crayfish and crayfish plague has had devastating effects on native white clawed crayfish populations. Crayfish plague is transferred via spores which can only survive in wet conditions. It is theoretically possible for spores to travel on any medium, so long as it remains wet. This could include wet fishing gear, fish scales, water, mud on vehicles or other equipment or by natural vectors such as fish, birds, mammals or other animals. Possible causes of spread may be on transferred fish, the water they are transferred in, or contaminated fishing equipment. Crayfish plague spores have a viability of only about 2 weeks without being present on a host such as signal crayfish. Equipment can be disinfected by iodophore or by thorough drying.

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Figure 79 Native crayfish (male on right)

“Natura 2000” SAC sites

In accordance with the Habitats Directive Guidance (EAS/3100/4/2), EN/CCW will require an “appropriate assessment” for any application to stock fish into a SAC where white-clawed crayfish have been listed as a feature of European interest, and where the source water meets any of the following criteria:

- A fish farm rearing or holding non-native crayfish;
- A fish farm that receives water downstream from a known non-native crayfish population;
- A river that contains, or is downstream from a non-native crayfish population;
- A stillwater or canal that contains non-native crayfish;
- Any fish farm or water with a known history of crayfish plague.

If the source of the fish meets any of the above criteria, then the conclusion of an “appropriate assessment” would be that the introduction should not take place, except where:-

- it can be demonstrated beyond reasonable doubt (e.g. presence of native crayfish in the source water) that crayfish plague is not present in the source water
- an alternative conclusion is acceptable to EN/CCW

The River Itchen, Hampshire is a good example of a site where this policy has been successfully implemented - the river is stocked with hatchery trout but also has a vulnerable native crayfish population.

Sites of Special Scientific Interest - SSSIs

While an “appropriate assessment” is not required, the above criteria should also apply to SSSIs that are notified for native crayfish. If the criteria are met the introduction should not take place. Environment Agency Biodiversity staff should be consulted as a matter of course for all S30 applications.

15.2.5 Hatchery trout and wild trout

Radford et al, (2001) evaluated trout fishing rights in England and Wales, estimating that still water trout fisheries valued £400m and rivers £200m. On rivers, the size of the water, typical catches and percentage of wild trout are important factors in valuation. A separate survey of fishing licence holders in 2001 (Simpson & Mawle, 2002) established a strong preference amongst anglers for wild trout although stocked trout are caught most often. Many anglers now routinely release any wild brown and sea trout caught. From these recent studies, the economic value of wild trout is apparent. Wild trout are therefore, well worth conserving both for their economic and conservation values.

Where natural populations of trout are present a range of potential effects arise from stocking. These include (Environment Agency National Trout and Grayling Fisheries Strategy 2003):

- An inability to monitor wild stocks because of confusion with stocked trout of various sizes and ages (including fry on some fisheries)
- Competition for food and space, predation of juvenile salmonids
- Inter-breeding with and genetic change of wild stocks
- Stimulating an influx of predators,
- Introducing diseases and parasites
- Stimulating fishing effort and increased exploitation of wild stocks

Clearly, care to assess potential risks to any wild stocks is needed before stocking with hatchery-produced trout.

15.2.6 Encouraging wild trout production (see also chapters 8 – Habitats, and 2 - Trout Ecology)

Trout streams, rivers and natural lakes have a limited carrying capacity for game fish stocks (Elliott, 1994 and comprehensive references therein). Upland acid waters will support a lower biomass (weight of fish present) and annual productivity (total weight of fish grown each year) than more fertile waters. Whether there are few large or many small fish will depend upon survival rates at different stages of the life cycle. HABSCORE (Barnard & Wyatt, 1995) and the Fisheries Classification Scheme (Mainstone et al, 1994) are useful tools to help Environment Agency staff assess likely population densities of game fish on a range of stream and river systems. Note that some river types are better suited to HABSCORE analyses than others.

Temperature regimes, fertility of the water and habitat quality are of fundamental importance in determining brown trout growth patterns. The population densities of trout of differing sizes and species may be affected by many factors including:

- Spawning success (often limited by area and quality of accessible spawning gravels).
- Survival of fry, parr, sub-adults (often affected by water quality, flows, physical habitat, predation, competition, disease, etc).
- Adult survival (often affected by angling pressure, commercial fishing, water quality, flows, physical habitat, predation, competition, disease, etc).

A successful fishery needs the right balance and availability of these habitat components or, at least, access for migrating fish to these habitat types. See chapter 8 on habitats for detailed advice on good management.

Determining which factors are limiting wild trout, grayling or char production at a given site is a difficult task. Sometimes the answers are obvious, sometimes they are probable, whilst elsewhere they can be apparently inexplicable. Stocking fish into a habitat already full up with wild fish (at 'carrying capacity') will cause increased fighting, competition for available resources (food, space), emigration and mortality. It is to be avoided. Deciding whether to support a wild stock which appears insufficient to sustain the imposed angling pressure involves the following issues:

Table 46 Should I stock my wild trout fishery?

Issue	Management option
Refer to T&G Strategy Policy 27 and 29	
Is the stock of catchable fish really as low as I think?	Carry out fisheries survey. Use catch returns for monitoring fishery performance.
Can the habitat be improved to increase the carrying capacity?	Identify and solve habitat problems. Take advice from Fishery Officer, see also chapter 8 - Habitats.
Is the angling pressure too high for the area and quality of fishery available?	Record and analyse catch and effort records. Take advice from Fishery Officer.
Will I risk damaging my valuable stock of wild trout by introducing stocked fish? What are the other environmental impacts of stocking?	Take advice, see next section.

If a supported fishery with significant wild production is to be converted from a stocked to a purely wild trout water the following actions are recommended:

Management options

- Assess, as far as possible what proportion of the current catch is comprised of wild fish, if high, this is encouraging, if low, take care. Wild trout have sharper fins, with few or no scars in the fin tissue whilst hatchery-produced trout usually (but by no means always) have some fin deformation due to healing of prior damage.
- Decide whether to gradually curtail stocking, monitoring catches all the time to see whether the fishery continues to perform adequately.
- If so, consider phasing out stocking and maximising wild trout production through good habitat management and careful conservation of the wild stock.
- The gradual phasing out of stocking may take three to five seasons, even on a productive wild trout water.

15.2.7 Minimising impacts on wild trout stocks

Bachman (1984) reviews how stocked brown trout can adversely affect wild stocks. It is commonly the case that trout fishery owner/managers wish to maintain catchable trout densities higher (sometimes very much higher) than those which would be naturally found on the fishery. Most trout fisheries survey data include both wild and stocked trout and so are impossible to interpret (Giles, 1989). Giles (1999), used research records and published sources to make a preliminary estimate of the numbers of takeable (>25cm) wild brown trout stocks in rivers with good habitat quality. He found that rivers tend to support densities of between 0.4 and 4 brown trout >25cm per 100 square metres of stream bed, depending primarily upon stream width. Narrower streams tend to support much higher trout densities (of all sizes), probably owing to the higher proportion of natural cover and food supplied by bank side habitats. Adult brown trout tend not to lie in open wide shallow streams - they seek safe physical cover, especially close to and under stream banks.

If a fishery manager wishes to stock higher than natural densities of adult trout to provide high-performance angling, this can potentially impose serious impacts on wild trout and other species through predation, competition, risk of disease etc (see chapter 18 - Diseases and Parasites). It is important to realise that, as part of the Section 30 consenting procedure and with due regard to socio-economic considerations, Environment Agency staff will assess whether proposed stock densities will impose unacceptable environmental risks for fauna and flora. Too many large trout, for instance, are unlikely to be of ecological value to a fishery, although they may well be attractive to some anglers. Care is needed to make the right decision, especially where the fishery provides nursery habitats for wild trout or salmon.

It is worth noting that 'trickle stocking' (relatively small numbers of stock fish every so often) may be a better management strategy than introductions of large numbers of fish once or twice each season. By trickle stocking to balance exploitation, relatively constant numbers of adult trout can be maintained in a water, avoiding excessive competition for natural resources. This however, does not overcome the vexed question of whether stocked brown trout may damage wild stocks through interbreeding.

15.2.8 Trout population genetics

The brown/sea trout, *Salmo trutta*, is the most genetically diverse species studied to date (Laikre, 1999) and as such, represents a very valuable natural resource for current and future generations. The long-term consequences of any genetic change to a trout population through inter-breeding with hatchery fish are unknown although Ferguson (2003) provides the following view:

"When stocked trout breed with natives they reduce the average performance of the native population in terms of production of offspring for the next generation. Repeated stocking cumulatively damages the ability of the population to survive and reproduce."

The scientific knowledge base is currently not able to inform us on exactly how a given genetic constitution confers survival and breeding advantages to individual fish. What is undoubtedly true however, is that genetic variability both within and between trout

stocks is essential to conserve as it provides for future adaptation and survival of the species. When trying to conserve genetic and phenotypic (appearance and capability) characteristics of a trout stock the aim is to ensure that average individual fitness remains unchanged (Youngson & Verspoor, 1999).
Anyone familiar with wild brown and sea trout knows that fish from differing streams and lakes and sometimes within large river systems and lakes, look and behave differently. Perhaps the best known examples are the genetically distinct brown trout variants of ferox (large fish-eating), sonaghan (slim, dark-finned open water feeding) and gillaroo (red-spotted bottom-feeding) found in some large natural lakes (e.g. by Ferguson in Lough Melvin, Ireland 1986, 1989).

Arctic char also have differentiated stocks within some large lakes, for instance in Loch Rannoch with slim open-water feeding and larger-mouthed benthic-feeding forms (Walker et al, 1988).

Some of this variation is heritable (genetically-based) whilst some is environmentally induced. Generally, biologists believe that the heritable elements of biological variation provide the basis for natural selection and adaptation to local environmental conditions. Such adaptation is believed crucial to the long-term survival of biological populations. Overall genetic variation is therefore, essential to conserve (Laikre, 1999).

An example from the River Dove
Recent DNA studies on the River Dove have shown that stocked hatchery-produced brown trout interbreed to a degree with wild brown trout, changing the genetic constitution of the population. The degree to which stocked trout genes have become incorporated into the wild population was estimated at 35% despite the fact that only around 2% of stocked fish over-winter (McMeel & Ferguson, 1997). Dove trout did not show reduced genetic variation but important genetic variation present in wild trout stocks could be reduced by intensive stocking, thus harming the overall potential for future adaptation to environmental change. This raises the possibility that such genetic changes due to stocking hatchery fish will have long-term adverse impacts on wild trout stocks. Under these circumstances, where the Environment Agency believes that a potential risk of stocking outweighs a benefit, the precautionary principle is invoked.

15.2.9 Hatchery production from wild trout broodstock

The use of wild broodstock for artificial production of trout can allow enhanced fishery performance without damaging the genetics of the stock.

- Broodstock should be taken throughout the spawning season
- Ideally, the resulting progeny should be planted out as ova or swim-up fry.
- Repetition over a number of years with a large number of juveniles is a good strategy.

When contemplating the stripping of wild trout for supplementing wild stocks, the following guidelines are provided by the Salmon Advisory Committee (1991):

- Use at least 30 of the least numerous sex (to avoid genetic 'bottle-necking), taken (ideally) from the same part of the same river as the progeny will be released to.

- Where this is impossible collect broodstock from a nearby tributary or river having similar physical (and chemical) characteristics. Care is needed not to over-exploit such a source.
- Stocked fish should not have been reared in captivity for more than one generation (to avoid artificial selection effects)
- Certify fish for stocking as disease-free and release healthy fish at densities appropriate to stream carrying capacities and the local abundance of wild fish.

Production from wild trout parents can be used to overcome population bottlenecks in natural production at the egg, fry, parr, sub-adult or adult level with fish of the appropriate size being stocked. Always, it is best to keep the hatchery phase of rearing as short as possible - trout in the wild are able to learn important survival skills. Trout are best stocked out as early as is practicable. The use of egg incubator boxes can be a useful way of circumventing serious siltation bottlenecks to trout production. Care is needed however, to check that natural salmonid incubation success really is very low and that eggs used in incubator boxes are from a broad range of the wild stock. Given adequate planning and careful siting this approach can be very successful (e.g. Rivers Test and Itchen, Hampshire, pers comm M. Sidebottom).

Management options
Note that the problems associated with removing and stripping wild adult trout from a small population need to be weighed, as far as possible, against the benefits.
Pros:

- Use of locally adapted brood stock - low risk of adverse genetic change
- No potential for introducing new parasites or diseases

Cons:

- May impact on wild spawning success if too many fish taken for brood stock programme.
- May bottleneck genetic variation of offspring if too few parents or a restricted range of parents is taken from wild. Parental fish should include large, small, differing shapes, timings of and location of spawning, etc. Include as much variation in parental appearance and behaviour as possible. Note that wild parents (not stocked fish) are required.
- Relative hatching success may be low and costs could be high.

15.2.10 Species choice for trout fisheries

Care is needed in managing risk of escape, into the wild, of non-native species as the ecological consequences of the establishment of new species are unpredictable and potentially very damaging to native fauna and flora. Examples include signal crayfish, grey squirrels and common carp.

Still waters
Put-and-take still water trout fisheries depend to a large extent on stocking with rainbow trout. These fish are often triploids or all female stock, both of which tend to maintain good condition throughout the year. On a few waters rainbow trout such as 'blue' or 'golden' colour variants have been selectively bred and are stocked to provide variety for anglers. Brook trout (char) can perform well in some peaty upland lakes.

Hybrids such as 'tiger trout' (brown trout x brook 'trout') are also occasionally used in England and Wales.

The vast majority of fisheries provide variety through offering differing sizes and densities of rainbow trout and brown trout. Such fisheries provide valuable recreational opportunities for large numbers of anglers and substantial local socio-economic benefits.

