Fisheries Research Services

Scottish Fisheries
Information Pamphlet
No. 22 2003

SALMON AND SEA TROUT

To Stock or Not?

ISSN: 0309 9105

Scottish Executive

Fisheries Research Services

Scottish Fisheries Information Pamphlet
No. 22 2003

SALMON AND SEA TROUT

To Stock or Not?

ISSN: 0309 9105

Scottish Executive

FOREWORD

Scottish salmon and sea trout rivers are amongst the best known in the world. Salmon and sea trout are an important natural resource and their fisheries play a major role in supporting the rural economy. When catches of salmon and trout decline there is understandable pressure to take immediate action. Stocking — the augmentation of natural production of salmon and trout by the addition of eggs or young fish reared in captivity — is one of the options available.

Stocking is intended to improve a fishery, and is best done as part of a management plan. The aim of stocking should always be to bring about a net increase in the numbers of adult fish on which fishing depends. To be effective, stocking must provide more fish. Ill-considered stocking however, (for example, that undertaken in the hope of short-term gain), may reduce numbers, and even threaten the long-term survival of fish stocks.

Advice on stocking is contradictory. Proponents raise expectations of large additional catches if the stocked fish survive. Critics emphasise the heavy costs set against the modest, if any, gains shown from past stocking initiatives, as well as the potential threats to health and genetic integrity of existing fish. What is clear is that stocking should only be considered as one of a number of possible courses of action.

In this pamphlet we consider the factors that should influence decisions on stocking and use our understanding of salmon and sea trout biology to help fishery owners and managers decide in what circumstances stocking may be appropriate. We also describe some of the other methods available to improve fisheries.

INTRODUCTION

What Factors Limit Natural Fish Populations?

Salmon and sea trout spawn and spend their early lives in fresh water before entering the sea to feed and grow more rapidly.

In fresh water spawning and nursery habitats are limited in extent, and set upper limits to the numbers of young salmon and sea trout which enter the sea each year as smolts. Whether or not these limits are reached depends mainly on the numbers and distribution of the eggs laid by the adult fish (Box 1).

Salmon go to sea on a long migration, lasting from one to three years, during which time they are very vulnerable. Sea water is a different medium and the ocean contains unfamiliar food items, and the fish are exposed to a range of new diseases, parasites, and predators, as well as commercial fisheries.

Studies on the North Esk indicate that the survival of salmon in the sea from the time of leaving the river to return to the river mouth varies from 30% at best to more typical recent levels of 5-10%.

Following the fate of the young fish derived from a specific spawning is difficult because the age the offspring may go to sea as smolts ranges from one to four years. Moreover, the adults may return after one, two or even three years at sea. The overall survival of wild fish between the egg and adult spawner, is very low, often about 0.04% in salmon.

Year-to-year variation in the numbers of smolts leaving a river, and in the proportion that survive to return as adults, is to be expected. Even in large, productive river systems, a threefold variation in annual salmon smolt production and even greater variation in survival at sea is quite normal. In contrast, a sustained downward trend in the proportion of smolts returning as adults reduces both the numbers of fish spawning, and the numbers of eggs laid, and, if this falls below a critical level, reduces smolt production. If the number of adult fish returning to the river remains low, or continues to fall, a sustained decline may develop. This may initially reduce fishing prospects and eventually result in the collapse of the stock.

Are There Separate Populations of Fish?

Salmon and sea trout are homing fishes. The adults tend to return to spawn in the streams where they hatched and spent their early lives. Many larger rivers and streams contain groups or ‘populations’ of fish with distinctive characteristics adapted to local conditions and to particular life styles, both in the river and the sea. Comparisons between fish populations at different locations have shown genetic differences between fish in different rivers, and even between fish living in different parts of the same river. Differences include their size and growth rates, marine migration pathways, run timing and the number of years that they remain at sea before returning to fresh water. These special characteristics have evolved over many generations and help ensure their survival. If their genetic integrity is altered by the introduction of different genes, their survival prospects may be impaired, meaning fewer smolts, less adult fish returning to the river, and poorer fisheries. The maladapted genes of introduced strains may persist within the population for many years.

The separation of fish into distinctive populations underpins the diversity of Scottish salmon and sea trout fisheries. The larger rivers in Scotland contain a wide range of salmon populations, living in different habitats. Their differing run characteristics, such as spring, summer, and autumn entry to the river, provide different fishing opportunities. The long-term survival of natural salmon runs depends on our retaining the diversity of fish that exist within our rivers.

What Methods Can Be Used To Improve Fishing Prospects?

Stocking is commonly considered when salmon and sea trout catches decline and takes place in fresh water, through the addition of eggs, fry, parr or smolts.

A range of other options for improving spawning, increasing juvenile production and thereby enhancing fisheries exists. These options include:

- Reducing exploitation of the returning adults;
- Opening up new spawning and nursery grounds through the removal of obstructions;
- Redistributing adult fish with similar characteristics from areas of surplus to areas of deficit;
- Improving spawning, nursery and rearing habitats;
- Improving feeding and growth opportunities for young fish.

STOCKING

What Do I Need To Consider First?

