Salmon & Trout Conservation

KEEPING OUR WATERS WILD · EST 1903

WILD FISH

www.salmon-trout.org

Acknowledgements

Without significant support from Pembroke College, Cambridge, the Cambridge Conservation Initiative, Patagonia Europe and Salmon & Trout Conservation (S&TC), the conference where WILD FISH began would never have taken place. But the enthusiasm and commitment of the S&TC team, in particular Nick Measham, Janina Gray and Immy O'Keeffe, made WILD FISH possible. We wish to thank them, our designer Jon Ogborne, our contributors and the Estate of Ted Hughes, who remains our inspiration.

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Contents

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Foreword

Nick Measham

Welcome to *Wild Fish*, which replaces the Gamefisher magazine we have published since our centenary year of 2003.

Wild Fish is a themed journal looking at some of the wider issues connected with Salmon and Trout Conservation's work to put more wild fins in rivers. The articles in this inaugural *Wild Fish* focus on wild salmon and stem from the highly successful Owned by Everyone (OBE) conference at Cambridge University in December 2019, in a world before Covid closed the International Year of the Salmon. We are delighted that the conference organisers, Mark Wormald from Pembroke College and John Fanshawe from the Cambridge Conservation Initiative, have edited this first issue which explores Atlantic and Pacific salmon conservation from a wide-ranging, multi-disciplinary perspective.

Wild Fish demonstrates the importance of scientific evidence in seeking to save wild salmon, in its Pacific and North Atlantic ranges. However, the articles it contains, and the stories it tells, also bring science into dialogue with poetry, culture, and ancient and modern cultures around the world. Mark and John hope that reading *Wild Fish* will remind you of the universal importance of our relationship with wild salmon and the water environments it inhabits throughout its life cycle. Whoever we are, we all need to find ways of reminding as many people as possible of what a cultural understanding of wild salmon and its fate might tell us about humanity's wider relationship with nature. As Ted Hughes recognised, and as we discovered during the Cambridge Conference, the salmon truly is 'owned by everyone'. The relevance of conserving wild salmon cuts far deeper into human existence than merely protecting just another species.

I hope you enjoy this first issue of *Wild Fish* with its focus on salmon from a diverse range of perspectives – some of which may seem far removed from our day to day work in gathering scientific evidence for our campaigning. Future issues will take the same wide-angle lense, relevance-maximising approach to different challenges to conserving wild fish and their habitats. I believe that conserving salmon and other wild fish requires us to make their importance hit home beyond the world of science-led conservationists. To give salmon as secure a future as possible, we must strive to make the problem 'owned by everyone'.

The Devon Avon at South Brent
Photo: Jon Ogborne

Introduction

Mark Wormald

Salmon and the waters they connect keep making the news. The week I write, Mark Kurlansky, best-selling author of a modestly titled new book, *Salmon: A fish, the earth, and the History of a Common Fate*, is interviewed on BBC *Today*. He observes: "The life story of salmon must have been written by a Greek tragedian." Then tells of the noble doomed arc of an individual salmon's journey from river to sea and back, to spawn and die, once the work for the species was done.

But Greek tragic heroes could rail at the gods as well as themselves; what can the salmon say to politicians, multinationals, trade negotiators? Two days after Kurlansky comes this in the *Daily Mail*, the thrashing tail of one administration to another preparing to leap: if you ban our chlorinated chicken, we will ban your farmed salmon. Think about what that implies about transatlantic toxicity. Meanwhile ocean temperatures rise, the polar ice caps melt. On this side of the pond, a scandalous 14% of English rivers are deemed of good ecological standard, while – unbelievable but true – for the first time no river has achieved good chemical status; the Environment Agency admits it has limited powers to regulate. Humanity has no one to blame but themselves for the peril that wild salmonids and their habitats find themselves in.

And let's not kid ourselves with the immediate and vivid memories of what, for many lucky readers of this magazine, may have been an unusually good salmon run on some but by no means all of our rivers in Northern Europe. Wild fish need our informed help more than ever. They also need our respect. More often than we like to recognize, confusing as we sometimes do the best of human intentions with the worst of their unintended consequences, they need us to leave them and their waters alone.

Welcome to *Wild Fish*. This new magazine contains a range of arguments from Scandinavia, the British Isles and North America to support both contentions. The articles smolted in short presentations at a conference held at the University of Cambridge in December 2019, at the end of the International Year of the Salmon. Now, after two winters at sea, they return to spawn ideas in you. We hope you will learn things in it, about the recent and much longer history of humanity's interactions with the salmon. Reading it, and following the links it contains, will both inform and unsettle your own attitudes to and encounters with salmon, whether in rivers or on the plate.

Its scope is deliberately international: we need to follow the fish and look abroad to catch the best of our understanding of wild

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'Wild fish need our informed help more than ever. They also need our respect.'

'Of course, the best science doesn't just help us recognize the wonders of these fish – their genetic plasticity, their resilience, the interconnectedness of every element of the riverine and marine ecoystems which salmonids connect.'

salmon, and the range of humanity's engagement with them, from devastating industrialization to humbling examples of communities' proper respect for the nourishment of their lands and forests and spirits the salmon can bring. *Wild Fish* ranges from Scandinavia to Alaska, from the salmon cages off the Irish west coast to the Scottish parliament and to a wonderful discovery about the genetic distinctiveness of chalk stream salmon.

It also spans disciplinary borders: every one of the experts who have written here – fisheries scientists, anthropologists, literary critics, poets, conservationists, anglers – were asked to reach beyond specialist jargon. They've risen to a challenge which, 27 years before, the Poet Laureate, environmentalist and passionate salmon fisher Ted Hughes had set all those involved in the fight both for the salmon, 'such sensitive glands in the vast, disheveled body of nature', and for the different parts of that body, known to be struggling even then. 'What is needed is a new kind of language that goes straight to the heart and soul, and changes things there. When we change here, then everything has to change, our whole way of life simply changes, and it can change quickly.' Our contributors all honour the instincts and initiatives of Hughes himself by making cogent sense to people outside their own patch, disciplinary or geographical.

We begin, as the conference did, with science, and with the numbers. Will Darwall, who heads the salmonid team at the IUCN, explains the crucial importance of the IUCN Red List in presenting governments with compelling and current data on the risk of species extinction. We need an up to date assessment of the global population of Atlantic salmon: without it, individual governments and multinational conglomerates, like the polluters of particular river systems, will press on with industrial practices that – knowingly, unnecessarily, wastefully – push wild salmon beyond the brink.

Of course, the best science doesn't just help us recognize the wonders of these fish – their genetic plasticity, their resilience, the interconnectedness of every element of the riverine and marine ecoystems which salmonids connect. Jamie Stevens, Ken Whelan and Nick Measham all write compellingly about recent discoveries, disturbing trends, remaining mysteries and practical successes on this front. But Kyle Young's searing reflections on the history of hatchery programmes in North America as well as the British Isles, Mikael Frödin's horrifying report of Norway's aquaculture and its courts, and Corin Smith's latest dispatches from Scotland reveal what can happen when science has its head turned, or wears blinkers.

The long view can help. Arlin Rickard's account of Ted Hughes's role in founding the Westcountry Rivers Trust, and the seeding and growth of Rivers Trusts since, is inspiring; Ehor Boyanowsky's passionate defence of steelhead runs on the Canadian west coast over decades is more of a cautionary tale.

But we also need other kinds of narratives to supplement and contextualise and sometimes give pause to the science, to remind ourselves of the cultural and spiritual value of these extraordinary fish. Here you'll also find stories of communities which have long recognized the value to them of wild salmon – Tom Thornton on the

Pacific seaboard of Alaska and British Columbia, Katrina Porteous on the Northumbrian coast. Tony Juniper's review of *Artifishal*, the film on hatcheries and salmon farming that moved and appalled us at a screening in Cambridge, gives a leading conservationist's view of its power.

And of course leading fishermen and fisheries are represented too, providing real hope to counter the gloom of these days. Steven Mackenzie provides a compelling vision of sustainable management of one of our finest old fisheries, and his work with the Oykel's anglers to promote non-contact catch and release; Mikael Frödin reminds us how tantalizingly close sustainable land-based salmon aquaculture is to providing a viable means of feeding the world while ensuring the survival of wild salmon.

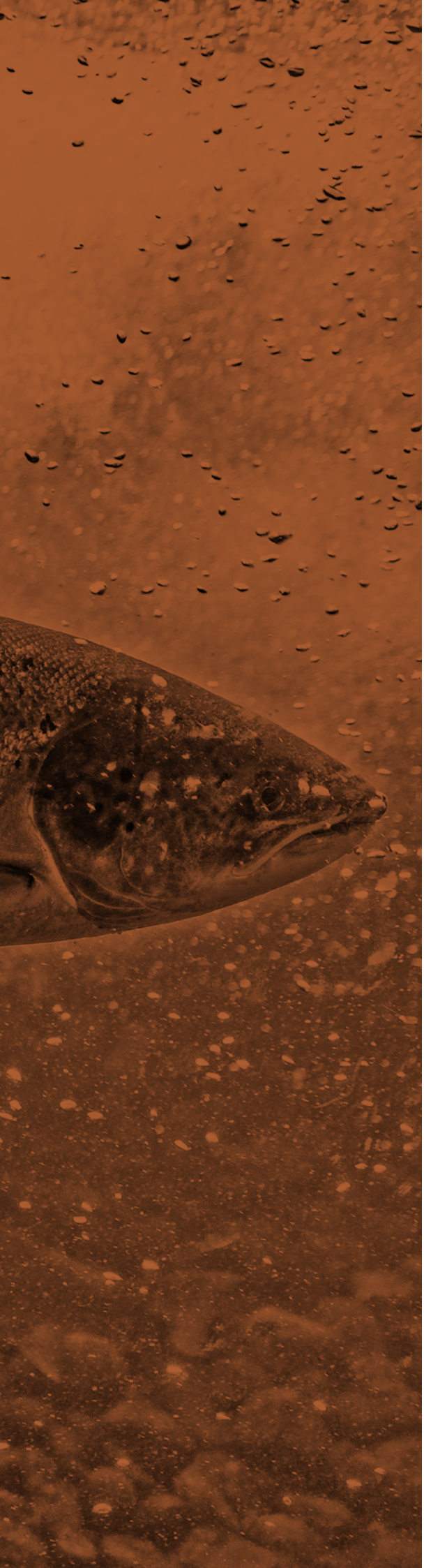
And you will also find individual stories. Many readers of *Wild Fish* will have caught salmon; many will have killed them. Two fine new poems by Harry Clifton set memories of fishing for salmon in the past against encounters of them in this turbid present.

And then there is Ted Hughes himself. He was once described by a Devon friend as 'a great killer of fish'. But he became their great protector, driven by just the informed reverence for the value of salmon we all still need. Katherine Robinson describes the insight into 'the oldest animal' Hughes brought to one of his finest poems about fishing one morning with his son Nicholas on an Alaskan river; bears were fishing too. The experience transfigured all involved.

But Hughes also observed that you couldn't write poetry without a subscription to *New Scientist*. Nicholas Hughes himself became a leading salmonid fisheries scientist in Alaska, and one of the scientific papers he wrote begins: 'Imagine a fish in a pool....' John Fanshawe shares our plans for how and why we want to continue doing this, whenever we can reconvene in person; our focus then will be on chalk streams. But for now, we end as our conference did, with Ted Hughes's favourite poem from his great collection *River*, looking into a pool on his beloved River Taw. Read this, aloud if possible: share it, along with the rest of *Wild Fish*. There's no more powerful evidence of what wild salmon, owned by everyone, must mean to us all.

Salmon ascending Shrewsbury Weir on the River Severn
Photo: © 2018 Kevin Wells – stock.adobe.com

Photo: © Jakub Rutkiewicz – stock.adobe.com



The future of salmon: Assessing species extinction risk according to the IUCN Red List of Threatened Species™

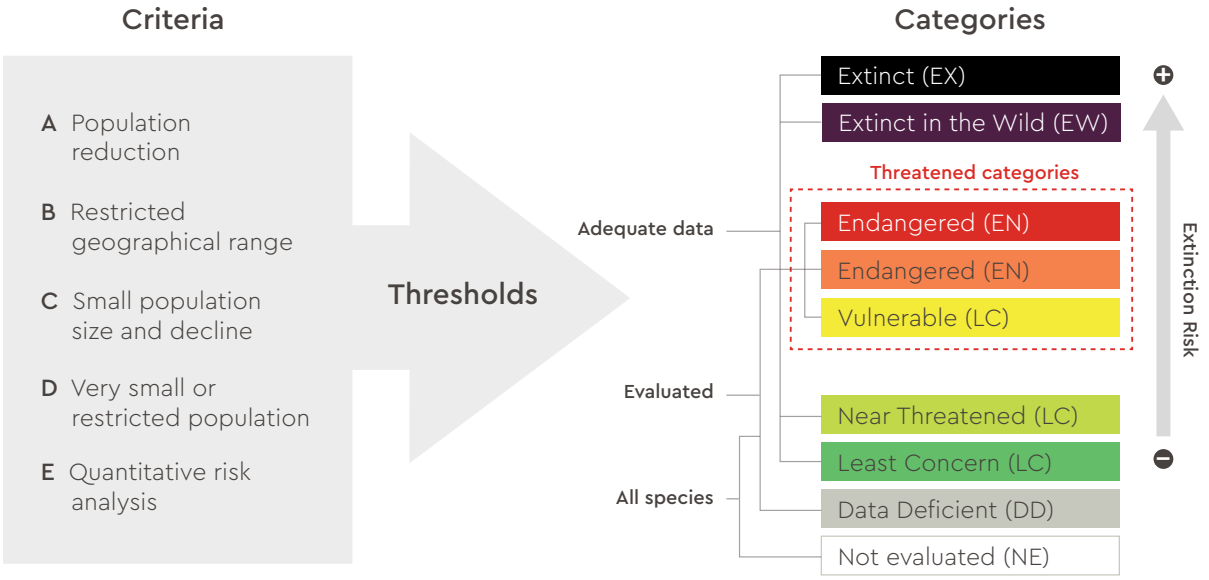
William Darwall

Salmon are in trouble. It is hard to believe that as recently as the 1960s when I was growing up in Devon two small rivers, the Torridge and Taw had recorded rod catches of around 5,000 salmon; by 2017 that number was reduced to just 315! Clearly something is not right and we need to understand what is happening. Among others, one tool we use to assess change is the IUCN Red List of Threatened Species (www.iucnredlist.org), forthwith referred to as the Red List. In this article I introduce the Red List, explain a bit about how it works, what it can be used for, and how it has been applied to evaluate the status of species of the family Salmonidae, which includes the salmon, trout, grayling, whitefishes and chars, collectively known as the salmonids.

Unfortunately most people view fish simply as food, but if we are to continue enjoying this "food" we need to ensure fish species are being looked after in the wild and that they are valued as an important, indeed iconic, part of our wildlife or "biodiversity", the term used in international and national agreements and policies designed to protect nature. Many of these species are also highly valued components of recreational fisheries, valued globally at over USD 100 billion per year (marine and freshwaters combined).

The Red List is a critical indicator of the health of the world's biodiversity, based on the best scientific information available. Far more than a list of species and their status, it is a powerful tool to inform and catalyse action for conservation and policy change, critical to protecting the natural resources we need to survive. It provides information about the species' geographic range, population size, habitat and ecology, use and/or trade, threats, and conservation actions that will help inform necessary conservation decisions. Species are assigned to one of nine categories based on criteria linked to population trend, population size and geographic range; species listed as Critically Endangered (CR), Endangered

(EN) or Vulnerable (VU) are collectively described as 'threatened'. The information is widely used to inform and influence biodiversity conservation, making the Red List the global gold standard for informing conservation research, policy and practice.



IUCN Red List categories and criteria at the global level

What does the Red List actually tell us? The assessment itself is an estimate of extinction risk – which, in the light of current knowledge, classifies species by their risk of becoming extinct. It is crucial to note, however, that the Red List is not just a list of high priorities for conservation. Indeed, a species with a high risk of extinction may not necessarily be the highest priority, and a species that has a very low risk of extinction may deserve some conservation action. Extinction risk is an important factor to consider when determining where to invest conservation resources, but it is not the only one. Financial, cultural, logistical, biological, ethical, social and other issues all contribute to maximize effective conservation actions. People undertaking assessments need to keep this in mind, and not to have a preconceived notion of how threatened a species "should" be or in which category it should be listed.

There are five criteria based on different parameters associated with extinction risk:

- Rate of reduction in population size over a specific time period. The faster the population is declining and the longer the generation length, the higher the risk of extinction because the species is less likely to have enough time to recover before being hit by the next threat.
- Extent of geographic range combined with degree of population fragmentation, decline, or fluctuation. In general a species with a restricted distribution that is also experiencing continuing decline will have a much higher risk of becoming extinct than one with a very wide range and little or no declines.

- Size of the global population combined with declining population size. A species with a relatively small population that is also declining will have a higher risk of becoming extinct.
- No current threats, but a very small global population or a very restricted geographic range. If the global population is very small or the species has a tiny range and there is a plausible potential threat, it has a higher risk of becoming extinct rapidly.
- Probability analysis of extinction risk. If a quantitative analysis is available that resulted in calculation of probability of extinction within a certain time period, this can result in the species being listed as threatened.

Each criterion has a series of thresholds and conditions attached to it, and it is these thresholds and conditions that determine into which of the nine Red List Categories a species falls.

So, who is responsible for compiling the information and carrying out the assessments? Anyone can carry out a Red List assessment. You don't need to be a scientist or a member of IUCN, but you do need information from the entire global range of the species you are assessing. So, in practice, most assessments are carried out by members of IUCN's Species Survival Commission's Specialist Group network (**www.iucn.org/commissions/species-survival-commission/about**). It involves more than 9,000 individuals who volunteer their time, data and knowledge to help IUCN.

