ATLANTIC SALMON

Decline or Extinction?

A paper discussing the decline of the Atlantic Salmon

and the future implications of Climate Change

set against the historical context of the River Wye

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FOREWORD

It was when I was asked by the Trout & Salmon Magazine to review Peter Gray's book "Swimming Against The Tide" that the idea for this Paper came to fruition. Gray's book makes the practical case for Hatchery enhancement crystal clear, but it is not happening; this is not to say that the Hatchery process is without problems – it clearly isn't.

The purpose of this Paper is to look objectively at both the evidence and the emotive issues which surround this debate. The long decline of the River Wye provides an informative historical context within which to explore these issues.

I come to this debate about the future of the Atlantic salmon primarily from the perspective of a passionate salmon fisher, but I own a small Trout Fishery, where I have also bred trout for 27 years. I am not a scientist, but I take a keen interest in the subject; however, any opinions expressed must be viewed as personal and unqualified.

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ABSTRACT

The managing authorities of England & Wales, and several of the Scottish River Boards have chosen to address the decline of the Atlantic salmon by the single expedient of Habitat improvement.

It is the central tenet of this Discussion Paper that Habitat improvement - however important - will not by itself reverse the salmon's decline.

The elimination of high seas predation (including netting) is not a practical management option. Hatchery enhancement of wild fish is the only management tool available to us that offers the arithmetic possibility of reversing the decline. Hatchery enhancement however, remains imperfect – the Relative Reproductive Success of hatchery salmon is currently poor. The reason for the observed poor RRS is unclear - research at the mechanistic hatchery level, should be able to answer this question.

This research has not happened in the UK - There would appear to be little or no desire to improve hatchery practice. The absence of such research raises its own questions.

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The Atlantic Salmon – Decline or Extinction?

WWF 2001 REPORT

The WWF say in their 2001 report that North Atlantic salmon have declined by 80% since 1970, and it is now locally extinct in at least 309 rivers in Europe and North America. This is a dramatic reduction, but 1970 was in no way a high point for the salmon - if the figures were available from 1870 or 1770 then the decline would be far greater. The WWF goes on to predict that the Atlantic salmon is likely to become extinct within the next 50 years, and this of course takes no account of the mounting evidence of Climate Change that has accumulated since the Report.

GEOLOGICAL RECORD

Geographically widespread species have left considerable geological evidence that extinction events occur over relatively long periods of thousands or even millions of years. An event that occurs within a few hundred years is effectively instantaneous in geological terms, and only occurs as a result of some catastrophic event. The Atlantic salmon has survived the complete loss of a large range of its habitat during periods of glaciation on several occasions, and yet within just a few decades, it has declined by 80% or more.

This requires a catastrophic event as causation. Quite clearly there have been no natural events during this time period that would qualify as catastrophic.

The only catastrophic event that can account for such a dramatic decline in such a short time-frame is human activity, the result of gross over-exploitation, habitat degradation and pollution!

DECLINE OF THE RIVER WYE

To appreciate just a little of the scale of exploitation to which we have subjected the salmon, the River Wye provides a graphic example. Even as long ago as the reign of Queen Elizabeth I, there were attempts to regulate the exploitation of salmon. There is even a Clause in the Magna Carta requiring the removal of fish weirs in the Thames. The salmon was looked upon as a never-ending resource which was to be killed by any method and at any time. By the middle of the 19th Century the river was netted from below Monmouth to as far as Builth; virtually every Riparian Owner would have operated nets. In addition to the nets, spearing salmon was quite the norm and a perfectly respectable pursuit for all classes, and spawning salmon were routinely speared on the redds as well as kelts, the argument being that if the locals did not kill the “old salmon” the nets-men further down the river would.

The misguided belief was that, because this mass slaughter had gone on for so long, it would simply continue the same; there was no accepted correlation between exploitation and reduction of numbers. Nothing illustrates this popular misconception better than the exploitation of salmon parr and smolts.

“Last Spring” - as they were known - were netted with just the same enthusiasm as mature salmon, and were sold by the hundreds of thousands.

The only limitation to this exploitation was getting the salmon to market. Once the local population had had their fill, further exploitation became less profitable. This all changed with the arrival of the steam train, and the easy availability of the London market.