Rainbow trout in rivers

Some rivers are stocked with rainbow trout and, although non-native, the species is now regarded as naturalised in England and Wales. A few successfully spawning stocks - notably in the Derbyshire Wye - have become established. Some fisheries have been stocked with rainbows for over 100 years (e.g. River Test). The vast majority of stocked rainbow trout do not breed successfully and may pose no greater threat to fisheries and conservation than similarly sized stocked brown trout (see IFE, 1997).

Disease transmission problems in the UK do not appear to be significant (IFE, 1997) but there is the potential for rainbow trout to:

- Compete for space and food with brown trout, grayling, Arctic char, salmon and other species, Vincent (1987) found that rainbow trout stocking adversely affected brown trout populations.
- Over-cut native salmonid redds, Hayes (1988a & b) has shown for a trout river in New Zealand that late-spawning rainbow trout severely affect the survival of incubating brown trout eggs.
- Eat juvenile salmon, brown trout, grayling and char (evidence from Agency Devon Area and North American studies - cited in IFE, 1997).

The ecological significance of these interactions needs to be assessed on a case-by-case basis. The IFE review (1997) revealed variable Environment Agency policy on rainbow trout stocking, between both Areas and Regions. As described in the introduction to this chapter, Policy 19 of The National Environment Agency Trout and Grayling Fisheries Strategy (2003) provides a unified approach for the future.

Some conservationists hold the view that it is inappropriate to stock rainbow trout into any running waters. However, because most anglers can readily distinguish rainbow from brown trout, stocked rainbows can be used to help protect wild trout stocks through the rainbow trout being taken and the wild brown trout released. Decisions on stocking should be taken at local level with full consultation of interested parties, in line with Fisheries Action Plans.

Management options

Table 47 Stocking - Native trout fisheries

Trout fishery	Stocking procedure	Management objective
River brown and rainbow trout.	Existing consents - fertile brown trout and rainbows, recommend trying triploids. New consents triploid or wild-parented brown trout. Rainbows stocking according to Policy 19 National Trout and Grayling Fisheries Strategy.	Conserve wild trout stocks. Maintain fishery performance.
Natural lake brown and rainbow trout.	As above.	As above.

Table 48 Stocking - Put-and-Take trout fisheries

Trout fishery	Stocking procedure	Management objective
Lake brown, brook, rainbow trout. ILFA licence required for brook trout.	In isolated lakes stock fertile or sterile brown trout, rainbows, brook trout or hybrid trout.	Maintain and improve fishery performance.

15.2.11 Grayling fisheries – stocking and removals

Grayling fisheries tend usually to be self-sustaining, indeed grayling are often prolific under good habitat conditions. Some fishery owners/managers may wish to introduce grayling to enhance existing grayling stocks, to reintroduce grayling to polluted rivers or introduce the species to new rivers. See introduction to this chapter for relevant policies (Policies 11 and 21).

The practice of removing grayling in an attempt to improve trout fisheries will be discouraged and relevant fishery owners will be provided with information about the effects of removing a large proportion of a grayling population. The usual consequence is a subsequent proliferation through the fishery of small grayling. The Environment Agency will only undertake grayling removals where it can be justified, where the fish can be utilised to re-establish a damaged stock and where suitable farmed fish are not available (Policy 11, National Trout and Grayling Strategy).

15.2.12 Still waters: trout numbers, size and stock density

When assessing still water trout stock densities, instantaneous figures are required, rather than simple numbers of trout stocked annually divided by fishery area. In an early review of reservoir trout fishery performance, Crisp and Mann (1977) analysed stocking and catch data from 18 British reservoirs. They found, at that time (largely 1960s and 1970s data) that:

- Lowland reservoirs were put-and-take, with little or no natural production. These waters tended to stock annually 40-60 (20kg) trout/ha, giving catches of 20-30 (12kg) trout/ha.

- Higher stocking rates led to higher catches but little increase over the 20kg/ha yield.
- In general, rainbow trout produced better percentage returns on numbers stocked than brown trout.
- Upland reservoirs often have a wild trout component, complicating management with respect to stocking.
- Unstocked (at that time) upland reservoirs such as Balderhead and Cow Green produced annual wild brown trout catches of 1-8 fish/ha (0.4-2.7 kg/ha). However, angling effort was much lower than in lowland waters and a sustainable yield coupled with acceptable fishery performance may be possible.

15.2.13 Practical examples of stillwater stocking

1. Draycote Water

North (1983) studied the relationship between stocking and anglers' catches at Draycote Water, a 240ha reservoir situated near Rugby, Warwickshire. He found the following results for the 1980 season:

- Of 32,960 marked (freeze-branded) brown and rainbow trout stocked, 69.8% were declared caught by anglers. 78.1% of rainbow trout and 44.2% of brown trout were recorded caught.
- Over 90% of all fish caught were taken within 45 days of stocking - 50% within 8 days and 75% after three weeks.
- The average catch per rod visit was closely associated with stockings of fish. The seasonal average catch per day was 1.21 trout (varying between averages of 0.15 and 5.3 trout per day). Peak catches occurred on days or just after when trout were stocked.
- The daily catch bore no relation to the overall numbers of trout present in the reservoir on that day. This is because the catchability of stocked trout diminished rapidly with time after stocking.
- Brown trout were much less catchable than rainbow trout.
- The total apparent mortality rate (actual mortality + undeclared catches) of stocked trout was 1.36% per day.

In his review of stocking policy at Draycote, North (1983) concluded that, in order to maintain an average catch rate of 1-2 trout per angler visit, stocking needed to be carried out every 8-10 days, or more frequently. Where feasible, frequent stockings with smaller numbers of fish would seem to produce a more even average catch per day than less frequent stockings of larger batches of fish. Then, however, fewer fish would have the chance to grow-on and so the inclusion of a few larger than average stock fish (say 2-3 kg) would compensate for the decrease in capture of occasional big grown-on trout.

North (1986) reviewed Draycote trout catches for the 1983 and 1984 seasons when 86.9% and 88.6% of stocked trout were recorded caught - a highly efficient stocking regime. He found no evidence that over-wintered fish contributed significantly to anglers catches. Current policy at Draycote (Severn Trent Water, 2001) is to stock twice weekly with a wide size-range of fish from 1.25 - 10 pounds weight.

2. Chew Valley and Blagdon Lakes

Wright (1986) estimated stock densities at Chew Valley lake of 35 trout per acre and at Blagdon of 67 per acre (87 and 167 trout per hectare respectively). The percentage of stocked fish recorded as caught on Chew between 1970 and 1986 ranged from a low of 45% to 100%-plus and for Blagdon from 83% to over 100%. Figures of over 100% are explained by grown-on fry and fingerlings excluded from stocking figures but contributing to subsequent catches. Average catch rates per rod visit (1976-1986) were, for Chew 1.4-2.3 and for Blagdon 1.4 - 2. In 1995 average catch rates per rod return were 2.4 fish at Chew and 2.2 fish at Blagdon.

3. Rutland Water

Ferguson and Moore (1986) reported the following results for Rutland Water, after twelve years of stocking and ten years of angling:

- Over-wintering survival of rainbow trout appears relatively low, but that of brown trout better.
- To maintain an average catch rate of around 2.5 trout per day in 1985 required a stock density of around 26 trout per hectare and stocking of 2000 trout from rearing cages at weekly intervals.
- Catches improved immediately after stocking and regular frequent stocking provided relatively consistent catches.
- Factors such as weather, water clarity and natural food availability all have effects on catches. Recently stocked rainbow trout tend to shoal for a period before dispersing, stocked brown trout are thought to disperse more rapidly (O'Grady, 1986).

Current practice on Rutland Water (D. Moore pers. comm.) is to stock with around 100,000 trout at 80/ha/year which produces an estimated 25-30 trout/ha at any one time, producing average catch rates of 3-3.5 trout per return. Catch expectations of anglers have increased since the 1980s.

15.2.14 Still waters - general advice

Templeton (1995) draws upon a wealth of practical expertise to provide the following guidance on still water trout fishery stocking:

- Most fisheries tend to stock a mix of brown trout and rainbow trout - most having a higher proportion of rainbows.
- Rainbow trout tend to be more tolerant of warm, relatively rich ponds than brown trout which thrive better on high levels of dissolved oxygen and lower water temperatures.
- Shallow alkaline lakes produce the best trout growth potential, rainbow trout tend to grow faster than brown trout.
- Rainbow trout tend to have shorter potential life spans than brown trout but are more catchable - a higher percentage return on stocked fish is usual for rainbows.
- Spring stocking and trickle stocking can both increase return rates - over-wintering (whilst sometimes producing well-conditioned fully-finned fish) can often be risky as losses may be high on some waters.
- On large lowland reservoirs 50-80 takeable trout per hectare produce adequate catch levels. On smaller still waters much higher stock densities are often maintained, e.g. 150-200 trout per hectare. Stock densities of less than 30-50 trout per hectare generally produce low catches (although c.f. with current Rutland Water practice above). Local experience and the monitoring of catches is the key to fine-tuning stocking rates and producing required fishery performance.
- Where catch-and-release is practised, catch rates may fall despite high stock levels being present - this is due to trout learning to avoid capture.
- Most still water trout fisheries stock fish of 500g-1kg although there is a market for 'specimen-sized' stock fish of 3-5kg - plus. Clearly, the high cost of large stock fish must be carefully weighed against the economic return which they actually generate.

15.2.15 Optimising returns on stocked fish

Brown trout in rivers

Cresswell (1981) notes that brown trout stocked into rivers in spring or the angling season have higher recapture (23%) than trout stocked in autumn (14%), the closer the fish are stocked in time to the time when anglers fish, the greater the recapture rate (Cresswell & Williams, 1982). Trout preconditioned to river life before stocking have higher recapture rates (Cresswell & Williams, 1983). Of takeable brown trout stocked into the River Ribble 27%, on average, were recaptured whilst on the River Lune the average proportion recaptured was 18.4% (Clifton-Dey & Walshingham, 1996). Most fish recaptured were caught in the following 5-10 weeks, the authors made the following recommendations; stock early (spring/early summer), in small numbers, spread the fish out, don't stock towards the end of the season and consider carefully the cost-effectiveness of fishery stocking policies.

Still water fisheries

North (1983) notes that the key factor in generating reservoir trout returns appears to be regularity of stocking - recently stocked fish are much more catchable than trout which have been at liberty for a number of days or weeks. Pawson (1982) found that the catchability of stocked trout varies between stillwaters of differing size. Clearly, stocking policy requires a careful trial-and-error approach on an individual fishery basis.

The importance of catch returns

Fishery performance and the consequent need to restock is best assessed through a carefully encouraged comprehensive catch return system. Honest, accurate returns permit a correct analysis of how many fish of differing species and sizes are caught, by what method and when. The good fishery manager will interpret these data, constantly monitoring catches per angler day (Catch per unit effort, CPUE) and re-stocking at the right time, with the right number, size and species of fish to maintain catches at the desired level (see North, 1983 for a discussion on still waters). This level needs to provide both anglers with an acceptable catch rate (on average) whilst maintaining adequate returns on capital invested and running expenses for the fishery owner/manager. The Association of Still Water Game Fishery Managers (ASGFM) is a good source of practical information.

Catch returns, both from anglers and, where appropriate, netsmen are also of obvious value for the monitoring of the abundance of wild brown trout, grayling and sea trout stocks. Although actual fish stock fluctuations are not directly linked to catches, CPUE can provide a good index of real population abundance. In the absence of scientific monitoring data, CPUE measures, if carefully interpreted, are of great potential value in stock monitoring for brown trout (Giles, 1989), sea trout (Elliott, 1992), char (Mills & Hurley, 1990) and grayling (Environment Agency, 2002b).

15.3 Summary of Management Options

When considering stocking a trout or grayling fishery the following points are important:

- Take advice from your Area Environment Agency staff on the likely costs, benefits and risks to your fishery from your proposed stocking regime.
- If you have a native trout fishery consider improving fishery performance via a combination of habitat improvement, catch and release angling, reduced bag/size limits and (if these fail) the stocking of wild-parented or sterile (triploid) trout which will not interbreed with the wild stock.
- If your fishery is on or near an SAC or SSSI or other important wildlife conservation site make sure that your proposed stocking will not pose risks to wildlife – e.g. native crayfish via crayfish plague. Take advice from Environment Agency, EN/CCW staff.
- Avoid stocking adult trout into salmonid nursery areas - this could result in excessive predation of juveniles and subsequent impacts on wild game fish stocks.
- At sensitive sites consider designating a Wild Fisheries Protection Zone where no stocking will be allowed.

Table 49 Stocking management requirements, options and good practice

Issue	Management requirements and options	Best practice notes
Permissions to stock	SaFFA - Section 30 ILFA WACA	Required on all fisheries. Required for all listed species on fisheries. Required for introductions of non-native fish species.
Health checks	Open waters Closed waters	Required before stocking. Buyer beware - health check strongly recommended.
Conservation	Awareness of status of fishery	Check potential impacts of stocking on flora/fauna of special interest (e.g. SSSI / SAC status).
Crayfish	If native crayfish are present on your catchment	Make sure that any fish stocking poses minimal risk of crayfish plague transfer to a new location.