How can the Red List be used? Red List data are used by many different sectors to inform and influence biodiversity conservation and are used widely in analyses, developing indicators and to influence conservation decisions and policy. For example, IUCN and its Red List Partners regularly publish analyses on the current status of the world's species; these are available to download from the Red List website. Such analyses are often used to inform conservation planning and priority setting, for example, determining where to site new protected areas. Spatial data can help identify the highest concentrations of threatened species and gaps in the protected areas. Red List data are also used in conservation action plans to determine which conservation measures are most critical to protect a species. Most countries around the world have agreed to international commitments to conserve and protect biodiversity and have adopted the Red List as an indicator of the status of biodiversity. Indeed, it is one of the indicators for the delivery of the Sustainable Development Goals. The Red List is also an extremely important tool for driving funding mechanisms, such that financial resources are channelled towards the conservation of threatened species. The information is widely used in safeguard mechanisms, and in planning, strategic and environmental assessment. Corporations and businesses consult the Red List to identify potential risks and opportunities early in their planning phases in, for example, major infrastructure developments, such as dams.

Finally, one of the most important roles of the Red List is as a communications tool, highlighting the importance of biodiversity and healthy ecosystems to the public, private sector, politicians, etc. One of the strengths of the Red List is that it doesn't just focus on threatened (CR, EN, VU) species, but can also highlight species that

'Most countries around the world have agreed to international commitments to conserve and protect biodiversity and have adopted the Red List as an indicator of the status of biodiversity.'

are Near Threatened (NT), Data Deficient (DD) and Least Concern (LC), many of which are also suffering declines; and those which are improving in status (the good news stories that highlight the effectiveness of good conservation actions where they are allowed to proceed). The Red List can also focus on the key threats that are affecting species, like the salmonids, which also have serious negative consequences for other species, and ecosysems, and for us.

How has the Red Listing process been applied to salmon? At the time of writing we have assessed the status of 152 species within the family Salmonidae, of which 13 species are declared Extinct (EX), two are Extinct in the Wild (EW), and 71 (60%) are classified as "threatened". Assessing the status of "salmon" species (Atlantic and six species of Pacific salmon), however, has been a challenge. Only two have been assessed, and one of these assessments, for Atlantic salmon (*Salmo salar*), is both outdated and incomplete according to the current standards required. Assessment of all the salmon species is therefore a current priority action for IUCN.

Scientific names	Common names	Global Red List status	Year of assessment
Salmon salar Linnaeus, 1758	Atlanic salmon	LC (Europe VU)	1996 (2014)
Oncorhynchus tshawytscha (Walbaum, 1792)	Chinook salmon	Not Evaluated	
Oncorhynchus keta (Walbaum, 1792)	Chum salmon	Not Evaluated	
Oncorhynchus kisutch (Walbaum, 1792)	Coho salmon	Not Evaluated	
Oncorhynchus masou (Brevoort, 1856)	Masu salmon	Underway	
Oncorhynchus gorbuscha (Walbaum, 1792)	Pink salmon	Not Evaluated	
Oncorhynchus nerka (Walbaum, 1792)	Sockeye salmon	LC (98 sub-pops)	2010

So what are the challenges we face when assessing the status of salmon species? Many of those involved in the management of individual salmon stocks have understandable concerns that an assessment of the global extinction risk of a high value, heavily managed species, such as a salmon, will mask the status of individually managed stocks, or "sub-populations" (the terminology used by the Red List). Consequently, in these cases the preference is to assess the global status of the species first and to then also assess the status of all sub-populations. This is time- and labour-intensive and has slowed progress.

Another difficulty in assessing salmon species is the accounting for hatchery-reared individuals often introduced in large numbers within the native range of a species. The Red List assessment is based on the status of the "wild" population so it has to take account of these hatchery-reared individuals when assessing rates of population decline, which is not easy. For example, in extreme cases, such as for some sturgeons, a species may only survive in the wild because of the release of hatchery-reared individuals, without which the species would be extinct in the wild. For salmon, decline in the wild populations and sub-populations may be "masked" by the regular introduction of hatchery-reared individuals. In a similar vein, the Red List assessment also has to account for any fish that have escaped from fish farms, again potentially masking declines in the wild population.

Given the challenges in assessing salmon species only one species has been fully assessed recently. This is the Sockeye salmon (*Oncorhynchus nerka*), for which an additional 98 sub-populations were assessed, reflecting the status of each discretely managed stock. Although the global status of Sockeye is Least Concern (LC) – meaning there is low risk that the species will go extinct under current conditions – five sub-populations were found to be Extinct and a further 19 threatened. For 31 sub-populations, there were insufficient data to make an informed assessment of extinction risk so these were assessed as being Data Deficient and in need of additional information. The authors of this in-depth study (**https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0034065**) concluded that without an understanding of risk to biodiversity at the level of sub-populations biodiversity loss in salmon would be greatly underrepresented on the Red List.

The Atlantic salmon has also been assessed globally as Least Concern (LC), but the assessment is now out of date, having been originally conducted in 1996, at a time when the assessment process was less rigorous. A global reassessment of the species is therefore now a priority. More recently (2014) the Atlantic salmon was assessed in Europe, and was found to be threatened (Vulnerable, VU), meaning the best available data indicated the species was facing a high risk of extinction in the wild in Europe.

There is more work required to assess the status of our salmon species. Work is, however, underway through IUCN to assess the remaining Pacific salmon species at the global scale, and plans are being made to complete a global assessment of the Atlantic salmon and its constituent stocks, or sub-populations, over the next year. An assessment similar to that for Sockeye will make a make a major contribution to our understanding of the status of crtically important wild Atlantic salmon, and, as Jamie Stevens explores in his article, help us understand how more distinctive taxa, such as the salmon of lowland chalk streams are faring. It is feared that some of these remarkable fish face serious declines, and risks from many quarters, including pollution and water abstraction.

'It is feared that some of these remarkable fish face serious declines, and risks from many quarters...'

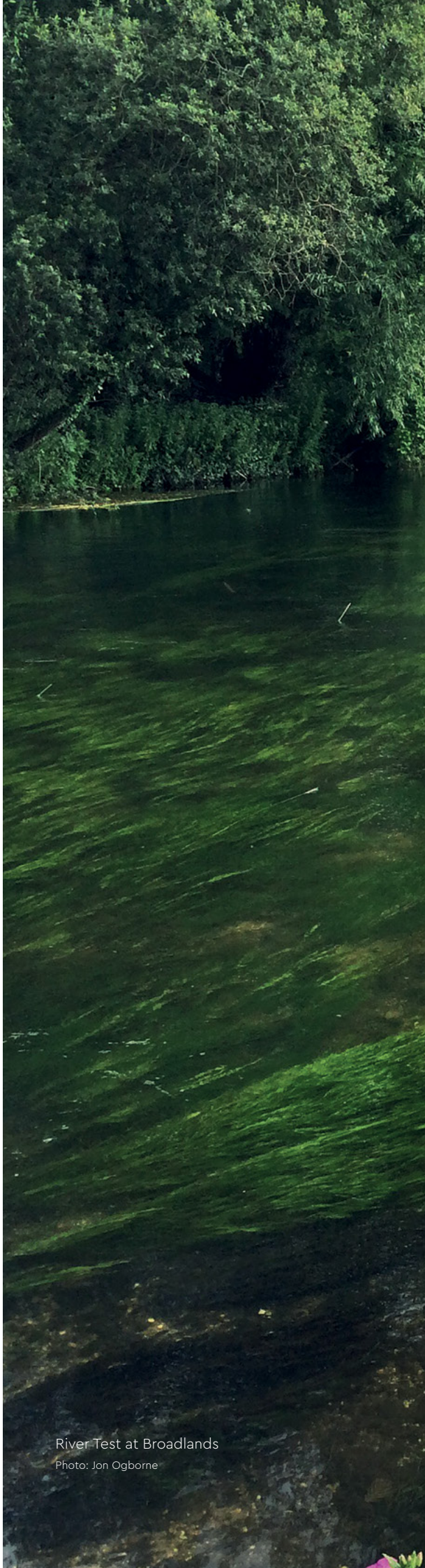
In summary, the Red List is a vital tool for determining the status of salmon and is a key input to conservation planning. A species' Red List status serves to trigger environmental safeguards under national and internatianl legislation, and it alerts the private sector and major funders to the presence of a threatened species, or to the "critical natural habitat" (determined in part by the presence of threatened species) that triggers mitigation processes. Finally, as mentioned above, the Red List has been adopted as a key indicator of progress for countries to meet their international commitments to conventions and to development goals, such as the SDGs, and so to ensure the conservation status of species has been improved and sustained. Throughout, the Red List helps focus attention on species most at risk of extinction and, sadly, this includes many of the salmonids that play a vital role in the well-being of river ecosystems, and in the lives and livelihoods of a huge range of people.

Exploring the genetic diversity of Atlantic salmon: The case for recognising the chalk stream salmon of southern England as a distinct taxonomic entity

Jamie Stevens

The gently flowing chalk streams of southern and eastern England are world famous, to conservationists as well as anglers, for the quality of their water, the quiet beauty of the farming country through which they flow, and the story their catchments contain of centuries-old management of land and water. To many fishermen, they also mean trout of rare quality. But these chalk streams are also home to migratory fish, sea trout and Atlantic salmon and recent research conducted by my team at the University of Exeter shows that chalk stream salmon have their own claim to fame as a genetically unique sub-population of *Salmo salar*, every bit as special as chalk stream trout. Running the gauntlet of dense conurbations at their river mouths, and navigating some of the noisiest and busiest marine areas (twice!) these chalk stream salmon and the threats they face have much to tell us about the fate of salmon everywhere, and may even inspire hope for the future.

Atlantic salmon require high standards of the waters they inhabit: their rivers need to be highly oxygenated, cool and clean. If any one of these conditions are not met, their eggs won't develop. But they have still successively managed to colonise a variety of habitats across a huge geographical area of northwest Europe and eastern North America. In Europe, viable populations can be found thriving in a variety of river types from snow-fed streams in northern Spain, to glacial melt-waters in Iceland and Norway, to the slow moving spring-fed rivers of southern England (Figure 1). Specific conditions, for example, in the rivers of northern Spain, which flow northwards off the mountains of the Picos de Europa, can provide localised conditions: river morphology, chemical characteristics and water temperature, suitable for Atlantic salmon at southerly latitudes that one might not immediately associate with being suitable for the



River Test at Broadlands
Photo: Jon Ogborne

Figure 1. Salmon rivers: a) the Sella, Asturias, northern Spain (above); b) the Frome, Dorset, England (below).

species. In contrast, over much of their length, the chalk streams of southern England are relatively low gradient, slow flowing rivers, which –being spring-fed from aquifers rising on chalk bedrock– are characterised by stable temperature (~10°C) and flow rates, high water purity and a mildly alkaline pH. They often form meandering water meadows in their lower reaches (Figure 1) and are highly productive in terms of plant life and their invertebrate fauna, providing excellent habitat for both salmon and trout.

So, if salmon are so good at inhabiting a wide range of freshwater habitats, can individuals from thriving populations be readily moved around to support threatened populations that have diminished in number and/or to restock populations that have been wiped out in a particular river or area? In short, the answer is typically, 'no' and the remainder of this article will explore the many reasons why this is generally so, and why this need to 'fit' to local conditions is so essential for chalk streams.

At this point, it is worth reminding ourselves of the evolutionary background of Atlantic salmon. Evolutionary studies indicate Atlantic salmon (*Salmo salar*) and trout (*Salmo trutta* L.) diverged around 12 million years ago (the mid-Miocene). Subsequently, a number of genetically distinct trout lineages appeared around 5 million years ago; the morphological plasticity of *S. trutta* is well recognised and numerous separate species, subspecies and morpho-types –some better supported than others– have been documented throughout Europe, western Asia and North Africa. In contrast, to date, no universally accepted taxonomic variants of Atlantic salmon have been recognised, though it is clear from genetic and immunological evidence that not all Atlantic salmon are the same, North American Atlantic salmon (with only 27 chromosomes) and Baltic Sea salmon (with their innate resistance to the parasite *Gyrodactylus salaris*) being obvious candidates for formal recognition as separate taxonomic entities.

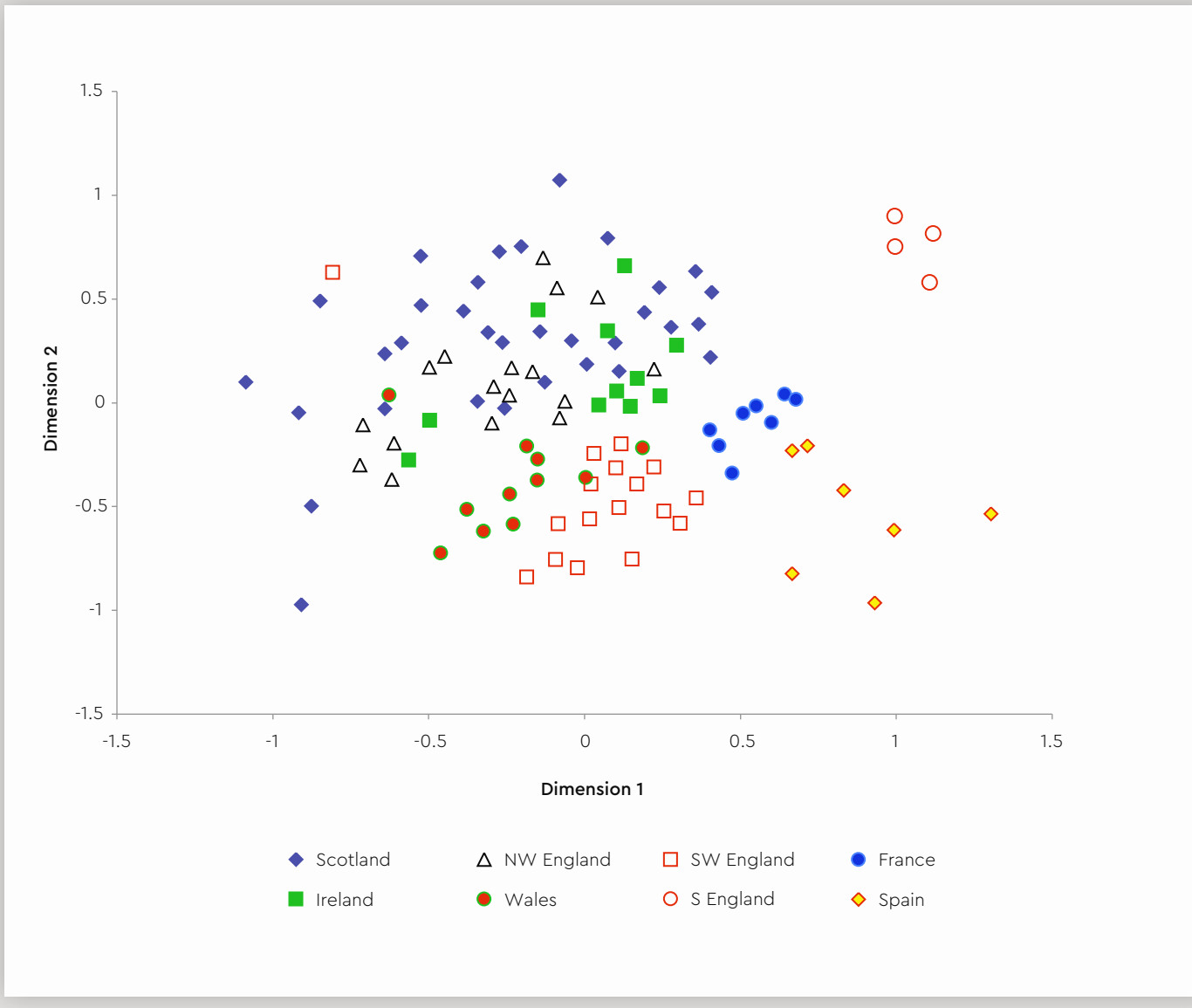
The recognition of different taxonomic variants of species is not just a book keeping exercise for academics and scientists obsessed with names. Mapping the diversity of distinct variants within a species or species-complex can have profound implications for its conservation: it can influence legislation framed to preserve the diversity of a species, and thus also its protection, its management and, ultimately, its survival. This is important, as conservation can only work effectively when we have an accurate understanding of what we are conserving! If everything is lumped together, attempts to conserve a species may not work – if distinct variants of a species are not being conserved, significant parts of the overall diversity of the target species are at risk of being lost.

'...if distinct variants of a target species are not being conserved, significant parts of the overall diversity are at risk of being lost altogether.'

As noted above, in North America *S. salar* have 27 chromosomes, while in Europe they have 29. Thus, major genetic differences exist between Atlantic salmon on the two continents. Knowing this allowed scientists in the 1990s to use relatively simple genetic techniques to ascertain whether salmon caught in the West Greenland fishery originated in Europe or America using relatively simple genetic techniques, for example: two informative restriction enzymes.

However, while such an approach may be useful for distinguishing a salmon's continent of origin, exploring patterns of intra-specific genetic variation at a finer scale, means genetic variation across a major component of the species' geographical range needs to be analysed. Several studies have now addressed this, beginning in 2004 with the Atlantic Salmon Arc Project (ASAP), the brainchild of Dr Dylan Bright of the Westcountry Rivers Trust; subsequent to this was the SALSEA-Merge project, a huge research undertaking launched in 2008 and spearheaded by NASCO, the Atlantic Salmon Trust and the Total Foundation. These projects were aimed at exploring where salmon go to at sea and where they are headed back to on their return migrations. To achieve this, a range of tools (tagging/mapping/molecular/ statistical) were developed to allow migrating salmon to be tracked at sea and assigned back to their population of origin. A precise understanding of salmon migration routes and the relative importance of different rivers in contributing to sea-going stocks, remain some of the last major unknowns in the continuing decline of Atlantic salmon.

Figure 2. MDS plot – salmon population genotypes analysed in ASAP project



Both research projects also provided compelling new evidence of the unique genetic make-up of Atlantic salmon inhabiting the chalk streams of southern England. Firstly, as seen in Figure 2, genetic distances between the majority of samples analysed correlated with the geographical distance between sample locations (in this case, between the natal rivers of sampled fish); population geneticists refer to this as Isolation by Distance (IBD). For example, the genetic profiles of Spanish salmon showed them to be most similar to salmon from French rivers, while they are least similar to salmon sampled from rivers in Scotland. However, while most samples conformed to this pattern of IBD, one group of fish stood out and didn't fit this trend – these were the chalk stream salmon of southern England! Their genetic profiles were highly distinctive and the data suggested that they were not exchanging genetic material – their alleles – with their nearest neighbours in England, France or, indeed, anywhere else. In a nutshell, the genetic differentiation of chalk stream salmon from other European *S. salar* is not related to geographical separation.