We can only wonder at the scale of this bounty which was able to satisfy such huge demand for so long, while - throughout the period - the salmon had to negotiate a river that was netted from end to end! Inevitably the industrial scale of netting took its toll, and the salmon population finally collapsed. The result was a Royal Commission in 1860 which led to the Salmon Fisheries Act of 1861. The Commissioners reported that the river was in a “state of extreme depression” and in a “lamentable condition”. It seems incredible to us now, but following the Act there was serious civil unrest and riots; people fought for the right to continue to kill the salmon.

Despite the 1861 Act, progress was slow because, incredibly, the nets were still not seen as the problem; it was the Chairman of the Wye Fisheries Association John Hotchkis who had the vision to make a start at buying out the nets. Among the last of the commercial nets-men was Alexander Miller who even as late as 1892 killed 12,000 fish but by 1901 their catch was below 3,000 a year - the Wye salmon run continued to collapse.

With all the freshwater nets finally removed by 1924, the salmon made something of a natural recovery, and 1927 was a high point with 10,807 salmon killed, but of course this pales into insignificance compared with the historic numbers of salmon running the Wye.

If the Wye was an individual tragic event, then for the salmon this would, in the scheme of things, be no more than just an unfortunate side-show, but of course that is not the case. The Wye has fared far better than several other rivers; the Thames for example, which had a prodigious salmon run in the past, saw its last salmon caught from Boulters Lock in 1821 - the exploitation was universal.

Today Wye salmon numbers have declined to just a few hundreds caught. If we could return to the “depressed and lamentable condition” of the Wye in 1860, it would appear to us today as if the river was full of fish! This relentless decline needs to be seen within a far broader context, and not just from the perspective of our human time-frame. It is impossible to piece together an accurate figure for the total number of salmon entering the Wye in its heyday, but it was obviously in excess of 100,000, probably far more, so the decline to the present day could even be as high as 99%, and that can be viewed as nothing less than the final stage of an extinction event!

WHY NO RECOVERY?

We know survival rates at sea are poor, and we know from the history of the Wye that once the salmon population crashed in the 19th Century it has never recovered despite the cause of the crash – the river nets –

being removed, and here is the obvious clue to the salmon's success, and its final demise. You only have to consider how many eggs a hen salmon produces to understand its reproductive strategy. A modest 10 pound hen salmon will produce 10,000 eggs or 1,000 eggs for every pound of weight. If you then multiply this by the probable number of hen salmon entering the Wye in its heyday, then it quickly becomes apparent that egg production was numbered in the millions. Evolution is nothing if not ruthlessly efficient, and if the salmon evolved to produce so many eggs then it is simply because this is the number required to maintain a healthy population in the face of such huge losses - a simple ratio between production and predation.

This is the salmon's survival strategy – abundance. It may appear to us to be inefficient, even profligate, but this naturally-evolved process of overwhelming predators with sheer numbers is common in Nature, and effectively ensures that sufficient numbers survive. Quite clearly, the relationship between predator and prey is symbiotic and, in Nature, a balance would normally prevail. As a consequence of our netting and disregard for the environment, we have disrupted that natural balance, and the salmon can no longer produce sufficient migratory smolts to overwhelm predation and netting at sea.

NETTING AT SEA

There are numerous examples of environmental degradation that have contributed to the decline of the salmon, but the single most overwhelming cause has been over-exploitation by the nets. We can all see, with the aid of hindsight, that the scale of the 19th century netting could only have one outcome, but very few at the time accepted it. The scale of today's netting is still significant as a proportion of the remaining salmon population, and much of it is licensed by the same people that purport to protect the salmon. We seem unable to learn the lessons from history but, as absurd as this situation is, there is another greater absurdity.

On the one hand there is a group of people who have spent vast amounts of money, and given endless hours of their time trying to restore salmon numbers. On the other hand there is a group of people who do their best to reduce salmon numbers. All the work and money invested in our rivers actually goes towards subsidising the nets-men who contribute nothing.

The question we all should ask about netting is – why do we net our estuaries and the vastness of the North Atlantic as opposed to our rivers? The salmon feeds cost- and pollution-free at sea, and then obligingly returns home to the narrow confines of its natal river, where it could be easily and cheaply harvested. River netting was finally banned because we belatedly realised that industrial harvesting of salmon threatened the very existence of the species. We then allowed that threat to continue in the estuaries and high seas. It is not remotely cost-effective to net at sea compared to a narrow river; it's only advantage for the nets-men is that it is less accountable.

PREDATOR RATIO

Losses exist in two separate environments:- in freshwater and in saltwater; but there is one crucial difference. In freshwater the losses are suffered by individual river populations; in salt water the losses are shared by all river populations. In the first instance a river system is dependant only upon its own production, but in the second in saltwater it is dependant upon all river systems to maintain the predator ratio.

