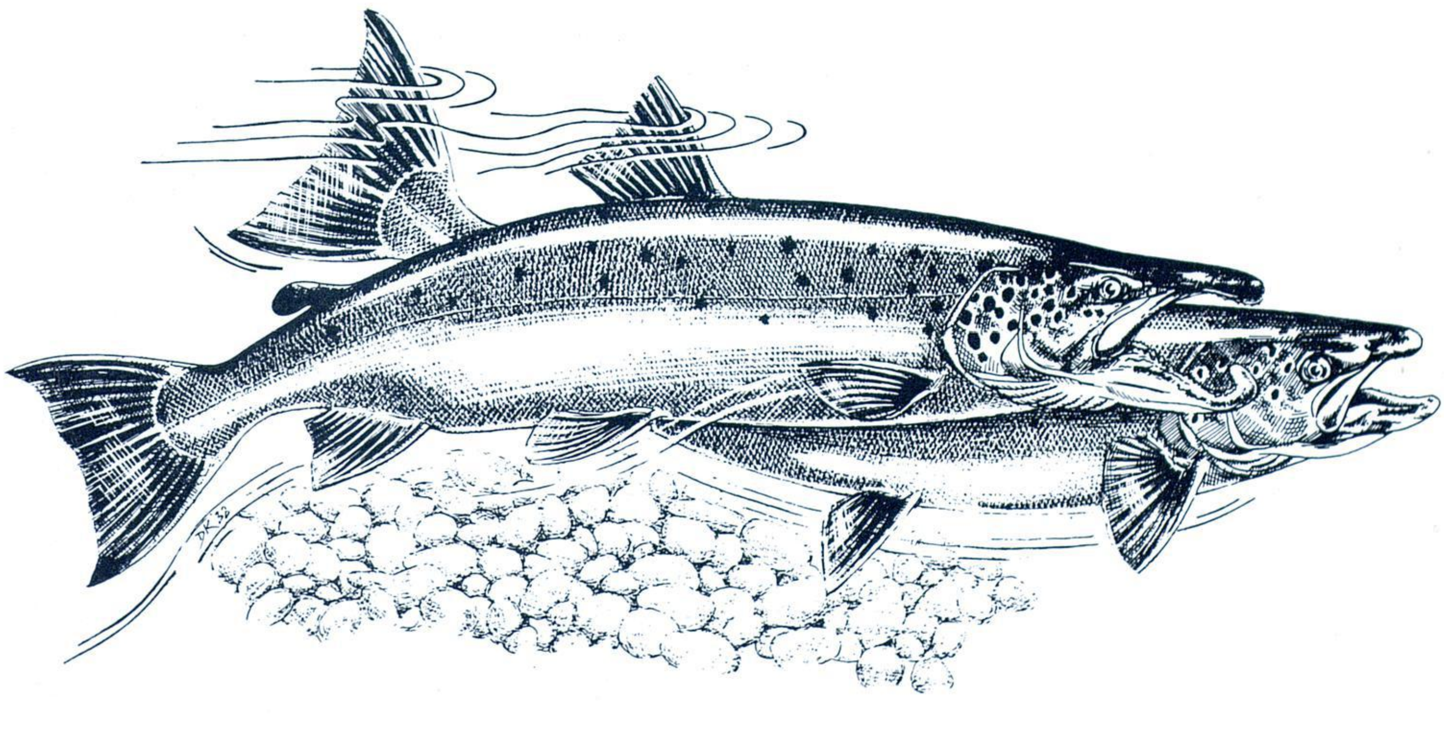
The Salmon Advisory Committee

Assessment of stocking as a salmon management strategy



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

ASSESSMENT OF STOCKING AS A SALMON MANAGEMENT STRATEGY

1. INTRODUCTION

Salmon have been stocked into very many river systems in Great Britain in the past. Stocking has been employed in the belief that it will improve the quantity or quality of catches and have long-term beneficial effects on the salmon populations in rivers. There also seems to have been a widely held opinion, which still prevails in some areas, that all rivers should contain salmon and that all stocking will be worthwhile. More recently, however, concerns have been expressed about the potential risks associated with the release of hatchery-reared fish and their subsequent interactions with wild stocks of both salmon and other fish species. There is therefore a need for fishery managers to be made more aware of the possible consequences of stocking both in terms of the effects on wild populations and the likelihood of improvement in stocks.