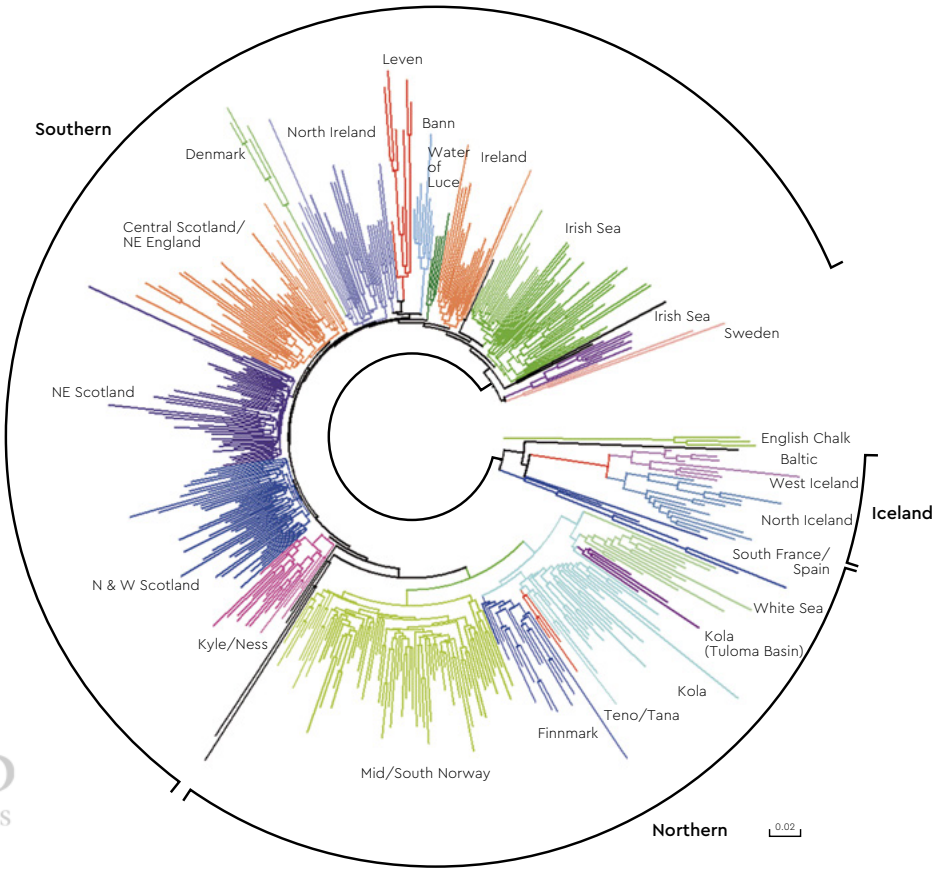


Figure 3. Neighbour-joining phylogenetic tree of sample sites based on D_A distances calculated from microsatellite genotypes (14 loci; major clusters coloured). *ICES Journal of Marine Science*, Volume 75, Issue 2, 2018, Pages 662–674, https://doi.org/10.1093/icesjms/fsx184

Secondly, it is apparent that the bulk of salmon analysed, including fish from rivers on the Kola Peninsula in northwest Russia, salmon from western (non-Baltic) Scandinavia, the British Isles (except the chalk stream salmon) and northern France, all share common ancestry Figure 3, while another group, comprising Baltic Sea salmon, Icelandic fish and salmon from the rivers of northern Spain, formed a second assemblage of apparently unrelated lineages, a

grouping which may be an artefact of the phylogenetic analysis (it is difficult to envisage a scenario that might convincingly explain shared evolutionary ancestry among this diverse group of salmon). This left one other group –salmon from the English chalk streams– as distinct from and apparently unrelated to any other salmon included in the study.

We were keen to explore the question of this apparent genetic distinctiveness further, so conducted a more detailed (more rivers, more fish, more genetic markers) molecular study focusing exclusively on just chalk stream salmon. As anticipated, the genetic profiles of chalk stream salmon were distinct from salmon in other nearby rivers in southwest Britain and northern France, as well as fish from further afield, e.g. Norway (Figure 4a). Norwegian fish were included in the study as a proxy for farm-strain salmon (many of which originate from Norwegian stocks); inclusion of these genotypes in the genetic baseline offered the potential to be able to identify farm strays that may have escaped and bred successfully with wild salmon. Our data showed little or no evidence of this, suggesting –thankfully– that, currently, fish farm escapees do not appear to be having any significant impact on the genetic make-up of chalk stream salmon (Figure 4b), though widespread contamination of wild fish populations by escapees is evident elsewhere. Only one or two populations of salmon from northwest France showed any marked indication of chalk stream genetic material (alleles) being present in their genetic profiles (Figure 4a). We can't yet be certain whether this apparently shared material (alleles) results from contemporary genetic exchange or whether this betrays their more ancient shared evolutionary history.

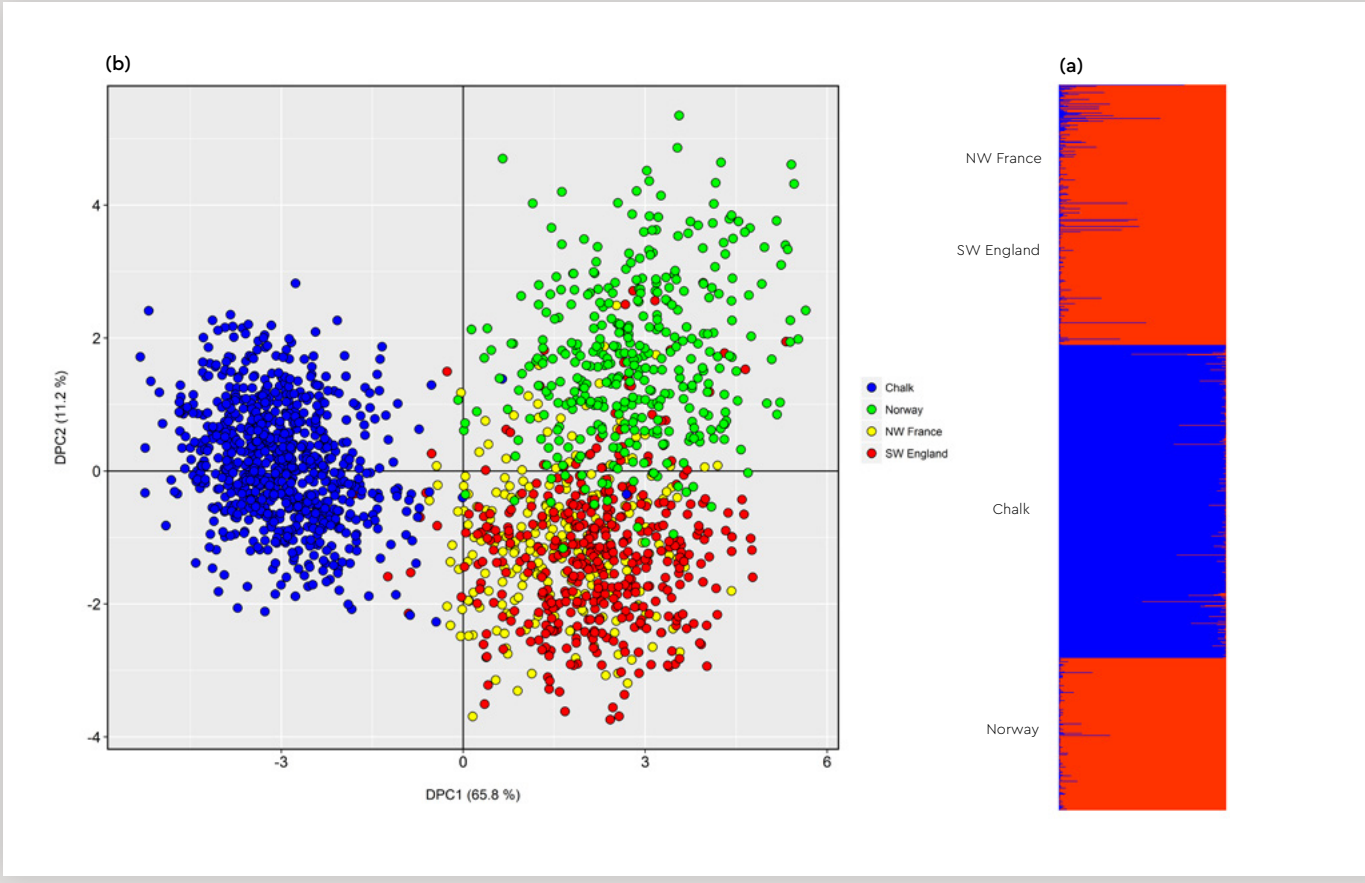


Figure 4. Principal components (L) and STRUCTURE (R) analysis of Atlantic salmon microsatellite data (12 loci)

However, compelling as they are, these results are based on analysis of no more than 14 genetic markers (so called 'microsatellite loci') distributed across the 29 chromosomes that comprise the genome of European Atlantic salmon, i.e. less than one genetic marker per chromosome! So, we need a methodology that covers more of the genome to give more confidence in the patterns observed. Such a molecular marker system is now available in the form of single nucleotide polymorphisms (SNPs), which allow us to sample thousands of independent points across the genome of multiple individuals of a species at relatively low cost and without the need for a fully sequenced and annotated genome for the species being studied. Unfortunately, recent studies that have undertaken genetic analysis across the range of European and North American Atlantic salmon populations did not include any fish originating from the English chalk streams. This is something that we at Exeter are currently working to address. Preliminary results of our own SNP-based analysis focusing on salmon populations in a number of chalk streams reconfirm the distinctiveness of chalk stream salmon, whilst offering a first insight into the apparent lack of genetic differentiation between different chalk stream populations. More work is needed, but, if confirmed, these results are indicative of little or no straying (or at least little or no successful –in terms of breeding– straying) of fish between chalk and non-chalk stream populations, along with potentially increased straying of chalk stream salmon between different chalk streams.

This last finding, if confirmed, could be critical to successful conservation and management of chalk stream salmon. A study by the Exeter team and the Environment Agency from 2011, which compared the genetic profiles of adult salmon entering the river Thames with fish released into the river as part of a 30-year stocking programme, demonstrates how such knowledge can be critical. Beginning in the mid-1970s, tens of thousands of Atlantic salmon at different life stages were put into the Thames as part of an Environment Agency programme to restock the river; the fish used originated predominantly from Ireland and Scotland. Unfortunately, the numbers of salmon caught in the Thames trailed off immediately the stocking effort stopped and it appears that the whole programme, over more than three decades, served only to create one of Europe's biggest put-and-take fisheries! What we now know about the genetic differences between chalk and non-chalk stream salmon, may explain why this project failed to re-establish a viable resident population of Atlantic salmon in the Thames. However, towards the end of the programme, in the late 2000s, adult salmon were trapped at Molesey Weir (west London); both tagged (stocked fish) and non-tagged fish were caught.

'The long-term future of these fish is unknown, but if water quality is good, the waterway is navigable, and fish are suitably adapted to the conditions present within a river, then, as also seen in the river Mersey, salmon are more than capable of recolonizing rivers from which they have previously been extirpated.'

Where did these untagged adult fish come from? Were they the product of a successful breeding population in the river originating from the stocked fish or were they fish that had strayed into the Thames from elsewhere? Comparing the genetic profiles of the adult fish caught at Molesey with our European data set showed them to assign to the chalk stream populations included in the database. It appears that salmon had strayed along the Channel from rivers in Hampshire, before entering and ascending the Thames. Straying in salmonids is not uncommon and straying rates of 8–11% have been reported – the important question is how often

River Test at Wherwell
Photo: Jon Ogborne

do straying fish succeed in entering and ultimately breeding in a river they weren't born in? Certainly, the Thames has got cleaner and many of its barriers to migration have been removed; it also appears that fish are now beginning to naturally recolonize the river.

The long-term future of these fish is unknown, but if water quality is good, the waterway is navigable, and fish are suitably adapted to the conditions present within a river, then, as also seen in the river Mersey, salmon are more than capable of recolonizing rivers from which they have previously been extirpated. Of these three key factors, legislation and actions on water quality, together with improvements in river navigability (e.g. removal of dams and weirs) have enabled major improvements for migratory fish in many of the rivers of Europe. But, humans have so far been unable accurately to recreate the third factor –local adaptation of a fish species to the specific conditions (geochemical, thermal, flow regimes and microbiological) within a river– which is intrinsic to the fish population and its genetic make-up. This is why it is so essential to understand the genetic make-up of a fish population and ensuring its suitability to the new environment into which it is to be translocated. The success of any future stocking activity will likely depend on this knowledge.

The salmon of the chalk streams of southern England harbour a unique component of the biodiversity of the species. Their genetic profiles clearly set them apart from any of the many other European populations of *S. salar* analysed, and indicate them to have a relatively narrow genetic repertoire compared to the genetic diversity found within a complementary set of populations from proximal non-chalk rivers in southwest England. Research indicates little or no contemporary gene flow between non-chalk and chalk stream salmon populations, suggesting a lack of straying and/or successful interbreeding between non-chalk and chalk stream fish. In combination, their stable, distinct genetic profiles and their highly localised geographic distribution conforms to the requirements for recognition as a distinct taxonomic entity, namely a distinct subspecies of *S. salar,* that I suggest be designated *Salmo salar calcariensis*.

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Figure 1.
Detail from "Deep Forest",

Cultivating and Classifying Salmon: Engagements with Sockeye in the Salmon Forests of the North Pacific

Thomas F. Thornton

Like a salmon returning to its natal stream, I recently returned from an ocean migration (to Oxford for a decade, directing the Environmental Change Institute's MSc/MPhil programme) to the campus where I held my first teaching post: the University of Alaska Southeast (UAS).

UAS may be unique among institutions of higher learning in representing ourselves as inhabitants of a Salmon Forest.

As you can see in Figure 1, from the cover of our recent strategic plan (https://www.uas.alaska.edu/UAS_StrategicPlan/index.html), there are no august campus buildings, or even students in the image – just a school of salmon swimming past the trees and plants that characterize our Tongass National Forest environs. The Tongass is America's largest national forest and the heart of the largest temperate rainforest in the world, a land and seascape not only characterized but literally nourished by salmon. The late Richard K. Nelson describes how migrating salmon, carried from streams by bears, birds and other predators, add nutrients to the forest

ecosystem – fertilizing forests over millennia: www.youtube.com/watch?v=g00fAKG31lw.

At the UAS Alaska Coastal Rainforest Center, research into water quality, stream habitat, and the food webs supporting juvenile salmon helps paint a picture of the complex feeding relationships of these species and how climate change and glacial retreat is altering the systems supporting them.

Already, such ecological thinking is leading to reconsiderations of our dominant managerial perspectives. There are increasing doubts about the efficacy of maximizing short term commercial yields through human interventions in salmon life cycles, such as fish farming (total domestication) and hatcheries (control of fertilization through fry development). Significantly, while large-scale salmon farming is now drawing significant criticism for its impacts on wild salmon and the environment, Alaska outlawed fish farming in its 1959 constitution in order to sustain the quality of its wild runs and the livelihoods of local small-scale fishing fleets. Sustained yield, with proper escapement and protections for salmon and other anadromous fish returning to their spawning streams, remains a bedrock principle in Alaska's fisheries management. At the same time, however, Alaska has for more than a century embraced wild run enhancements, such as hatcheries, as a tool to boost salmon returns. But how many hatcheries, which types of salmon, how much production, and where?

These questions have not been systematically addressed beyond the scale of the stream or local fisheries management districts which constitute just a fraction of the Pacific salmon lifeworld. The consequences of this gap in our thinking could be grave. Just as Alaska has sought to build hatcheries to enhance its salmon runs, so too have Canada, Russia, Japan, and others. In the North Pacific this has resulted in an uncoordinated salmon production race, fueling a potential tragedy-of-the-commons scenario (Hardin 1968) at the ocean scale. Without limitations on local enhancement there is little incentive for hatcheries to stop pumping more and more salmon into the North Pacific until the ocean's ability to sustain them collapses, with devastating effects on salmon and other species that share the marine commons. Fortunately, at the stream and watershed scales we are beginning to realize that caring for salmon requires us to think beyond this single-species production mindset towards recognition of the complex social-ecological systems that support salmon and their habitats, as exemplified by the concept of the Salmon Forest.

UAS sits on the Indigenous territory of the Áak'w Kwáan (People of Áak'w, in the local Tlingit language). *Áak'w* means "Little Lake" but is rendered, redundantly, as "Auke Lake" in English (Figure 2). Along with its short outlet stream, Auke Creek, or *Gathéeni* (Sockeye Creek), *Áak'w* plays host to anadromous sockeye (*O. nerka*), pink (*O. gorbuscha*), and coho (*O. kisutch*) salmon, as well trout and char. Áak'w Kwáan Tlingits have cherished this multispecies salmon stream, productive from late spring through mid-autumn, as a foundation for their subsistence economy for centuries. Sockeye are especially prized among Tlingits due to their comparative rarity, high oil content, and rich taste, especially when smoked.

'Tlingit emphasize some particular distinctions among sockeye that highlight their elite status.'

‘Throughout the Pacific Northwest, we find similar behavior and sacred techniques, such as the first salmon ceremony, for cultivating the renewal and respect of salmon runs.’

Figure 2. Auke Lake (Áak'w) is the center of Áak'w Kwáan Tlingit territory,and also the home of University of Alaska Southeast, and an important sockeye, pink, and coho salmon stream and forest.
(T. Thornton)

Thus, when it comes to naming salmon multi-species streams, sockeye salmon are typically singled out in toponyms (as evidenced in the name *Gathéeni*), underscoring their cultural and ecological importance. In addition, sockeye have high stream fidelity, impressive instream longevity (lingering in the lake systems within which they prefer to spawn), and typically share streams with at least two other types of Pacific salmon — and often four or all five species — with complementary spawning schedules. The effect of this multi-species complementarity is to provide longer salmon harvesting seasons than streams without sockeye. While fall runs of coho and dog (*O. keta*) salmon are also celebrated for extending summer fish production, and all three species can be found among the major crests (emblems of identity) of Tlingit clans, sockeye are special.