This is significant, because – while some rivers still have what we perceive as reasonable salmon runs – many have none, or virtually none at all, and they tend to be the big ones that were once huge producers of salmon, for example:- the Thames, Rhine, Seine, etc, and of course the Wye whose once- massive contribution is now insignificant. It is clear that the Atlantic salmon’s overall production has been reduced by orders of magnitude.

It seems likely that once a “critical mass” has been lost, then the salmon’s recovery is in doubt, and logically why should it not be in doubt. In order to disagree with the strategy of abundance, you would have to re-write Darwinian evolution!

Not only has the ratio between prey and predator shifted, so has its nature and distribution. Changing ocean temperatures are altering the distribution of both the salmon’s prey and those species which prey upon the salmon. The abundance and distribution of sand eels, which is affecting many seabird colonies, is one very tangible example. Sea bass are becoming far more numerous around the UK coast, and as any sea-fisher knows, the fish are particularly numerous around estuaries where a migrating smolt must run the gauntlet. Seals are now without control and are increasing in number and perhaps of even greater concern are the increasing number

of dolphins which are specifically targeting salmon.

CLIMATE CHANGE

Within this sobering context, it is difficult to envisage any new threat that the Atlantic salmon has not already encountered, but of course there is a new danger. Climate Change will be a challenge for all animal species, especially those unable to adapt quickly.

Historically, the salmon has faced Climate Change many times before; they simply adapt to where conditions are more favourable. This time, however, there are significant differences – the speed of Global Warming is without precedent, and of course the salmon is not starting from a position of abundance. In the short term, the challenges which the salmon faces will likely be confined to drought and flood events on the freshwater side of the equation, and to changing ocean temperatures on the saltwater side. For the longer term, say 40 to 60 years hence, the danger for the salmon is far more acute. Salmonids generally are a cold-water species, and temperatures could – as a worst-case scenario - rise by as much as $4^{o}C$ within this time-frame. If and when this happens, there will no longer be any salmon remaining in the UK, other than in the far North. Between now and then, our remaining salmon will face gradually increasing heat stress and more extreme weather events.

Extreme weather events are not some vague possibility for the future – they are having devastating effects around the World, and they are happening now. In the UK, 2011 was a severe drought year; 2012 is the wettest year on record to date. Droughts prevent salmon from reaching safer head-waters; it also encourages them to remain in estuaries where they are vulnerable to nets, seals and dolphins. Floods simply wash redds away. It is perfectly reasonable, therefore, to speculate that recent weather events - which have been the worst on record – have most probably, in terms of salmon spawning success, also been the worst on record.

Once again, we choose to believe what it is convenient to believe, and the usual response to the danger of extreme weather events is that the salmon has survived extreme weather events for thousands of years - which is quite correct. The difference now is that, while the salmon could cope perfectly well with a major flood or drought once in a hundred years,

we are now suffering these once-in-a-hundred-year events almost annually - the floods of 2007, the drought of 2011, the floods of 2012 being the latest manifestation.

The reality is that, far from coping with these events for thousands of years, the salmon has not faced such a rapid change in climate for hundreds of thousands of years, if ever; this is not business as usual. We must at the very least expect huge variability in spawning success, and large swings in migration timing.

MANAGEMENT POLICY

Two hundred years ago, the river Wye had one of the largest salmon runs in the UK. Today the salmon population is counted in hundreds, not thousands. It is quite possibly the largest numerical decline of salmon for any single UK river during this 200-year period, and we have presided over every decade of its fall from grace.

There is a common thread that extends from the 19th Century right through to the present day; we have continually failed to accept reality or to recognise the obvious. Throughout the 19th Century, we never once considered that the mass slaughter might affect salmon numbers. Even after the 1860 collapse, it took another 60 years to fully remove the river nets, because people would not accept that they were the problem. Following the final removal of the river nets, we then failed again to realise that the estuary- and sea-nets would further deplete salmon stocks - a situation that continues to this day.

Current Environment Agency (and now NRW) policy is predicated upon the belief that if we improve the in-river habitat, the salmon will make a natural recovery. In other words, the balance between in-river production, afforded by good habitat, and saltwater predation including nets, would swing in favour of the salmon if the river habitat was improved.