- ***Is the river system providing smolts at full capacity?***
  If it is not, the reason may be that adult fish may find access over a weir difficult. This could be rectified by providing, or improving a fish pass. If a shortage of adult fish is causing the under-production, you could use stocking to restore production. If, after full evaluation of the options, the decision is taken to stock, the major question is where to obtain the broodstock. In deciding whether to take adult fish from wild populations to act as broodstock for stocking, the first consideration must be whether there will be a net gain in smolt production and adult returns.

- ***Will the reduction in the number of eggs laid naturally in the river as a result of removing broodstock reduce smolt production?***

- ***Is this loss more than balanced by the survival of eyed-ova or young fish resulting from stocking?***

- ***Will the survival of the reared fish at sea match the survival of wild fish?***

Questions like these require knowledge of the structure and current status of the local adult fish populations and of the abundance and distribution of young fish. Usually, specialist advice, based on representative sampling, historical records and surveys is required. Many stocking schemes have either failed or compromised the survival of depleted wild populations because a short cut has been taken at this first stage.

Why Stock?

There can be four reasons for stocking:

- Restoration to promote the rapid recovery of natural populations which have been reduced in numbers, once the cause of the decline has been identified and removed;

- Enhancement to increase the number of fish returning to a fishery above natural levels of production;

- Ranching to produce adult fish through the release of reared smolts, with the intention of harvesting the fish which return to fresh water. (Ranching bypasses the restrictions the river imposes in producing juvenile fish);

- Mitigation where smolts may be released below man-made obstructions to compensate for a loss of rearing habitat that cannot be restored.

What Are the Main Methods of Stocking?

Stocking involves supplementing natural production with fish reared in captivity. There are five main methods:

- The planting-out of eyed-eggs and fry into nursery areas;
- The release of hatchery-reared parr into streams;
- The liberation of hatchery-reared smolts into rivers;
- The transfer of wild adult fish to under-populated spawning areas;
- The creation of 'put-and-take' fisheries by the release of reared adults of catchable size directly into rivers and lochs.

Where Do I Obtain Fish For Stocking?

Fish for stocking can come from a variety of sources:

- From eggs obtained by catching adult fish and removing them to a hatchery for stripping;
- From eggs supplied by District Salmon Fishery Boards for stocking purposes, taken from wild broodstock.

CONSEQUENCES OF STOCKING

Smolt rearing hatcheries can have a 90% survival rate compared with less than 1% in the wild. The advantages of using hatchery-reared smolts seem obvious, but stocking with these fish can be expensive.

There is a risk attached to taking fish from the wild to be reared in captivity. They have to be caught, transported, stripped of their eggs and their offspring reared successfully in an artificial environment. Stocking also has the potential to damage wild populations.

How Can Stocking Damage Wild Populations of Fish?

Stocking can harm wild populations of fish in a number of ways, for example by:

- Modifying the genetic characteristics of wild populations to make them less suited to local conditions in the long-term;
- Causing harmful competition with wild fish;
- Spreading diseases and parasites;
- Attracting predators;
- Increasing the exploitation of natural populations.

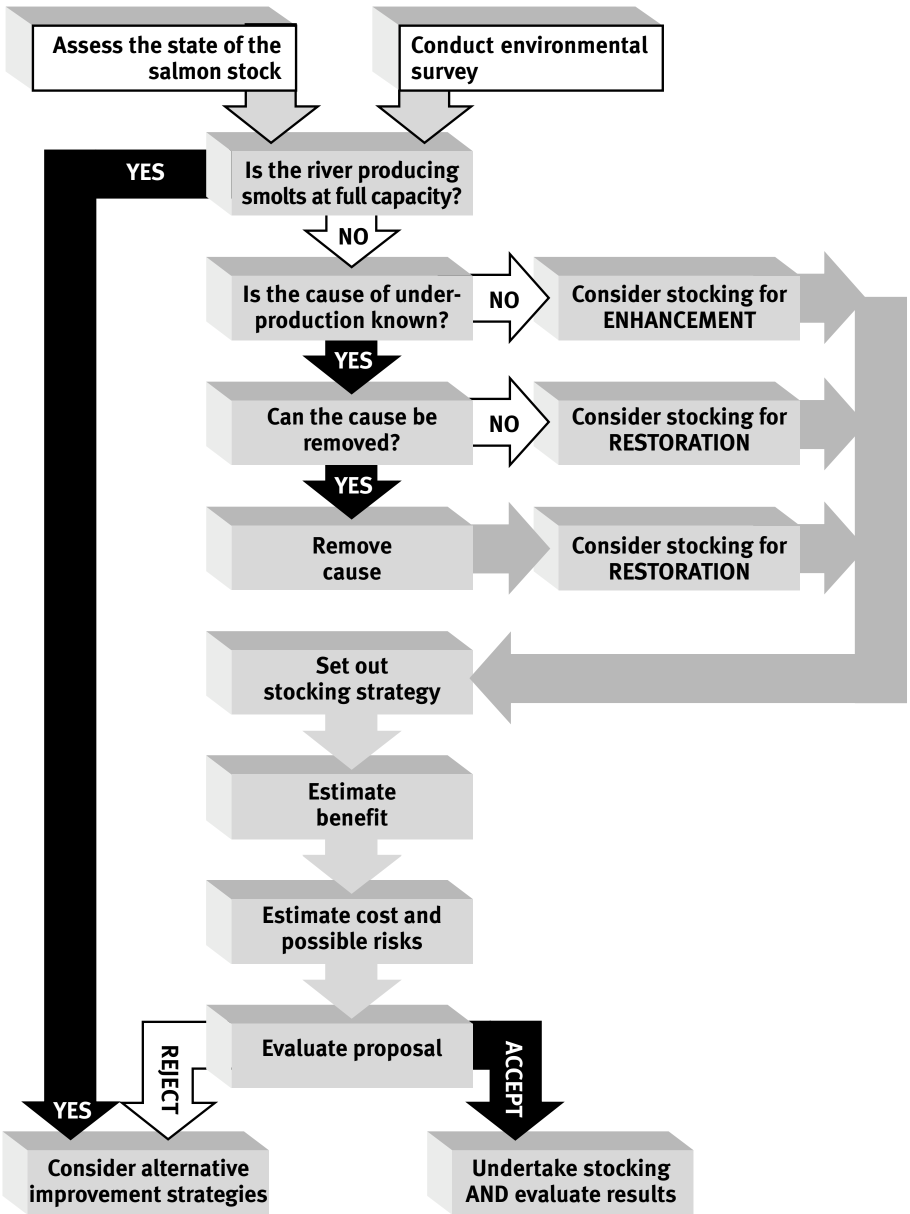
How Can Damage Be Avoided?