Table 49 cont'd

Issue	Management requirements and options	Best practice notes
Wild trout / grayling rivers	Conserving adult wild fish	Catch and release, bag/size limits. Improve key habitats for wild fish. Carry out fishery survey on wild stocks and habitat quality. Limit numbers/size to fishery carrying capacity. Consider stripping wild trout.
	Stocking brown/rainbow trout	Stock wild-parented progeny as early in growth cycle as possible. Consider triploids / rainbows to stop breeding with wild stock. Stock close to time of peak angling pressure. Trickle-stock to maintain sensible overall stock density and high catchability. Avoid stocking nursery areas. Start catch record scheme and analyse returns to assess fishery performance.
	Catch records	Where surveys or catch records show declines or where long-term pollution problems have been solved, permission may be granted to stock.
	Grayling removal	Large-scale grayling removal is unlikely to benefit trout fisheries.
Still water trout fisheries.	Brown trout, rainbow trout or brook 'trout' (note requirement for ILFA licence).	Brown trout perform well in cool shallow water, (spring and autumn) or deep water in summer. Rainbow trout tolerate warmer, richer waters with more variable DOs in summer. Brook trout tolerate peaty waters with low food availability. Lowland lakes usually require 50-80 trout/ha on large waters and 150-200 trout/ha on smaller waters to sustain adequate catch rates. Remember that recently stocked trout are the most catchable.

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Environment Act 1995
Rio Declaration 1992.

Note: references marked with an * are key sources of information.

16. INTERACTIONS BETWEEN FISH SPECIES

16.1 Introduction

Trout, grayling and, sometimes, char fisheries may often be mixed with active coarse fisheries. The classic riverine fish zones proposed by Huet (1959) - the trout zone; grayling zone; barbel zone and bream zone - can be clear-cut on higher gradient catchments but often merge on many lowland rivers. Quite commonly, trout and grayling intermingle naturally with barbel, chub, dace and roach. Game and coarse fisheries can successfully be run together, examples include sections of the middle Hampshire Avon, the upper Bristol Avon, the upper Severn, middle Wye, Teme, Wharfe and Ribble. Examples on still waters include Pitsford, Rutland Water, Grafham and Chew Valley reservoirs - here, pike fishing is combined with put-and-take trout fishing. Grafham also offers zander fishing. Many Cumbrian lakes combine opportunities for wild game and coarse fishing. On rivers with salmon, brown trout, grayling and coarse fish stocks, year-round angling is legally possible - the Wye, Wear and Hampshire Avon are just three examples. Clearly trout waters can occur on many river and lake systems in combination with other fisheries.

Where game angling is given precedence over coarse fishing it is often the case that coarse fish may routinely be removed in order to try and improve the performance of the trout fishery. In rivers, trout and grayling could potentially compete for invertebrate food and for living space with coarse fish such as barbel, dace, chub and roach. There seem to be few published studies on the specific subject of competition between game and coarse fish. Angling writers have cited chub as serious competitors and predators of young trout (e.g. Carter Platts, 1930). Modern ecological studies have not to date, substantiated this view but the literature is sparse and effects may occur.

In still waters trout could compete with perch, roach and rudd for emerging insects but are much more likely to benefit from feeding on the fry of these species. Fry-feeding by reservoir and natural lake trout is well known and anglers deliberately target these fish with purpose-tied lures (Church & Jardine, 1989).

Still water trout fisheries may however, suffer from having high densities of adult common carp or common bream, both of which can often have substantial negative effects on water clarity, weed growth and invertebrate availability (Giles, 1992, refer also to chapter 9 - Aquatic Plants). Reduced numbers of these coarse fish could potentially improve water quality, weed growth, invertebrate availability to trout and reduce numbers of fish lice (*Argulus*) and other parasites which can cause serious problems for still water trout fisheries (see chapters 6 - Water Quality, 9 - Aquatic Plants, and 18 - Diseases and Parasites).

On small river and still water fisheries pike may be significant predators of wild or stocked trout and of grayling. Decisions on whether pike control programmes are likely to be cost-effective are best made on a case-by-case basis. In this context, it is worth remembering that shoals of medium-sized cyprinids may provide a respite for trout from predation by cormorants.

16.2 Technical and Practical Advice

16.2.1 Eels

There is concern amongst fishery managers that eels may have impacts on game fisheries via predation pressure. Moriarty (1978), who has analysed thousands of Irish eel stomach contents, describes eel diet in detail, finding it dominated by a range of ten aquatic invertebrates including tiny planktonic crustaceans (*Daphnia*), water lice, shrimps, insect larvae (chironomid midges, mayflies, caddis flies), snails, swan mussels and two fish - perch and eels. Fish eating is most common amongst large (50cm plus) eels. In Lough Corrib most eels eat invertebrates (Figure 80 below) but juvenile Arctic char are regularly eaten by larger eels which may congregate where char densities are high (Moriarty, 1978). Note how smaller eels have higher proportions of all invertebrates than larger eels.

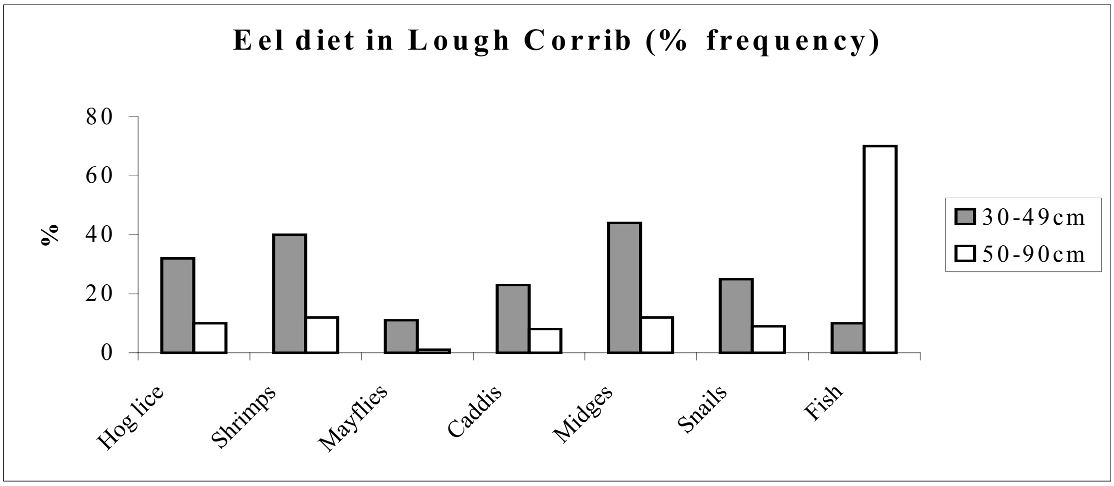

Figure 80 Diet of 30-49cm and 50-90cm eels from Lough Corrib (after Moriarty, 1978)

In rivers, eels of 20cm plus regularly eat small fish, usually smaller eels, perch, stickleback but also young salmon, trout and lampreys. Tagged, stocked salmon parr have been found in the stomachs of large chalk stream eels (M. Sidebottom, pers comm). Eels have been found with salmon and char eggs in their stomachs - probably foraged from spawning grounds, rather than from redds deep in the gravel. Moriarty thinks it unlikely however, that eels make significant inroads into salmonid stocks.

Eels normally retire to their burrow when inactive, hunting for food by sight, smell and touch during the hours of darkness. Since salmonid spawn is only available during the winter and early spring and eels are generally inactive at low water temperatures, there seems little risk of heavy predation. Also, since young trout live either in fast, shallow riffle and glide habitats in streams or in the open water and boulder littoral zone of lakes, again there seems little likelihood of substantial predatory activity by eels. There is no doubt however, that eels living in both rivers and lakes certainly do take fish prey.

The following data (Figure 81 below), from the River Blackwater are also from Moriarty (1978, Appendix, Table 3). Note, as for the Lough Corrib data, larger eels progressively eat fewer invertebrates and more fish.

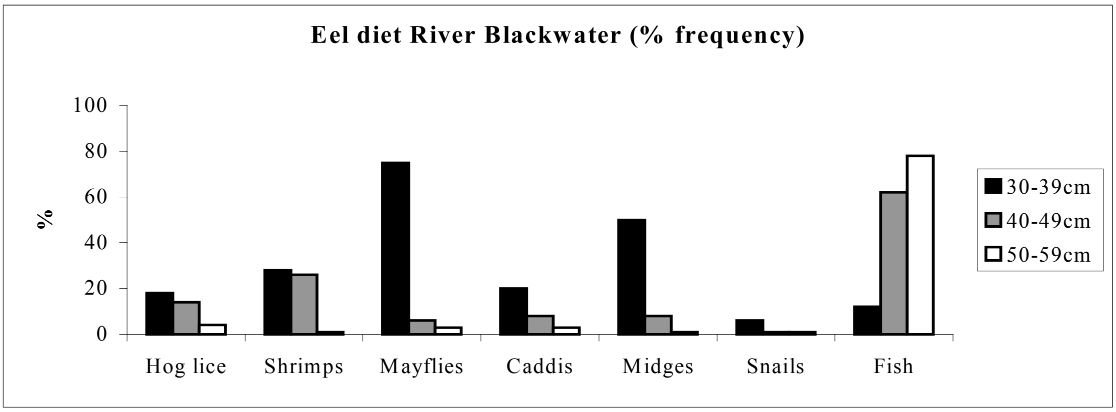

Figure 81 Diet of 30-39cm, 40-49cm and 50-59cm eels from River Blackwater (after Moriarty, 1978)

Maitland and Campbell (1992, Table 46) provide data from Hartley (1948) on eel diet from the River Cam:

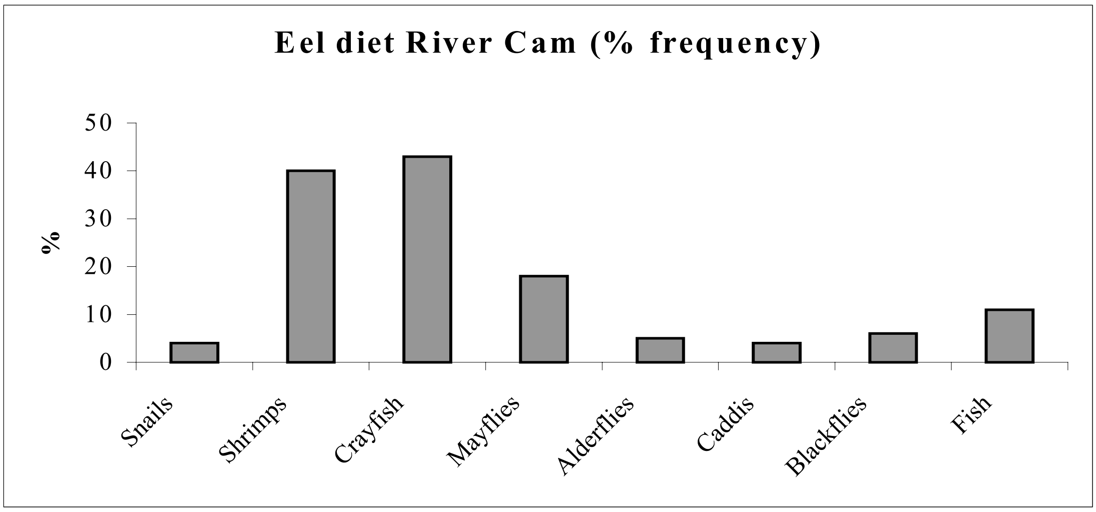

Figure 82 Diet of eels from River Cam and Shepreth Brook (after Hartley, 1948)

As with Irish eels, River Cam eels eat a variety of invertebrates (including native crayfish) and fish (minnow, gudgeon, stone loach, stickleback, bullhead).

16.2.2 Cyprinid removals

Still waters

Local management decisions need to be made regarding the pros and cons of having substantial coarse fish stocks in still water trout fisheries. Coarse fish can harbour parasites such as *Argulus* which may transfer to trout, causing them great irritation and disrupting angling. Coarse fish may also compete with trout for invertebrate foods; conversely, they can be an important source of food for large trout which often become largely predatory in their feeding behaviour. On natural waters fish-eating brown trout, preying on smaller trout and char, are sometimes termed *ferox* and can be a genetically distinct sub-species (Ferguson, 1986).

Private fishery managers are at liberty to move fish between waters provided that prior consents/licences for removing fish by methods other than rod and line (e.g. netting, trapping, electric-fishing) and S30 consents for stocking have been obtained. Generally, the Environment Agency operates a 'Buyer Beware' health checking system for enclosed still water coarse fish removals and transfers - the onus being on the vendor and/or recipient of the fish to ensure their health status. Clearly, serious potential health risks to fisheries are taken through the introduction of new stock (see chapter 18 - Diseases and Parasites).

When a request to the Agency for a fish removal from a still water arises, that meets ecological and disease criteria, the numbers, species and size of the fish will be cross referenced with the Environment Agency Area Stocking Program (ASP). Where these are compatible, then the transfer operation can go ahead. Note that the ASP refers only to Agency operations and does not affect fish movements by external operators. Where these fish do not meet the needs of the ASP, then neighbouring Areas/Regions may be contacted. At this stage the Areas need to consider the degree of importance of the removal to the fishery with the ability of the Agency to find an appropriate receiving water i.e. not 'stocking for stocking's sake'. In these circumstances, unless the removal is crucial to the health or performance of the fishery in the short term, the fishery owner/manager may be advised to use a contractor. Before fish are removed from a water the removal must be categorised and assessed. Risk to the environment versus socio-economic benefit analyses should be carried out. The decision on whether to carry out the removal should also include an assessment of whether and where to stock the removed fish. Both aspects should be cross-referenced to ASPs. The water receiving the removed fish must be capable of holding the additional stock.

Rivers, Drains and Canals

There will be a presumption against carrying out any removal operations of fish from one river system to another. The removal of coarse fish from trout fisheries should only be carried out due to a demand for those coarse fish not being met by Agency Fish Farms. The removal of these fish by the Agency should not be driven by any potential benefits to the trout fishery. It is the Agency's policy not to carry out any removal either for fish supply or predator control.

16.2.3 Pike

Pike removal by netting, trapping or electric fishing needs Environment Agency consent and the Agency does not provide this removal service to fishery owners/managers. This Agency policy is based upon the view that, on many waters, pike removal does not appear to be a cost-effective, sustainable practice. For example, in Anglian Region, pike removal was annually practised on several miles of the trout reaches of the Rivers Lark, Wissey and Cam but, by the following year many pike had immigrated back into these stretches (A. Taylor pers. comm.).