This theory is appealing for many reasons, but there is no evidence to support it. Pristine rivers may be quite rare in the UK, but some near-pristine examples do exist, and none of them have good salmon runs remotely approaching previous peak levels, and the reason is perfectly

clear – the balance between in-river production and salt-water predation is firmly in favour of the latter.

The reality of the situation is actually quite simple; if the salmon run of any river was able to reproduce in sufficient numbers to consistently over time increase the numbers of returning salmon by an average of just a hundred fish each year, which as a percentage of egg production is an immeasurably small amount, then over a relatively short period, the population will have increased by thousands. We can then add to this scenario the “magic of compounding” as a small increase in returning fish increases still further recruitment. The very obvious fact is that there is not a river in the UK where salmon runs have naturally increased to levels of pre-industrial abundance. The conclusion is obvious: natural recruitment cannot keep pace with predation and netting.

The Environment Agency’s response to this catastrophic decline has been on a river-by-river basis; in effect the management of each river is a stand-alone policy. There is no coordinated approach in fresh water that addresses the decline of the North Atlantic salmon population as a whole.

There is no evidence that an individual river’s salmon population can thrive in isolation; there is only evidence that an individual river’s population can become extinct.

The tragedy of the uncoordinated individual river approach is that we inevitably create the individual salmon. As soon as a river’s salmon population is considered in isolation to the North Atlantic population as a whole, we have de facto given it special status which, once applied, becomes a self-fulfilling prophecy, which then “requires near certainty regarding lack of adverse effects” (NRW Policy Statement).

We can only assume that these Agencies cling to the notion that the Wye salmon represents a distinct species for which the loss of its genetic integrity represents a greater threat to its existence than even the huge losses at sea.

The very existence of the “stray” salmon negates the theory of a population specifically adapted to a local environment. (*Page 19*) Such a fish (genetically adapted to another river) would theoretically be unable to stray into a different river, and breed successfully. Evolution clearly does not recognise this special status, as is demonstrated by the constant genetic

exchange provided by “stray salmon”. The nets-men do not recognise this special status, and the salmon’s predators at sea certainly do not recognise this special status.

The real effect of special status, indeed its intention, is to “ring-fence” the population and to prevent any human intervention. This is our response to the North Atlantic salmon’s drastic decline. By creating a “special-status” salmon, whose protection from adverse effects only extends to its fresh-water environment, we have once again failed to follow the logic of our decision making to its obvious conclusion.

The only alternative to a “wait and see” policy is Hatchery enhancement and, while there are undoubtedly problems with relative reproductive success *(page 12)*, this is not really the issue. The issue is that the Environment Agency would appear to be ideologically opposed to Hatchery enhancement. This is evidenced by the fact that while there is research sponsored by the Environment Agency to demonstrate that previous examples of stocking have been ineffective, the Agency has not sponsored any genetic research at the mechanistic Hatchery level with the aim of improving results. There is clearly no desire to see an effective Hatchery programme.

In the absence of a stocking policy, the only management tool is habitat improvement which, however desirable, essentially requires the salmon to make a natural recovery. It is the central tenet of this Paper that today’s vastly reduced salmon populations are not capable of reproducing in sufficient numbers to overwhelm the continued sea-netting and predation.

IDEOLOGICAL OPPOSITION

Those who oppose Hatchery enhancement are quick to point out the problems, and there are indeed some issues *(page 12);* but one seldom hears the question:- how can that problem be overcome, or how can we improve that? The reason is quite clear; for the vocal minority who oppose hatchery enhancement, even a perfectly flawless enhancement program would still not be desirable; this is opposition on ideological grounds, not evidence-based science, and this goes to the very heart of the debate.

A good example can be seen on the banks of many of our trout streams. Ask anyone who has just caught a trout, if his trout is a wild fish or a Hatchery fish. The chances are that, especially if it is a good fish, it will be

vehemently pronounced as ‘wild’, and yet in all likelihood it will be a trout of Hatchery origin. This classic case of the Emperor’s Clothes persists because – for the fisherman – only a wild trout possesses those intangible qualities that make it a noble and worthy adversary. The paradox is that the proud captor sees all those attributes in his Hatchery fish!

This may initially seem to be no more than a harmless nonsense, but the reality is the complete opposite because, in order to sustain the illusion of the wild and worthy adversary – we must also create its antithesis – the inferior and unworthy Hatchery fish. It seems nothing short of incredible that the management of our trout and salmon stocks in the UK is influenced to a greater or lesser extent by this illogical belief.