Before considering any form of stocking, it is essential to;

- Have a clear idea of the objectives;
- Consider all the options, including the alternatives to stocking;
- Seek to understand the causes of under-production and the prospects for improvement;
- Consider the need to reduce levels of exploitation on populations in decline;
- Evaluate the scope for improving juvenile production through improved access for spawning adult fish;
- Evaluate the scope for improving the productive capacity of accessible habitat through in-river and bankside improvement.

The first objective of any stocking exercise is to produce a ***net gain*** in the returns of adult fish to the fishery. This gain must be achieved without creating additional problems for wild populations already under pressure. The best way to achieve this result is to develop a clear stocking strategy (Figure 1).

Figure 1.
Stocking strategy *



*from SAC - 'Assessment of stocking as a salmon management strategy'. MAFF PB 0641.

Whose Permission Is Required Before Stocking Takes Place?

The permission of the local District Salmon Fishery Board is required before proceeding with stocking salmon or sea trout. In addition, if the stocking site is within an area designated as a Special Area of Conservation (SAC), permission will be required from Scottish Natural Hertage (SNH).

CHOICE OF EGGS AND FISH FOR STOCKING

What Precautions Must Be Taken In Choosing the Source of Reared Fish?

One of the greatest causes of damage from stocking lies in the choice of the eggs or fish to be used.

- Careful consideration is necessary before removing adult fish from areas where spawning and nursery habitat is plentiful and where fish spawn naturally. Survival of offspring under hatchery conditions is not always better than that in the wild. Moreover, rearing in the hatchery can change the genetic constitution of the population and the behaviour of individual fish. For example, released fish may be highly vulnerable to predators, which they fail to respond to in the normal way. Two questions to consider are: '*will a net gain in production be achieved by transferring wild fish to a hatchery?*' and '*will the young fish put back into the river survive as well as fish spawned naturally?*'

- Where salmon and sea trout taken from captivity are stocked in a new location there is a risk that they will carry diseases and parasites with them. There are many examples of natural fish populations being devastated by diseases and parasites introduced with stocked fish (Box 3). It is wise to insist that the fish to be stocked are certified as free from serious diseases and parasites.

- The fish to be stocked have similar biological characteristics to the native fish.

- The approval of the local District Salmon Fishery Board is required if salmon or sea trout are to be removed from a river outside the fishing season.

Where Do I Get the Broodstock?

Unless there is clear evidence of a shortage of spawning or nursery habitat, it can be counter-productive to obtain donor broodstock by taking spawning members of a depleted population from the river. These valuable fish are usually best left to spawn naturally. The only exception is if natural spawning is confined to a small area and dispersal of the progeny is insufficient to populate nursery areas fully.

Kelt rehabilitation offers a possible way forward. Here, fish which have already spawned are taken into captivity, cared for and fed, so that in succeeding years they yield eggs for stripping. It is a labour-intensive and expensive procedure. However, because such fish rarely spawn a second time in the wild, their transfer to captivity has the advantage of producing additional eggs of local origin without harming natural production. On some rivers, kelt reconditioning has been remarkably successful (Box 4).

Another possibility is to rear juveniles to adulthood in captivity and to use these on-grown fish as broodstock. Such a supportive breeding programme is likely to be especially important where adult broodstock are no longer available from the wild. It is also relevant when sea mortality is especially high so that the release of fish into the wild produces very few adult returns. This option is labour intensive and expensive, but its success is proven. A possible problem with this approach is that hatchery rearing induces artificial selection for certain genes and so affects the genetic constitution of the stock.

Is Local Broodstock Better?

Salmon and sea trout home to their native rivers to spawn and once there, they form more or less reproductively isolated populations. Several such populations may co-exist in our larger rivers where they often differ in such important characteristics as run-timing and sea age. There is increasing evidence that some of these differences, including the capacity to survive well under particular local conditions, are inherited. In undertaking stocking for restoration, enhancement and mitigation, the use of local broodstock is therefore very important. Broodstock taken from elsewhere may produce offspring with only poor survival under local conditions, and thus yield adult fish with very different characteristics to wild fish (Box 2 – Lessons from Spain).