On small trout streams and rivers pike can however, be important predators (Mann, 1982, 1995). Trout are also often eaten by pike on still water fisheries and fishery managers may well decide that their removal is worthwhile (D. Moore pers. comm.). Attempts at improving wild and stocked trout abundance through adult pike removal may sometimes lead to reduced cannibalism, increased survival of young pike and consequent increased predation on young salmonids (Lewis, 1997). Large pike are very effective predators of smaller pike. The pros and cons of attempted pike population control needs to be assessed on a case-by-case basis.

Small streams
Pike certainly eat trout and grayling and may, especially on small streams, be important predators suppressing wild salmonid abundance. When working on the River Piddle, Dorset, The Game Conservancy Trust found that wild brown trout densities were very low where pike numbers were appreciable and that surviving adult brown trout caught during electric-fishing surveys were almost all scarred on the belly, from pike attacks. After complete pike removal, wild trout densities rose markedly but this was probably due to combinations of various types of habitat improvement as well as pike removal (author's observations, D. Summers, pers comm).

Mann (1982) found that the main diet of adult pike on the Dorset Frome was dace and eels, however on this river, the best brown trout fisheries are upstream of the stretch studied. Mann (1985) analysed electric fishing data from the upper Hampshire Avon where pike were removed from a 6km stretch for each of 5 years. On average, more than half of the one year-old and older pike were removed each year and their density declined from 3.7 per hectare to 1.4 per hectare over the five year study. Young-of-the-year pike however, continued to be produced in similar numbers and their mean weight doubled - it is likely that their survival was enhanced by the reduction in numbers of cannibalistic adults. On the Rivers Test and Itchen pike are routinely removed to conserve brown trout stocks, but the effectiveness of this work does not seem to have been evaluated.

Lake Windermere
On the North basin of Lake Windermere the Freshwater Biological Association had a long-term pike netting experiment where, between 1940 and 1980 they removed a high proportion of adult pike. Catches of char in gill nets rose appreciably over the same period (see Figure 83 on the next page) - a change attributed to the reduced predation pressure (Mills & Hurley, 1990):

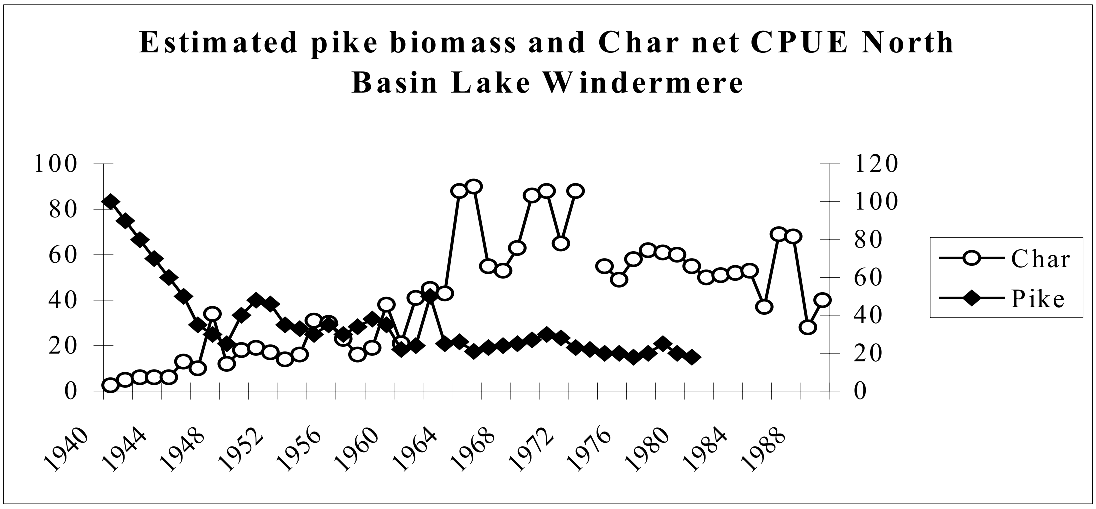

Figure 83 Possible relationship between pike and char stocks in Windermere

Lough Corrib
O`Grady (1990) describes an Irish Central Fisheries Board initiative on the very large limestone-based Lough Corrib to gill net, long line and trap pike so as to try and boost wild brown trout and char stocks. The resulting reduction in pike numbers was successful, for instance juvenile pike numbers trapped from 1961 to 1975 fell markedly. O'Grady (1990) concluded that the pike culling programme was a success, with most adult brown trout in the Lough dying of old age at 6 or 7 years, but whether life expectancy of trout increased or the sport fishery improved because of reduced pike numbers was not established. Presumably, some large trout, as well as pike, were killed during the netting programme.

Management options
A sensible approach for most fishery managers to the potential need to cull pike is to:

- Assess their abundance on your fishery and to respond to evidence of serious depredation.
- On small rivers and ponds, pike removal can be very efficient and resulting decreases in predation may make a discernible difference to wild or stocked trout and grayling abundance and thus to angling performance.
- On larger, especially weedy rivers and lakes the likelihood of efficient pike removal (unless you have major resources) declines rapidly and there is a good argument for leaving the bigger pike in place so that they can cannibalise smaller ones (Munro, 1957, Giles, et al, 1986, Wright & Giles, 1987). In this way, on some fisheries at least, pike populations may be relatively self-limiting.
- Also, there is a market for catch and release pike fishing - now exploited on many reservoir trout fisheries (e.g. Anglian Water, Bristol Water, Welsh Water), on western Irish loughs, including Corrib and on Scotland's Loch Lomond. The economic value of the pike fishery may outweigh any damage to trout stocks via predation, especially by extending the fishing season through winter, filling the gap which the trout closed season imposes. Pike fishing within the trout fishing season is allowed on Anglian Water reservoirs to extend the diversity of fishing on offer.

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Figure 84 Pike

16.3 Summary of Management Options

Table 50 Coarse fish management options and best practice

Issue	Management options	Best practice notes
Eels	Eels can be harvested as a sustainable crop from suitable fisheries. Large eels do eat fish but the balance of evidence indicates little probable damage to trout fisheries.	Manage eel stocks on a sustainable basis. Note the need for Environment Agency licences for fyke nets and adherence to National Eel Strategy.
Pike	Small rivers - annual electric-fishing. Larger rivers/lakes - probably best left to self-limit numbers of smaller pike.	Winter pike fishing on trout reservoirs is increasing in popularity. The economic returns of leaving the pike in the fishery and exploiting them may be better than any increased trout survival afforded by a pike control programme.
Coarse fish removals	Cyclical netting of coarse fish can generate income and produce improvements in habitat and water quality. However roach, perch and bream provide an important food source both for cormorants and for trout.	Judge the pros and cons of coarse fish removal, take advice from Agency Area fisheries staff. Bottom feeding species like carp should be removed from a trout fishery.

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Note: references marked with an * provide key sources of information.

17. INTERACTIONS WITH OTHER SPECIES

17.1 Introduction

Questionnaire responses indicated that this section should be limited to consideration of predation effects. Predator-prey relationships are an integral part of the natural world and need managing with care and sensitivity to conservation priorities. Whilst predators are appealing and often, protected species, they can cause substantial economic and ecological impacts on fisheries. A fish eaten does not always however, diminish the productivity of a fishery because other fish may survive in its place and growth rates may be enhanced (Giles, 1994, Tapper, 1999). Control of predation needs careful consideration and is subject to legal restrictions (Salmon and Freshwater Fisheries Review, 2000).

17.1.1 Piscivorous birds

Piscivorous (fish-eating) birds include cormorants, sawbill ducks (goosander and red-breasted merganser) and heron, all of which are protected by law (EC Birds Directive, implemented in Great Britain by the Wildlife and Countryside Act, (WACA), 1981). WACA Section 1 makes it an offence to kill or injure a wild bird, Section 4(3), however, provides a defence for an authorised person if he shows that his action was necessary to prevent 'serious damage to fisheries'.

Piscivorous bird populations can eat very substantial amounts of fish, including salmonids, and can cause local fishery impacts, e.g. Kennedy and Greer (1988), Feltham and Davies, 1994, MAFF/FRCA 2000). Licences for the control of piscivorous birds are issued by DEFRA/National Assembly for Wales (NAW) in consultation with EN/CCW under WACA Section 16(1)(k) in response to applications from fishery owners/managers which substantiate significant damage to fisheries (MAFF/FRCA 2000). Such licences specify the numbers of birds licensed to be shot, the area and method of killing.

17.1.2 Mink

Mink are an introduced North American species which has established widespread feral populations in the British Isles. Mink eat freshwater fish, including salmonids, as well as birds, mammals, amphibians and invertebrates (Environment Agency, 1995). Mink are not protected by law (although trapping must be legal and traps inspected at the specified intervals - at least once a day). Mink control as a protection for water voles is encouraged by the Environment Agency and Wildlife Trusts as well as by many fisheries organisations. Advice on mink trapping is available from FRCA staff or from The Game Conservancy Trust. The Environment Agency may be able to help by supplying traps but do not offer a mink control service.

17.1.3 Otters

Otters are protected under WACA Section 1 and their legal protection was strengthened under the Conservation (Natural Habitats, etc) Regulations, 1994 which implement the EC Habitats Directive in the UK. It is an offence to kill or disturb an otter or to damage or destroy its holt (den). No offence is committed however, if the person killing the otter is authorised (i.e. the landowner, occupier or authorisee) and can show that the action was necessary to prevent serious damage to fisheries. This defence is not available to people who are aware of the likelihood of the need to kill an otter and who have not applied to DEFRA/NAW for a licence, or have been refused a licence, or who have not adhered to the terms of the licence (Salmon and Freshwater Fisheries Review, 2000). Licenses to kill otters are only issued where NAW/DEFRA are satisfied that there is no satisfactory alternative and that the action will not be detrimental to the maintenance of the otter population at a favourable conservation status.

17.2 Technical and Practical Advice

17.2.1 Cormorants and sawbill ducks

Figure 85 Cormorant drying its wings

Cormorants seen in the UK are from two sub-species *Phalacrocorax carbo carbo* and *P. carbo sinensis* and numbers have risen rapidly in Europe over the past 25 years. Wintering cormorants in the UK increased 5-10% annually between 1987 and 1994 but may now have stabilised at around 15-16,000 birds; of these around 10,000 winter inland (MAFF/FRCA, 2000). Most cormorants migrate in spring to breed around the coast but there are some inland colonies. Around 1,400 pairs nest inland although only four sites hold more than 100 pairs. There would appear to be scope for expansion of this inland-breeding population as summer feeding and potential nesting sites are available.

Cormorant diet is comprised largely of (Marquiss & Carss, 1994):

- At sea; wrasse, cod family species, flatfish, eel, eelpout, sprats and sand-eels.
- In estuaries; sand smelt, mullet, bass, flounder, trout, eel and coalfish.
- On fast flowing rivers; trout, salmon and grayling.
- On slow-flowing rivers; roach and bream.
- In lakes; roach, rudd, perch, ruffe, brown trout and eel.
- In stocked trout fisheries many brown and rainbow trout are wounded but not eaten. Cormorants leave characteristic slashing cuts with their beaks.

The sizes of fish taken by cormorants vary from 30-650mm with most being of 100-300mm. Diet seems to vary with the abundance of the principal prey fish available.

Food consumption by any predatory animal will vary with time of year, prey availability, type of habitat and body condition and degree of skill exhibited by

individuals. Marquiss and Carss (1994) provide average estimates of 340-520g of fish per day eaten by cormorants. This equates to around 20% of their body weight.
Both cormorants and goosanders can make substantial inroads into fish stocks and the need for control must be assessed on a case-by-case basis. Fish stocks on thriving fisheries with excellent habitat quality are likely to be more resilient to all forms of predation than poorer stocks in struggling fisheries where cover habitat is sparse.

Management options

Cormorants - habitat solutions
Where a predation problem from cormorants has been demonstrated, the following potential solutions can be tried (efficacy varies with local circumstances, MAFF/FRCA, 2000):

- People walking around the edge of a fishery scare cormorants away.
- Pop-up dummies with or without propane-fuelled gas cannon can be effective over ranges of up to around 200m. Moving scaring devices regularly helps to extend their period of effectiveness before the birds become used to and ignore them.
- Roosting/nesting trees can be cut down but nests must not be destroyed in the breeding season.
- On put-and-take trout fisheries, trickle stocking and spreading out stock fish may reduce risks as may stocking very large trout (although these may still be wounded by cormorants).
- Habitat modification to include fish refuges in lakes may be successful but more work is needed to check their effectiveness.
- On rivers, if habitat cover is already good, only human presence and shooting to scare or kill birds may be effective. No licence is required when shooting to scare birds, as long as none are killed or injured.

If all valid attempts at scaring cormorants, modifying stocking practice or providing fish with better physical cover prove ineffective on a fishery, it may be justifiable to apply for a licence to shoot birds.

Cormorants - legal control
Where fish-eating birds are causing serious damage to fisheries DEFRA or NAW may grant a licence to kill a limited number of birds as a reinforcement to trying to scare the birds away. Note that killing cormorants may just create a local vacuum which is then rapidly filled by other birds. Shooting the licensed number of birds may therefore be ineffective. Also of course, birds frightened away from one fishery may just move locally to another.

Licence application forms are available from local DEFRA/NAW offices and, on receipt of a completed form, an officer will visit to assess the merits of the application. Applicants should supply evidence on the numbers, species and feeding behaviour of birds on site, fish stock data, numbers (and photos) of damaged fish, changes in fishery performance (e.g. catch per rod day), income and their financial implications for the owner/manager. Information on scaring or habitat improvement methods used and their effectiveness will also need to be supplied. The onus is on the applicant to convince the FRCA officer that permission to kill an otherwise protected species is justified.