Although large sums of money have been spent on stocking activities, few programmes have been properly evaluated to assess the results. In many cases very simple examination will reveal that they can have been of little or no benefit. However, research on Atlantic salmon (*Salmo salar*) in Ireland, Baltic salmon (*S. salar*) in Sweden and coho salmon (*Oncorhynchus kisutch*) in British Columbia, have all shown that relatively small changes in stocking programmes can have very significant effects on the numbers of adult fish returning. Thus, although few stocking programmes have been shown to have improved stocks in the past, there may be potential for well researched stocking to be very successful.

The purpose of this report is to explain some of the factors that must be considered when evaluating stocking as a strategy for improving fisheries. It provides guidance on the steps that should be followed before undertaking any stocking programme but is not designed to give details of how fish should be reared or released. This report refers only to Atlantic salmon, but the principles discussed may apply to other species, particularly sea trout and brown trout (*S. trutta*).

2. STOCK IMPROVEMENT STRATEGIES

Salmon are usually stocked as 'eyed' eggs, unfed or fed fry, parr or smolts, although adult fish may also be transferred to under-stocked streams to spawn naturally. Eggs and milt are usually removed artificially from mature adults, mixed to effect fertilisation and reared in a hatchery for the appropriate length of time. The longer the fish are held in captivity the more extensive are the facilities required and the more expensive will be the process. However, the increasing costs must be balanced against the greater survival of older fish after release.

Stocking is only one of a range of possible strategies for addressing an apparent decline in the abundance or quality of a salmon population. Whether the aim is to restore an indigenous stock which has decreased from previously higher levels or to increase the overall production of the river, alternative approaches are likely to be available. These may take a variety of forms, including increasing the accessibility of parts of the river to spawners, improving the quality of the natural habitat or creating new spawning or rearing areas. Efforts may also be made to reduce or modify patterns of exploitation on the most vulnerable components of the population.

As will be discussed in more detail below, any proposal to add fish to a river system should be preceded by a careful evaluation of the state of the wild stock, its environment and the factors limiting production. Wherever possible any factors limiting production should be removed or alleviated before any additional work is carried out. If there is then a desire to speed up the natural rate of recovery, the merits of stocking should be assessed against alternative methods of improving stocks.

3. THE VALUE OF STOCKING ACTIVITIES

The circumstances in which people might wish to consider stocking may be put in three categories, which are related to the status of the wild stock and the ease with which factors limiting natural production can be removed or alleviated. These categories are defined and discussed below to help in understanding the range of situations for which stocking may be appropriate and some of the problems associated with each strategy.

3.1 Stocking for enhancement

Enhancement stocking is carried out to supplement an existing stock where production is believed to be less than the river could potentially sustain, but where the reason for this under-stocking cannot be identified. This would normally include attempting to establish a new stock in a river which is not thought to have held salmon previously but to which they could have access.

The majority of past stocking activities probably fell into the enhancement category; fish have frequently been released into rivers which contain wild populations in the hope of increasing the number of those returning or improving the quality (eg age composition) of the adult stock. However, in many cases it is likely that the fisheries managers' assessments of the state of their stocks have been unduly pessimistic or the estimates of the potential for the system have been unrealistically high. If production is already limited by an unknown factor, it is unlikely that stocking will have a beneficial long-term effect. Alternative river improvement strategies such as habitat management should thus always be evaluated against any proposal for enhancement stocking.

Ranching is effectively a special form of enhancement stocking, where the intention is to increase the number of smolts going to sea above the current carrying capacity of the system and to harvest all the excess adult fish which return. Fish may be harvested in net or rod fisheries or by trapping.