The high status of sockeye and local differences among them lead to important Indigenous distinctions in classification, which are more nuanced than the scientific taxonomy. While most Alaska Native languages have basic terms for the sockeye (red), chinook (king), chum (dog), coho (silver), and humpback (pink) salmon that exist within their territories, Tlingit emphasize some particular distinctions among sockeye that highlight their elite status. Among the most celebrated of these is their recognition of a separate, smaller sockeye known not as *gaat* or its diminutive, but as *dagák'*, a distinct term. These "little sockeye" are significantly smaller than conventional ones (the downsizing said to be an evolutionary adaptation to surmount long, fast-flowing falls in returning to their lake spawning grounds) and have a distinctive texture and oil-rich flavor when smoked, which is prized. Finally, *dagák'* are famous for the fact that they are said to have become insulted and withdrawn from one of their spawning streams near Sitka because their way was blocked by a weir (note: stream weirs are an Indigenous technology in Southeast Alaska dating back some 4,000 years, but also used by colonizing Russians and Americans). The abandoned stream was subsequently (re)named in their honor as *Dagák' Aax̲ Aawateeni Héen* (Little Sockeye Going Away [Insulted] Creek).

The incident serves as a poignant reminder of the importance of respecting salmon lifeways and taking care to insure sufficient escapement to their spawning grounds. It is also the source of a proverb among the Sitka Tlingit, still used today at ceremonies like the multi-day memorial potlatch or *ku.éex'* (invite). A host, entreating his guests to stay longer, may enjoin: *Tleil dagák' aawateeni yík*, "Don't go away [insulted] like those little sockeye" (Thornton 2008). The proverb equates hosting ceremonial guests with hosting salmon: both must be treated respectfully, nourished and cared for, and not insulted. And just as a ceremonial host may carry the title *Hit S'áati* (House Master),the Tlingit give the title *Héen S'áati* (Stream Master) to the local leader who has the best knowledge of how to host and care for the local salmon and their stream so that the salmon are not offended, or depleted, thus ensuring sustainability and food security. Throughout the Pacific Northwest, we find similar behavior and sacred techniques, such as the first salmon ceremony, for cultivating the renewal and respect of salmon runs (see Deur, Thornton, Kitka 2015; Langdon 2007). In this Indigenous ecological paradigm, the Salmon Forest is not just a community of species and habitats to be "optimally managed" as

Figure 3. COVID-masked staff at the Auke Creek Research Station. Left to Right: David Tallmon (Professor of Biology, UAS), Scott Vulstek (National Marine Fisheries Service Lead), Josh Russell (NMFS), Hailey Quinto (UAS), and Padraig New (UAS). (Photo T. Thornton)

Figure 4. Haley Quinto, left, with fellow UAS student Padraig New, takes a sample from a sockeye returning to Auke Creek. They are contributing to among the best long-term wild salmon data sets in the world. (Photo T. Thornton)

'All this suggests that we have to be more attentive to the cultures and environments that support salmon, and not just on producing and capturing more at all costs.'

"resources" for humans, but rather a moral economy in which other species, like salmon, must be treated as sentient other-than-human persons with agency, prerogatives, and needs. Thus, people talk to the salmon respectfully, as Tlingit elder Joe Hotch relates, "We are supposed to say 'Ey Ho!'; you see a fish [salmon] jump, 'Ey, Ho,' [then] they know they're being appreciated so they keep jumping. And I guess our people say it so they can know which way it's going. Just keep saying 'Ey Ho', and that's the way they want to be talked to; the fish want to be appreciated (in Thornton 2012: 50– 51).

In comparison to the massive, world-famous wild sockeye runs at Bristol Bay, AK (50+ million strong of late), the fate of *dagák'*, now found only in Necker Bay, *Dagák' Geeyí* (Little Sockeye Bay, and small sockeye systems like *Áak'w* may seem like "small potatoes." The *Áak'w* system supports just a few thousand sockeye and no commercial harvest. Yet it endures because it has been cared for and carefully cultivated for centuries, mainly by Áak'w Tlingits, but also by scientists since the twentieth century, who recognized its values to the local community, and as a cipher to decode what's happening more broadly with salmon in the region.

Alaska's colonization, beginning in the 19th century, brought fur and gold rushes followed by timber and salmon production on an industrial scale, leading to the dispossession of Alaska Natives' salmon streams, along with other changes to the landscapes of Southeast Alaska. By the time Juneau was established as Alaska's capital in 1906, pressure from industrial fishing and canning on salmon streams was already taking its toll. The creation of the Tongass National Forest in 1907 signaled a more scientific approach to the region's development, balancing industry and conservation interests. Yet knowledge of the importance of the riparian habitat and stream structure for salmon (well developed in the Indigenous knowledge) was not well developed in scientific forestry, leading to further degradation of the Salmon Forest system.

Meanwhile, early salmon science focused on enhancing production. Auke Creek became host to some of the first "citizen science" experiments with salmon enhancement and hatcheries but never on an industrial scale. This attention culminated in the establishment of a federal research station, known as the Auke Creek Fish Hatchery, in 1979 under the National Marine Fisheries Service (Figure 3), in conjunction with the Alaska Department of Fish & Game and the Territorial Sportsmen, Inc. (recreational fishermen who championed early conservation and enhancement efforts). This research station now partners with University of Alaska to employ both undergraduate and graduate students in salmon research (Figure 3). Utilizing a weir designed for counting sockeye, pink and coho as they move up upstream through a constructed "ladder" into a holding pen, the students collect genetic and other samples from the fish (Figure 4) and spawning grounds. Researchers have counted every fish that has passed through the weir for 40 years, yielding perhaps the most comprehensive long-term data set on Pacific salmon in the world.

What does this data tell us? According to UAS fisheries biologist David Tallmon, who mentors student researchers along with Auke Creek Research Station lead Scott Vulstek, it shows that, with

'Researchers have counted every fish that has passed through the weir for 40 years, yielding perhaps the most comprehensive long-term data set on Pacific salmon in the world.'

Figure 5. A 2004 commemorative USA First Class stamp, depicting a carving of the Salmon Boy story. (US Postal Service)

climate change and its environmental impacts, salmon migration patterns are also changing. Warmer ocean temperatures have led to earlier migrations into spawning streams, shifting the whole spawning period by about three weeks. There has also been a contraction in the temporal span of the combined salmon runs, which have compressed into a period (July to September) approximately 30 days shorter than in the early 1980s. The data also show that the quality of runs at Auke Bay may fluctuate in ways that other systems don't; for example, Auke Creek may support strong or stable sockeye runs when nearby systems, like the Taku River, are down. This diversity is important to the resilience of the regional salmon system as a whole, and contributes to what is known as the "portfolio effect" (Schindler, et al 2010), wherein regional fisheries stocks, like those stocks you might hold in a personal investment portfolio, benefit from diversification because it mitigates the variability of returns, thus reducing overall risk.

All this suggests that we have to be more attentive to the cultures and environments that support salmon, and not just on producing and capturing more at all costs. The traditional Tlingit story of the "Salmon Boy," widely shared among communities of the Pacific Northwest salmon region, commemorated in art, including a USA stamp (Fig. 5), and taught in school curricula (**www.youtube.com/watch?v=iGH8cmKKZ78**), makes this point in a compelling way.

The story tells of a Tlingit mother who offers her boy a dried piece of salmon with a bit of mold on the end, all that remains of last winter's stores as the family awaits the return of this year's salmon at their smokehouse camp near the stream mouth. Irritated, the boy flings the moldy salmon away in disgust, committing a taboo of disrespect which offends the Salmon People. As result they sweep him away into their ocean world, where he is transformed into the "Salmon Boy" and given the name him *Shanyaak'utlaax* (Moldy End) to mark his insult. In their underwater world, the boy learns that the Salmon People are organized like humans into tribes (species) and house groups (spawning schools) and respect each other as well as their adopted guest. In this way, the Salmon Boy learns to see, appreciate, and relate to the world as a salmon.

After several years *Shanyaak'utlaax* migrates back to his home stream with the Salmon People, and is returned to his family, who are able to ceremonially transform him back into human form. Restored, he is given the name *Aak'wtatseen* (Alive in the Eddy) completing his rebirth at the stream mouth where he was first taken. *Aak'wtatseen* becomes a powerful shaman and teaches his human relatives the ways of the salmon and how to respect and cultivate them as moral, sentient beings. This transformation toward moral-ecological cognition and respectful relations with salmon is a profound one, and a paradigm that should continue to guide us as we engage with salmon and the Salmon Forest today.

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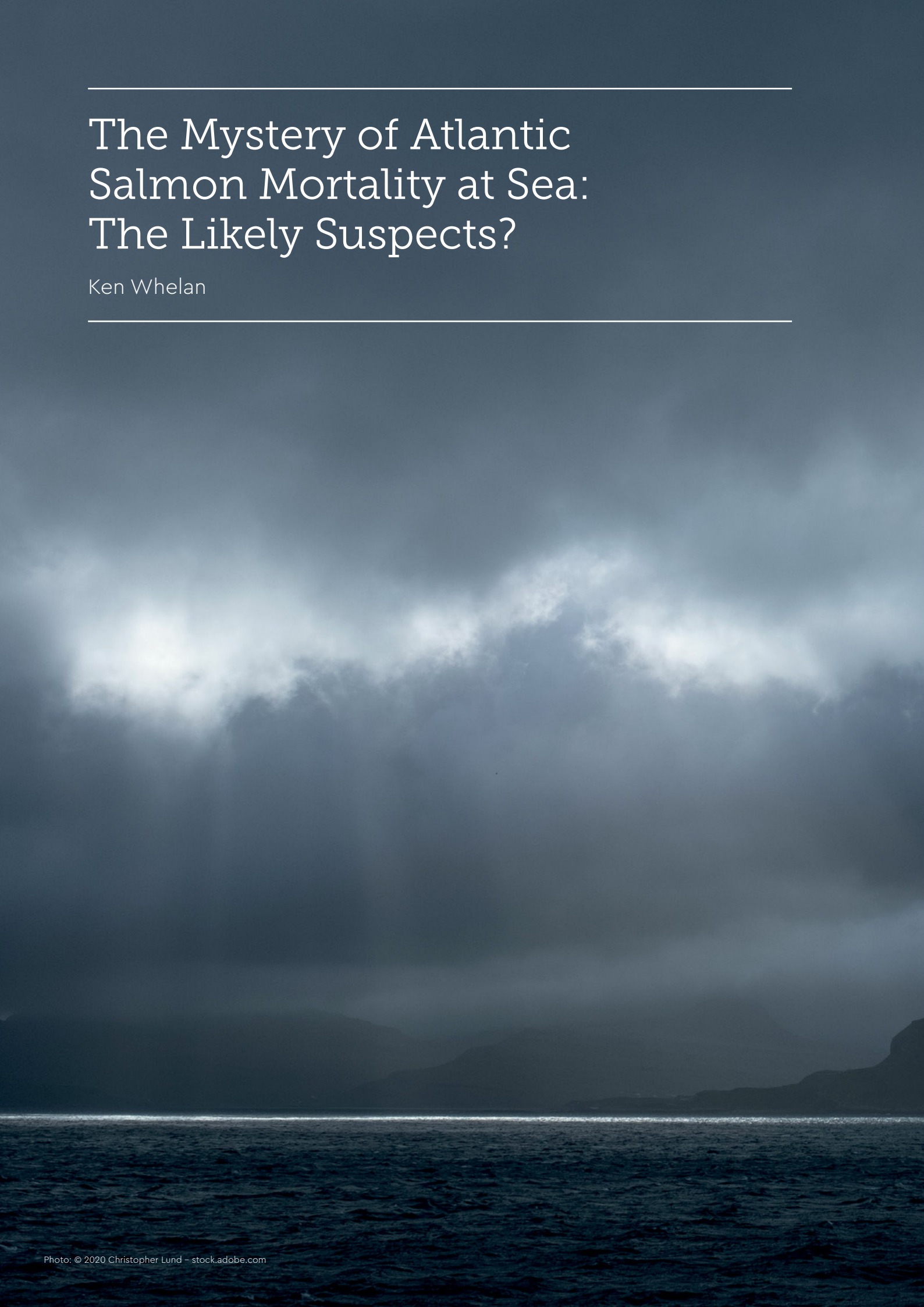
Figure 6. A view of the North Pacific at Auke Bay, the mouth of Auke Creek, as photographed from the Auke Creek Research Station weir. Sockeye, pink, and coho salmon make their way up the creek to their spawning grounds at outlet of Auke Lake (Áak'w).
(Photo T. Thornton)

The Mystery of Atlantic Salmon Mortality at Sea: The Likely Suspects?

Ken Whelan

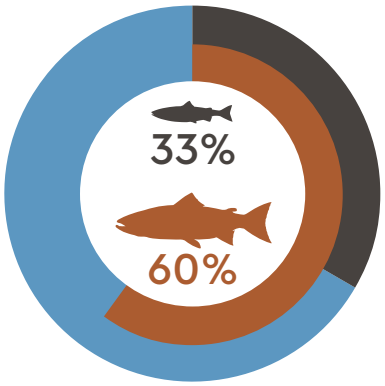


"Freshwater temperatures are rising, smolts are growing faster and the smolt age is dropping. Younger smolts are often smaller and therefore do poorly at sea. Countering the effects of increasing water temperature through providing cover and shading and ensuring that abstraction and water regulation are done in a manner which ensures overall temperature stability are just some of the actions that must now be prioritised. We have long talked about the impacts from forestry, pollution, aquaculture in the marine and freshwater environments, and perhaps in the past believed that we had the luxury of time to deal with these issues. In the face of what we have recently learned about the stocks which are under pressure and the stocks at risk at sea, taking urgent management action in these areas is no longer a choice – it is an imperative."

Ken Whelan, 'Salmon at Sea', *Trout and Salmon* magazine, December 2011

Atlantic salmon are regarded as a keystone species and play a unique and crucial role in our aquatic ecosystems. They are a superb biological indicator: their migration pathways traverse lakes, rivers, estuaries and the high seas. Tracking the movements and overall welfare of salmon stocks across these distinct biotopes can tell us a great deal about the health of our oceans and our freshwater resources.

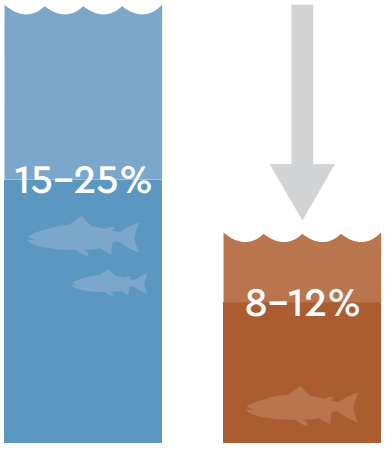
Some sixty years ago the feeding grounds of the Atlantic salmon were discovered off the coasts of Greenland and the Faroe Islands, and the discovery swiftly led to their commercial exploitation, and a significant impact on salmon populations. For the next twenty years resource managers struggled to curtail and eventually eliminate the larger of these high seas fisheries. It was assumed that once this problem was solved stocks of Atlantic salmon would bounce back and we would see a level of abundance similar to that recorded throughout the early decades of the 20th century. However, recovery was painfully slow and it soon became obvious that other man-made factors such as home-water commercial fisheries, pollution, loss of salmon habitat, river impoundment and abstraction and the growth of high seas aquaculture were all taking their toll locally on the remaining stocks of Atlantic salmon. Massive resources were poured into single issue conservation campaigns, but despite localised improvements the overall stocks of Atlantic salmon, particularly in the southernmost catchments of Europe and North America, stayed stubbornly low.



Salmon spend on average between 33% (grilse/one-sea-winter salmon) and 60% (large salmon/multi-sea-winter salmon) of their life at sea

Salmon spend on average between 33% (grilse / one-sea-winter salmon) and 60% (large salmon / multi-sea-winter salmon) of their life at sea but we know relatively little about the key factors regulating the mortality of salmon in the ocean. As indices of marine survival were developed it became clear that despite the many and at times very serious local problems besetting stocks of Atlantic salmon, there was an overriding issue, or issues, impacting on the survival of Atlantic salmon at sea.

In the case of the Irish salmon, many of which spend a little over one year at sea (grilse), marine survival has declined over a period of some thirty years from a range of 15% to 25% down to 8% to 12%. In recent times, smolt survival has dipped below 5%! Losing 95% of the young salmon stock at sea is unprecedented.



Marine survival for Irish salmon has declined over a period of some thirty years from a range of 15% to 25% down to 8% to 12%

A major marine study of salmon (SALSEA) undertaken by the North Atlantic Salmon Conservation Organisation (NASCO) from 2008 to 2011 defined for the first time some of the migration pathways of salmon at sea. Studies on their growth, condition and survival have clearly indicated a link with climate change, particularly the warming of the surface layers of the oceans. It is through these surface layers that the young salmon or smolts migrate northwards towards their feeding grounds. Warming of the ocean is also impacting on the food resources of the Atlantic Ocean, particularly in the eastern Atlantic. As is the case with many aspects of climate change, patterns are constantly changing and far from simple to interpret and fully understand. While significant trends can be picked out through detailed analysis of the scientific data, variations in the overall health and survival of young salmon on a year-on-year basis can cause confusion and at times offer false hope that a recovery is under way. In contrast a very poor first year at sea for the salmon

post-smolts may result in very low grilse returns, which often feeds speculation that the salmon as a species in endangered. We now know that at peak abundance in the 1960s there were approximately 10 million adult Atlantic salmon in the North Atlantic and this has fallen to some 3 million fish at present. In the Eastern Atlantic the stocks are hardest hit in the southern-most areas of the salmon's range; this includes fish from countries such as UK, Ireland, Spain and France. Stocks in the more northerly countries, such as Norway, Finland and Russia are apparently more stable.

Whatever part of the salmon's range you visit, you will find advocates for particular mortality factors which they feel passionately are the main cause of these problems. Aquaculture impacts, bird predation, seal predation, water quality, pelagic by-catch, river drainage, hydro-schemes – all have been blamed over the years. Every salmon angler, and indeed every salmon manager, has their own views on the principal causes of the massive decline in overall salmon survival. Some of these views are well supported by scientific data while others depend solely on raw, sincere passion and outspoken conviction.