What Is Meant By 'Local' Broodstock?

Within 10 km of the intended stocking site has sometimes been used as a rule of thumb for large catchments. However, this takes no account of physical or population boundaries. In large rivers, there is often a strong temptation to collect adults for broodstock from the lower reaches for stocking in upland burns. There is a risk of mixing fish from several populations and damaging those which are to be improved. If in doubt seek specialist advice from the FRS Freshwater Laboratory.

Surely People Have Been Moving Salmon Broodstock Around For Over One Hundred Years Without Doing Any Harm?

It is quite true that there have been many occasions, especially during the Victorian period, when attempts have been made '*to bring in new blood*' by using broodstock from other rivers or even countries. In most of these instances, the stocking was undertaken on a relatively small scale and in places where there was already a healthy wild population. The stocked fish were probably out-competed by the indigenous fish and no long-term harm was done.

Where fish are scarce there is a much greater risk of swamping depleted wild populations through the use of broodstock taken from elsewhere. Clear evidence of such long-term damage has now been obtained for a number of threatened salmon and trout populations. Choosing the right brood stock is the most important of all stocking decisions. Using local broodstock maximises the chances that the stocked fish and the wild ones are compatible.

Do ‘Springers Beget Springers’?

Spring-running salmon (springers) are multi-sea-winter members of more broadly based populations which include early-running grilse. There is good evidence that inheritance influences both run-timing and development rate. The extent to which early-running characteristics are expressed depends on environmental factors. In attempts to restore or enhance ‘spring runs’ it is important both to select local early-running broodstock and to plant out the stocked fish within or close to the normal range of early-running salmon in the river.

What About Selecting Broodstock for Sea Trout Stocking?

Sea trout are trout in which there is a strong inherited tendency to smolt before sexual maturation. In restoring or enhancing sea trout runs use a local strain and plant the stocked fish out in areas used by wild sea trout when the population was healthy.

METHODS OF STOCKING

What Are the Options for Stocking?

Given a suitable source of spawning adults, the main options available for stocking under Scottish conditions are shown in Table 1. This table lists each main technique and presents the arguments for and against.

Table 1
Arguments For and Against Different Stocking Options

Technique	For	Against
Move surplus mature adults to areas of low spawning activity.	Hatchery facilities not required.	Surplus fish must be found.
		Some fish may die during handling.
		The fish may leave the areas to which they have been moved.
		It may be difficult to transport adults to remote locations.
Planted eyed-eggs.	This life stage is robust and easily transported.	Broodstock are required.
	High survival may be achieved if stocked at low densities.	A hatchery is required.
Stock unfed fry.	Less sensitive than eggs to acid flushes and redd washout.	Broodstock required.
		Hatchery required.
	High survival if stocked at low density.	Short time window of only about one week for stocking out.
Stock fed-on fry/parr.	There is a longer time window for stocking out compared to unfed fry.	Broodstock are required.
		Both rearing and a hatchery are needed.
Stock smolts.	There may be no competition with naturally occurring parr.	Large-scale rearing facilities are required.
	Easily stocked.	There may be poor performance after release.
	Predation on wild smolts may be reduced.	Many of them return as grilse or, if sea trout, mature as brown trout.
		Fishery for stocked fish may over-exploit native fish.
		Predation on wild smolts may be increased.

What Will the Results Be?

Expectations should be modest and realistic. As a general rule, the longer young fish are held in a hatchery the poorer their survival will be when they are returned to the wild. The stocked fish will also deviate from their wild kin in such characteristics as growth-rate, sea age at return and run-timing. Poor relative survival after release may result from the inexperience of the stocked fish. They will be less adept at finding shelter, gathering food, and avoiding predators.

There is evidence from studies in Ireland and Scotland that hatchery-reared salmon smolts are more inclined to return after one sea-winter as grilse rather than as multi-sea-winter salmon. This is probably because the greater feeding opportunities in the hatchery speed up the early stages of sexual development. Also, if the poor early marine survival of hatchery smolts continues throughout their lives at sea, the returning population will be dominated by fish exposed to the higher losses for the shortest time, which are grilse. In the case of sea trout, generous hatchery feeding may trigger maturation and lead to the production of a high proportion of freshwater-resident (brown) trout. As with salmon, poor sea survival has its greatest effects on the older sea age fish.

WILL STOCKING MAKE A DIFFERENCE?

Enhancement

To the angler on the riverbank the purpose of stocking is to improve fishing results. If the purpose of stocking is to enhance already healthy populations, then it must raise the local abundance of salmon and sea trout above the normal range of natural variation. Such an increase is difficult to achieve because the carrying capacity of the river is limited. Any gain is likely to be small.

Instances where true enhancement has been achieved are rare in Scotland, mainly because most Scottish rivers are rich in spawning and nursery habitat, and naturally sustain large numbers of young fish. It follows that, for the effects of stocking to be readily detectable without recourse to tagging or marking, the stocking operation has to be very large.

Restoration

Stocking that is intended to restore declining wild populations is usually undertaken in conjunction with other measures intended to halt the decline. Deciding whether stocking has been successful can be a problem. Nevertheless, an assessment of the results of the whole exercise should be attempted.