3.2 Stocking for mitigation

Stocking may be conducted as a voluntary action or statutory requirement to mitigate lost production due to an activity that cannot be removed. Thus, for example, fish might be reared and released to compensate for the loss of spawning and nursery areas under a reservoir.

Mitigation stocking has frequently been considered to be the simplest way to compensate for such activities. However, the reared fish may have to be released in an unaffected part of the river, and the impact on the wild stock in these areas must be considered. If the remainder of the river is fully productive, then fish would have to be released as smolts in order not to compete with and displace the wild population; this would essentially become a ranching exercise to restore lost catches. Such stocking should not, however, be carried out to compensate for over-fishing resulting in too few fish getting up river to spawn as this could result in the gradual replacement of wild stocks by the hatchery-reared populations. (See section 4.2)

Alternative strategies could involve opening up inaccessible tributaries, restoring other parts of the river system or increasing natural production capacities through habitat improvement.

3.3 Stocking for restoration

Stocking which is carried out after the removal of a factor which has been limiting or preventing natural production may be termed restoration. This could be carried out, for example, to restore a stock that has totally disappeared as a result of pollution in the estuary or where access to spawning grounds above a weir has been limited. In either case the cause of the problem can be removed and stocking may be considered as a means to restore the population to its optimum size. Although not strictly 'restoration', this category would also include attempting to establish a new stock in a river or tributary which has not held salmon previously because of a natural obstruction to upstream migration.

This may be the easiest stocking strategy to justify because it will usually be carried out in an area which is known to have been suitable for salmon in the past but which contains a reduced natural population. Even where the cause of the underlying problem is known and being tackled, however, it may take some time to restore the river to its original condition. Stocking may have a role to play while such situations are improving but will have to be particularly carefully planned if the problems limiting production in the river persist.

4. THE POTENTIAL RISKS OF STOCKING

Stocking has generally been considered to be, at worst, an ineffective but harmless activity. More recently, however, concerns have been expressed about the potential adverse affects of stocking on wild salmon populations. These concerns principally relate to the possibility that the introduced fish may be genetically different to the resident wild stock and thus less well adapted to particular river environments. However, more is now known about the factors limiting production and the ways these may be affected by adding fish. In addition, the risks from diseases and parasites have been clearly demonstrated by the introduction of *Gyrodactylus salaris* into Norwegian rivers; this has resulted in the disappearance of some stocks and the deliberate destruction of others as a management measure. Concerns have also been expressed about the possible effects on predation and fisheries of substantially increasing a fish population.

4.1. Genetic risks of stocking

4.1.1 Evidence for genetic differences

Simple observation suggests that there are differences between salmon populations from some different rivers. For example, some rivers are renowned for the size of their salmon while others appear to sustain runs of grilse rather than multi-sea-winter fish. Rivers may also be characterised by the timing of adult returns, usually as spring or autumn runs. However, examining the genetic basis of differences like these is very difficult.

One approach has been to use electrophoretic separation, to examine variation in genetically determined proteins. In every fish each protein is coded by two genes, one gene being provided by each parent. For some genes there are two or more variants (alleles) which will produce slightly different proteins. Individuals are characterised by the combinations in which the alleles are paired, and populations can be compared by the overall frequencies with which the alternative alleles occur. Such electrophoretic studies have demonstrated genetic differences between salmon populations, even from adjacent river catchments or tributaries in some cases. However, these differences are usually not large enough to permit individual fish to be identified as originating from a particular river or even a country.

Electrophoresis can be used to examine only a small part of all the genetic variation which is likely to exist in fish, and the genetic differences which can be examined represent a specific class of genes. However, it is usually assumed that differences in the small numbers of proteins examined reflect similar levels of variation throughout all the genetic material within individuals. The situation is also complicated by the fact that most performance characters are not determined by single genes but by the interplay of many variable genes. These may exert their effects in an even greater number of unique combinations.

4.1.2 Adaptive significance of differences

Most of the genetic differences investigated by electrophoresis are thought to be neutral in that the slight variations in the proteins produced by different alleles are unlikely to affect the outcome of fishes' lives. If this is so, the differences between populations indicate that there is a degree of 'reproductive isolation' between them. This is because exchange of genes through reproductive mixing (gene flow) has not been great enough to counter-balance the effects of random changes (genetic drift and bottle-necking) which occur within partly isolated groups.