To be clear in the context of this Paper, we are only concerned with the hatchery enhancement of wild fish; in other words, brood fish taken from the wild, whose prodigy are returned to the river in far greater numbers than would otherwise be the case.

In this situation, the wild fish of hatchery origin is exactly the same fish. Anything that is added or taken away (genetically) is in the eye of the beholder. There is a problem related to Reproductive Success (*page 12)* but this is a relatively new issue, and is not the principal reason for the prevailing ideological opposition.

Stocking with fertile fish (trout or salmon) from closed breeding programmes is a totally different issue, and the evidence indicates that this should not be used to support wild stock.

HATCHERY ENHANCEMENT

The fact that hatcheries can increase salmon recruitment by orders of magnitude is surely not in dispute. There is only one river system where salmon runs have improved significantly in recent decades, and this is the Tyne. The Rod Catch for the Tyne for 2011 was 5,611 salmon; the Wye in contrast caught 705 salmon. In fact, the Tyne accounted for about 25% of the total English and Welsh Rod Catch for 2011. The Environment Agency have dismissed these results, they say the recovery was already underway, and is the result of environmental improvements. It is difficult now to prove conclusively which course of action has had the greater effect. The river Wye has benefited from enormous environmental improvements, and yet the salmon population shown no sustainable

improvement. The same can be said of other rivers, only the Tyne has shown such a dramatic improvement. Can anyone seriously doubt that Peter Gray's work at the Kielder Hatchery has been the key to the recovery of the Tyne?

The Aberdeenshire Dee provides another example of Hatchery enhancement from a Century earlier. The Dinnet Hatchery alone was producing a million fry each year, and there were numerous other small-scale Hatcheries often run by local ghillies. (There is interesting archive film at Cairnton, of A.E.Woods helping to net salmon for the Hatchery). The Dee example is interesting because, for most of the years that we now regard as the river's "heyday", the salmon run was being supported by the hatcheries. It may also be relevant that commercial fry food was not available until well into the 20th Century, and so before this time fish must have been released as unfed fry. This may be significant with regard to Reproductive Success *(page 15).*

The issue for some people is:- are hatchery fish still wild fish? This is a hypothetical argument often motivated by ideology, and it is essentially the wrong question. The real criteria for the success of a wild fish of Hatchery origin is not if it returns from migration, or if it adds to Rod Catch statistics. The real question to ask of the hatchery fish is:- how successfully does it reproduce in the wild, and here at least there is research to refer to. Genetic Science is proving to be a very useful tool in this regard and many studies use DNA microsatellite-based parental assignments to evaluate reproductive fitness.

Not all the studies referred to here are based upon the Atlantic Salmon, but it is perfectly reasonable to assume that most of this research is applicable. This is not to say that the studies are unequivocal in their results; there is considerable 'noise' generated, especially in studies where some form of stocking has been going on for a length of time. Assigning parentage in conditions where wild / hatchery interaction has taken place over many generations obviously confounds the results. Another confounding factor is incomplete evidence and data which is an unavoidable situation when research is outside laboratory conditions. Where such data voids exist, assumptions have to be made, and often complex mathematical formulae are used to extrapolate results. Such results should be viewed objectively, but despite this, there is some consistency emerging from the research.

REPRODUCTIVE FITNESS

There is plenty of evidence which indicates that current hatchery practices – particularly closed breeding - can have detrimental effects upon the reproductive fitness of wild fish:- (Araki et al 2007B, 2009); (Blanchet et al 2008); (Christie et al 2012); (Williamson et al 2010); (Chilcot et al 2011); (Theriault et al 2011); (Milot and Perrier et al 2012).

The research indicates that reproductive fitness - referred to as Relative Reproductive Success (RRS) - which is defined as the ratio of average numbers of wild-born offspring from one type of parent (eg hatchery fish), compared to those of another parent (eg wild fish) returning to the same river - seems to decline per generation in the hatchery**.** (Araki et al 2007B, 2009) (Theriault et al 2011); (Milot and Perrier et al 2012). These changes are most strongly observed in the closed-breeding situation, and are far less pronounced when wild fish are used as Brood Stock. (ARAKI et al 2008). The time that the fry / parr/ smolts spend in the hatchery environment also seems to be a factor in RRS. (Theriault et al 2011); (Milot and Perrier et al 2012). It is possible that the longer a juvenile fish spends in the Hatchery, the greater is the observed effect, although such effects are difficult to quantify because early release of un-fed fry will suffer high mortality, and smolts will suffer the least as a percentage of fish released.

