THE AST/IFM SALMON POPULATION MODELLER

Introduction

There are constant discussions among salmon anglers – and in the angling press – about such issues as the decline in salmon stocks, how stocks should be restored, whether catch and release makes a significant difference, or would stocking help? Too often, though, the points made show a lack of understanding of how salmon populations work i.e. the relationship between the number of spawning fish, the number of juveniles they are likely to produce, and how many of these are likely to survive, and, in their turn, spawn. It is to help anglers, and all those interested in salmon, to understand these relationships better that the AST and the IFM have commissioned their Salmon Population Modeller. This web-based demonstration tool is designed to provide anglers, managers and everyone interested in salmon with a clearer understanding of how salmon stocks work (stock dynamics) and what the constraints are on increasing salmon numbers. It is intended to illustrate typical levels of loss at the different stages of the salmon life cycle, and the impact that changing these can have on the viability of the stock.

The Modeller is based on a notional pristine river stock, and the survival rates shown are typical of many British and Irish rivers. The Modeller can show either a grilse only stock, or one with both multi-sea-winter (MSW) fish and grilse.

The Modeller uses a notional pristine stock because all stocks in Britain and Ireland are impacted to varying extents by human activities, and it would be very difficult to come up with a typical impacted stock. Using a theoretical pristine (i.e. unimpacted) stock as the base line for the Modeller makes it possible to illustrate the effects of impacts at different stages. It is then possible to show the effect of reducing the losses caused by these impacts by reversing the process.

The number of salmon that return to a river is affected by the conditions that the fish face throughout their lives. Under completely stable conditions the population would be expected to reach an equilibrium state where the numbers at each life stage will, on average, be the same from one generation to the next. A change to a new set of conditions would cause the population to move to a new equilibrium state after several generations. In real life, numbers of even a stable stock will fluctuate, sometimes dramatically, from year to year, but the Modeller removes this year-to year variation to show how a typical stock is affected on average by changes in survival at different stages.

The Modeller allows impacts to be imposed at different stages in the life cycle, simulating, for example, the effects of a dry spring resulting in reduced survival of emigrating smolts or a dry autumn preventing some adults from reaching the spawning areas. It also allows the amount of available spawning and parr habitat to be increased or decreased.

The Salmon Life Cycle

Spawning

Salmon, in common with many fish, produce large numbers of eggs. As a rule of thumb, a female produces 600 eggs per 1lb weight, so an 8lb female will produce around 5,000 eggs. Because the number of eggs increases with body size, multi-sea –winter (MSW) fish produce considerably more eggs than do grilse.

The Juvenile Phase (Fry and Parr)

The numbers of eggs that hatch and of fish that survive their juvenile phase, from swim-up fry to smolting parr, are dependent on the extent and quality of the river system's spawning and juvenile habitats. Salmon need suitable areas of clean, well-oxygenated gravel to spawn, and pools and riffles for their fry and parr to survive and grow, and the number of fry that survive to become smolts will be limited by the extent of suitable habitat at different life-stages, most notably the parr stage – a river's carrying capacity. As the young parr grow, they compete for space and the weaker ones are pushed out, to starve or be eaten by predators. Provided that the number of spawners does not fall below the number needed to produce sufficient eggs, increasing the number of spawners will not automatically boost smolt numbers. For this reason, the best way to increase the number of parr that become smolts is usually to increase the amount of suitable habitat, by improving its quality or by opening up previously inaccessible stretches. Conversely, because female salmon produce large numbers of offspring, if conditions in a river improve, and more habitat becomes accessible or a source of pollution is removed, juvenile numbers can increase very rapidly.

The relationship between numbers of spawners and smolt numbers can be demonstrated with the Modeller. In pristine conditions there is normally a large surplus of spawners and eggs, so substantial reductions in egg to parr and parr to smolt survival have a limited impact on the number of smolts that leave a river, and so on the number of adults that return. For example, reducing egg to parr survival by 20% (an impact of -20%) has little effect on smolt numbers, and even a 50% reduction reduces the number of smolts by only around 12 %.