Under these circumstances natural selection may result in reproductively isolated populations becoming differentiated with respect to characters which suit different environments. These may manifest themselves as differences in, for example, size, age at maturity and season of return to fresh water.

Interestingly, all the above possibilities appear to be encapsulated by the results of a study of the genetic variation in one of the variable proteins which can be examined by electrophoresis. Study of the two alleles which code for the protein known as MEP-2 has demonstrated geographical genetic variation, even on a local scale, which appears to be related to performance.

In populations, frequencies of the alternative MEP-2 alleles change progressively across the salmon's range. Only one allele is present in Labrador; only the alternative form is present in northern Spain; but both forms are present at intermediate latitudes at varying frequencies. The exact form of the relationship between latitude and allele frequencies suggests that the variation is associated with temperature. Differences can be demonstrated even within a single river catchment. Within the Kyles of Sutherland rivers for instance, the frequencies of the alternative MEP-2 alleles vary, and frequencies are again correlated with water temperature. In addition, and most importantly, differences in the performance of individual fish have been shown to be associated with the different pairings of MEP-2 alleles (genotypes). These different genotypes differ with respect to growth and age at sexual maturity, although the exact nature of the link between the genotypes and performance is not known.

These findings therefore suggest that geographical genetic differences may be linked with variation in the environment and with differences in performance with respect to adaptively important characters. Differences in characters such as age at maturity and growth rate are also of direct relevance to the work of fishery managers.

4.1.3 Adverse genetic effects of introductions

Since some genetic differences are likely to have adaptive significance, salmon from a foreign stock, or fish which have undergone deliberate or accidental selection in a hatchery, may be less well adapted to the river environment into which they are released than the indigenous stock. Any of these fish surviving to reproduce with indigenous individuals may also confer a reduced adaptiveness upon some or all of their offspring. In addition, husbandry practices may result in reduced levels of genetic variation in hatchery reared fish which may reduce the ability of the stock to adapt to varying environmental conditions. Such problems may be exacerbated when stocking persists for several years.

It is often argued that natural selection will minimise any such adverse effects, ensuring the final failure of genetically unsuited individuals to reproduce. However, this view may prove to be optimistic. Although allele frequencies may be fluid and quickly responsive to change, it is also possible that current patterns of variation have been optimised by many generations of selection. Patterns, disturbed by even a single introduction of genetically different fish, may take a similarly long time to restore. If the effects of natural selection are not strong enough to ensure the elimination of unsuitable genes in the first generation, the interbreeding of introduced and indigenous fish may alter the frequencies with which adaptively important combinations of genes occur and these may be even slower to return to their original state.

In some instances there may be a desire to introduce into a population a characteristic prevalent in another stock, such as spring returns. While there is currently no evidence that such policies carry any more risk than other stocking practices, this desirable feature may be linked to other (possibly undesirable) characteristics. Recent advances in the understanding of the genetic basis of salmon life history characteristics suggest that there might be considerable potential for properly-planned breeding programmes to select traits that are considered desirable, eg spring-running. However, such an approach is fraught with problems and even risks to wild stocks if proper regard is not paid to critical aspects such as the avoidance of inbreeding. For the time being this sort of development must be considered at the research stage and cannot be recommended for adoption in routine restocking programmes.

Ranching could pose additional risks, even where native broodstock are used, because fish will tend to be reared in captivity for several generations and releases will take place over many years; even a single generation of captive rearing may result in genetic changes in the population. If the exploitation rates on the wild and ranched fish are equal, the ranched stock will progressively dilute the native population because a proportion of the reared fish will enter the wild spawning population each year and thus to prevent this, attempts should be made to catch all the returning ranched fish. If that is not possible ranching exercises should use fresh wild broodstock for each generation.