The evidence, however, strongly suggests that RRS of hatchery fish released as fry is greater than those released as smolts. The reason appears to be strongly linked to the number of winters spent at sea. MSW fish of both wild and hatchery origin have better reproductive success than SSW fish. This is probably linked to size, where a MSW fish is larger than a SSW fish, and size relates to fecundity. In one study of North Atlantic salmon (Milot & Perrier et al. 2012) the percentage of returning MSW fish was lower among smolt-stocked fish (12.7%) than among fry-stocked (33.3%). The overall percentage of MSW fish was 21.8% for hatchery-born and 38.5% for wild-born. Clearly, in this Study, the overall percentage of returning MSW hatchery fish is reduced by the greater number of smolts returning after a Single Sea-Winter. Once again, the reasons for this are not clear, but the faster growth rate of hatchery smolts may be a factor. However, this kind of research has implications for current smolt-release programmes.

If the reduction in RRS is shown to be related to the time spent in the hatchery, then this will be a very important observation because, if the

observed effect is time-related within the hatchery, then it must therefore be quantifiable. It therefore follows that, if the reduction of RRS is an exponential effect, then the effect must be happening at all stages of the hatchery process. This effectively rules out input variables such as how wild broodstock are collected, selected, and how eggs are fertilised and hatched.

The significance of the observation that RRS is probably reduced relative to the time spent in the hatchery cannot be overstated. It makes clear how detrimental escaped farm salmon might be to wild stocks, and when the number of escapees is considered, this is potentially an enormous problem. It also casts serious doubt upon such practices as kelt reconditioning, where fish spend possibly years in captivity. It also has implications for smolt production due to the extended hatchery time, and maybe adds support to the use of semi- natural rearing ponds which, by definition, is a more natural environment than the hatchery.

EPIGENETIC EFFECTS

If the observed reduction of RRS proves to be related to the time spent in the hatchery, then this narrows the possible causes considerably, and epigenetic effects would appear to be the prime suspect. Epigenetic effects occur where external environmental stresses affect gene expression.

This is not the same as genetic alteration; the genome is unaltered but the expression of some genes may be affected. Provided that water quality is good, it is difficult to see an environmental condition which might have a significant epigenetic effect, other than stress or food quality. Stress-related epigenetic effects are recognised in animal studies, and there is now evidence that altered gene expression is heritable. Stress in the hatchery environment is nearly always related to overcrowding. There is a critical density of fry for any given size of hatchery tank, beyond which stress becomes apparent in the form of fin biting. It is perfectly reasonable to assume that overcrowding at any stage of growth might have epigenetic effects upon the fish. Whether or not those effects are significant, and if so, how significant, seems not to be known; this is an essential area for research.

Fish feed is another possible cause of environmental stress, because the only diet available is the feed specifically designed for the salmon farm

industry, and their requirements are completely different.

Epigenetic inheritance has always been a mystery; the effects of environmental stress upon the expression of genes is recognised, but it has not been understood how this effect is heritable when the genetic code is unaltered. Epigenetic inheritance can be clearly demonstrated, and there is currently ongoing research that will no doubt discover the inheritance mechanism .

NATURAL SELECTION

The question of natural selection and the absence of it in the hatchery is very difficult to quantify. Most fry, parr and smolts which are lost to predators in the wild are probably lost with a high degree of random chance. However, it is undeniable that an otherwise “weak” fry might survive in the hatchery environment, and this is very likely the important issue. It could well be argued that nothing is produced in the hatchery that could not have been produced in the wild. The difference is possibly not genetic mutations introduced, but genetic mutations that are not removed. In other words, selection is important, but the really necessary requirement is de-selection. If this is the case, then the longer that fry are exposed to natural selection, the better, and perhaps early stocking-out of fry would be indicated. There is obviously a trade-off between early fry stocking and high mortality, and smolt stocking and low mortality.

Natural selection is obviously an ongoing process, and selective pressures come to bear as soon as the hatchery fish is released. That selection process is on-going into future generations in the wild; it is self-evident that poor Reproductive Success will be rapidly de-selected, and any second- or third- generation of salmon returning to spawn must be regarded as genetically successful.

GENETIC DIVERSITY

Another argument against hatchery fish is paradoxically their success; it is often claimed that genetic diversity is lost because so many fish are produced from relatively few brood fish. Once again, hatchery procedure can reduce this effect by using more brood fish, and perhaps by using mixed milt rather than using one cock fish per one or two hens. There is, however, an element of nonsense in the diversity argument.