We are in a time when arguments for policy change must be evidence-based. It is the job of the research scientist to disentangle and objectively examine each of the arguments put forward by the proponents of the various factors, to see which are supported by hard data and to prioritise areas for urgent research where such data do not exist.

As scientists, we've struggled to prioritise which areas should be examined, for in truth salmon populations are extremely complex and the mortality factors impacting on juvenile and adult salmon are highly variable, particularly when looked at on a regional or a catchment scale. To demonstrate the complexity of the salmon's life cycle, Atlantic Salmon Trust (AST) has a salmon modeller on its website (see link below). The salmon population modeller is a web-based demonstration tool designed to provide anglers, managers and anyone interested in salmon with a clearer understanding of how salmon populations work.

Over the past number of years, the Atlantic Salmon Trust has developed a concept that seeks to provide a coherent approach on how to assess the importance of the various candidate mortality factors and how future salmon research areas can be targeted and prioritised. This is known as the *"The Likely Suspects Framework" (LSF)*. The development of such a framework has been actively supported by international bodies across the Atlantic and the Pacific - (NASCO, ICES, NPAFC). In the UK the Missing Salmon Alliance has been formed to provide required scientific resources and expertise to ensure the implementation of the LSF initiative.

But what exactly is the Likely Suspects Framework and how will it work? The Likely Suspects Framework places candidate mortality factors ("likely suspects") within an overall framework covering the freshwater, migration and marine phases of the salmon's life cycle. The starting point is to identify zones or "ecosystem domains" in the life cycle of salmon where significant mortality is believed to be taking place. Such domains can be placed at geographical locations or allocated to particular phases where significant mortality factors

'As is the case with many aspects of climate change, patterns are constantly changing and far from simple to interpret and fully understand.'

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operate (e.g. juvenile growth in rivers, estuarine and coastal waters; near-shore; migration to feeding grounds and coastal return/river entry). The overall objective of the framework is to identify the various mortality factors involved and quantify the potential for each to influence salmon survival. In an approach more akin to financial accounting than to mathematical modelling, the cumulative effect of these factors is made to account for the observed survival of smolts to sea or the number of adults returning from the sea. You start with the answer and build a framework which explains why and where the observed mortality over the life of the salmon from smolt to adult is taking place. This can be used to identify the likely impact, both individually and cumulatively, of the various "suspects".

Doubtless there will be domains where mortality factors impact many different stocks, while in others only a few or even a single stock may suffer. In visualising this, it is useful to think of salmon from a given stock on their migratory journey passing through successive mortality domains, where they are joined by salmon from other stocks, and so on. It is important to concentrate on the big numbers and on places and periods where any mortality impacts are likely to affect a large number of stocks. Major areas of interest are not necessarily at an oceanic scale; space/time axes in freshwater and estuaries, for example can be discrete, such as hotspots where fish are slowed down or delayed and are preyed upon. Conversely, oceanic domains can be on a vast scale and lessons from the Pacific suggest that marine survival is a very dynamic process: factors causing significant losses to some stocks in some years may be less significant or absent in other years.

Climate change is likely to be a driver of major significance, with effects being felt at very broad scales and in different ways. For example, there are clear trends towards general ocean warming,

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but also there is potential for short term or single year anomalies, where "big" events, such as unusually severe floods or droughts, have a disproportionally high impact. Climate change may also have a worldwide impact on salmon species. The mechanisms of change involved are likely to be very complex and multifactorial. Teasing these apart will be challenging.

What are the management implications of this research over the decades to come? Most importantly, what exactly can we do to protect and support our salmon at this time of change? Our immediate challenge is to reduce the man-made pressures currently on the populations at risk so as to give them time and space to adapt and to recover. Management actions will primarily take place in freshwater, where optimising wild smolt output is fundamental to at least partially countering the effects of climate change. However, there are also direct actions we can take to reduce mortality at sea such as the quantification and elimination of salmon by-catch in the great marine pelagic fisheries.

Salmon scientists must also link more closely with their marine science colleagues to ensure that the salmon is universally accepted as a legitimate member of the pelagic family of fishes. We must argue strongly that those funded to study the changing oceans, and particularly the impact of such changes on the pelagic ecosystem, are charged with monitoring the welfare of our salmon at sea. It is sad to relate that despite our new knowledge regarding salmon migration corridors and a much more detailed understanding of the factors influencing the growth and survival of post-smolts at sea, we have not, since 2009, carried out any further monitoring of our salmon stocks in the ocean. Regular monitoring of the ocean corridors could provide vital information to salmon managers on the success of individual year classes of post-smolts at sea and the likely overall survival of adult salmon back to their rivers of origin.

FACTFILE – Links to further information

Salmon Summit – 2011:
salmonatsea.com/salmon-summit/

Atlantic salmon at sea: Findings from recent research and their implications for management
nasco.int/pdf/reports_other/Salmon_at_sea.pdf

ICES Journal of Marine Science (2012): International Symposium on Salmon at Sea: *Scientific Advances and their Implications for Management. Volume 69, Issue 9, November 2012*

NASCO
www.nasco.int

Atlantic Salmon Trust
atlanticsalmontrust.org

AST – Salmon Modeller
atlanticsalmontrust.org/knowledge/resources/salmonpopulationmodeller/

Smolts- AST Blue Book / Headwater to Headland
atlanticsalmontrust.org/document/?_sfm_publication_year=2017

Likely Suspects Framework – AST Blue Book
atlanticsalmontrust.org/wp-content/uploads/2020/07/LSF-Blue-Book-June-2018-June-2018-copy-2-.pdf

Missing Salmon Alliance
missingsalmonalliance.org/

ICES
ices.dk

NPAFC
npafc.org/

Photo: © lifeonwhite.com – stock.adobe.com

Invertebrates and nature's hatchery: unlocking the code to clean up our rivers

Nick Measham

Conservationists are starting to realise the importance of freshwater habitat in saving salmon and sea trout. Nick Measham, CEO of Salmon & Trout Conservation (S&TC), explains the crucial role S&TC is playing to improve nature's hatchery to boost salmonid survival.

Ted Hughes' understanding of water, fish and fishing was uncanny. Much of his work highlights the ecological interconnection between fish and their habitats. He understood the truth that healthy waters are the bedrock. Underlying his mayfly poems, for example, is the hard, scientific fact that thriving invertebrate populations are an essential element of healthy rivers. In a real sense, his "poetic electrons" are building blocks and indicators of water quality and at S&TC we have been harnessing them to tell us what is right or wrong with our rivers and what we do to improve the habitat for wild fish.

It has been acknowledged for years that water quality is critical in supporting robust salmonid populations (see *Water Quality for Salmon and Trout* by John Solbé, (1997), for a detailed discussion). The only problem is that its role in nature's hatchery and nursery has been largely ignored in the conservation of salmon and sea trout. Problems at sea and predation have dominated the debate.

We have recorded a loss of mayfly species in our chalkstreams of up to

44%

since 1998.

S&TC has been pioneering the analysis of invertebrate populations to decode pressures facing salmon and sea trout. This work has ushered in a focus on water quality, challenging the popular perception that our rivers have never been cleaner and that habitat for wild fish has never been better. Nothing could be further from the truth.

Freshwater biodiversity (a key measure of ecosystem health) is declining at a faster rate than on land. Since 1970, the Freshwater Living Planet Index shows an 83% decline in the populations of the species it measures globally. The UK experience is not dissimilar. In our chalk streams we have recorded a loss of mayfly species of up to 44% since 1998. The nature of pollution has changed. Although gross pollution from dark satanic mills and raw sewage has declined, these toxic sources have been replaced by more insidious, subtle but ultimately lethal impacts from treated effluent and agriculture. The 'enemy' is different now, but the pressure on our waters has never been greater.

Scoping the problem

'The nature of pollution has changed but the pressure on our waters has never been greater. Gross pollution from dark satanic mills and raw sewage has declined but these toxic sources have been replaced by more insidious, subtle but ultimately lethal impacts from treated effluent and agriculture.'

Our forensic work into these subtle impacts kicked off in 2015, with a three-year Riverfly Census of invertebrate populations. The aim was two-fold: to benchmark invertebrate populations to provide a baseline for future change; and to use invertebrate community composition to indicate what water quality pressures our rivers are experiencing.

Invertebrates are an amazing source of water quality information. As nymphs and larvae, they are constantly exposed to water and all it contains, making them a continuous living record of the pollution stresses a river is experiencing. Each species, whether lowly Gammarus shrimp or lordly Mayfly, has a unique tolerance to types of water pollution. Comparing the species present in a sample, against what species should be there, allows us to calculate pressure scores for certain types of pollution. Essentially, the invertebrates provide us with a score card for water quality, with impact 'grades' for the following pressures: organic, nutrient, sediment, chemical and flow.

Over three years, the Riverfly Census saw the collection and analysis of invertebrate samples from 12 rivers all over the country. Five samples were collected per river, twice a year (in spring and autumn). The process was simple. Our consultant entomologist, Dr Nick Everall, carried out the standardised three-minute kick-sweep sample with one-minute hand search at the sixty sites. He then preserved the samples in alcohol for later analysis. In the lab, the invertebrates were identified to species-level and the community composition used to generate impact values for a water quality 'score card' per site.

We analysed over 34,000 individuals from more than 480 different species. Three main pressures were consistently indicated in our survey rivers: sediment, phosphorus and chemicals. Although hard (sometimes impossible) to see, these pressures have a huge impact on river function. Without species-level monitoring through the Riverfly Census, we would still be without vital understanding

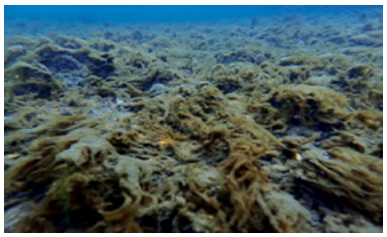
Photos: © Jack Perks Wildlife Media

of the magnitude and general whereabouts of these water quality stressors. Some of the key findings include:

- Sediment pressures were evident at three or more sites in 58% of our rivers. It is estimated that agriculture and land management are responsible for 75% of this adverse load. Sediment chokes fish and invertebrate eggs.
- Chemicals were impacting our rivers badly: nearly 50% of autumn samples failed the proposed Water Framework Directive standard. Incredibly, out of the more than 300,000 regulated chemicals in the UK, only 45 are checked for in UK rivers.
- Phosphorus was a concern at one or more sites on all the chalk streams we monitored. Some 25% of the phosphorus comes from agriculture but the 70% bulk is from sewage. Phosphorus directly and indirectly increases mortality of fish and invertebrate eggs.

Acting on the evidence

Despite being one of our most highly protected rivers, the Upper Itchen Riverfly Census samples showed a worrying lack of mayflies and Gammarus, and produced concerning scores for chemical stress. This led us to investigate a salad-washing and packing factory on the river's headwaters. Owned by Icelandic food producer Bakkavör, this factory started life washing locally grown watercress but had expanded to wash salad leaves from all over the world. These imported salads are routinely treated with pesticides and we suspected pesticide residues were being discharged straight into the river.



Photos: © Nick Everall

In spring 2018, we sampled a site immediately downstream of the point at which Bakkavör was discharging dirty water. The results were mind-blowing. The two photos indicate the full horror. The bed of a chalk stream should be clean, with un-sedimented gravels and submerged plants. What we found was a bed covered in sediment-choked algae and some fungal growth. We complained to the local Environment Agency (EA) in June 2018 under the Environmental Damage Regulations (EDR). Our complaint compelled the EA to monitor the factory's discharge for chemicals including pesticides. In June 2019, the EA's EDR findings concluded that sewage and pesticides discharged – may present a serious threat to aquatic invertebrate life. Quantities of pesticides such as the neo-nicotinoid Acetamiprid, were found to be significantly above recommended levels. The EA had imposed strict pesticide monitoring requirements and pesticide discharge limits on Bakkavör when the company announced it was closing the factory in August 2020. One main threat to the river has been eliminated as a direct result of our evidence-led campaigning.

> 'One main threat to the river has been eliminated as a direct result of our evidence-led campaigning.'

We must now ensure that the EA imposes similar strict conditions on other activities discharging pesticides into UK rivers. Following the Bakkavor case study, the EA has identified tens of other potential problem sites. We will fight for them to be dealt with and dealt with quickly.

In short, our work, starting with a three-minute kick-sweep sample or two, is forcing the EA to tackle the threat to our rivers from pesticides. It is a complex and difficult subject, but we are determined that the EA does not put the problem back into their rather over-full "too difficult to deal with" box. This is just one example of the benefits to the water environment stemming from our evidence-led advocacy on the back of the Riverfly Census.

SmartRivers: citizen science protection into the future

SmartRivers is a citizen science programme for volunteers and helps to extend the reach of the Riverfly Census. SmartRivers gives volunteer groups the knowledge and tools to conduct near professional species-level invertebrate monitoring. From fishing clubs, to water companies and local wildlife trusts, we work with a variety of groups to select sample sites and establish river 'hubs' who undertake the following process:

- Professional benchmarking – Once a new hub has selected their five SmartRivers sites, a professional will collect and analyse invertebrate samples in spring and autumn. This provides an invertebrate baseline and a list of species the volunteers will learn to identify.
- Training – We provide expert-led courses to teach the volunteers correct sampling technique and analysis. Depending on the hub's preferences following the training, they choose a pathway. The group can 'sample and send' where they collect samples and post them for identification, or 'sample and identify' where they collect and identify the samples themselves. A sample 'quality control' system is in place so we can have confidence in the results and our volunteers can fine tune their skills.
- Data analysis and action – The species found in each sample are uploaded to our open-access online database. The database uses this information to generate the water quality score card. The pressure scores are loaded onto an interactive map and displayed using a traffic light colour scale. When we have multiple years of data, our policy team work with hubs to take action, driving improvements to water quality at a local and national level.

Since launch in 2019 we have established 8 hubs and trained over 50 volunteers, bringing SmartRivers intelligence to spawning headwaters of important salmon rivers such as the Ribble and Hampshire Avon. We aim to have over 20 hubs and 200 volunteers up and running by 2022, but this is just the start. The potential and need is huge with over 700 river catchments in England alone. The EA is paring back its own monitoring programmes, so the burden of evidence collection increasingly depends on our volunteers.

In addition to our chemical and pesticide campaigning, SmartRivers and Riverfly Census data feed in directly to our campaigning for urgently needed agricultural regulation and enforcement across the UK. We take no government funding for any of this work. This independence allows us to carry out our advocacy using the invertebrate evidence without fear or favour. We would like to thank our supporters who continue to make it all possible and hope you might be persuaded to join them.

Further reading:

J, Solbe (1997) Water Quality for Salmon and Trout
environmentdata.org/archive/ast:78

The Riverfly Census National Outcomes 2019
salmon-trout.org/wp-content/uploads/2019/05/15MB-STC-Riverfly-Census-National-Outcomes_compressed-1.pdf

The Oldest Animal

Katherine Robinson

Photo: © Jamie – stock.adobe.com

The extraordinary final lines of 'That Morning' (*River*, 1983) are inscribed on Ted Hughes's memorial stone in Westminster Abbey:

> **So we found the end of our journey.**
>
> **So we stood, alive in the river of light**
> **Among the creatures of light, creatures of light.**

The lines are alive with light and sound: 'alive in the river of light'. Try reading that aloud, and listen to the current of sound patterns, enlivening and immersive as the sound of a river. Hughes erodes the familiar distinctions between rivers, creatures, and men: the same light illuminates them all. But who are these creatures of light? And where did that journey lead?

'That Morning' describes an exhilarating morning of salmon fishing in Alaska in July 1980 with Hughes's son Nicholas. In the poem, the two men have waded into the river, a living current of wild fish, and stand '[w]aist-deep in wild salmon'. At the end of the poem, they watch two gold grizzly bears, pursuing those same salmon, climb into the river and swim 'like men'. But the poem also transcends distinctions between past and present, between stories we inherit and our own most visceral experiences. Describing that Alaskan morning also conjures a far different journey and a much older fish; the Salmon of Llyn Llyw from the Welsh medieval story 'Kilhwch and Olwen'. 'Kilhwch and Olwen' is a story about the importance of nonhuman language and about our own need for animal knowledge. The Salmon of Llyn Llyw, it tells us, is the oldest animal in the world.

As a teenager, Hughes loved Henry Williamson's novels about animals. In *Salar the Salmon* (1935), Williamson describes salmon traveling 'along the undersea paths they had travelled as smolts, to where ancestral memory became personal memory— to where the river currents frayed away in the tidal rhythms of the sea.' Hughes's incorporation of 'Kilhwch and Olwen' into the rhythms of 'That Morning' is something far more exciting than a literary reference; it's the process through which inherited literary memory becomes personal memory. The salmon of Llyn Llyw, whose story survives in manuscripts transcribed by medieval Welsh monks, becomes the astonishing wild Alaskan salmon gleaming in the river where Hughes and his son stand.

'Kilhwch and Olwen' takes its title from Kilhwch's quest to marry Olwen, a woman with '[t]he eye of the trained hawk' and an unusual trait: 'four white trefoils sprung up wherever she trod.' ('*Ôl*' means 'footprint', '*gwen*' fair.) Olwen agrees to marry Kilhwch, but she warns him that her father is a giant, Ysbaddaden, who will die the day she marries and is loath to give his blessing. Sure enough, when Kilhwch enters Ysbaddaden's palace, the giant throws poisoned darts at him. Dodging the darts, Kilhwch asks for Olwen's hand in marriage. So Ysbaddaden devises a new strategy: he grants consent on the condition that Kilhwch first complete a catalogue of seemingly impossible, often life-threatening tasks.

One of these tasks is to find Mabon, who 'was taken from his mother when three nights old.' No one has heard of him since. King Arthur, Kilhwch's cousin, sends two warriors, Kai and Gwrhyr, to search for Mabon. Arthur chooses Gwrhyr because he knows 'all languages'

including 'those of the birds and beasts'. The warriors travel until they find a blackbird who is very old, but the bird knows nothing about Mabon. He sends them to a stag, who is even older, who sends them to an owl, older still, and the owl sends them to the Eagle of Gwern Abwy. The Eagle knows nothing about Mabon, but he says that there is an animal even older than he is: the Salmon of Llyn Llyw. The Eagle describes once flying as far as Llyn Llyw ('*llyn*' means lake):

> I stuck my talons into a salmon, thinking he would serve me as food for a long time. But he drew me into the deep, and I was scarcely able to escape from him. After that I went with my whole kindred to attack him, and to try to destroy him, but he sent messengers, and made peace with me; and came and besought me to take fifty fish spears out of his back.