Assessment

Predicting whether or not a stocking exercise is likely to meet its objectives is an important part of planning.

- Assess the state of spawning stocks, either through use of a fish counter, by trapping fish, or through redd counts.
- Measure the numbers and distribution of young fish in the population to be augmented.
- Consider the scope for safe and effective stocking and therefore the likelihood of making a detectable improvement to the fishery. Many realisable stocking exercises will be too small in scale to make a readily apparent difference to angling success.
- Be realistic in assessing the gains to be achieved. In many instances stocking may simply provide an additional safety margin for a population.
- In all instances of stocking, it is good practice to mark or tag a representative sample of the stocked fish to evaluate the success of the exercise and inform future plans.

WHAT ARE THE ALTERNATIVES?

Is Ranching A Good Idea?

Ranching involves the release every year of large numbers of smolts reared in captivity. The return rates in some circumstances can be good. The main problem is that the fish have spent their early lives in a hatchery. The survivors are those best adapted to hatchery conditions. Moreover, their rearing history will influence their behaviour and survival at sea, and the timing of their return. Such fish are not a good source of broodstock for restocking an extensive and complex river system. The main role for ranching is to take a small unproductive river system and provide a much larger return of fish than is possible naturally. The process is a continuing one, with stocking having to be repeated year after year because natural capacity can never produce large numbers of returning fish.

What About Broodstock for Ranching?

As with other forms of stocking, broodstock of local origin is probably the best starting point for ranching exercises. There is good evidence, especially from Ireland and Iceland, that using the returned adults from one generation as the broodstock for the next does improve return rates. This improvement may build up over several generations.

The improved returns achieved in this way demonstrate the effects of local adaptation. However, the rearing conditions which give rise to such ‘ranched strains’ are very different from those which prevail naturally in the river. It is therefore vital to ensure that all the fish returning to ranching operations are re-captured and do not mix with wild spawning populations in the vicinity. The aim should be to remove all the ranched fish before they enter the river. Returning fish may stray to other rivers, and these should also be removed to prevent them spawning with wild fish. The management of a ranching operation must therefore extend beyond the river being stocked. What this means in practice is that ‘ranching to the rod’ is not a biologically sound way of enhancing or restoring a normal productive salmon river.

What About Broodstock for Mitigation Stocking With Smolts?

When stocking smolts to mitigate losses of spawning and nursery habitat above a man-made obstruction, the use of local broodstock is essential. This is because returning adults derived from the stocking will inevitably mix with the naturally produced fish below the site of the obstruction. If non-local broodstock is used, there is a danger of contaminating the wild stock with poorly adapted genetic material.

It is particularly important to avoid using ranched strains in mitigation stocking, even if they were originally derived from local broodstock several generations before. This is because the selection processes in the hatchery which give rise to ranched strains are unlikely to promote good survival when the progeny of such fish are exposed to the full rigours of life as young fish in the river.

How Many Broodstock Fish Do I Need?

The objective in choosing broodstock is to retain as much locally adapted genetic material as possible, whilst retaining sufficient variation to avoid the deleterious effects of in-breeding. Each case is different and specialist advice should be sought at the planning stage from the FRS Freshwater Laboratory.

Where Can I Get More Information on Kelt Reconditioning?

Reconditioning kelts is an effective way of making the most of scarce broodstock. In Scotland the technique was jointly pioneered by the FRS Freshwater Laboratory and the Tay District Salmon Fisheries Board.

Kelt reconditioning enables the fishery manager to make repeated use of adult fish that would otherwise have died after their first spawning. The technique is demanding and labour intensive, and raises genetic as well as rearing issues. Specialist advice is essential before undertaking kelt reconditioning and is available from the FRS Freshwater Laboratory.

ASSESSING STOCKING OPTIONS

We Can Only Afford To Spend So Much on Stocking — Which Method Gives the Best Return?

The earlier in the life cycle that intervention takes place, the lower the unit cost of each young fish produced, and the less likely it is to differ from a wild fish.

Table 2
Success Rates for Stocking

Table 2.1.
Total reported recaptures within the Tay system of young salmon released into its Braan tributary, 1989-1997.

Stage stocked	Stage tagged	Nº released	Nº recaptured	% recaptured
Unfed Fry	1+Parr (autumn)	14,000	164	1.17
Unfed Fry	Smolts	253	15	5.93
Hatchery Smolts	Smolts	21,000	63	0.30

Table 2.2.
Total recaptures within the Lochy (Argyll) system of cage-reared S1 smolts released in 1987 and 1989.

Year	Nº released	Nº recaptured	% recaptured
1987	5,000	4	0.08
1989	5,000	2	0.04

Table 2.3.
Total recaptures within the Lussa District (Mull of Kintyre) of ranched smolts released in 1985.

Year	Smolt type	Nº released	Nº recaptured	% recaptured
1985	S1	8,355	175	2.1
	S2 (immature)	2,325	33	1.4
	S2 (mature)	1,418	9	0.6

S1 = smolt which was released in the spring 1 year after hatching.
S2 = smolt which was released in the spring 2 years after hatching.