Consider the often-acclaimed success of a newly-opened tributary that had previously been denied to the salmon for generations due to an obstruction. In this instance, the tributary can only be colonised by a few fish that “stray” from their previous natal rivers. At today’s depleted levels, the initial number of colonising fish will very likely be in single figures; indeed, there may only be a single cock or hen fish contributing to a mating. Such a colonisation would, however, be heralded as a great success, despite the fact that this initial cohort of fish will all be of single parentage. There is an inconsistency here, sufficient to dismiss this as an argument against hatchery enhancement.

It is also interesting to note that in a review of 266 peer-reviewed papers conducted by (Araki Schmid 2010), no studies were found which provided direct evidence for either positive or negative effects of hatchery stocking on stock enhancement in this regard.

GENETIC INTEGRITY

Another objection is the importance of genetic integrity. The theory is that local populations of salmon are very specifically adapted to their local river environment, such that anything which might affect that finely-tuned genetic balance will adversely affect the whole population. This assumption has far reaching implications because this is presumably the reasoning behind the creation of “special status” salmon, such as is the case for the River Wye, where the river is a special area of conservation and the salmon “require near- certainty regarding lack of adverse effects”. *(page 9)*

Certainly in the case of Brown Trout, they have been shown to have among the highest reported levels of polymorphism of any vertebrate

species, and so we should expect the salmon to display a high degree of genetic variability. It would appear that geneticists have found a range of genetic variability as would be expected, but then assumptions appear to have been made about the reason for that variability, and – rather than accepting that random genetic drift is a constant factor – the variability has been attributed to specific local adaptation. This author can find no evidence for this assumption, not a single gene can be attributed to a specific local adaptation.

The evidence indicates that any animal living in genetic isolation will suffer inbreeding depression. The salmon has evolved to avoid this and a percentage of returning fish will stray into non-natal rivers. The “stray” salmon makes a nonsense of the genetic integrity argument, because the constant genetic exchange, both in and out of the river, simply negates the notion of specific local adaptation. It would be impossible for a salmon to “stray” if they were uniquely adapted to a specific environment. There is an inconsistency here, sufficient to dismiss this as an objection against hatchery enhancement.

MATE SELECTION

There is an argument that spawning fish select mates, and certainly cock fish can be seen driving other cock fish away, but at the same time, precocious parr are well known for their fecundity. It seems highly unlikely that mating selection is a significant factor. In the case of the restored tributary, where very few “stray” fish are present, the result is regarded as a success, despite little or no mate selection. Again, there is an inconsistency here sufficient to dismiss this as an argument against hatchery enhancement.

LEARNED BEHAVIOUR

It is sometimes suggested that salmon are capable of a learning process in the hatchery with a resulting modification of behaviour. If modification of behaviour is possible, then my own 27 years’ experience of closed breeding should have demonstrated it, especially regarding feeding. Does a captive- bred hatchery trout learn to obtain hatchery food at the expense of natural food? The answer is absolutely not. A wonderful demonstration is to draw a pencil dot one inch above the water-line of a hatchery trough,

and to watch a fry at swim-up stage - which has never eaten food of any kind - jump up at the “insect” it perceives above the water-line. Even something as basic as feeding from a pendulum feeder is not a learned behaviour, and as soon as the stock density drops to a level where the pendulum is no longer accidentally knocked, it ceases to be useful.

In all respects, the observable behaviour of a hatchery Trout certainly appears to be unaltered; their basic reactions are clearly innate, and while this is anecdotal evidence, it does indicate that the same applies to wild fish of hatchery origin.

CARRYING CAPACITY

The ability of a river to support a given number of juvenile salmon is obviously limited by its productivity, which will be variable on a yearly basis. It is often claimed that a river’s carrying capacity is a significant limitation to hatchery enhancement; it is even mentioned that some of our rivers are at, or are near, their carrying capacity at today’s reduced population levels.

This appears to be an issue that is impossible to quantify. All that we can do is to extrapolate back to presumed previous peak salmon populations as an indication of this limiting factor. There might also be some loose correlation provided by the Pacific salmon, where – even today – salmon runs for some rivers - and even specific tributaries - is numbered in millions.

It might appear that most of our rivers today are a long way from maximum carrying capacity; perhaps this might not be such an unwelcome problem.