The genetic risks will be low in restoration programmes if the native stock has been completely lost, although the potential effects on neighbouring stocks must be borne in mind. The genetic risks are more complex, however, if a residual indigenous population remains. The population may be too small to provide sufficient broodstock but may be swamped by large releases. In such cases there may be merit in cross-breeding foreign female salmon with a smaller number of local males.

4.2 Ecological risks of stocking

Salmonid nursery streams have an upper limit to the numbers of fish they can carry; if too many fish are present then predation and starvation will reduce the population to the level which the stream can support. Natural populations also normally include fish of more than one age class occupying different stream habitats. Thus, while stocking programmes may produce large increases in fish numbers at certain times or in localised areas, no more fish will survive than the natural habitat will allow. In addition, when fish are added to a system they will compete with and may displace some of the resident wild fish, particularly if these are smaller, and this may upset the natural age class structure of the population. As discussed in the preceding section on genetic risks, such introductions could also reduce the overall production if the released fish are less well adapted to the particular system than the wild fish.

The production of the system could also be reduced below the carrying capacity by over-stocking. Data from some studies suggest that when the spawning population exceeds an optimal level the number of smolts produced may decrease. This may occur because heavy competition between individuals results in the condition of all surviving fish being reduced. A similar effect might be seen if excessive numbers of fish are added to a system. Large increases in the population may also attract predators, particularly if fish are released in large batches or in poor condition, and the heavier predation may impinge on the wild stock resulting in an overall decline in the population.

Stocking of one species may have effects on other species either through predation or competition. For example, the habitat requirements of salmon parr and young trout overlap (although they do not coincide entirely) and their diets are very similar. Such interactions must be considered when planning a stocking programme.

It is clearly important that no new pathogen or parasite is introduced to a natural population by stocking. The catastrophic effects of transferring alien parasites or diseases have been demonstrated by the introduction of *Gyrodactylus salaris* into certain Norwegian rivers. This has resulted in the complete loss of salmon from some rivers, and, in some cases, treating the problem has involved the clearance of all fish species from the system. These risks have long been recognised and are reflected in legislation controlling fish imports and movements. However, there is no requirement within these regulations for eggs or fish used for stocking in Great Britain to be certified disease-free. When fish are transferred between catchments or reared in a fish farm an undertaking should be sought that the source has been tested and shown to be free of disease.

It is also possible that fish introduced from one river into another may not be resistant to an endemic disease. While this may present little danger to the receiving stock, the stocking exercise is unlikely to be successful and there is a possibility that the introduced fish will act as a reservoir for the proliferation of the disease.

4.3 Implications of stocking for fishery management

Increasing the size of salmon populations by stocking or other means is likely to have extensive effects on fisheries. Effort in existing fisheries may increase and new fisheries may become economic. In addition, there may be conflicts with fisheries for other species, such as when salmon are introduced into rivers which previously held only coarse fish.

Many fisheries, even in estuaries or rivers, exploit salmon from a number of different stocks or sub-stocks. However, fishing effort and thus catches are often dictated by the most abundant stock. Thus, if the number of fish entering a fishery is increased as a result of a stocking exercise this may encourage fishermen to increase their effort. While the enhanced stock may be able to sustain the increased level of exploitation, other stocks which have not been enhanced may become over-exploited. Ranching programmes pose particular problems as there may be a desire to maximise the harvest of the ranched stock without increasing pressures on wild populations. Thus there is a need for careful evaluation of the effects of any stocking on stocks and fisheries.

4.4 Reducing the risks of stocking

In view of the above concerns, the following procedures should be adopted when rearing and releasing fish in order to reduce the risks:

a. sufficient fish (at least 30 of the least numerous sex) should be used as broodstock to avoid reducing the genetic variability of the offspring;

b. broodstock should, if possible, be taken from the same part of the same river into which the reared fish will be released;

c. where broodstock have to be taken from another source they should be collected from a nearby tributary or river having similar physical characteristics;

d. stocked fish should not have been reared in captivity for more than one generation in order to limit the possible effects of selection within the hatchery; particular care therefore needs to be taken when obtaining fish from farms;

e. diseased or poor condition fish should not be released, and, where fish are transferred between catchments or reared in a fish farm, they should be certified disease free;

f. fish should be released at appropriate densities relative to the carrying capacity of the stream and the numbers of wild fish present; they should not be released in large groups, which may attract predators;

g. close attention should be paid to changes in fishing effort following a stocking programme.