This is a remarkable evocation of the Salmon's age and endurance, of his size, power, and his readiness to forgive. The men travel to Llyn Llyw and ask this salmon if he knows anything about Mabon. He tells them that, when he swims up the river Severn towards Gloucester, he hears a terrible wailing. He offers to take them there: 'Let one of you go thither upon each of my two shoulders.' Kai and Gwrhyr ride this salmon up the river until they, too, hear that wailing and find Mabon imprisoned in a 'house of stone'. They return to King Arthur, who gathers warriors. Once more riding the salmon, Kai and Gwrhyr lead them up the Severn. They storm the prison and free Mabon.

Hughes knew this story well. He had read *The Mabinogion* by the time he was fifteen and regarded it as his 'specialty'. The first English translation was published by Charlotte Guest in a collection of Welsh tales titled *The Mabinogion* (1838–1845), and when Hughes was in grammar school, that translation was the only one available. Hughes's library includes evidence of that early discovery: he owned a 1902 edition of *The Mabinogion*, and he also owned a 1949 edition of a translation by Gwyn Jones and Thomas Jones. His interest had clearly persisted, and as a Cambridge undergraduate, Hughes encountered 'Kilhwch and Olwen' afresh in Robert Graves's *The White Goddess* (1948), a 'going up' gift from his grammar school English teacher. It recounts some of Guest's *Mabinogion* stories, and Hughes underlined the name 'Olwen', his sister's name, in Graves's retelling. At Cambridge, Hughes also read R.S. Thomas's poem, 'The Ancients of the World', a poetic reimagining of the story's ancient creatures. Thomas's poem stayed with him: it is included in *The Rattle Bag* (1982), an anthology Hughes edited with Seamus Heaney.

In *Shakespeare and the Goddess of Complete Being* (1992), 'Kilhwch and Olwen' is one source of Hughes's own imaginative conception of Britain's creaturely mythology. The boar embodies the imaginative and natural cycles of death, sexuality, and rebirth that Hughes sees unfold in the natural world and in Shakespeare's dramas. The boar is the god who 'dies for and by the Goddess and who is reborn to destroy her'. In British myth, that boar is 'Twrch Trwyth, the terrible Boar King who is hunted through the Celtic world in the great Welsh myth of Culhwch and Olwen', Hughes writes. This is, in fact, the reason Kai and Gwrhyr must free Mabon.

'This is a remarkable evocation of the Salmon's age and endurance, of his size, power, and his readiness to forgive.'

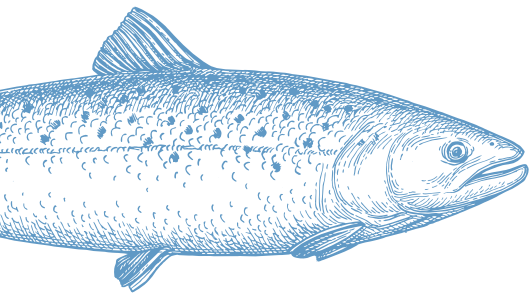
'But the poem also transcends distinctions between past and present, between stories we inherit and our own most visceral experiences.'

One of Ysbaddaden's dauntingly difficult orders for Kilhwch is to retrieve a comb and a pair of scissors from between Twrch Trwyth's ears. But there is only one dog, Drudwyn, who can hunt Twrch Trwyth. And there is only one man in the world who can hunt with Drudwyn: Mabon. (Ordering Kilhwch to retrieve that comb and scissors, surely assuaged Ysbaddaden's fear of acquiring a son-in-law.)

We know, then, that the creatures in 'Kilhwch and Olwen' informed Hughes's erudite yet deeply personal mythic schema. Welsh tales also shaped his own mythic poetry. I have argued elsewhere that Welsh stories informed the audaciously inventive poems in *Crow* (1970) that shocked and exhilarated readers. And a Welsh story, *The Mabinogi's* Fourth Branch, underpins the hypnotic poems in *Cave Birds* (1978) whose riddling power comes, in part, from that half-revealed, half-hidden Welsh substructure. By the time Hughes wrote 'That Morning', imagery from Welsh tales had already become connective tissue between personal imagination and literary inheritance.

At the beginning of 'That Morning', the speaker stands in a river teeming with salmon, 'swaying massed / As from the hand of God', and like Mabon, he experiences freedom possible only because of the salmon. In that river, 'the body / Separated golden and imperishable / From its doubting thought'. The body, wholly immersed in what Hughes described as the 'active concentration' fishermen find 'in a wild lonely place', is briefly free from the constraints of doubt. But this golden body also evokes another tradition that intrigued Hughes: alchemy. In the alchemical cauldron, gold separates from a mass of combined elements. But, within the complex web of Hughes's literary framework, alchemical imagery was also connected to 'Kilhwch and Olwen'. He owned a book by Jungian psychologist John Layard with a title long enough to rival Kilhwch's list of tasks: *A Celtic Quest: Sexuality and Soul in Individuation, a Depth-Psychology Study of the Mabinogion Legend of Culhwch and Olwen (1975)*.

For Layard, 'Kilhwch and Olwen' represents the Jungian process of individuation whereby the individual becomes free from the psychological forces that have subconsciously shaped him and achieves chosen integrity and autonomy. Individuation requires the integration of superego and id, a process Layard sees reflected in the relationship between the Eagle of Gwern Abwy and the Salmon of Llyn Llyw. Hauling the eagle down into the lake, the salmon represents the 'intellect' being 'dragged down into the depths of the unconscious by the salmon, lord and denizen of the water'. But, when the salmon asks the eagle for help removing fish spears from his back, that relationship changes. The eagle's assistance brokers peace between superego and id, the latter 'sorely wounded by the superego'. This is another moment of liberation—creaturely life released from what had damaged and encumbered it.



When Hughes wrote 'That Morning', all these traditions, like alchemical ingredients, filled Hughes's imagination—medieval Welsh stories, alchemy, and Jungian psychology. And, indeed, the poem juxtaposes that early alchemical imagery with language recalling 'Kilhwch and Olwen'. The body, 'separated from its doubting thought', is 'lit' by the salmon that keep coming '[a]s if we flew

slowly, their formations / Lifting us [....]'. Men carried by salmon: that image evokes Gwrhyr and Kai, carried on the shoulders of the oldest animal in the world. In that river, it seemed as if our own '[f]allen / world' had come to an end:

> As if the fallen
> World and salmon were over. As if these
> Were the imperishable fish.

That 'as if', repeated like a cast spell in the poem, ushers in an alternate world, simultaneously mythic and creaturely. Becoming 'the imperishable fish', Alaskan salmon give the Salmon of Llyn Llyw immediate, gleaming presence. Their 'formations' lift the poet and his son towards some 'dazzle of blessing', but those salmon also carry Hughes back to his own literary beginnings.

Those imperishable fish will outlast the men. In *The Winter's Tale*, time itself speaks: 'Let me pass / The same I am ere ancient'st order was / Or what is now received.' The world seems to have passed away, but the salmon swim the way time passes, the same in an ancient Welsh story and in an Alaskan river in 1980. Following the salmon run, the men themselves briefly become creatures of light, luminous as the oldest animal. The poem also tacitly acknowledges that something has been passed on: Hughes's personal passion for salmon has become one that he shares with his son and that will outlast him, shared, too, with readers who find their own love for this oldest animal given eloquent life in 'That Morning'.

But in the context of this Welsh story, the image of a world that has passed away also has a vividly literal meaning. When Gwrhyr and Kai talk to the animals, those creatures contrast their longevity with man's impact on the world. The blackbird's beak has reduced a smith's anvil to the size of a nut. The stag has outlived an oak tree that grew up out of an empty plain. The owl has watched the up-rooting of two forests by a 'race of men'. Now there is a third forest. The eagle tells how he 'pecked at the stars every evening' from a high rock. Now that rock is only a 'span' high.

King Arthur chooses Gwrhyr to search for Mabon because Gwrhyr knows the language of 'birds and beasts'. In this story, a language barrier is all that divides human and animal knowledge, a barrier that can be crossed with the right effort. But why, finally, can the salmon find Mabon when no other creature can? Why is the salmon the oldest animal? 'Kilhwch and Olwen' survives as a tale with no known author; to assign literary intentions would be a slippery business. But we know that salmon have an extraordinary ability to return to their place of birth, to find a specific place. This salmon's name might also offer a clue: Salmon of Llyn Llyw, Lake of the Rudder. '*Llyw*' means 'rudder', but it also means a rudder-shaped tail—bird and fish tails used to control the animal's direction. In this story and in 'That Morning', salmon help men find their journey's end. A salmon's sense of direction is so astonishing that, to men, it is preternatural, the ability to find something impossible to find again.

The coast at Alnmouth, Northumberland

Photo: © Steven Hedley - stock.adobe.com

Naen Skyells: Salmon Netting on the North Northumberland coast

Katrina Porteous

I'm trying to name them – the Byre End Hard,
The Benty Smooth and the Barnyards...

Not just a map, but a mesh of stories
Lit up who and what we are...

I am a poet and historian on the north Northumberland coast. I write about the local fishing culture, of which salmon netting was only ever one strand. I'd like to share with you the inspiration for my poems, drawn from 30 years of living alongside fishing families with generations of experience, from Holy Island to Amble. I emphasise the word 'culture', because fisher people feature more strongly in my poems than do fish. Although few of my poems are about salmon, nevertheless the salmon weaves through them, invisibly; an inescapable unseen presence. It is the interdependence of people's lives and imaginations with the natural world that fascinates me. Now the place of the salmon, and the fishing culture, are changing; and I want to examine what that means.

Stephen Douglas at the beach nets, 1996
Photo: Katrina Porteous

Katrina rowing Jack Douglas to the beach nets, 1994
Photo: Katrina Porteous collection

Launching the Golden Gate, 1994. A coble represented a whole community
Photo: Katrina Porteous

My home village, Beadnell, lies about 20 miles south of the River Tweed, and about 40 miles north of the Tyne. Between these two major salmon rivers, Northumberland's coast has several smaller salmon and sea trout rivers. In my own village, the salmon netting season was short. It usually lasted from early May to the end of August, and featured both drift nets and static beach nets. Concurrent with this, and for the rest of the year, the men also potted for crab and (from August) for lobster. Historically, until about 1950, their staple had been the winter 'long line' season for cod and haddock, and in the 19th century their grandparents' generation had participated in turbot fishing and in an industrialised herring fishery in the summer. So salmon and sea trout had been a small but significant part of a wide 'portfolio' of fishing. This meant that, when one kind of fishing was poor in any given year, another kind might make up for it. For artisan inshore fishermen, this diversity had contracted as the technological and industrial advances of the 19th and 20th centuries narrowed their economic options, placing more pressure on shellfish and salmon.

The men I knew fished from the archetypal Northumbrian sea boat, the coble. That name, which appears in the margins of the Lindisfarne gospels circa AD 720, today refers to two kinds of boat, one used at sea, the other, quite different, rowed by salmon fishers on the Tweed. Maritime historian Dr Adrian Osler has argued convincingly that shared features, such as a high bow and flat stern for shooting nets aft, suggest that the two are related, and that the sea boat's development is intimately connected to salmon fishing. I want to call attention to this beautiful traditional craft for two reasons. First, limited in size, from 25 to 32 feet, the sea-going coble was unable to carry large quantities of gear or fish, or to work in bad weather, so was in many ways more sustainable than its modern counterparts. Secondly, unlike a modern fibreglass boat, worked by a single individual, a coble required a whole community to maintain and work it. There have been no new boats of this kind built on the Northumberland coast for nearly 30 years now. To me, the coble is symbolic of a community with the salmon close to its heart.

I am aware that there are many people who deplore the idea of commercial salmon netting. But every fisherman I worked with worried about declining salmon numbers, was sensitive to conservation as part of his long heritage, and thought about much more than the monetary value of fish. They wanted the salmon to be there for the next generation. Indeed, salmon held such a powerful place in their imagination that, for many, the name itself was taboo.

They would talk about 'red fish'. I have written elsewhere that the fishermen's dialect could be so expressive, it conjured its subjects, its creatures, bringing the listener into their presence. This ancient incantatory connection between language and nature is one which Ted Hughes would have understood.

Against this age-old relationship, the fishermen found themselves caught up in modern global environmental change, and in what they perceived as a battle with powerful riparian interests. My work explores these conflicting points of view, tensions and paradoxes. Above all, I want to articulate the perceptions of people whose voices are not often heard, whose knowledge and skills add immeasurably to our understanding of the natural world. Human culture is, after all, an essential part of ecology.

'Aah like t' see the corks ga'n doon,' says Jack Douglas. 'That means a fish is pullin'.' The small rowing boat rocks in Beadnell Bay, close to the shore beneath the dunes. Much of fishing is waiting: the nod and dip of the boat, that wonderful, effortless, weightless swaying, slopping, the soft washing sound of the oars as water drips from the blades; the seas lazily slapping the boat's side; the rattle of corks against its bows. Eider ducks bob around us. Fish scales cling to Jack's boots. In the boat's bottom, water sloshes beneath planks, a dark marinade. The air smells tangy, savoury, salt. A sudden thrash. At my feet a sea trout heaves, silver-blue.

Dependent on oars, tide and wind, this beach net fishing feels timeless. Salmon and sea trout have probably always been part of the catch on this coast, but as Adrian Osler has shown in his 2004 essay for *Maritime Life and Traditions*, it was only from the mid-19th century that they became a significant sea fishery. Throughout the medieval and well into the modern period, salmon netting was associated with rivers and estuaries. Until the dissolution of the monasteries between 1536 and 1541, it was controlled on the English side of the Border by the Church. From at least the 12th century, and probably well before that, seine netting stations operated on the Tweed, worked from the shore, using river cobles.

Bill Dixon landing salmon, Beadnell harbour, c1930
Photo: Katrina Porteous collection

George Purvis salmon netting on the Tweed at Paxton House, 2006
Photo: Katrina Porteous

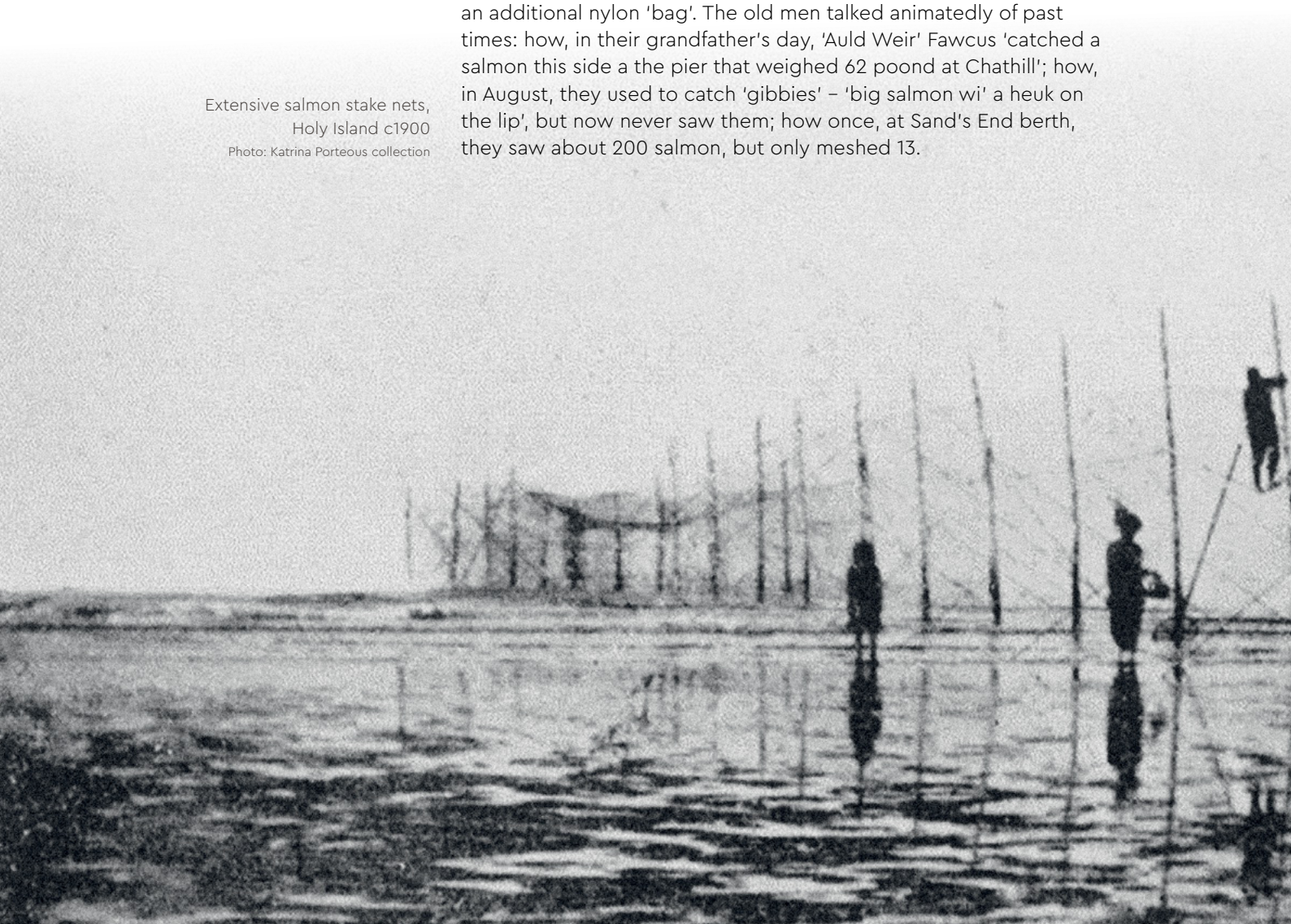
Jack Douglas at the beach nets with a sea trout, 1992
Photo: Katrina Porteous

'But the poem also transcends distinctions between past and present, between stories we inherit and our own most visceral experiences.'