Licences are only issued for sites where there is clear evidence that serious damage to a fishery is being (or has recently been) done by piscivorous birds and that all other applicable scaring techniques have been tried and found to be ineffective. Licenses to kill will only be issued for a limited number of birds and in situations where shooting will help prevent damage and there is no other satisfactory solution (MAFF/FRCA, 2000). Anyone found guilty of illegally killing protected birds can be fined £5000, given 6 months imprisonment, or both.

Note that Fishery Action Plans may well be a suitable local forum for the discussion of and agreement to appropriate predation management strategies for given river or lake catchments.

Cormorant management on Anglian Water reservoirs

As long ago as 1984 the October release of small brown trout to grow on over winter, was abandoned in the face of the growing cormorant population (Gale et al, 1992). Since 1994 anglers on Rutland Water and other Anglian Water reservoir fisheries have recorded wounding scars by cormorants on all trout caught. In response to widespread damage to trout by cormorants, Anglian Water fisheries management staff have delayed stocking until closer to the start of the season and increased the minimum size of stocked trout to 650g, with most being over 750g. Stocked fish have been better distributed in the reservoirs and boats containing 'dummy anglers' have been moored in stocked areas to help scare birds away.

Before the management changes around 8% of all trout caught by anglers showed cormorant damage, now the proportion has fallen to around 1% - a management success (Anglian Water, 2001). Cormorant numbers on both Rutland Water and Grafham Reservoir fell in 2000 - possibly in response to lowered coarse fish stocks. The decline in cormorant numbers corresponded with a sharp rise in the proportion of stocked trout subsequently caught - the highest for 10 years. It is thought that cormorants may have driven their principal food source (10cm-25cm roach and bream) into decline and have moved away to feed on more productive waters. The situation will be kept under review.

Goosander

Sawbill ducks are more common in Scotland than in England and Wales, they usually rear their broods of chicks on upland rivers where salmon and trout breed. Each winter the UK has around 8,900 resident goosanders (MAFF/FRCA, 2000). Marquiss and Carss (1994) provide average estimates of 240-520g of fish per day eaten by goosanders. This equates to around 18-50% of their body weight. Goosanders generally eat smaller fish than cormorants - 50-110mm, on average. Favoured species are salmonids, grayling, lampreys, bullheads and perch. Licences to shoot goosander are subject to the same procedures as those given above for cormorants.

Mink

Mink eat the following prey (NRA 1995). Note their potential impact on water voles, this is the usual primary driver for mink control programmes:

- On lakes, roughly equal proportions of small mammals, water birds and fish.

- On acid rivers, around 50% fish, 30% small mammals with the rest being comprised of birds, amphibians and invertebrates.
- On nutrient-rich rivers, around a third fish and the remainder small mammals with birds, amphibians and invertebrates.
- On rocky shorelines around half small mammals, with additional birds, fish and invertebrates.

Management options
Mink control is not easy; individual animals are easy to catch but immigration to replace them is common. The species has gained a strong foothold throughout England and Wales and is undoubtedly here to stay. In some small-scale situations mink can be fenced out (26mm mesh, 1.2 m high minimum, buried 30cm, turned outwards and with a steel baffle along the top). Local reductions in mink abundance are possible to sustain through protracted trapping operations but costs are high. River keepers employed to look after lakes or stretches of river may have time within their normal routines to set and check daily (a legal requirement) authorised traps. The Game Conservancy Trust, are able to provide professional advice on legal, humane predator control and efficient methods of mink control.

The UK Water Vole BAP steering group advised the following:
Water voles undergo a high winter mortality and the mink's early breeding season ensures that the female mink will be taking winter-surviving water voles before they have had a chance to breed. Consequently, the best time to trap the mink is prior to their breeding season in the early spring, (February-April). Obviously, mink will take water voles at other times of the year but spring time is when the trapping effort is likely to be most effective for vole conservation. Trapping should however, be continued throughout the year if resources allow. Trapping in August-November would intercept dispersing juvenile mink.

The following guidelines should be followed (UK Water vole BAP steering group):
- Any trapping of mink must be done humanely.
- Only live traps must be used so that non-target species can be released unharmed.
- Otter exclusion guards must be fitted to prevent the accidental trapping of otters.
- Traps must be set away from known otter holt sites.
- Set traps away from open areas and away from public paths or those used by anglers.
- Traps must be placed above any possible rise in water level and secured to prevent any trapped animal rolling them into the water.
- Traps must be checked twice per day around dawn and dusk (at least once is the legal requirement).
- To despatch mink humanely, the only presently-accepted method is shooting. They must not be drowned and there are no approved methods of killing them by gassing.
- Traps should be covered with hay and twigs which a trapped animal can pull into the cage as bedding material. Traps may be baited with fish, eggs or day old chicks (dead), providing the trapped animal with food.
- Once positively identified, trapped mink must be shot in the head with a .22 inch calibre rim fire rifle, a powerful (.22 inch) air rifle or a shotgun. [Safety glasses must be worn in case of ricochet] To cause the least distress to the animal, this

should be done by an experienced individual, having the requisite certificate, if using a .22 inch rim fire rifle or shotgun. Note that a 12 bore will destroy a cage trap at close-range.

- Once caught, it is illegal to release mink back into the wild.

Otters

An abundance of wild otters means that fisheries are thriving and that the aquatic environment is likely to be healthy. Normally, otters live at low population densities and so pose little potential threat to freshwater fisheries. Corbett and Harris (1991) note that otters normally eat fish but may, in some habitats, also eat frogs, crayfish, waterfowl and wading birds and even occasional mammals, including water voles. In coastal habitats crabs can account for around a fifth of the diet, the rest being fish. It appears that relatively slow moving benthic fish such as eels, rocklings and butterfish are preferred otter prey species.

Daily food consumption is around 12-15% body weight in adult males - approximately 1kg of fish. Breeding females need more food to supply the needs of their cubs. Kruuk et al (1993), working in Scotland on the catchments of the Rivers Dee and Don found that otters were eating a large proportion of the available one year-old salmon and trout. Whether such levels of salmonid predation are commonplace on upland catchments in England and Wales is unknown but threats to adult salmon stocks are thought to be minimal (Salmon Advisory Committee, 1996.)

Conservationists have now concluded that the artificial re-introduction of otters is not a sound policy, it is better to let these animals spread and re-colonise suitable habitat as their wild populations allow. Otter damage to carp fisheries, to stocked trout fisheries and to fish farms is quite commonplace and this has led to a concerted effort by conservationists and anglers to find solutions to the problem (Environment Agency, undated, Liles, 1999).

Key facts on otter predation on stocked fisheries include:

- Predation is most intense in winter.
- Most problems occur on carp fisheries and on trout rearing ponds.
- Otters will kill carp of up to 11kg and often take the largest ones first.
- Even solitary large fish in large lakes are vulnerable to hungry otters.
- Most trout farms within otter home ranges are likely to suffer fairly low-level problems.

Those seeking advice on otters are recommended to contact their local Wildlife Trust. The Wildlife Trusts Otters and Rivers Project ran until recently and produced many useful publications (e.g. Liles, 1999) and practical projects helping to re-establish otters in many of their former strongholds. Otter surveys via the recording of faeces ('spraints') and other signs of activity have been carried out under the management of this project, showing a recent eastward spread of the species. The Trusts work on wetland habitats has now developed further with the Water for Wildlife programme whose officers are willing to advise on otters and fisheries matters.

Management Options

Temporary electric fencing

Electric rabbit fencing, well pegged down can keep otters away from sensitive fishery areas. The netting consists of twelve horizontal electroplastic twines and one non-electrified bottom strand spaced at 6.3cm intervals. Plain non-conducting vertical twines are spaced at 7.7cm intervals. The fence must be kept electrified and fully earthed at all times.

Permanent fencing

The electric fence described below has protected a 9 acre trout lake successfully for 4 years but a similar design failed to keep otters out of a carp fishery. Local circumstances will dictate the success of these schemes:

Posts were made from scrap timber 20cm high, insulated with plastic tubing, stapled to the posts with fencing staples. The otter soon learned to climb over this fence at a post which was not electrified; this problem was overcome by looping a live wire over the post. A taller fence would also have worked.

The design below, used successfully by fishery owners in north Cornwall and Devon is recommended by The Wildlife Trusts:

- A physical barrier is provided by 25mm wire mesh with a 40cm buried underlap running away from the fishery.
- The mesh is supported on standard (140cm) wooden fence posts, with strainers at corners to allow tensioning. An insulated electrified wire is run along the top of the fence to deter otters from climbing over. A second electrified wire around half way up the fence will deter livestock. At 50m intervals electric fence warning notices should be attached.
- Where there are no livestock a cheaper, slacker fence built on lighter posts and with no strainers is adequate to deter otters.

17.3 Summary of Management Options

Table 51 Predation Issues

Issue	Management options	Good practice notes
Cormorants and sawbill ducks	Scare away feeding birds. Shoot to miss. Remove roosting/nesting trees (in winter). Take DEFRA/NAW advice on licensed shooting.	Scaring cormorants away is an effective measure where problems are not intense. Licensed shooting to kill may have rather limited effectiveness because other cormorants often move into the habitat vacuum created. Also, cormorants are wary and not easy to shoot.
Mink	Live trapping in cage traps or killing mink in tunnel-set spring traps can both be effective. Trapping legalities must be observed.	Water voles (a UK BAP species) are under threat from mink predation. A joint fisheries management / conservation mink control effort may be possible on some fisheries.
Otters	On some smaller carp and trout fisheries or trout farms fencing can successfully deter otters. On large lakes in open country or rivers otter predation is best accepted as part of the natural cycle.	The presence of otters on wild game fisheries indicates healthy fish stocks and is a good sign of overall high environmental quality. Natural predator-prey behaviour is part of wild fishery management. Take advice from Wildlife Trusts Water for Wildlife Officers.

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18. DISEASES OF TROUT, CHAR AND GRAYLING

18.1 Introduction

The potential impact of disease on fisheries is frequently overlooked until a serious incident or outbreak occurs. No action taken by a fishery manager can guarantee that fish are, or will remain, free from disease, however, well-informed management can minimise its occurrence. The following sections highlight the importance of fish health management and the diseases of most concern to trout, char and grayling fisheries managers.

18.1.1 Fish Health and Fish Disease

Many of the pathogens (parasites, bacteria, fungi and viruses) that cause disease are a natural part of the fishery environment. Under favourable environmental conditions, the fish and potential pathogen are in a balanced equilibrium; the immune response of the fish is able to cope with the level of attack at any given time (Figure 86).

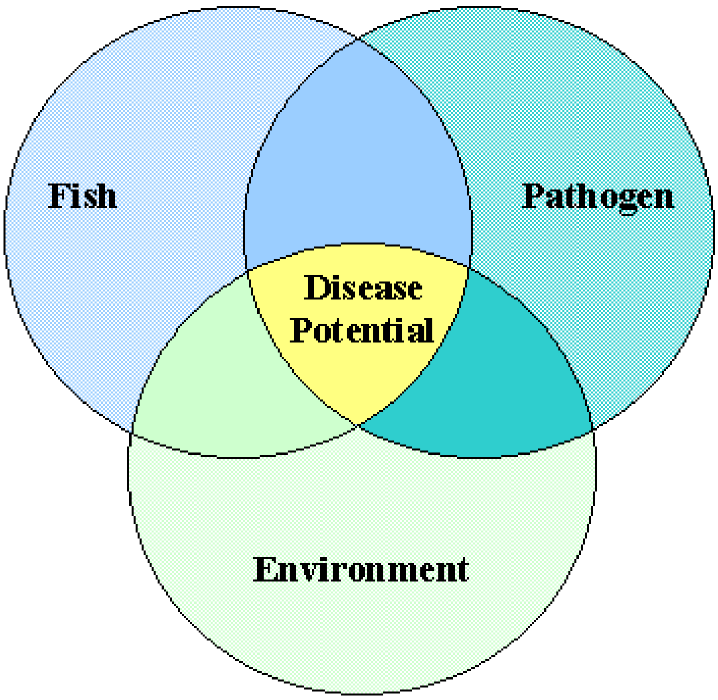

Figure 86 The relationship between fish, pathogens and their environment (After Snieszko, 1974)

The natural equilibrium may be disturbed by alterations to the condition of the host fish (e.g. depression of the immune system in the lead up to spawning); reduction in water quality (e.g. low dissolved oxygen levels); or changes to the pathogen burden (e.g. introduction of new pathogens to the fishery, or change in virulence of those already present). Any of these changes can increase the potential for a disease outbreak. It is, therefore, important to consider the contribution of fish health and the quality of the water environment to the occurrence of fish disease.

Once a disease outbreak is underway there is very little that can be done to restore the fishery by curing the affected fish. Treatments cannot be effectively, or in many cases legally, applied to either rivers or stillwaters. The majority of outbreaks are a symptom of underlying fisheries management problems. If the treatment or action taken does not address the primary cause, then recurrent outbreaks are likely.

The possible impact of any management action on the natural balance is difficult to assess, which makes it essential that fish health issues are considered in advance of any planned activity that may cause significant change to a fishery.

18.1.2 Stress and fish health

Fish are susceptible to many of the disease agents that affect other types of animals. In fish, however, stress appears to play a considerably larger role in causing disease (Walters & Plumb, 1980). Stress increases susceptibility of fish to disease by depressing the immune system (Bonga, 1997). This can directly result in an increased occurrence of disease or may produce behavioural changes in the fish, again increasing the risk of infection.

Sources of stress of particular importance to trout, grayling and char fisheries are;
- handling during stocking
- high stock densities
- sub-optimal water quality (particularly water temperature)
- low flow rates in rivers.