5. ASSESSING THE NEED FOR STOCKING

Figure 1 provides a step by step approach to planning and assessing a stocking programme. First, a series of questions must be answered as a basis for deciding the type of stocking strategy which might be appropriate; this provides the background to the proposal, which must then be set out in detail. Finally, the benefits and drawbacks must be fully evaluated and compared before the proposal is accepted or rejected.

The questions and planning steps are discussed in detail below.

5.1 Stock assessment and environmental surveys

The first step when considering any stock improvement activity must be to establish whether the stock is below optimum size or whether the quality of the stock (eg the age composition) could be improved. In evaluating the state of the stock it is necessary both to estimate the current size and composition of the population and to assess the potential production of the system. Methods for assessing the status of stocks were addressed in the Committee's first report ('Information on the status of salmon stocks'); it may require detailed population surveys or analysis of available data, and river managers may require specialist advice or assistance. These assessments must be based on firm evidence from such sources as counters, catch statistics, spawning studies or juvenile surveys, which may indicate, for example, particular parts of the river which are under-stocked.

In addition, the river environment should be surveyed to describe the condition of the river and the natural and artificial factors that may be limiting production.

5.2 Establish the cause of underproduction

If production is thought to be less than the potential of the system then it is important that the reason for this under-production is established and resolved before stocking is carried out. Similarly if a system has not held salmon in the past it is important to establish whether it is suitable for the species before stocking is considered. In the latter case the potential impact on other indigenous species requires particular attention.

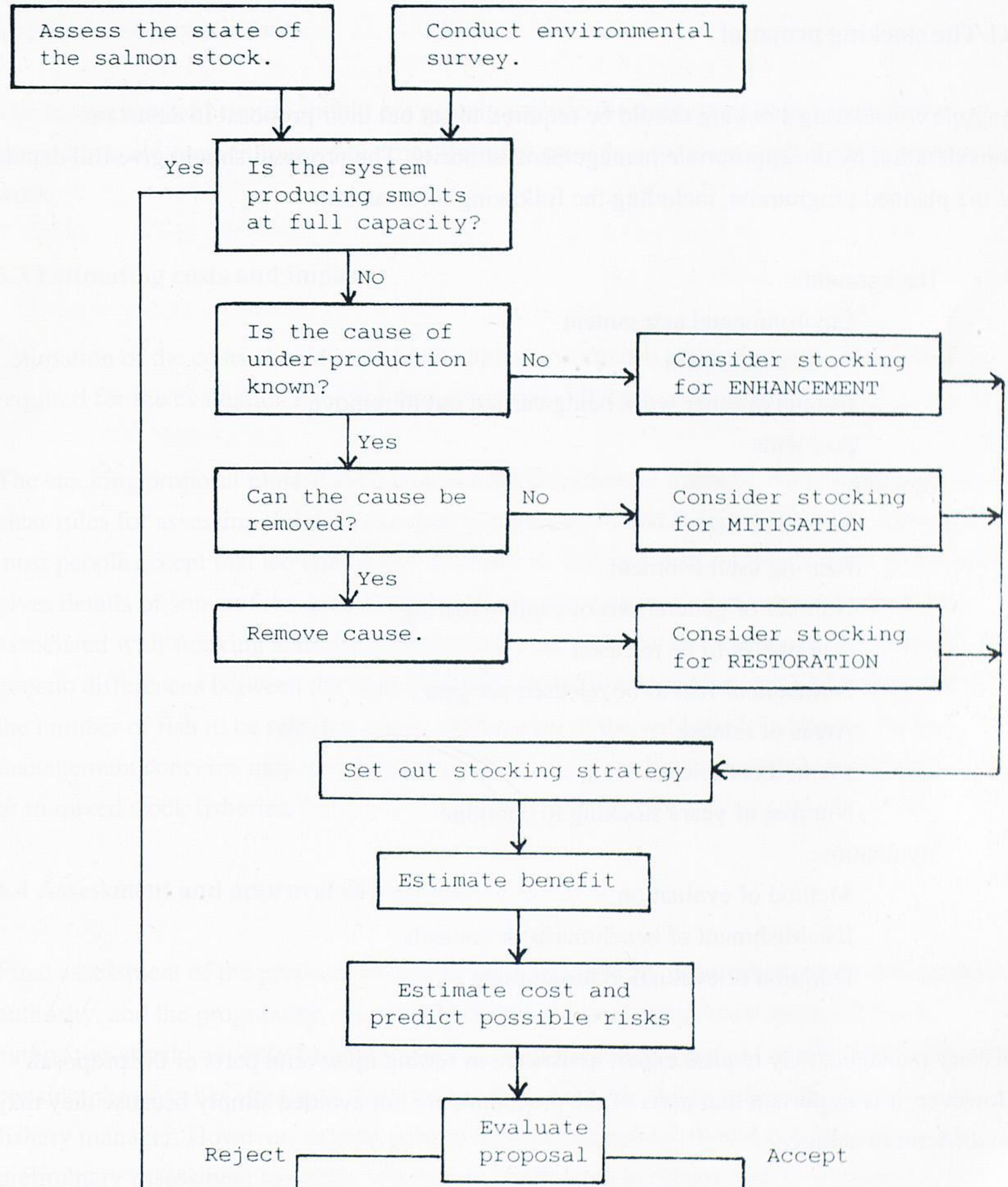
In some cases the cause of stock decline or deterioration may be obvious but in others it may be very difficult to identify. If no clear cause can be identified, it may be worth considering enhancement stocking or ranching to improve fisheries, but alternative strategies may have better long-term results.