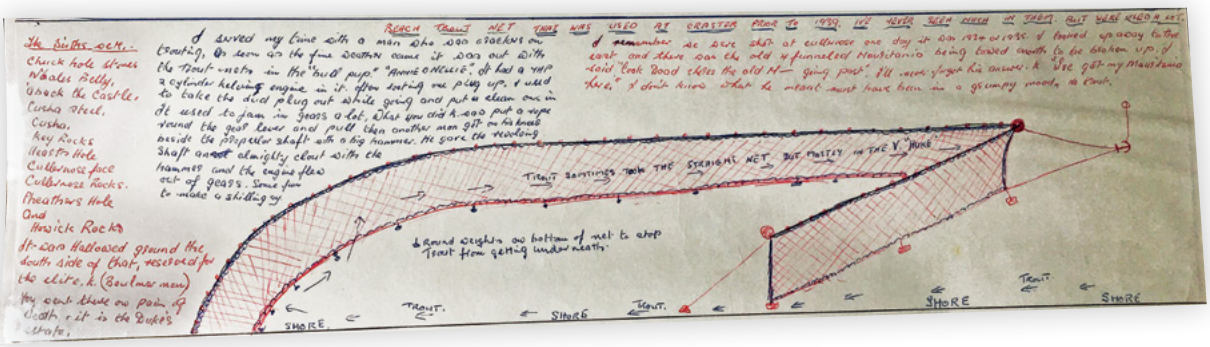
We think of over-fishing as a disease of our time, but the 18th and 19th centuries saw tremendous excesses both on the rivers and at sea. On the Tweed, special fast sailing 'smacks' carried huge numbers of live salmon to London. In 1816, 300,000 fish were exported on ice from that river. As river catches fell, from the 1850s, local gentry and Scottish agents introduced vast 'stake nets' for salmon on the Northumberland beaches. At about the same time, salmon drift netting or 'driving' began around the mouth of the Tyne. The first regulation of salmon on the North East coast swiftly followed. The Tweed Acts were passed in 1857–9 to forbid 'fixed engines', or nets anchored to the shore, and the first licenses were introduced around the Tyne in the 1860s.

The ancient Tweed netting stations continued, with regulation, for another century, until 1987 when, with the exception of Paxton for scientific research, and Gardo at Berwick, they were finally closed. Their last year was recorded in photographs by Jim Walker. The river netsmen handed down within their community a deep, intimate and ancient knowledge of fish, tides, currents, weather, and the interaction of these natural phenomena, and Jim recognised that this cultural and scientific heritage was vanishing. It was his work that gave me the initial inspiration to record fishing in my own village.

On a calm summer's morning, when the sun sparkles on clear water under the bluest of skies, I can think of no greater pleasure than lying at the beach nets in Beadnell Bay. The Beadnell men used simple 'heuk nets', close to the shore. The fish swam along, guided by a 'running net' at 90 degrees to the beach, into the 'heuk', where they were either meshed by the gills, or sometimes trapped in an additional nylon 'bag'. The old men talked animatedly of past times: how, in their grandfather's day, 'Auld Weir' Fawcus 'catched a salmon this side a the pier that weighed 62 poond at Chathill'; how, in August, they used to catch 'gibbies' – 'big salmon wi' a heuk on the lip', but now never saw them; how once, at Sand's End berth, they saw about 200 salmon, but only meshed 13.



Extensive salmon stake nets, Holy Island c1900
Photo: Katrina Porteous collection



These men remembered big days, of 80 or more fish, especially sea trout. But by the 1990s, catches were diminishing; very rarely as many as 50 trout, sometimes as few as five or six, in a day lasting anything up to 14 hours. In July or August there might be a few grilse among them. Beside the beach nets, in these later months the two local skippers occasionally went drift netting, or 'driving'. This consisted of shooting 600 yards of monofilament net downwind across the tide, further out to sea. The nets drifted alongside the coble for a short time. It was a skilled job; you needed to steer close to the net, yet avoid fouling it with the propeller. The nets were hauled and shot repeatedly.

The men had only begun fishing this way relatively recently. Before the introduction in the late 1960s of barely visible monofilament, driving had been a night time occupation, using heavy hemp nets. Driving was more commercial and competitive in areas close to river mouths, and in previous generations some Beadnell fishermen had fished at night around the Coquet or the Tyne. There is no salmon river in Beadnell Bay, just a little sea trout burn. Salmon driving was always extremely unpredictable. As fisherman Redford Armstrong told me at Amble, 'Salmon'll mek a fool a the best fisherman ever born.'

Bill Smailes's drawing of a simple heuk net without a bag, 1992
Photo: Katrina Porteous collection

John Douglas with his father Stephen and Billy Hume, Beadnell c1998
Photo: Katrina Porteous

Murdoch Allan and John Dixon salmon driving from Beadnell, 1992
Photo: Katrina Porteous

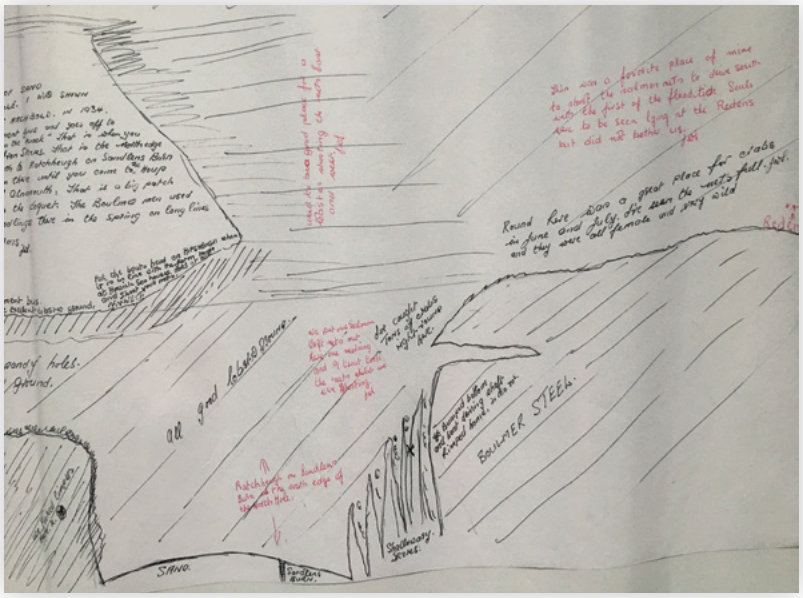
In my time, even driving, the Beadnell men rarely caught large numbers of salmon. For driving you needed the right kind of day – 'a little bit lipper an' the sun covered up', a northerly or southerly lift, ebb or slack tide, the edge of a tideway – and it was only later in the summer you might catch a salmon. A good day's catch would be a couple of dozen sea trout and half a dozen grilse. Many days they did not catch double figures of fish. Drift netting ended from my village in 2000, when the North Atlantic Salmon Trust bought out all but 16 of the remaining drift net licences on the North East coast.

Driving for salmon could be frustrating. No sooner did you see a cork go down than an oily patch would appear in the water as a seal took a bite. Grey seals breed in large numbers on the Farne Islands nature reserve. Until the 1970s, numbers were limited to 2–3,000 by a bi-annual government-supported cull, but now seals are protected by law and by the National Trust and the colony has spread enormously. No one seems to know exactly how many seals there are on the coast, or how much salmon they consume. They certainly enjoyed exploiting human fishing efforts, and were instantly attracted to the sound of a coble's engine.

'A good day's catch would be a couple of dozen sea trout and half a dozen grilse.'

I began with poetry about the 'marks' and how the men knew where to fish. I'll end with an excerpt from a map drawn for me in 1992 by Craster fisherman Bill Smailes, then aged 72. It shows his favourite area for salmon driving, just off Boulmer Steel, together with ground favoured for potting and for the long lines. The map illustrates, first, how salmon was once part of a varied and flexible fishery; and, secondly, the intimacy and detail of the fishermen's knowledge of their ground and its varied conditions in different winds, tides and weather. *Not just a map, but a mesh of stories*... Scientists and conservationists would do well to listen to fishermen's accumulated wisdom. That is what is being lost as the fishery contracts. We need to bring this empirical, experience-based knowledge together with science to properly understand how to live with salmon.

Excerpt from one of Bill Smailes' maps, showing favourite area for salmon driving off Boulmer Steel
Photo: Katrina Porteous collection



Bill talked about how, in the hungry 1930s, his father used to set an illegal salmon net in a particular place close to Dunstanburgh Castle. In 2004, English Heritage undertook an archaeological survey of that area. They discovered, in the same place that Bill's father used to shoot his heuk net, a stone fish trap of at least medieval, and possibly Roman, origin. It is within that scale of tradition, that depth of knowledge, that the fisherman works.

In 2016 I made a radio poem about Beadnell which included an interview with a young fisherman, David, talking about his connection to the salmon. David fished until 2019. That year, for the first time, Northumberland fishermen were forbidden by the government's Environment Agency to catch salmon even on the beach. Beach nets are still permitted for sea trout, but only in the months of April and May. This year, 2020, there are 'naen skyells' (no scales) on David's sea boots. No one from Beadnell is fishing on the beach. I'll end with an excerpt from that radio poem, *Conversations on a Bench:*

'So you've been out in the boat this morning?'

'Yes, with Dad. Since 6 o' clock this morning.'

'Your Dad was saying that he can't pass the licence on to you?'

'No. It's not hereditary any more.'

In the Arctic sway of the Greenland sea
The salmon remembers with its whole body.

'When I was a kid, when I was at school, summer holidays and that, I always was on the boat with Granddad. I've always done it.'

Slowly, it feels its way along roads of unknowing,
In strands of varying salinity, tasting its path,
Swilling the bitter salt through its feathery gills;

'Dad and Granddad's taught us everything I know about it.'

The tug of a magnet, a chemical imprint,
Remembered river fug of gravel and mud,
Exact as a sat nav. Where is it heading?
To the end of its longing.

'One of the biggest fish I ever caught was with Granddad. Just behind the harbour. There's a picture in the house of Granddad, the fish and me. The fish from tail to head is standing taller than us. I think it was a 22 pound salmon, it was. Aye, it was bigger than me.'

One of the last salmon licence holders at the beach nets, c2010. Dunstanburgh Castle in the background
Photo: Katrina Porteous

Andrew Fawcus and his father Bob, Beadnell c1920
Photo: Katrina Porteous collection

Further reading:

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Ted Hughes, The Rivers Trust and Salar the Salmon

Arlin Rickard

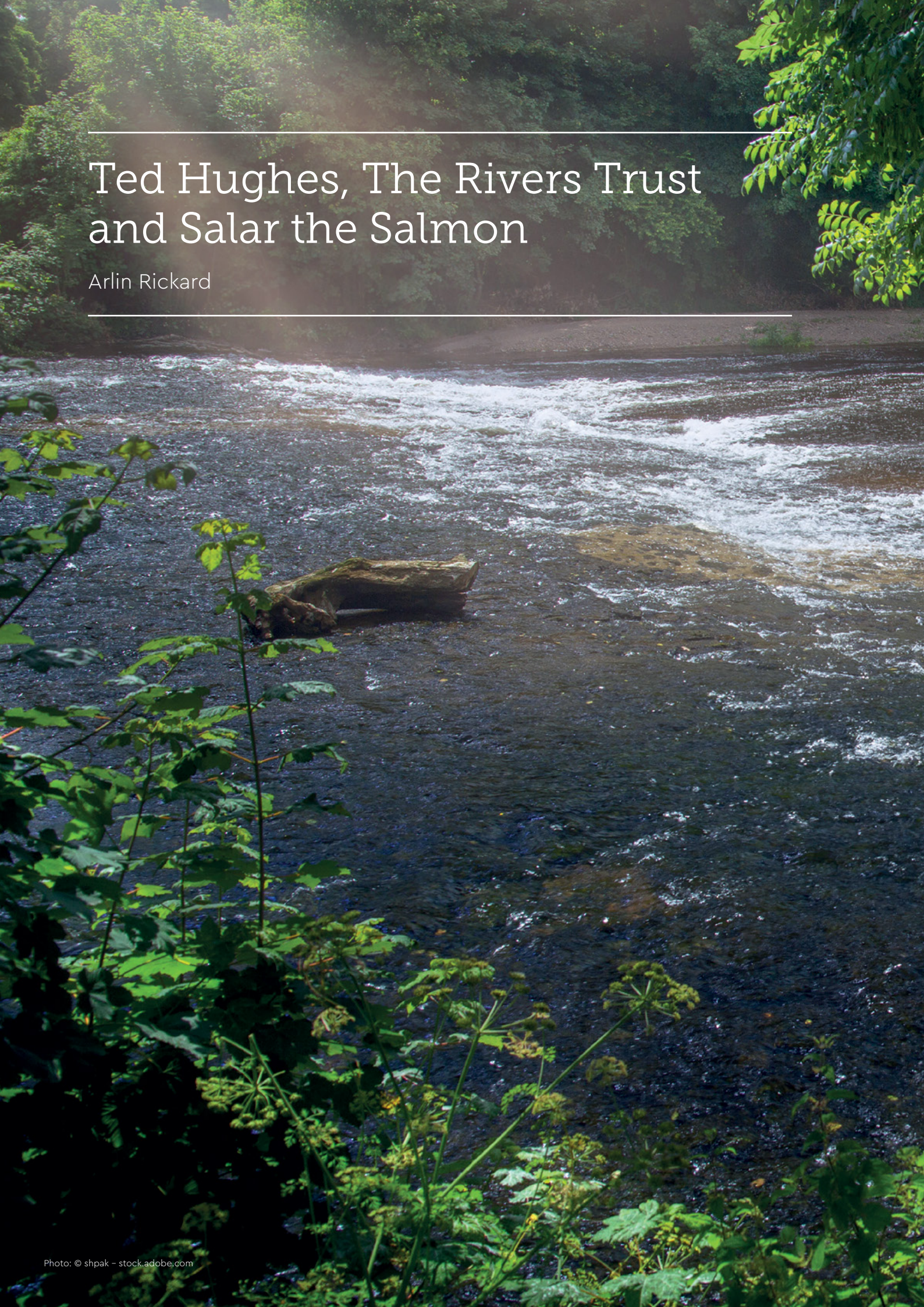


Photo: © shpak – stock.adobe.com

Trustee Ted Hughes (standing) and Director Arlin Rickard at the Westcountry Rivers Trust's press launch at Exeter in June '95

As well as being the International Year of the Salmon, 2019 celebrated 25 years of The Rivers Trust movement. There are now 60 Rivers Trusts in the UK and Ireland, and many more around the world, but it all began with the formation of Westcountry Rivers Trust (WRT) back in 1994, in which Ted Hughes played a key role. Arlin Rickard was WRT's first Director, and thereafter led The Rivers Trust (the umbrella body of the Rivers Trust Movement). Here he reflects on working with Ted Hughes in those early days and the progress since achieved.

I had the great pleasure to work with Ted Hughes from 1993 onwards, along with others who later became the founding Trustees of the Westcountry Rivers Trust. Ted was driven to highlight the demise of his beloved rivers, publicise and address the plight of the salmon and to initiate concerted action. He had two parallel aims: to see those in positions of authority held to account, and to encourage community action on the ground.

Ted's claim that salmon are indeed 'owned by everyone' may be interpreted in a number of ways. For centuries man has assumed the right to exploit the salmon. We have also systematically abused their favoured ecosystems and habitats. So, it may be said that the salmon's oceanic life cycle, and its exploitation and mismanagement, are an example of 'the tragedy of the commons'.

However this history is framed, there is no question that the responsibility for the future of this iconic species lies in our hands.

Much of my youth was spent on Bodmin Moor and Dartmoor, timeless places which engendered a love and fascination for rivers, wetlands and the sea. My feelings are captured by Gerard Manley Hopkins:

> What would the world be, once bereft
> Of wet and wildness? Let them be left,
> O let them be left, wildness and wet;
> Long live the weeds and the wilderness yet.

I grew up reading Henry Williamson's *Tarka the Otter* and *Salar the Salmon* and took up angling at an early age and, like Ted, have endured a lifetime of watching salmon decline, along with much of our natural world.

In Michael Morpurgo's introduction to *Salar the Salmon* (Little Toller Books, 2010), he writes that he never met Williamson, but:

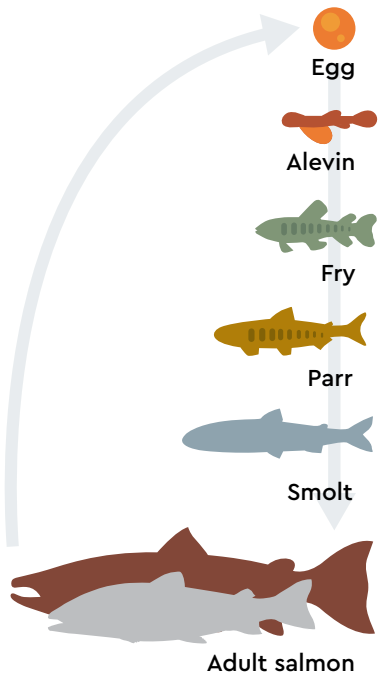
> *knew someone who did, a poet who knew him well. I met this poet down by the River Torridge, the sister river of the Taw – a place of herons and kingfishers, otters and salmon. He was fishing for seatrout late on a summer's evening, and loomed up from under the river-bank. I remember a giant of a man who greeted me warmly enough, and introduced himself as Ted Hughes. ...I learnt later that he'd known Williamson well, that he was a great writing hero of his, a kind of mentor in a way, and a huge admirer of both Tarka and Salar [...].*
>
> *Both of them knew also what we know, but may prefer to ignore: that as we leave the agrarian way of life behind us, abandoning it ever more for the comfort and convenience of this urban world, we will inevitably be in grave danger of destroying so much that we hold dear, and in doing so may well destroy ourselves.*

The salmon's wondrous lifecycle tests every aspect of our ecosystem, from one of thousands of eggs deposited in headwater gravels, to a returning adult fresh from the ocean. The species is one of our finest indicators of the health of our seas and rivers.

But we have failed the test salmon set us in our stewardship of these ecosystems. There are 79 salmon rivers in England and Wales with 64 designated as principal salmon rivers. Salmon stocks in the North Atlantic now stand at the lowest levels since records began, with spring salmon (Multi-Sea-Winter fish) particularly at risk. Scientific estimates over a 20-year period indicate a return from sea survival reduced from ~25% to ~5%, with absolute numbers decreasing from ~10m to ~2.5m. Only 14% of all the Atlantic's salmon rivers now hold sustainable stocks.