Eyed-Eggs

The planting of eyed-eggs is a low intervention method, which requires minimal hatchery facilities. Eyed-eggs are tough and there is a period of several weeks during which planting out can be undertaken. Experience in Scotland and elsewhere has shown that, when eyed-eggs are planted out at low densities (one or two eggs per square metre at most), in habitats which contain no or few other young salmon, survival levels can be high (up to 50% to the end of the first growing season).

Unfed Fry

Unfed fry have many of the advantages of eyed-eggs, being easily carried and dispersed into streams. They have a further advantage in that they are less sensitive than eggs to acid flushes. The levels of survival are comparable with eyed-eggs provided the receiving habitat is well chosen. The main disadvantage with unfed fry is the short time period available for planting them out. This can be a problem if river conditions are poor at the time, or if a large stocking exercise has to be undertaken by a limited number of people. Unfed fry have higher oxygen requirements and are less robust than eyed-eggs. For these reasons they are more difficult to transport. It is essential to stock out unfed fry before their reserves of yolk are completely exhausted otherwise starvation can occur while external feeding is learned. As with eggs, it is very important to plant fry out at low densities and to avoid the temptation to 'dump' large numbers of fry at places such as bridges or beside roads simply because they are easy to drive to.

Young Fish

Feeding fry in the hatchery after yolk sac resorption, adds to hatchery costs and runs the risk of compromising the later development of the fish. The longer the period of feeding, the more these disadvantages are likely to be felt. As with unfed fry, high initial survival is achievable at well-chosen sites throughout which the young fish have been carefully dispersed at low density. There are two advantages of a short period of on-growing in the hatchery.

- An increase in the time period for stocking.
- Higher survival rates can be obtained by allowing the fish to reach a size at which they can occupy a wide range of habitats within the river.

Feeding fry requires specialist skills, if done badly it can lead to high death rates.

Holding young fish for longer periods (until autumn or even smolting) incurs high hatchery costs and runs serious risks of producing fish which differ substantially from wild fish in post-release survival, sea age at return and, perhaps, run-timing. Stocking with fish held for long periods in a hatchery is probably justifiable only for mitigation purposes, or where a supportive breeding programme is underway (that is, where fish are being taken right through to full maturity in captivity).

What Happens Later — How Many Of Our Stocked Fish Will Come Back As Adults?

Estimating the efficacy of stocking in increasing adult returns is usually judged by marking a proportion of the stocked fish in a way which provides certain identification. This is best done from the parr stage onwards.

If eyed-eggs or fry are the life stages stocked, it is still possible to mark samples obtained by electrofishing at the parr stage. A temporary trap downstream of the stocked site provides the opportunity to tag fish later in their lives at the smolt stage.

For instance, in a recent study by the FRS Freshwater Laboratory, over 1% of unfed fry stocked into tributaries of the River Braan in Perthshire and micro-tagged in their first autumn were later recaptured as adults in the Tay nets. For fish with the same stocking history but marked at the smolt stage (i.e. after all losses at the parr stage had taken place) the corresponding figure approached 6%. By contrast, recaptures of hatchery-reared smolts of local origin carefully reared at low density at the Almondbank hatchery, were only 0.30%. That is to say, only three adults were recaptured for every 1,000 smolts released.

All of the figures above are based solely on reported recaptures and contain no estimate of the numbers of marked fish which returned, but were not reported. In making decisions based on tag return data, estimates of tag loss rate, tag reporting rate and fishing effort are also required. All of these factors are river-specific.

What About the Good Results Achieved In Some Ranching Exercises?

Results published to date show that the success of ranching exercises varies greatly in levels of return. Survival usually falls well short of that for wild fish. Periods of low sea survival affect ranched as well as wild fish.

Ranching is the most expensive form of stocking and, for the ecological reasons indicated previously, it is not a valid management option in a productive river which already contains wild salmon.

Some salmon rivers in both Ireland and Iceland have been operated as salmon ranches. Smolts are produced at high unit cost using mostly ranched strains. The resulting adults return mainly as grilse and survival varies (among operations).

Two attempts have been made to ranch salmon in the west of Scotland (in the Mull of Kintyre and the Western Isles). The returning fish consisted principally of grilse, and in neither instance did the levels of return justify the heavy financial investment. In the case of the Mull of Kintyre operation, a high proportion of the recaptured fish came from the Irish drift net fishery.

What About Surplus Smolts from Fish Farms?

Surplus smolts can often be obtained from fish farms. The strains used in aquaculture are the result of intensive selection under fish farm conditions. Micro-tagging experiments have shown conclusively that the survival rate of fish farm smolts in the wild is extremely low.

The use of fish farm smolts in stocking also risks the transfer of diseases and parasites and the creation of a 'honey pot' for predators. In both instances, the welfare and survival of wild fish is put at unnecessary risk.

Do We Need Management Plans — Can't We Just Get On With It?

- Stocking is only one of the tools available to fishery managers to restore or increase fishing opportunities. The decision as to whether or not to stock should not be taken in isolation, but as part of a broader plan for the management of the fishery as a whole. Such a plan should consider all the possible options. These include altering the level and distribution of fishing, improving access for spawners, controlling predators and upgrading the spawning and juvenile habitats already accessible.