5.3 Remove the cause of underproduction

If the stock size can be seen to be limited by one or more factors, efforts must be made to resolve these problems before resorting to stocking. If the cause cannot be removed, as in the case of a reservoir for example, then mitigation stocking may be considered. However, it must be recognised that if the system is producing smolts at full capacity then such a programme may have to be conducted as a ranching exercise and this may pose further problems.

If the cause of the decline is removed the population may recover without any stocking. Habitat improvement throughout the system may therefore be, ecologically, a safer use of available resources and may have greater long-term benefits than stocking. Stocking is often considered because it is seen as a way of demonstrating to anglers that managers are doing something useful. This type of public relations activity should be strongly discouraged except where sound ecological benefits can be predicted.

Figure 1 STOCKING STRATEGY



6. EVALUATION OF STOCKING PROPOSALS

If stocking appears to be worth considering then the proposal must be carefully planned and evaluated in preparation for formal approval.

6.1 The stocking proposal

Anyone considering stocking should be required to set out their proposal in detail for consideration by the appropriate management authority. The proposal should give full details of the planned programme, including the following information:

Background:
- Environmental assessment
- Stock assessment
- Details of other work being carried out to remove problems

Stocking:
- Source of fish
- Rearing establishment
- Number of generations of captive rearing
- Age of fish to be released
- Numbers of fish to be released per year
- Areas of release
- Methods of release
- Number of years stocking to continue

Evaluation:
- Method of evaluation
- Establishment of benchmarks or controls
- Duration of evaluation programme

Fishery managers may require expert assistance in setting up several parts of the proposal. However, it is important that parts of the procedure are not avoided simply because they may be difficult to achieve.

6.2 Estimating benefits

Relatively simple calculations may be carried out to quantify the potential benefits of a stocking exercise. It is important, however, that these are realistic and that due account is taken of mortalities after release and the lower survival of reared compared to wild fish. Catches may not increase in proportion to increases in the stock size and increased adult returns may not have equal effects on net and rod fisheries. The financial benefits to net fisheries may be roughly in proportion to the increase in catches. However, this may not be the case for rod fisheries, where small increases in catch may do little to attract new anglers and thus to improve income.