Of course, a river's carrying capacity is not fixed; for example it will vary depending on river flow. Low flows may in the autumn reduce the area of spawning gravels that is accessible to spawners or in the summer reduce the area of juvenile habitat. But the basic principle remains valid that it is not possible to increase the number of parr in a river beyond its carrying capacity.

Downstream (Smolt) Migration

Once the smolts begin their downstream migration, the situation changes radically. Up to this point, the critical factor in the number of parr that survive is the availability of suitable habitat. From now on, there are no carrying capacity constraints**; losses directly affect the number that will return as adults**. Percentages for marine survival are usually based on the number of smolts that leave a river[1], but losses before then can be high. In rivers in their natural state smolts migrate downstream rapidly to minimise predation. Anything that delays them, such as barriers, can expose them to increased losses from predation. Hydropower installations may pose a particular problem through such losses and damage from turbines. Delays also increase stress on smolts, which can adversely affect their physiological adaption to salt water, and so their chances of survival at sea. Some chemical contaminants can also affect the ability of smolts to adapt to and survive in sea water. All these problems may be exacerbated by low flows. On many rivers, plans to improve fisheries place too much emphasis on increasing the number of spawners, without ensuring that there is habitat for the parr and that smolts can leave the river and adults return to spawning areas freely. In many cases putting effort into increasing smolt survival (by, for exampling, tackling barriers to downstream migration), may be the most effective way of improving, or at least stabilising, salmon numbers.

The Marine Phase

The marine phase starts when smolts leave the river and lasts until they return, one, two, and in exceptional cases three or even four, years later. Fifty years ago losses at sea were relatively low, and as many as one smolt in four, or 25%, might survive to return as an adult, but losses have increased dramatically, and survival can now be as low as 5% (and sometimes lower) or one fish in 20 .To put these survival percentages in perspective, they mean that in the 1960s a river producing 100,000 smolts would get a run of 25,000 adults; now, the same number of smolts would produce only 5,000 adults. In reality, most salmon stocks have not declined by 80%, but these figures illustrate the potential impact of declining marine survival on numbers of returning adults.

The Modeller clearly demonstrates this impact. Increasing marine mortality by 10% reduces the numbers of returning grilse and salmon by 20%, and a 25% increase almost halves numbers of returning adults. Again, though, the impact on smolt numbers is limited, showing the resilience of salmon stocks in pristine conditions. However, with lower marine survival it only takes a relatively small reduction in

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[1] Please note that the Return Rates shown in the Modeller in the Salmon at Sea box represents the proportion of smolts that **start** their migration in freshwater that return as adults and so is not directly comparable with traditional marine survival rates. These are generally calculated from the point where smolt numbers are counted, which may be some way upstream of the estuary.

juvenile survival before a population becomes unsustainable, for example a 25% increase in marine mortality linked to a 12 % reduction in parr to smolt survival.

This increase in mortality at sea is one of the main factors driving the fall in salmon numbers across their range. It seems clear that the principal cause of this reduced sea survival is changing oceanic conditions, with warmer water, and changes in plankton numbers and types

There may be other factors involved. Possible culprits include the effect of fish farms, by-catches of salmon and post-smolts in pelagic and other fisheries and increased levels of predation. None of these are likely to be the principal reason for the general decline, which is too widespread to be linked to any local cause. But they are all worth addressing, as any reduction in marine mortality will increase the number of salmon that return to the coast.

The Return to Coasts and Rivers

The final phase of the salmon's life cycle is the return to coastal waters and to its river of origin. In the past losses, particularly in coastal waters could be high – in 1970 nets in English and Welsh waters caught up to 125,000 fish a year. Closures and buy-outs of net fisheries have greatly reduced these losses. Similarly, the widespread practice of catch and release has meant that well over half of rod-caught fish survive to spawn. Nevertheless, leaving aside losses to rods and nets, there are still other sources of mortality. Low flows, sometimes accentuated by abstraction, can prevent salmon from entering fresh water, which can lead to substantial losses in estuaries. Barriers, even when they don't prevent upstream migration, can reduce the number of fish that succeed in reaching their spawning grounds.