Primary factors affecting the fish / pathogen equilibrium in trout, grayling and char fisheries are outlined in Table 52. Disease outbreaks are likely to result from unfavourable combinations of some of these factors. Whilst outbreaks are almost impossible to control – nature usually takes its course – it is possible to manage factors that contribute to the health of the fish.

Table 52 Principal modifiers of wild fish health

Group	Factors
Nutritional	Deficiencies
	Excesses
Environmental	Poor water quality
	Population density
Physical	Introduced disease
	Spawning
	Angling
	Stocking

The management of fish health is an integral part of good fisheries management. The provision of good quality fishing tends naturally to include benefits to fish health. Specific issues related to fish health and the control of disease are outlined below. In addition to these factors there are specific issues related to stillwater fisheries, outlined on page 227.

18.1.3 Nutrition

Nutritional problems are primarily associated with fish farming. A lack of required nutrition can result in depression of the immune system, increasing the susceptibility to disease. Usually, trout, grayling and char fisheries should not be subject to nutritional problems, although catch-and-release fisheries and those buying-in fish should monitor fish quality. In such cases, examination of turn-over and the level of removal should minimise nutritional effects on fish health.

18.1.4 Environmental Quality

Poor water quality
Acute pollution incidents have an immediate effect on fisheries which are not possible to manage. They usually result in significant and catastrophic effects on fish populations. Chronic water quality problems can lead to increased susceptibility to disease, although this is difficult to demonstrate. Low lever water quality problems have been associated with immune system effects. Sub-lethal effects can also increase stress or longer-term habitat degradation.

Population density
Managing fish population density is critical in preventing disease outbreaks. Overstocking greatly increases the chances of problems caused by parasites in particular. High fish densities enable certain parasites to increase in number by enhancing their transmission rate from fish to fish. Under some conditions, massive infestations of ectoparasites may occur, with associated fish kills (these are particularly common in the warmer months). Such fish kills will not abate until the fish population falls to a level where the parasite has a significantly reduced chance of completing its life cycle. Parasite outbreaks in highly stocked trout fisheries have sometimes resulted in almost 100% mortality rates.

High population density can also lead to increased interaction between fish, increasing stress and allowing outbreaks of bacterial diseases to occur, which would normally be controlled by the immune system. Additionally, high population density has been associated with fungal disease outbreaks in trout before and during spawning.

The control of population density is an important tool available to fisheries managers. On fisheries that are dependent on stocking, records of fish numbers introduced and removed are frequently maintained and used to assess stocking requirements. These assessments should also take fish health issues into account. Turn-over of fish, in terms of the amount of time an individual fish is in the water before removal, is also important. Fish present in a water for only a short time are less likely to cause problems than those which persist for longer periods.

Fisheries that are more dependent on natural recruitment tend to be self-regulating and predation will play a greater role in controlling recruitment. This is particularly important in wild trout and grayling fisheries where fish are not routinely removed.

There is no hard and fast rule about population and stocking levels. The viable population density varies with the type of water and prevailing environmental conditions, and should be taken into account when assessing population management.

18.1.5 Physical Factors

Spawning
The physiological stress associated with spawning depresses the immune response in salmonids (Slater & Schreck, 1998) and physical injury may also occur on the redd, which often leads to secondary fungal or bacterial infections. On naturally recruiting fisheries the impact of spawning on fish health can be minimised by ensuring that other, more manageable, factors are optimal.

Introduced disease
Non-indigenous pathogens can be a particular problem as native fish stocks may have little or no resistance to these diseases. Both the Environment Agency and Centre for Environment Fisheries and Aquaculture Science (CEFAS) have roles in controlling the introduction and spread of non-indigenous diseases (see section 1.5).

To minimise the risk ensure that farmed fish are from a CEFAS registered site and also that they have not been held at an intermediate site without further health checks. CEFAS fish farm health checks only cover notifiable (Category 1) diseases; a further check for Category 2 parasites would provide greater protection.

Angling
Under circumstances where fish are removed after first capture or where fish have adequate recovery time between captures, angling has little effect on the disease susceptibility of fish. However, trout in small catch and release stillwaters may be subject to disease problems related to frequent capture or inappropriate handling.

Stillwater fisheries operating catch and release should monitor the condition and quality of the fish removed. The turnover of fish should be regulated and the number of catches and returns should also be monitored. Customers should be educated in catch and release techniques and rules or guidelines enforced to reduce handling to a minimum. For example, barbless hook, unhooking whilst still in the water or knotless small meshed landing nets will all reduce the amount of handling and damage.

Stocking
Stocking, while a vital operational need for many fisheries, carries the highest risk of any management activity. Newly stocked fish can carry disease or parasites which affect resident stocks, or *vice-versa,* leading to disease outbreaks in the fishery. The transportation and handling associated with stocking can result in physical damage and stress, leading to secondary infections of bacterial or fungal diseases. Post-stocking recovery will be determined primarily by local water conditions.

To minimise the potential impact of stocking always use fish from the same source, ideally within the same catchment as the fishery. Ensure that fish are purchased from a known and trusted supplier who can ensure that fish are from a single source and not traded between a number of farms or suppliers.

18.1.6 Stillwater trout fisheries

Stillwater trout fisheries with no natural recruitment represent an essentially unsustainable ecosystem where only a limited natural ecological equilibrium can develop. This increases the risk of disease outbreaks caused by common, indigenous parasites such as the crustacean *Argulus*. There are also problems related to high stock densities and the predominance of a single species, usually rainbow trout. In some cases waters operated as stillwater fisheries may be unsuitable for trout as they are subject to severe disease and fisheries management problems. To avoid such problems and the financial burden that goes with them, the requirements of the fish should be considered before any stillwater is considered for operation as a trout fishery.

18.2 Technical and Practical Advice

18.2.1 Keeping disease out – Legislative controls

Categorisation of disease in England and Wales

Diseases in the England and Wales are split into the following three categories (see also Table 54 below);

Category 1
Category 1 diseases are those listed as Notifiable Diseases as specified in the Diseases of Fish Act 1937 (amended in 1983) and cited as List I, II or III diseases under the EC Fish Health Directive 91/67. The control and regulation of category 1 disease in England and Wales is carried out by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), an Agency of the Department for Environment, Food and Rural Affairs (DEFRA), which also acts on behalf of the National Assembly for Wales, Agriculture Department (NAWAD).

The notifiable status of a disease is not solely dependent on its identification. In some cases the disease is only notifiable if it is found in a specific fish species or on fish farms. All of the category 1 diseases are non-indigenous to England and Wales. The UK as a whole is designated as a free zone for List I and II diseases. To maintain this status CEFAS carry out routine testing of all registered fish farms in England and Wales.

Where a Category 1 disease is suspected there is a legal requirement to inform DEFRA. The action subsequently taken is dependent on the disease found, the species affected and the location of the outbreak. Action taken would be very likely to include restrictions on the movement of fish.

Category 2
Category 2 includes those diseases or agents which are considered to have significant disease potential for receiving waters. It includes novel agents whose pathological impact is unclear and distribution limited. Category 2 diseases are controlled by the Environment Agency, through Section 30 of the Salmon and Freshwater Fisheries Act 1975. This control prevents the introduction of any fish found to be infected with a Category 2 disease, into any water where a significant risk of infecting the wider environment exists. Such waters are:

- Rivers
- streams
- canals
- drain systems
- connected (on-line) waters
- waters within the known floodplain.

Fully enclosed stillwaters, where there can be no escape into the wider environment are not subject to the same level of control, and Category 2 diseases may be knowingly introduced. In such cases the Environment Agency operates a policy of “Buyer Beware” and strongly advises against such introductions. The Agency has produced a leaflet called “Buyer Beware – Your guide to stocking fisheries”, which describes the policy and gives guidance for introducing fish.

Category 3 – Clinical Disease
Category 3 includes all signs of clinical disease caused by agents not listed as Category 1 or 2 or by other physical, physiological or behavioural causes. Category 3 disease outbreaks are the most common in fisheries in England and Wales. They are caused by indigenous disease causing agents or poor environments and are frequently linked to fisheries management problems.

18.2.2 Disease Symptoms

The impact of a disease outbreak may be dependent on the speed at which a disease outbreak is recognised and reported. It is therefore important that fisheries managers can assess the condition of their fish and recognise the symptoms associated with fish disease. Not all diseases cause obvious symptoms and some may result in the rapid death of fish without any obvious decline in condition. However, knowledge of common symptoms may prove useful in identifying the early stages of disease outbreaks. The main symptoms are outlined on the next page in Table 53. Specific symptoms of trout, grayling and char diseases are given in Table 54.

Table 53 Common fish disease symptoms

Area	Symptoms
Behaviour	Lethargy or Sluggish movement Twisting, spiralling or erratic swimming "Flashing" against weed or substrate Loss of balance
Skin	Haemorrhaging (reddening) Grey coloration (excess mucus) Colour changes (darkening or pale) Scale loss Ulceration Visible parasites
Eyes	Exophthalmia (pop-eye) Clouded lenses or surface
Fins/Tail	Haemorrhaging at base Erosion White edges Visible parasites
Vent	Haemorrhaging around vent Protrusion. Trailing faecal casts
Body shape	Distended abdomen Twisted body
Gills	Pale or uneven colour Bleeding from gills Visible parasites

18.2.3 Diseases affecting trout char and grayling fisheries

The following tabulated section outlines diseases that are commonly found to affect trout, char or grayling in fisheries in England and Wales. It does not represent a comprehensive list of all disease causing agents but lists those problems most likely to be seen by fisheries managers. In all cases where a disease outbreak is suspected it should be confirmed by laboratory examination by a competent person. The obvious symptoms of many disease outbreaks may be secondary to the primary cause.

Table 54 Diseases affecting trout, char and grayling fisheries

Disease	Category	Symptoms	Notes	Control
Viral Diseases				
Viral Haemorrhagic Septicaemia (VHS)	1 reportable	Symptoms include darkening of the body, protruding eyes, swollen abdomen and haemorrhaging at the fin bases, in the eyes and gills. Fish may congregate around pond outlets and margins and show erratic swimming behaviour, such as darting, spiralling and swimming on their sides.	Absent from England and Wales. If suspected, inform NFL immediately.	N/A
Infectious Haematopoietic Necrosis (IHN)	1 reportable	Symptoms include swelling of the abdomen, protruding eyes, darkening of the body and haemorrhaging at the fin bases and anus. Affected fish are typically lethargic though they may display brief periods of hyperactivity, and often trail very long faecal casts.	Absent from England and Wales. If suspected, inform NFL immediately.	N/A
Infectious Pancreatic Necrosis (IPN)	1 reportable (salmon only)	Darkening of the skin, abdominal distension, exophthalmia and haemorrhaging around the vent and pale gills. Spiral swimming has also been observed.	Widespread in trout farms and associated with disease outbreaks in rivers and stillwaters.	Regulation of stocking practices. Stocking with fish older than 6 months and controlling stock density may be beneficial.

Table 54 cont'd

Disease	Category	Symptoms	Notes	Control
Bacterial diseases				
BKD (Bacterial Kidney Disease)	1 reportable (fish farms only)	Dark coloration, exophthalmia, pale gills, a distended abdomen or haemorrhaging at the vent or base of the fins. May also occur without any visible external symptoms.	Sporadic outbreaks of BKD have been recorded in a number of fish farms. Has been recorded in a number of rivers. Most salmonids are susceptible to BKD.	Preventing the introduction of BKD is the best control method. CEFAS inspectors test for BKD. Movements from infected fish farms are not permitted.
ERM (Enteric Redmouth)	None	Haemorrhaging under the mouth and around the opercula. Can include darkening of the skin, haemorrhaging at the tips of the gills and exophthalmia.	Primarily affects farmed rainbow trout. However, all salmonids, both wild and farmed are potentially susceptible.	Stocking from fish farms with good husbandry practice.
Furunculosis: *Aeromonas salmonicida* (typical)	1 reportable (salmon only)	**Acute form**: Few if any external symptoms **Chronic form**: large swellings or furuncles in the musculature. Occasionally, haemorrhaging on the gills and at the base of the fins, slight exophthalmia and bleeding from the nasal cavities and vent is observed. The fish are also likely to be lethargic.	Primarily affects salmon, the typical strain also affects brown trout. Rainbow trout appear to be more resistant. The typical strain has been recorded in grayling in the wild, but no losses have been reported.	Preventing introduction is the best method of control. CEFAS inspectors carry out tests for bacterium. Movements from infected fish farms are not permitted.
Aeromonas salmonicida (atypical)	None	Distinctive shallow lesions or ulcers in the skin of the fish.	Widespread in Britain where associated mortalities are common. The atypical strain of the bacteria causes a number of common ulcerative diseases in non-salmonids, can affect trout, char and grayling.	Primarily associated with stress. Fisheries management action should attempt to minimise stress. Particular regard should be given to stocking methods and to stock density.
Fin Rot	None	Clearly visible erosion of the fins, most often the tail. A white edge is usually visible. Classically the erosion to the tail removes the two points of the fork.	Causative bacteria are present in all waters.	Primarily associated with stress. Good management actions can avoid outbreaks. Presence on stock fish prior to introduction indicates poor husbandry.