The assessment of benefits should not usually include the public relations value of the programme although in many situations this may provide a major incentive for beginning work.

6.3 Estimating costs and impact

Estimation of the costs should include all capital and current expenditure including that required for the evaluation exercise throughout the duration of the programme.

The stocking proposal must also be assessed for its potential impacts. As yet, there are no clear rules for assessing the risks attached to releasing reared fish into the wild. Although most people accept that the risks exist, there are diverging views on their extent. Section 4 gives details of some of the genetic risks and possible fishery and environmental effects associated with stocking activities. The genetic risk will tend to increase as, for example, the genetic differences between the reared population and the receiving stock increases and as the number of fish to be released relative to the size of the wild stock increases. Fishery management concerns may also be greater where there are limited controls on fishing effort or in mixed stock fisheries.

6.4 Assessment and approval of proposal

Final assessment of the proposal should be the responsibility of an appropriate management authority, and the programme should only continue if it receives their approval. Such authorities should not only be able to provide an impartial assessment of the proposal but also consider the possible effects on fisheries and rivers outside the jurisdiction of the river or fishery manager. However, anyone putting forward a proposal should conduct their own preliminary assessment to decide whether an application to release fish is worthwhile.

The expected benefits must be evaluated against the costs and potential risks. This may not be straight-forward as the risks will not be expressed in financial terms. In addition, stocking should be compared with alternative stock improvement strategies, such as habitat improvement or poaching controls, and particular attention should be given to the long-term effects.

6.5 Continuous assessment of the programme

One area which may call for specialist advice is planning the methods for evaluating the outcome of a stocking exercise. Such evaluation should, however, be considered as an integral part of the programme, and stocking should not be approved without it. Evaluation should be the responsibility of the stocking agency.

Once underway the programme should be kept under continuous review and the results of other similar stocking exercises noted. Those responsible should be prepared to terminate or modify the rearing or release programme at any time if adverse results or methods for improving return rates become apparent from the evaluation.

June 1991

7. APPENDICES

7.1 Glossary

adaptive value - the property of a given genotype when compared with other genotypes that affects the ability of an organism to survive and breed in a given environment.

allele - any one of the alternative forms of a specified gene.

bottle-necking - the process by which genetic frequencies may change due to biased sampling in small populations.

electrophoresis - the movement of charged molecules in solution in an electric field.

electrophoretic separation - the process by which different variants of a molecule bearing different electrical charges may be separated in an electric field. This technique is used to detect some genetic differences between individual fish.

gene - a unit of heredity in a chromosome which determines a specified difference between individuals.

gene flow - the spreading of alleles through a population resulting from cross breeding through repeated generations.

genotype - the genetic make-up of an organism as distinguished from its physical appearance (phenotype)

genetic drift - the process by which genetic frequencies may fluctuate due to random sampling of breeding pairs

genetic variation - measure of the variation between individuals of a population due to differences between their genotypes.

pathogen - any disease producing micro-organism or substance.

reproductive isolation - the absence of interbreeding between members of different populations.

7.2 The Salmon Advisory Committee

The Salmon Advisory Committee was established by Fisheries Ministers in October 1986. Its terms of reference are:

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

Membership:

Chairman: Professor G M Dunnet

Mr G H Bielby
Mr C G Carnie
Mr R M Clerk
The Hon Edward Davies
Mr J H Ferguson
Mr N W Graesser
Dr M M Halliday
Mr D Heselton
Mr A V Holden
Dr P S Maitland
Mr I Mitchell
Mr M J Morgan
Mr M Owens
Mr D R Paton
Dr J D Pirie
Dr D J Solomon
Mr W A C Thompson (until 15 February, 1991)

Previous Reports By The Salmon Advisory Committee

- "Information on the Status of Salmon Stocks", published in September 1988 (Ref No UR 145, price £3)
- "The Effects of Fishing at Low Water Levels", published in March 1989 (Ref No PB 0176, price £3)
- "Factors Affecting Natural Smolt Production", published in May 1991 (Ref No PB 0535, price £3.95)

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