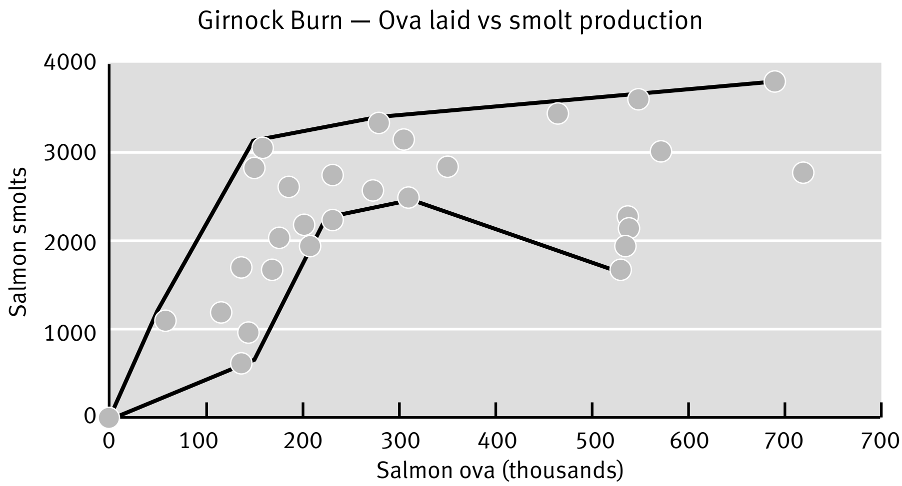
- If the decision to stock is taken, critical-minded planning at all stages from the initial habitat surveys to final evaluation is the key to success. The choice of broodstock, the adequacy of the receiving environment and the life stage and stocking protocol chosen can greatly affect the outcome. Specialist advice in all of these areas is available from the FRS Freshwater Laboratory.

- Evaluation of the size and diversity of the natural fish populations, relative to the numbers of fish to be stocked, is a vital step in the planning process. It is the only way of estimating the benefits likely to be gained through stocking.

- Stocking can do harm as well as good, and ill-considered stocking exercises can have a deleterious effect on the wild resource. Careful planning in the light of specialist advice is the way to avoid falling into this trap.

BOX 1

Figure 2 shows that the numbers of smolts derived from each year's spawning in a particular stream are limited by egg numbers, up to a total of some 300,000 eggs. Adding more eggs does not increase smolt production because of the limits set by the amount of space and food in the Girnock Burn. Year-to-year variation in smolt production per brood year is influenced by the distribution of female salmon at spawning time and by such factors as temperature and rainfall during the years over which the young fish grow to the smolt stage. In any one year, the population of smolts that goes to sea includes members of several brood years (1-4). This 'sharing' of the smolt population between brood years smoothes out year-to-year variation in the success of spawning in particular years. Provided spawning stocks are healthy, the full potential of the stream is generally achieved. Only when the numbers of adult fish are significantly reduced does the stream fail to reach its carrying capacity.



BOX 2

Lessons from Spain

Between 1971 and 1992, in an attempt to enhance the severely depleted native populations, millions of Atlantic salmon eggs were exported at great expense to Spain for stocking into local rivers. In 1992 this stocking stopped as the evidence increasingly showed that it had failed to improve salmon runs cost-effectively and that interbreeding of any fish which did return with the native stock could have negative consequences for population viability.

Analysis of adults returning to two Spanish rivers, the Ason and the Nansa, between 1984 and 1988 showed that ova of northern European origin planted out were largely unsuccessful in contributing to the fishery. The return rates meant that each non-native fish caught in the fishery cost a minimum of at least £1,000 (in 1999 currency units) in the cost of eggs alone. This would perhaps be doubled if the costs of hatcheries and planting out were also taken into account.

The poor returns to the fisheries could have two causes — poor juvenile survival or poor marine survival of post-smolts or maturing adults. An EU funded study showed that inferior freshwater performance of the non-native fish is at least part of the story. Survival of eyed Scottish ova planted out under identical conditions with native Spanish ova in the River Ulla showed that while Scottish salmon hatched at a bigger size and grew faster than native fish in the first year of life, by the time of smolting the following year there was no difference in size. However, survival of non-native juveniles was much lower and smolt production from native ova was in the order of 2-10 times greater than from the non-native stock. The results showed that the native stocks, during the juvenile freshwater phase of development at least were superior in their adaptation to local river conditions.

BOX 3

Diseases and Parasites

Moving fish from one area to another carries a high risk of transferring infection. Unless fish are reared in totally protected waters, they will be exposed to a wide range of locally endemic infections. There is an axiom "*fish which share waters share their diseases*". Moreover, fish from different waters can carry a different range of diseases. When fish are transferred from one area to another for stocking they will take their diseases with them. In general, a lower risk attaches to moving eggs rather than live fish, and the risk is further reduced if the eggs are disinfected with *Buffodine* immediately post-fertilisation and again at the time of transfer.

There are many examples of serious infections being transferred with fish, particularly from one area to another. The current widespread distribution of the bacterial disease furunculosis in Norway is associated with a spread from introduced smolts of foreign origin. Indeed, furunculosis, which is now endemic in many UK rivers, also appears to have arrived in Britain with introduced fish in the early part of the 20th century. The parasite *Gyrodactlylus salaris* which has devastated wild salmon stocks in a number of Norwegian rivers, appears to have been introduced to that country with fish from the Baltic rivers. Though native salmon from the Baltic rivers have a high resistance to infection by this parasite, Norwegian and Scottish fish do not.