Table 54 cont'd

Disease	Category	Symptoms	Notes	Control
Bacterial diseases				
Other Bacterial Disease.	None	The non-specific symptoms associated with bacterial diseases.	There are a number of bacterial diseases that can affect fish, but are primarily of concern in fish farm conditions. Examples include Bacterial Gill Disease, Cold Water Disease, Columnaris and Vibriosis.	
Protozoan diseases				
White Spot, Costia, *Chilodonella* & *Trichodina*	None	White spot visible to the naked eye in later stages. General signs can include excess mucus and a grey coloration on the skin. Fish may become lethargic and remain static in the margins or near the surface in open water, they may scrape and "flash" against the gravel or plants.	Present in all waters and affect all fish species.	Primarily associated with stress and poor habitat / fisheries management. Correct management actions can avoid outbreaks. Stock density is a major factor.
Myxozoan diseases				
PKD (Proliferative Kidney Disease) caused by the Myxozoan, *Tetracapsula bryosalmonae*	None	Darkened skin, exophthalmia, pale gills and distended abdomens. Fish become lethargic and do not respond to stimuli. Internally the kidney can appear swollen and enlarged with areas of grey coloration or nodules.	PKD effects wild and farmed salmonids, grayling and arctic char. It has a wide distribution in England and Wales.	It is not possible to fully safeguard against introducing PKD. May prove less problematical to fisheries reliant on stocked fish of a catchable size. Ensuring good habitat and water quality may prevent serious losses.
Monogenean parasites				
Gyrodactylus	None (ex *G. salaris*: - Category 1 reportable)	Excess mucus and grey coloration on skin.	Present in all waters. Species of parasite specific to trout and grayling. *G. salaris* not present in UK.	Good fisheries management practices. Stock density and habitat major factors.
Dactylogyrus	None	Grey coloration on gills. Loss of gill structure. Lethargic.	Present in all waters.	Good fisheries management practices. Stock density and habitat are major factors.

Table 54 cont'd

Disease	Category	Symptoms	Notes	Control
Digenean parasites				
Eye Fluke (Diplostomum sp., *Tylodelphus* spp.)	None	Parasites visible as a clouding of the lens, leading to cataract formation in heavy infections. Fish may swim "high" in the water.	Present in all waters. Parasite cycles through fish eating birds and water snails.	On affected waters stock management may reduce impact. Control of snails has limited success. Expert advice should be sought on water by water basis.
Crustacean diseases				
Argulus *spp.*	None	Flat disc like parasite of up to 5mm across. Greater than 10 parasites per fish may be indicate future problems.	Present in all waters. Severe economic impacts on many stillwater trout fisheries.	Widespread illegal chemical treatment is reported. Outbreaks often due to unsuitable habitats. Existing and potential fisheries should take into account the potential for *Argulus* outbreaks.
Ergasilus *spp.*	2	Visible as white spots on gills. Egg sacks of parasite form distinctive "maggot" shape in summer. Affected fish may be lethargic and show rapid loss of condition.	*Ergasilus sieboldi* is on the category 2 list and its spread is controlled by the Environment Agency. Geographically widespread, but not common. This parasite represents a serious threat to trout fisheries due to its host size preferences.	Prevent stocking from infected sources by requiring specific health checks. If present stock manipulation can reduce parasite numbers.
Fungal diseases				
Saprolegnia	None	White or grey cotton wool like growth on fish.	Present in all waters. Strictly a secondary pathogen related to other diseases, physical damage or severe stress. Significant outbreaks associated with spawning stress and stock density in riverine brown trout populations.	Good fisheries management practices.

18.2.4 Disease Outbreaks – What To Do

Impact

Disease outbreaks, whether resulting in mortalities or not, cause a severe environmental and economic impact on affected fisheries. Economic losses result from a short-term reduction in angling quality and a possible longer-term perception of the presence of "diseased" fish. This perception may affect business long after the fishery has recovered. The ecology of the fishery may also be severely affected. The long-term, chronic impact of diseases or parasites is of concern because these agents are difficult to eradicate and may require specific management responses (e.g. altering stocking frequency or the size of fish stocked). In the most severe cases, fish disease problems caused by both native and exotic parasites have closed trout fisheries or forced a change of use to coarse fisheries.

Actions – Investigation

In the event of fish deaths or suspected disease problems the local Environment Agency office should be informed as soon as possible. Agency staff will determine whether the incident is suspected to be a result of water quality issues (including pollution) or a disease outbreak. The Environment Agency contact numbers are:

Emergency Hotline 0800 80 70 60

Local Office general enquiry line 0845 722 33 44

Environment Agency National Fisheries Laboratory 01480 414 581

Where a fish disease problem is suspected fish should be submitted for examination. Contact the NFL for advice on investigating fish mortalities and fish transportation (01480 414 581 or Internal Solutions index). Post-mortem analysis routinely includes examinations of physical condition and gross pathology, parasitology, bacteriology, virology and histopathology. In addition to this, details of the fishery, the fisheries management practices and the mortality are also collected to aid the examination.
A total of 5 or 6 live fish that exhibit the symptoms shown by the dying fish should be submitted. Care should be taken to ensure that they remain in the same condition as when they left the water. Fish should be transported in water from the affected fishery, and never in tap water. Fish sent for examination should never be caught by rod and line.

Where a notifiable disease is suspected CEFAS should be informed (see Legislation section). Where fish are submitted to the Environment Agency's National Fisheries Laboratory (NFL), CEFAS are routinely informed as a part of the examination.

Actions – Minimising Impact

Stop all fishing activity. This will reduce the impact on remaining fish.
Do not attempt to rescue fish from the affected water. This may spread disease to other waters.
Do not stock any further fish until the mortality has stopped and the cause has been assessed.
Inform the Environment Agency of any changes in the mortality.

18.3 Summary of Management Options

Table 55 Prevention of disease and management of outbreaks

Timing	Management	Action
Prevention		
	Stress	Minimise handling stress when stocking. Provide fish with adequate cover (weed beds, dead wood in margins, etc)
	Nutrition	Ensure good quality feed is used for fish rearing and good quality habitat with abundant invertebrates is present in fishery. See chapter 5.
	Water quality	Be aware of all potential pollution problems and devise plan of action in event of pollution. See chapter 6 – Water Quality.
	Stock density	Maintain catch rate whilst ensuring that overly-high stock densities do not build up.
	Spawning season	Stock with sterile (triploid) trout if fishing during breeding season (winter).
	Introduction of disease	Be very cautious to disinfect nets and to only introduce fish from disease-free sources.
	Angling	Manage angling pressure and methods so as to minimise stress on fish.
	Argulus skin flukes	Relatively warm shallow waters with high coarse fish stocks may harbour *Argulus* and may not be suitable for development into trout fisheries.
Outbreak		
	Contacts	If you suspect a disease outbreak, contact your EA Area Office.
	Examination of fish	Send 5 or 6 live fish showing typical symptoms to National Fisheries Laboratory (01480 414 581) or to a private fish vet.
	Notifiable disease	Inform CEFAS of the outbreak of any notifiable disease.
	Angling	Stop all angling activity.
	Stocking	Do not stock or move any fish.

In any aspect of fish disease related to fisheries management the maxim that ***prevention is better than cure*** holds true. In practical terms little can be done stop a disease outbreak once it is occurring in a water. Ultimately, some disease problems are unavoidable and can not be affected by fisheries management actions, however, good fisheries management that takes account of the potential for disease can greatly reduce the chances of disease effecting a fishery.

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19. POACHING AND THEFT

19.1 Introduction

Trout fishery managers can do much to limit losses of fish to poachers by maintaining good surveillance and readily enforced rules. The IFM advisory booklet on bailiffing is a good starting point to learn the law relevant to fisheries and fish stocks. Howarth (1987) and Carty and Payne (1998) provide lay guidance on fishery law. Environment Agency officers are able to advise on fisheries enforcement. Regular contact with Area fisheries officers helps keep fishery managers informed of local poaching activity and likely levels of risk. Remember to note as much detailed information as possible when reporting a suspected incident. In potentially hazardous situations, reduce conflict or walk away, rather than risk being physically assaulted. Fisheries laws are enforced by trained, warranted Environment Agency bailiffs who know how to assess risks and benefits of tackling poachers. Agency officers will attend an incident where a SaFFA offence is suspected of being committed. Local police wildlife liaison officers are a further useful source of help and advice.

Key legislation in England and Wales is:

The Theft Act (1968) Schedule 1, para. 2 – the taking or destroying of fish from private property.
This Act makes it illegal to take or destroy or attempt to take or destroy any fish in water which is private property or in which there is any private right of fishery. An offender is liable to both a fine and confiscation of equipment. Angling during the day carries a lesser maximum fine than angling at night or the use of any other methods (nets, traps, spears, poisons, etc). A 'public arrest' of suspected person(s) and temporary confiscation of equipment (pending a court decision) is covered by the Act. This Act is enforced primarily by the Police and private fishery owners. The Environment Agency can take proceedings with permission of the aggrieved party, especially if the theft is associated with a SaFFA offence. If a person is taking fish with a rod and line and has a relevant rod licence, any offence is prosecutable under the Theft Act.

Salmon and Freshwater Fish Act (SaFFA, 1975)
This Act includes provisions for prosecution of offences including those relating to use of prohibited instruments, taking 'unclean' fish, disturbing spawning fish, discharging poisonous or injurious materials, using poisons, noxious substances or electrical devices to catch fish, fishing near protected weirs or obstructions, fishing without a valid licence, sale and export of illegally obtained fish and fishing without owner's consent.

Police and Criminal Evidence Act (PACE, 1984)
This Act strengthened the powers of Agency bailiffs in dealing with unidentified suspected offenders.

Trespass
Any person entering private property without the owners consent, acquiescence or without lawful authority is trespassing. On leased waters, the leaseholders have possession of the land. Civil action against a trespasser need not involve any proof of damage but, if contemplating prosecution, it is best to seek legal advice owing to other Parliamentary Acts and Common Law rights.

Enforcement action in the Agency Fisheries function is to protect, conserve or enhance fisheries, or to ensure compliance with the fisheries legislation enforced by the Agency. Agency policy is to:

- Seek the severe punishment of persons causing any damage to fisheries
- Seek the punishment of licence evaders
- To ensure that, where appropriate, remedial work is carried out.

The Agency can, under appropriate circumstances, seek to obtain a criminal prosecution, issue formal cautions or written warnings. Agency officers have certain powers of entry and search and powers of arrest under certain circumstances (SaFFA, 1975). Water bailiffs are deemed constables for the purposes of enforcing SaFFA and further powers of arrest are provided under the Police and Criminal Evidence Act, 1984 (PACE).

Fisheries offences vary greatly in their seriousness – perhaps from a teenager who has forgotten to buy a rod licence through to a violent armed poaching gang using a cyanide compound to poison salmon and sea trout. Actions by the Agency should be measured responses to a given circumstance. The Agency has the Common Incident Classification System (CICS) which is used for recording and categorising incidents and assessing the appropriate response level.

CICS Category 1 (e.g. assault on bailiff, licence evasion) incidents generally lead to prosecution,

CICS Category 2 incidents lead to prosecution or formal caution and

CICS Category 3 incidents lead to a written warning (unless there are repeated offences).

Factors determining a course of action include:

- Severity of potential environmental / fisheries impact,
- Nature of offence, whether intentional or unplanned,
- Previous history and attitude of offender, likely deterrent effect of punishment and
- The offender’s personal circumstances.

19.2 Technical and Practical Advice

19.2.1 Fisheries offences and suitable actions

The Table on the next page provides examples of fisheries offences and actions to be taken or considered (after Environment Agency 1999, Table 2).

Table 56 Fisheries offences and actions

Offence	Statutory reference	Action to be taken	Actions considered
Fishing with prohibited instruments	S1 SaFFA	Prosecution / formal caution. Seizure of instrument, fish, etc	Seizure of vessel or vehicle and application for forfeiture.
Taking unclean fish	S2 SaFFA	Prosecution / formal caution. Seizure of instrument, fish, etc	Seizure of vessel or vehicle and application for forfeiture.
Disturbing spawning fish	S2(3) SaFFA	Prosecution / formal caution / warning	
Discharging poisonous / injurious matter	S4 SaFFA	Prosecution / formal caution / warning. Water Quality enforcement also.	Seizure of vessel or vehicle and application for forfeiture. Seek compensation through Water Quality enforcement.
Using explosives, poisons, noxious substances or electrical devices to take fish	S5 (1) SaFFA	Prosecution / formal caution.	Seizure of vessel or vehicle and application for forfeiture.
Unauthorised fixed engines	S6 SaFFA	Prosecution / formal caution.	Seizure of instrument and application for forfeiture.
Offences relating to screens, sluices or fishing weirs	S12 (1&3), S13, S14, S15, S18 SaFFA	Prosecution / formal caution / warning.	Remedial works, carry out, recover costs.
Illegal fishing near obstructions	S17 SaFFA	Prosecution / formal warning.	Seizure of equipment, fish, etc, and application for forfeiture.
Fishing in close season	S19, S20 SaFFA & byelaws	Prosecution / formal caution / warning.	Seizure of equipment, fish, etc, and application for forfeiture.

Table 56 cont'd

Offences relating to possession, sale and export of salmon & trout	S22, S23, S24 SaFFA	Prosecution / formal caution / warning.	Seizure of fish and application for forfeiture.
Fishing without valid rod licence	S27 & S35(3) SaFFA	Prosecution / formal caution / warning.	Seizure of instrument, fish, etc if in conjunction with other offence or identity in doubt. Application for disqualification to hold a licence.
Failing to produce a valid licence.	S35 SaFFA	Prosecution / formal caution / warning.	Seizure of instrument, fish, etc if in conjunction with other offence or identity in doubt. Disqualification to hold a licence.
Giving a false name and address	S35 SaFFA	Prosecution	Seizure of instrument, fish, etc.
Unlicensed fishing (other than rod and line)	S27 & S35(3) SaFFA	Prosecution / formal caution / warning. Seizure of instrument, fish, etc.	Seizure of vessel or vehicle. Withhold/ban from holding licence.
Introduction of fish without consent	S30 SaFFA, S14 WACA	Prosecution / formal caution / warning.	
Byelaw offences	National / Regional Byelaws	Prosecution / formal caution / warning.	Seizure of equipment, fish, etc, and application for forfeiture.
Handling salmon in suspicious circumstances	S32 Salmon Act, 1986	Prosecution / formal caution / warning.	Seizure of vessel or vehicle and fish
Obstruction of bailiff	S31(2) SaFFA & Para 7 Schedule 20 WRA	Prosecution / formal caution / warning.	
Assault of bailiff / constable	S4 & S5 Public Order Act	Prosecution / formal caution.	