NEED FOR RESEARCH

Hatcheries can enhance a river’s salmon population - the Kielder Hatchery almost certainly demonstrated that, as have other examples.(page 11). The Tyne success also demonstrates that the success can be on-going, but equally there are examples where the ongoing success has been poor. Proponents of hatchery enhancement need to understand that there is far more to success than just the number of hatchery salmon which are

returning to our rivers. Opponents of hatchery enhancement need to see past what is often an ideological opposition, and that they should look for solutions not for problems.

In the absence of research and development, there is very little evidence with which to form an opinion regarding the poor RRS observed in wild fish of hatchery origin. We can only speculate in this regard. Having studied the research, and with the benefit of some hatchery experience, it seems likely that the causes of poor RRS will be traced back to some aspect of hatchery practice. The possible areas of concern can probably be viewed on a scale from likely to unlikely. What seems unlikely to this author is learned and modified behaviour, mate selection, genetic diversity and genetic integrity issues. What seems likely are epigenetic effects and natural selection. Between these parameters, there is a range of other possible causes.

Of all these factors, for this author, epigenetic effects sound the most plausible, and – if so – the environmental cause will almost certainly be overcrowding stress, or feed or water issues. If genetic research can pinpoint the cause of such effects, then the solution should be self-evident and probably quite straightforward to achieve. This kind of research will obviously happen, and because it can be carried out in controlled conditions, the results should be clear. The hatchery process is a very simple straightforward procedure, if the will existed, a flawless hatchery system should be easily attainable.

This is reflected in one research paper “A Mechanistic Understanding of the Genetic Effects of Hatchery Rearing Is a Top Priority Issue because it will provide a way of Mitigating Negative Effects without giving up Stock Enhancement via Hatchery Stocking” (Araki Schmid 2010)

THE SPORT FISHER

The fact is that current policy is not interested in restoring the salmon to a state of abundance for the benefit of the sport fisherman. The River Wye is designated as a special area of conservation, and it is the salmon not the fishing culture that is the subject of conservation. Salmon fishing tradition is a generational concept, and today on many Middle Wye Beats that culture and tradition is gone, replaced by coarse fishing.

It is a strange paradox that those who pursue the salmon for sport are in fact its greatest champion. We should never forget that the principal architects of efforts to materially help the salmon have usually come from sport fishermen, not from Managing Authorities; John Hotchkis, Orri Vigfusson and Stephen Marsh-Smith would be just three examples. The sport fisher wants the salmon to be abundant, and the salmon needs to be abundant for its own survival; there is a symbiotic relationship between fish and man in this respect. When the sport fishing fraternity finally becomes irrelevant, or worse, banned, because we are fishing for an endangered species, the salmon will have lost its most passionate supporter and, with it, probably any hope of a future.

CONCLUSION

The Wye salmon population "require near-certainty regarding lack of adverse effects"(page 9) and this status effectively excludes any intervention other than habitat improvement. The situation, therefore, is at least clear:- if habitat improvement and natural recruitment does not of itself reverse the decline, then there is no alternative plan, and the salmon will become locally extinct. The only remaining question is the time-scale of these events.

If the decline continues into future decades (still instantaneous in geological terms) our natural confirmation bias will reassure us that it is not a decline at all. In other words history will go on repeating itself, we will refuse to believe the salmon will become locally extinct - until it is!

There is a second scenario, one in which climate change plays a decisive role in tipping the balance. In this scenario local salmon populations which are at critical levels (unable to increase population density) could quite suddenly collapse.

There is a third scenario, one in which extreme weather events escalate dramatically (as some predict) and the North Atlantic salmon population as a whole, declines still further. Changes in ocean temperatures and predator distribution could create a situation where a tipping point is reached, where critical mass is lost, and reproductive success goes into reverse. At this point the predator ratio swings full circle in favour of the predator. In this scenario we could see a sudden almost universal

decline, or even a collapse in all salmon stocks. Such a collapse might be counted in years rather than decades.

Just a few hundred years ago salmon numbers in the UK would have been counted in millions, we have now reduced those numbers to a few thousand. The salmon is already extinct in many of our rivers. The scale of our mismanagement is monumental, and it continues. Our current management policy reduces us to the level of observers only, and so all we can do is wait and watch as the decline unfolds.

For the sport fisher the loss of the salmon is as incomprehensible as it is tragic. Many refuse to accept the reality of the situation, and prefer to live in denial. Those responsible for our management decisions will not be held accountable, they will simply move on. The current generation of salmon fishers are likely to be the only people left who will remember and grieve the loss of the Atlantic salmon.

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