Other fish diseases which have been spread with the movements of fish or eggs include spring viraemia of carp (SVC), brought into the UK from China, the spread of infectious haematopoietic necrosis (IHN) in rainbow trout throughout continental Europe, and the current spreading of epizootic ulcerative syndrome through the Asian subcontinent associated with the culture of ornamental fish.

The only measure of protection which can be provided against the transfer of specific diseases is to have the health of the fish tested before they are moved. Do not accept verbal assurances that eggs or fish come from 'tested' stock. Ask to see recent and historical health records relating to the hatchery or river and discuss these with the laboratory that carried out the testing. Such testing does not provide full protection, as only a representative sample of fish can be tested, and current disease tests may not detect the lowest levels of pathogens.

BOX 4

Kelt Reconditioning

The reconditioning of Atlantic salmon kelts has been practised on a small scale in both North America, Canada and Western Europe for about 20 years. Adult salmon can be reconditioned, and matured repeatedly in successive years, without needing to return to sea. Some fish have been reconditioned and spawned for more than ten successive years.

Kelt reconditioning is a technique that should be used primarily to maximise egg production from valuable stocks of salmon whose falling numbers are giving cause for concern. Stocking with progeny from reconditioned kelts should be undertaken cautiously. Every effort should be made to maximise genetic diversity by using multi-way crosses at stripping and not using the same crosses in successive years.

Collecting Adults

It is important that the appropriate stock of salmon is collected to be reconditioned. For example, early-running spring salmon are considered desirable in most river systems but their numbers have declined severely in recent years.

Autumn Collection

Fish are best collected from a known spring salmon- producing tributary after they have spawned. Fish caught in the autumn in this way may not necessarily be early-running salmon, it is therefore important to choose a tributary with a reliable history of spring fish runs that is at the head of the river system. Only fish that are completely free from abrasions and fungal infections should be kept and they should be checked regularly for any sign of infection.

Spring Collection

Anglers are often willing to donate fish caught early in the year (before May) to a reconditioning programme. Care must be taken when handling and transporting such fish to the holding site. Fish collected in this manner are of known run time, but if the river is large and has sub-stocks, then the destination tributary and thus the sub-stock will be unknown. Once at the holding site, it is important to keep disturbance to the fish to an absolute minimum and to treat them with anti-fungal agents as soon as any infection is seen.

Feeding

Introducing kelts to artificial food begins as soon as possible after capture. Depending on the holding facility, it is useful to be able to extend the day length to 12 hours as this stimulates the feeding response, even when the water is cold. In the FRS programme at Almondbank, the food consists initially of whole prawns, sprats and sandeels, but changes later to a moist dough made up of pureed fish, fine commercial salmon fry food and added oil, pigment, minerals and vitamins. Salmon caught early in the year and kept in tanks until the autumn before spawning are easier to start feeding than those caught as kelts. These early caught salmon are in better condition after spawning as they have not experienced the rigours of an upstream migration, and have higher body reserves. Autumn-caught spring salmon kelts have low body reserves, as they may not have fed for twelve months, and take longer to feed freely.

The fish are initially encouraged to take whole prawns from the tip of a long pole by holding the prawn just upstream of the fish and moving it to provoke a feeding response. Once they have taken food offered in this way they will then move actively to seize the food from the tip of the pole and then take food items drifting freely in the current.

Feeding continues at a low level throughout January and February, introducing small sprats and sandeels to the diet to give variety. By the end of February, the intake of food increases noticeably and it is important to feed the fish as much as they will take, two or three times a day. The introduction of moist feed is started in March and fed to appetite three times a day. The daily intake increases each month until the end of May when it decreases and continues to fall to July when the maturing fish stop feeding altogether. Fish that continue to feed through August and September will not mature that autumn, but will do so the following year.

Disease Control

Minimising stress is the one major factor in maintaining healthy, newly caught, brood stock over long periods. Keeping tanks shaded or even dark, with minimal disturbance to the fish is the first step to preventing disease.

When wild fish are brought to the holding facility they should be given a dose of furunculosis vaccine to protect them during the year. Booster doses are given each year just after stripping. Routine baths of anti-fungal and bactericidal agents should be given twice weekly for two to three weeks after capture to keep the fish free from infection. Subsequent treatments need only be given when signs of infections are seen. Whenever the fish are examined or handled for stripping they are anaesthetised lightly, making handling less stressful.

Spawning

From mid-October the female salmon are examined regularly to assess maturity and ovulation. Males are usually mature from October onwards. Stripping is carried out in the traditional manner, but the ova from each female fish are split into several batches and each fertilised by different male fish, and then recombined for incubation. This procedure ensures greater genetic variation within the fry than when the ova from a single female are fertilised by mixed milt from two males. Directly after stripping the fish are given a broad spectrum, long-acting, antibiotic, and a dose of furunculosis vaccine before they are returned to the tanks to start the cycle once more.

Fisheries Research Services is an agency of the Scottish Executive
FRS Marine Laboratory PO Box 101 375 Victoria Road Aberdeen AB11 9DB UK
tel +44 (0)1224 876544 fax +44 (0)1224 295511
enquiries@marlab.ac.uk http://www.marlab.ac.uk