Key

SaFFA	Salmon and Freshwater Fisheries Act, 1975,
WACA	Wildlife and Countryside Act 1981,
WRA	Water Resources Act 1991,
ILFA	The prohibition of keeping or release of live fish (specified species) Order, 1998.

19.2.2 Improving fishery security

The best advice on this is to set up an effective observation system on a fishery. Syndicates normally 'self police' well, clubs less well and private fisheries are variable. Regular appearances around the fishery at irregular times, security fencing lights at night, guard dogs and, even, CCTV systems all have their place. Take advice from local Police and Environment Agency fisheries staff.

19.2.3 Environment Agency bailiffing

The Agency does not have the financial resources or duty to bailiff private fisheries. The Agency also offers comprehensive advice on good bailiffing practice and procedures, staff enforce law on private fisheries and have the power of entry in order to do so. The Environment Agency also responds to reports of poaching on club waters, especially where there may be migratory salmonids involved. Use the Freephone Hotline 0800 807060 to report suspected poaching incidents.

19.3 Summary of Management Options

Table 57 Fisheries protection management options and good practice

Issue	Management options	Good practice notes
Improving fishery security	Take advice from Environment Agency staff. Take advice from local Police. Make sure that all cost-effective steps have been taken to deter potential poachers.	Fisheries with good deterrents tend to suffer least from theft. An irregular patrol route, good lighting and security, with dogs all help to prevent fishery crime. If encountering professional poaching gangs be very careful before challenging them, especially if you are alone.

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20. CATCH AND RELEASE ANGLING

20.1 Introduction

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Figure 87 Releasing a sea trout

Game fishermen have traditionally released undersized or out of condition fish as a wise use of a natural resource. Increasing numbers of salmon, trout and grayling anglers are now releasing takeable wild fish as part of their standard approach to angling (Weaver, 1991, Environment Agency National Trout and Grayling Fisheries Strategy 2003). Catch and release allows more people to catch wild salmonids whilst having a minimal impact on wild stocks. Knotless landing nets or the release of fish whilst still in the water minimise physical damage and stress. Tools to facilitate hook-removal from fish whilst still in the water are available.

Catch and release is a long-established fish conservation management policy in the USA, pioneered by Lee Wulff (1983). The economic value of wild salmonids is increased if they are available to be caught more than once and stocked trout effectively become less expensive if they are caught more than once. Catch and release can be mandatory or voluntary and may involve the taking of (say) just one wild fish and the return of the rest.

Some wild fisheries adopt 'slot limits' whereby only fish of a certain size may be killed with all others returned. Some put-and-take trout fisheries are adopting catch-and-release methods in the following ways:

- Anglers can either fish until a limit bag has been taken or they can fish catch-and-release all day but are not allowed to kill any.
- After taking a small limit bag (one or two fish) anglers are allowed to fish on, releasing all subsequent fish.

Catch and release tends to work best in larger waters where the chances of an individual fish getting caught more than once over a relatively short period are low. Where angling pressure and trout stocks lead to frequent capture rates, the fish soon learn to become very cautious and caught fish tend not to return quickly to their original lies (Lewynsky & Bjorrn, 1987). Increased wariness of trout adds to the challenge for many keen anglers but may put off the less able who can find it difficult to catch anything at all. As in all fisheries management, a correct balance of exploitation and conservation must be struck.

It is worth noting that some anglers regard mandatory catch and release as unacceptable because it necessarily involves going fishing without the potential to take home fish to eat.

20.2 Technical and Practical Advice

20.2.1 Long-term experience of catch and release wild trout angling in the USA

Figure 88 US Catch and Release logo

Riehle et al (1989) compared fish population and creel census data from 1976-77 to similar data from 1986-87, after 10 years of catch and release regulations for rainbow trout in Silver Creek, Idaho. They found that:

- Rainbow trout growth rates had increased slightly, total mortality had declined, the proportion of 40cm+ fish in the population increased.
- 50cm+ brown trout had taken up residence in the catch and release fishery and there was a healthy stock of smaller browns.
- Catch and release regulations had allowed more angling effort, a higher catch rate and a better-growing wild rainbow trout stock with more large fish.

Barnhart and Engstrom-Heg (1984) reviewed the success of absolute and partial harvest restrictions on wild brown, rainbow and brook trout fisheries in New York State. They concluded that these regulations have:

- Increased angler catch rates, a reduced need for stocking, restoration or enhancement of some wild brown, rainbow and brook trout stocks and, in some cases, increased maximum size and abundance of wild trout.
- Initially caused a decline in angling participation but that this recovered partially or completely after several seasons. Most New York trout fisheries allow a small bag limit. Total catch and release is imposed on only a few fisheries.

Jones (1984) reviewed the success of 10 years catch and release regulations in Yellowstone National Park. Where angling pressure is intensive, close to roads, catch and release has protected and enhanced cutthroat trout stocks (e.g. on Slough Creek and the Yellowstone River). Brook trout and brown trout stocks have improved to lesser degrees.

Marnell and Hunsaker (1970) found that liberated spinner-caught cutthroat trout from Yellowstone Lake suffered no greater mortality at higher water temperatures, when reproductively mature or when deliberately 'played' for ten minutes to tire the fish out, than control group fish. Overall mean mortality was around 5% - as expected for this species when caught by spinning.

Nehring and Anderson (1984) reviewed the success of catch and release fishing in Colorado finding:

- Regulations ranged from no-kill, species limits, size limits, slot limits, and terminal tackle restrictions.
- Management objectives were met, angler acceptance was high, enforcement problems were minimal.

- During autumnal electric fishing surveys 50-75% of trout >15cm show hook scars / inflamed areas on mandible or maxillary bones.
- Angling mortality associated with catch and release was estimated at less than 5% of the spring standing crop.

Hunt (1987) compared creel survey statistics from three catch-and release brown trout fisheries where few fish are allowed to be killed with records from six other fisheries governed by normal regulations. On catch and release waters:
- Each set of catch and release regulations was successful,
- Angler use and catch rates were both high for brown trout waters.

Wells (1984, 1987) reported the success of trout angling restrictions in Montana, finding that:
- Catch-and-release was adopted on 20 miles of the Madison River in 1978. After 5 years numbers of wild brown trout over 13 inches tripled and wild rainbows increased even more.
- On the Big Hole River a slot length restriction protecting trout of 13-22 inches, after 3 years, raised 18inch+ brown trout densities from 40 to 140 per mile. Numbers of 13inch+ rainbows doubled over the same period.

Jones (1987) reviewed the success of a decade of catch and release fishing in Yellowstone National Park concluding that:
- Angler use and effort has increased whilst, in most cases, catch rates and average sizes of trout have also increased. Trout population structures reflect a near-natural state.
- Fisheries within Yellowstone Park are managed as part of natural ecosystems where trout provide a prey source for predators such as eagles, ospreys, otters and bears as well as a recreational resource for anglers.

20.2.2 Catch-and-release angling in practice in England and Wales

Rivers

Weaver (1991) describes successful catch and release wild brown trout fishing on the Dorset River Piddle where good habitat quality sustains excellent trout stocks. He predicted that catch and release angling would increase. Ten years later, The Annual Review of Fisheries Statistics reported that catch and release angling for sea trout certainly has increased appreciably (1993 - 29%, 2000 - 50%) and that similar trends for wild brown trout and grayling are thought, by fishery managers to have occurred (Environment Agency 2001, 2003).

Stillwaters

Experience in England has shown the importance of maintaining a turnover of stock by combining catch and release with a low bag limit (D. Moore, pers. comm.). Those fisheries which have operated purely catch and release have accumulated a large stock of wary fish and risked exceeding the carrying capacity of their waters. Introduction of catch and release at the 40ha Ravensthorpe Reservoir, Northamptonshire with a two fish limit bag doubled the catch/stock ratio compared with a four fish limit and no fish returned (D. Moore, pers. comm.). At times of high water temperature it may be best to suspend catch and release and to remove all fish caught up to the bag limit.

Simpson and Mawle (2002) found that, in a representative survey of rod licence holders, only 16% of those who fished for trout never practised catch and release. Over half the trout anglers always or usually practised catch and release, especially young anglers and those fishing for wild trout.

Management options

The key to successful catch-and-release is to minimise damage to a fish. This is achieved in several ways (Environment Agency, 1998):

Tackle

Game fish are more likely to survive if caught by the jaws, tongue or inside of the mouth, rather than the gill arches or deep in the oesophagus. Deeply hooked fish can sustain damage to the gills, heart or other vital organs. Fish which are bleeding have better chances of survival in cool, rather than warmer water.

- Barbless hooks or hooks with flattened barbs are more readily removed than barbed hooks and single hooks tend to be less damaging than double or treble hooks.
- Fly-caught fish are more likely to survive than spinner-caught fish, with bait-caught fish (which often take the bait deeply) least likely to survive.
- It is worth releasing any fish which appears to have a good chance of survival.

Hooks

The literature review of Wydowski (1977) concluded that barbless hooks probably have no significant effect on reducing mortality (except for reduced handling time) and that single hooks on lures usually caused higher mortality rates than treble hooks when used with bait or on lures. In contrast, Nuhfer and Alexander found that wild brook trout caught on spinning lures equipped with single hooks suffered lower mortality over the following 48 hours (2.4%) than fish caught on treble hooks (8.3%).

Trout caught on jointed Rapala plugs suffered no mortality as hooking was almost always superficial. The authors attributed high hooking mortality to damage to gill arches or other organs deep in the throat of the fish. Carbines (1999) reports that blue cod caught on large single hooks suffered no mortality but fish caught on smaller hooks suffered 25% mortality due to deep-hooking. Similarly, Diggles and Ernst (1997) found that marine yellow stripey and wire netting cod suffered less mortality when caught on treble-hooked lures than on baited single hooks - again, deep hooking caused problems. Two deeply hooked fish where the line had been cut subsequently regurgitated the hooks and survived.

Schisler and Bergersen (1996) compared post-release mortality in rainbow trout caught on flies, moving bait and static bait. Overall mortalities were 3.9% for fly-caught fish, 21.6% on moving bait and 32.1% on static baits. Deaths were directly related to numbers of fish hooked 'critically' i.e. deep in the oesophagus or in the gill arches. Length of playing time, length of time out of the water, increasing water temperature and bleeding intensity all contributed to mortality.

Schill and Scarpella (1997) compared barbed versus barbless hook mortality studies on non-migratory salmonids. Results were fairly well balanced with little overall difference between the hook types. They stress that mortality differences associated with hook types (0.3%) are far less than overall annual mortality rates in trout stocks (30-65%) and so are of little fisheries management significance.

Tactics

As a fish fights it develops an oxygen debt in its muscles which it will gradually repay through respiration if it survives. Exhausted fish have a poor chance of survival if not helped. Fish tend to recover less well in warm as opposed to cold water. The Environment Agency (1998) Salmon catch and release leaflet provides good practice guidance:

- Use tackle of adequate strength.
- Play fish firmly so as not to prolong the fight.
- Avoid landing fish, unhook them in the water (air exposure increases physiological stress, Ferguson & Tufts, 1992).
- Don't squeeze the fish hard - hold it gently in wetted hands and use forceps or a de-hooking tool to remove the hook carefully.
- If deep-hooked, cut the line as close to the hook as possible. Fish often survive better if released with a hook still embedded than when handled for relatively long periods by anglers trying to remove hooks (Wydowski, 1977). Hooks can be regurgitated some time after capture.
- If you wish to assess the size of a fish, measure it quickly - the length can be converted to a good estimate of its true weight. Photograph fish in the water.
- Hold a fish gently with its head facing the current allowing it to breathe without expending any further energy - this will help it to recover.
- Allow the fish to swim away when it is ready - this may take several minutes - be patient.
- Choose to catch and release when conditions favour fish recovery (cool water, Nuhfer & Alexander, 1992).

Survival rates of caught-and-released salmonids are dependent on local conditions, angler's handling abilities and fish behaviour. Long-term experience in the USA and Canada has shown that catch and release regulations can be a very effective fisheries management tool.

Education

Education to inform anglers of best practice when catch and release angling is important - the Salmonid 21C video, 'While stocks last' is a good example as is the Fisheries Research Services “Catch and Release” video and the Environment Agency leaflet: Catch and release - a guide to careful salmon handling.

20.3 Summary of Management Options

Table 58 Catch and release best management practice

Issue	Management options	Best practice notes
Wild or Stocked fishery **Is catch and release a viable option for my trout fishery?**	It is wise to ask anglers what they think. If supportive, the next stage is to assess whether the fishery is likely to be sustainable and, if not, how wild stocks might be improved. Take advice from an experienced Fisheries Officer.	Have fishery professionally appraised. If assessment is positive implement any suggested habitat improvements or regulation changes. Gradually reduce stocking and monitor CPUE and angler satisfaction.
Put and take fishery **Is catch and release a viable option for my trout fishery?**	It is wise to ask anglers what they think. If supportive, the next stage is to reduce stocking and monitor the survival of caught and released stock fish. If CPUE starts to drop introduce a small number of new stock fish to increase catch rates. Continue to monitor fishery performance and angler satisfaction.	Gauge angler attitudes and, if positive introduce reduced bag limits + C&R, followed by full C&R if results are good. Monitor CPUE and angler satisfaction. Introduce extra stocks to increase catch rates, if required. Consider allowing killing of fish above a given size to harvest older fish before they die.

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