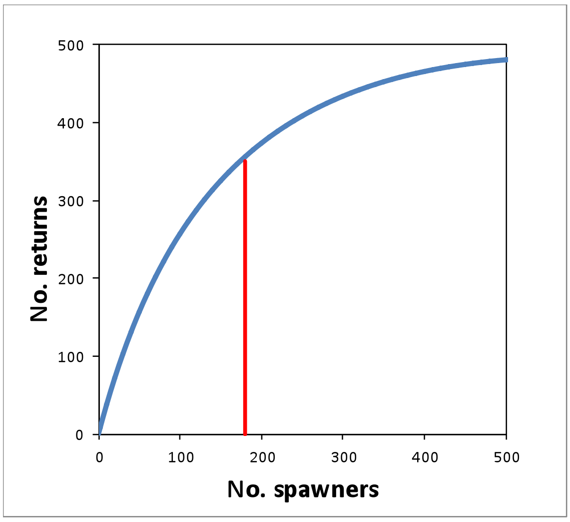
There are a range of measures that can be taken to reduce these impacts and so increase the numbers of spawners, including boosting catch and release rates. On those rivers that are consistently below their conservation limits (see below), action to increase the number of spawners is essential..

Conservation Limits

The principle of conservation limits is widely accepted internationally, and their use is strongly supported by NASCO, the international organisation dedicated to the conservation of Atlantic salmon. Conservation limits are a key element in the management of salmon stocks in nearly all countries with salmon rivers. If the number of salmon returning to a river consistently falls below its conservation limit, the stock will be under greater threat of collapse.

Conservation limits for rivers are worked out using complex statistical methods, but the principle underlying them is quite simple. It is based on the relationship between the number of spawning adults in a river and the number of their offspring that survive to spawn in the next generation. This relationship, though, is not simple; for example a doubling in the number of spawners in one generation will not normally result in a doubling in the number in the next generation.

The graph shows a typical example of the relationship, with the number of spawners along the bottom and the number of returns from their offspring in the left-hand side.



As can be seen, when the number of spawners is low, a small increase can result in a rapid improvement in the number of returns. At higher stock levels however, this increase flattens out, as the entire juvenile habitat is used. The conservation limit is fixed where the curve begins to flatten out (the red line); this is because once spawner numbers fall below this point the number of offspring that are produced begins to decline rapidly. To keep a salmon stock in a river in a healthy condition it is obviously sensible to aim to keep numbers well above the conservation limit. There are also good conservation and management reasons for aiming to maintain a higher number of spawners. A larger spawning stock will help maintain genetic diversity, and will also provide resilience against natural disasters such as floods and droughts

In reality, salmon numbers fluctuate widely from year to year, reflecting changing conditions in rivers (low flows, floods, etc.) and at sea, so failing to meet a conservation limit from time to time is not a cause for real concern. In England and Wales there is also a higher ‘target’ level, the Management Target, which is the stock size that needs to be aimed at to ensure that a river exceeds its Conservation Limit in 4 years out of 5; on average, the Management Target on a river is typically around 35% higher than the Conservation Limit.

Useful web links:

Management:

The Code of Good Practice for Freshwater Fisheries Management 2012: Part 1: Salmon and Brown Trout. https://ifm.org.uk/wp-content/uploads/2016/02/IFM-Final.pdf. In the autumn of 2012 the Scottish Branch of IFM published this code, which fills a very important void in terms of explaining the basic biology of salmon and trout populations and the fundamentals of salmonid fisheries management. This article draws heavily on it.

Details of the way Conservation Limits are calculated and implemented in England and Wales can be found in Annex 7 of the **ANNUAL ASSESSMENT OF SALMON STOCKS AND FISHERIES IN ENGLAND AND WALES** https://www.gov.uk/government/publications/assessment-of-salmon-stocks-in-england-and-wales