Sadly, the decline of a naturally fecund species like the salmon is part of a much wider problem that goes beyond simple overexploitation. Globally, WWF's Living Planet Report shows that populations of freshwater species have declined by 81% since 1970, faster than in any other group. But we can't blame

The Cherry Brook, Dartmoor
Photo: Jon Ogborne



The life cycle of an Atalantic Salmon

'The species is one of our finest indicators of the health of our seas and rivers.'

other countries for this statistic. The UK is one of the world's most nature-depleted; with more than 1 in 7 species facing extinction and more than half in decline.

The cause of these declines is clear and an indictment of the quality and quantity of our water. Only 14% of rivers and lakes in England are healthy (as assessed by EU Water Framework Directive), with agriculture and the water industry providing key pressures. Poor regulation and agricultural practices account for diffuse pollution and massively costly soil erosion. Moreover, water companies are responsible for over 50 serious sewage-related pollution incidents a year. Water abstraction, for drinking, crop irrigation and industry, reduces our rivers, while Invasive Non-Native Species (INNS) continue to spread and impact on native flora and fauna. And climate change compounds the damage, producing rise in water temperature, floods and droughts.

Ted Hughes and Westcountry Rivers Trust

Ted Hughes witnessed fish declines first-hand as they hit rural North Devon. As both a great countryman and angler, he was deeply aware of the changes affecting his beloved rivers in the 1970s. The Taw and the Torridge ran brown with sediment after rainfall, the stench of cattle slurry was in the air, and algal blooms flourished. The variety and abundance of river-flies declined along with the fish and 'Tarka' could no longer be seen on the banks of the river immortalised by Williamson.

During the latter part of the 20th century many of us were waking up to a range of emerging environmental issues, perhaps first captured and articulated in Rachel Carson's *Silent Spring* (1962). The agricultural application of chemical fertilisers and pesticides had an alarming impact; DDT caused a decline in birds of prey; Aldrin and Dieldrin hit otters' ability to reproduce. River-fly hatches and pollinators reduced; songbirds fell silent. Scandinavia fisheries grappled with a deadly invader from the Baltic Sea, the salmon fluke *Gyrodactylus salaris*; and applications of Rotenone were made as a last resort, killing everything in an effort to purge rivers of this insidious killer of Atlantic salmon.

In the West Country, new invasive non-native species like the American Mink *Neovison vison* caused a catastrophic decline in numbers of water voles *Arvicola amphibius*, which have never really recovered; riverbanks became choked with alien Japanese Knotweed *Fallopia japonica* and later Himalayan Balsam *Impatiens glandulifera*. Salmon were suddenly affected by UDN (ulcerative dermal necrosis) a new disease to most of us. New intensive farming practices played their destructive part during the 1970s too. Intensively fertilised fields, treated with chemical pesticides, silage replaced hay, intensive ryegrass leys were sown in old meadows; winter cereals replaced spring crops and maize was developed as a livestock feed, and farmyard manure gave way to slurry-based systems. All this accompanied increased stocking and mechanisation, and meant larger farm units. Some of the most damaging pesticides have now been banned and our birds of prey and otters have returned, but the decline of songbirds, pollinators and riverflies continues, along with the invasion of non-native species; Ash die-back is one recent consequence.

The headwaters of the
River Taw on Dartmoor
Photo: annacurnow – stock.adobe.com

Ted worked tirelessly with other like-minded people, including Ian Cook on the Exe, to defend freshwater fisheries and hold the authorities to account, including the recently privatised Water Companies and the National Rivers Authority (NRA). He also strongly supported the formation of the South West Rivers Association (SWRA) of which Lord Clinton became Chair, with Stuart Gardiner as Secretary. The SWRA represented riparian owners and representatives from each of the South West's 20 or so salmon rivers.

Then, inspired by the salmon-focused Tweed Foundation in Scotland led by Ian Gregg (another hero of the movement), Ted promoted the concept of a 'River Taw Fisheries Foundation' or Trust. He worked closely with Michael Martin, Stuart Gardiner, Alan Hawken, Anne Voss-Bark, Ian Cook and Lord Clinton, to apply – unsuccessfully, alas, to the Charity Commission for charitable status.

The application's rejection made us think more strategically. A Working Group was formed, chaired by Michael Martin, and after seeking a counsel's opinion on the rejection, Stuart Gardiner and I developed a fresh proposal. Stuart was a highly intelligent and brilliant administrator, and drawing on my agricultural background, I had a strong vision for a 'Charitable Trust for Rivers' based on applying the Ecosystem Approach at a catchment scale.

So, after many meetings with anglers, riparian owners, farmers, the water company, the NRA and other conservation charities, in 1994 the concept became a reality and the Westcountry Rivers Trust (WRT) was born, led by Stuart and me, supported by a new Board of Trustees (elect), with Michael Martin as Chair. Ted served on the Board and later became our first President.

As 'Director' or chief executive of the Trust, I had already drafted our charitable deed and objects with Stuart and Alan Hawken. Now I was tasked with designing our logo. With help from my wife and brother in law (a graphic illustrator) we settled on river ripples, a stonefly, otter and trout representing a simple food chain and the wider ecosystem. Ted supported the process and took a great interest in the logo and developing the prose around the Trust's vison and first Business Plan.

'The Plan was ambitious. It embraced the concept, 'If you look after the land, the river will look after itself' and meant working closely with all those who own and manage the resource: including farmers, river owners and anglers, water companies and regulators.'

The Plan was ambitious. It embraced the concept, *'If you look after the land, the river will look after itself'* and meant working closely with all those who own and manage the resource: including farmers, river owners and anglers, water companies and regulators. The aim was to address land use and management issues, empower communities and restore ecosystem function in the wake of the privatisation of 10 regional water authorities in 1989 and the formation of the National Rivers Authority (replaced in 1996 by the Environment Agency). The Trust would apply the best possible science combined with 'on the ground' delivery at a catchment scale. Later we adopted the term *'wet feet'* which captured the simple but effective ethos of the trust. The Charity Commission accepted the new Trust's objects and deed and soon after, granted the all-important charity number. After starting work quietly in 1994, the following year saw the WRT's public launch as a charitable trust with a full project programme, and by 1996 Stuart and I had succeeded in winning our first major partnership grant for the 'Tamar 2000 SUPPORT Project'.

The Association of Rivers Trusts

Our Westcountry success soon led other river communities to seek our help, with most then adopting our charitable objects and deed as a model. By 2001 there were four engaged 'rivers trusts' operating in England and Wales: Tweed Foundation (TF), Westcountry Rivers Trust (WRT), Wye & Usk Foundation (WUF) and Eden Rivers Trust (ERT); the Ribble Rivers Trust (RRT) followed swiftly.

A meeting on the banks of the River Wye, hosted by Stephen Marsh-Smith and led by Ian Gregg, decided to establish an Association of Rivers Trusts (ART) as an umbrella body, to lead and support the movement. Its remit was not just to share information, helping and supporting the formation and development of new rivers trusts, but also to develop and guide national policy. The Association would operate for the benefit of its members based on the principles of Consent, Subsidiarity and Partnership drawing on the Ecosystem Approach to, *"Think globally and act locally"*.

Ian Gregg had already been instrumental in the formation of the Tweed Foundation and Eden Rivers Trust and was also working on an ambitious salmon awareness and management programme called 'Salmonid 21C'. He now became chair of the Association, and I was asked to be its CEO.

By 2004 the number of Rivers Trusts had grown, and the movement really began to take off. So, after ten years with Westcountry Rivers Trust, I stepped down to lead the Association of Rivers Trusts, later known simply as The Rivers Trust (RT). The Rivers Trust Movement now has over 60 Trusts in the UK and Ireland, with groups formed around the RT model in Europe, North America, Mexico and even Brazil.

In the early days at Westcountry, I would be asked to present the Board with our management accounts, project activities and expenditure. After we had pored over the spreadsheets Ted would fix me with his eye and ask, "Yes that's all very well but, how many extra fins will it mean in the river?" He was right, of course. A healthy abundance of fish is the best indicator of success. Westcountry Rivers Trust's offices at 'Rain-Charm' House celebrate one of Ted's local poems; when I am on the river, he is omnipresent.

The Future

The Rivers Trust Movement continues to grow beyond expectation and the good work continues. But what of Salar? Salmon have survived for millions of years; *homo sapiens* has only walked the earth for a couple of hundred thousand. We must be positive about the salmon's long-term survival, as an adaptable and resilient species.

However, the short-term situation is of serious concern, as anthropogenic pressures including global warming, now threaten the whole planet. The Rivers Trust and Catchment Based Approach stands ready with other organisations to play our part, honouring the spirit of the International Year of the Salmon and working for a return to abundance in the coming quarter century.

Bristol Avon Rivers Trust (BART) undertaking a habitat improvement project on The Little River Avon

theriverstrust.org

catchmentbasedapproach.org

ownedbyeveryone.org

Photo: © Corin Smith

Science will not save wild salmon

Corin Smith

The plight of wild salmon and sea trout inhabiting the West coast of Scotland, those dogged by the plagues of parasitic sea lice propagated by open cage salmon farming, currently rests in the hands of a couple of acronyms, TWG and SIWG; two "working groups" which fell out of 2018's two Scottish parliamentary inquiries into the environmental impacts of salmon farms.

parliament.scot/S5_Environment/Inquiries/20180305_GD_to_Rec_salmon_farming.pdf

digitalpublications.parliament.scot/Committees/Report/REC/2018/11/27/Salmon-farming-in-Scotland#Summary-of-conclusions-and-recommendations

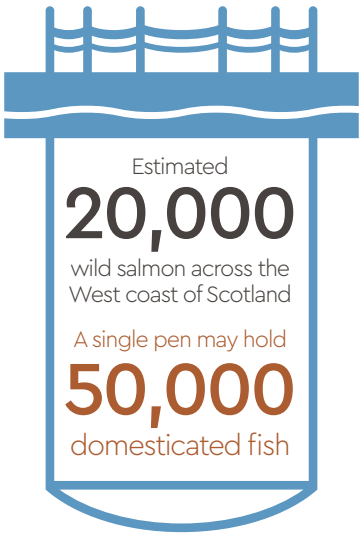
We have been asked to have faith that the now long overdue output of these working groups will herald a brave new world for wild Scottish salmon and sea trout. We are promised an entirely new regime to regulate the emissions of huge quantities of parasites from salmon farms that infect and kill wild salmon and sea trout. These emissions are, euphemistically, referred to as "interactions".

The TWG, "Technical Working Group", made up of regulators and salmon farming corporations, "led by industry expertise", have built a virtual model they say represents the best understanding of where and how wild fish will interact with the abnormally elevated levels of sea lice produced by salmon farms.

The SIWG, "Salmon Interactions Working Group", made up again of regulators, salmon farming corporations, but also including Fisheries Management Scotland. FMS are an umbrella organisation that represents the Fishery Boards (government-appointed public authorities that are responsible for managing wild salmon numbers in Scotland). SIWG have developed a plan to have local Fishery Boards conduct observations of sea lice levels in the areas they manage, and by some mechanism yet to be defined, "adaptively manage" the commercial operations and decisions made by salmon farmers as to what level of sea lice is appropriate on their own salmon farms.

There are believers, those who welcome the prospect of more study at ever finer resolutions. They have faith that salmon farmers "will do the right thing", that salmon farms will be relocated and sea lice numbers reduced, "just as soon as we have shown exactly what harm is being caused and where farms can be safely relocated to". Of course, we have been here before – Fishery Boards and salmon

'We have been asked to have faith that the now long overdue output of these working groups will herald a brave new world for wild Scottish salmon and sea trout.'



farmers have worked together in two previous incarnations with the same intent – but they are sure, at the third time of asking, that it will be different.

web.archive.org/web/20081218030708/http://www.tripartiteworkinggroup.com/content.asp?ArticleCode=2

I am sceptical in the extreme.

Because, you see, regulating the impacts of salmon farms is no more an issue of objective science than the setting of corporation tax is an issue of objective economics. This is an issue of politics. And the only thing the politicians are saying is that they want more salmon farming, lots more, twice as much by 2030.

To a cynic, a hugely complex system of regulating the abnormal emissions of sea lice from salmon farms – that has arrived two years late and conveniently close to the end of the parliamentary session to preclude any prospect of meaingful primary legislation legislation – might seem like the flourishing conclusion to a long filibustering dance around what is a relatively simple issue. While of course there should be room for more research about sea lice levels on salmon farms, there is frankly no shortage of it now. Moreover, it is not the only method by which safe sea lice levels on salmon farms can be derived. After all, salmon farmers do have to place their own domesticated smolts in the sea at the beginning of each cycle and, for purely economic reasons, they have to protect those smolts (it is at the smolt stage that wild salmon and seatrout are most susceptible to sea lice owing to their small size) from the potential explosions of sea lice numbers that occur due to the abnormally high number of hosts in a very small area. It is estimated that 20,000 wild salmon remain across the entire West coast of Scotland, but a single pen on one of the 300 licensed salmon farms may hold 50,000 domesticated fish, a single farm up to one million. The data that salmon farms produce about sea lice levels on their own farms during this period tells us pretty accurately what they know to be "safe" levels of sea lice when it comes to protecting their own domesticated smolts.

salmon-trout.org/2020/06/09/salmon-farmers-own-data-makes-the-case-for-much-lower-sea-lice-limits/

So, in the course of their business, salmon farms run the experiments that are impossible to run on wild Atlantic salmon smolts and populations: self-contained cohorts that are monitored all the way through to maturity. Endless iterations of variables allow the accumulation of large datasets and powerful regression analyses and the reality is that we know exactly what the safe sea limit is for smolts, wild or farmed. Given that the Norwegian, Canadian and Faroese corporations which own 99% of Scottish salmon farms see profit in every farmed smolt, and clearly recognise the harm that sea lice cause them and that profit, they go to great lengths and expense to protect their investment. Surely, it is unconscionable that the same salmon farmers do not accept an obligation to offer protection to Scotland's wild Atlantic salmon smolts from the same harm caused by the same sea lice, simply because they are on the other side of a net a few millimetres wide. This is why Salmon & Trout Conservation are advocating for a sensible and effective form of regulation, precautionary limits.

Norwegian, Canadian and Faroese corporations own

99%

of Scottish salmon farms

Photo: © Corin Smith

'Fishery Boards and salmon farmers have worked together in two previous incarnations with the same intent – but they are sure, at the third time of asking, that it will be different...'

Photo: © Corin Smith

Photo: © Corin Smith

Photo: © Corin Smith

salmon-trout.org/2020/06/24/why-a-strict-ceiling-on-sea-lice-must-be-applied-to-all-scotlands-salmon-farms/

Clearly, the devastating impacts of salmon farming on inshore marine ecosystems are well known, but recently the Scottish Government appeared to reiterate its position that the cause and extent of those impacts are not quantified. In the Programme for Government issued in early September, the First Minister Nicola Sturgeon gave salmon farming warm support, writing that: "This will include supporting the sustainable growth of aquaculture – which provides many jobs in the most remote locations and island communities".

The salmon farming industry, in the form of five multi-billion-dollar global corporations domiciled in Norway, Canada and the Faeroes, has failed to admit it causes any real harm, in any region, let alone Scotland. In what must be the most passive-aggressive argument ever, they effectively say: "Yes, we have an impact, but prove it, exactly and definitively. Only then we will take action." The manifestation of this culture is the legal challenge that these very same salmon farming corporations are mounting in Norway. They are challenging the system of regulation, prima facie, on the basis that their business should not be restricted in favour of environmental protection.

salmonbusiness.com/salmon-farmers-assemble-crack-force-team-of-lawyers-to-file-giant-lawsuit-against-state/

The dance goes on, the status quo remains of course. Different background music perhaps, but the steps seem all too familiar to those employed by the tobacco industry many years ago.

So it is with this backdrop that I remain highly sceptical when a mathematical model is used, and data are collected by non-research public authorities within a regulatory framework where those supportive of the expansion of salmon farming set the rules and which could have no more of a statutory underpinning than a complex set of voluntary agreements.

There is no doubt that there should be a solid scientific foundation to inform open cage salmon farming, but we have it all back to front, and the science which is being conducted in the name of saving wild salmon seems to be enabling its decline by constantly pushing out the point at which protective primary legislation is laid. In too many cases, wild fish advocates accept responsibility to show harm definitively when there is no prospect of quantifying the impact of salmon farms on specific runs of wild salmon precisely. As a pre-requisite to any form of restrictive regulation, this is chasing rainbows. In the complex and dispersed lifecycle of wild Atlantic salmon there are too many variables, and the speed of study (and science) cannot be expected to resolve them absolutely. It is exactly these uncertainties that are recognised in law in the concept of the Precautionary Principle.

Crucially, the proper application of the Precautionary Principle places the onus, the burden of proof if you will, on the operator to demonstrate safety, not on civil society to demonstrate harm.

Here is an extract from a ruling in favour of Friends of the Earth Limited, Re Judicial Review [2017] NICA 41:

"37. Given the repeated finding that the operations are likely to have significant impact on the environment the decision maker cannot simply put in the balance the absence of evidence of harm...What has been disregarded ... is that these operations are considered likely to have significant impact, that the nature and extent of that impact has not been established, that prior to the grant of permission is the requirement to establish that there will be no significant impact and that it is imperative that the precautionary principle be applied. What must be put in the balance is the absence of evidence that there is no harm. To approach the matter with a requirement for evidence of harm is the negation of the precautionary principle."

The pursuit of science alone in the false hope of some objective truth that will one day be placed before a politician. That will be the end of wild salmon.

"Even if we lose all wild salmon, it will be worth it". A quote from a Norwegian politician on salmon farming.

Of course the real issue at stake is not that of science. This isn't an academic debate about whether one prefers one theory or another to explain an observed phenomenon; the fundamental issue is wholly political in nature. Political judgements that have been made to grow GDP rapidly and at all costs in Scotland must be set against the value placed on natural assets, on slower but infinitely more sustainable growth and on community wellbeing. It is within this much wider context that we have to make a compelling case for restricting salmon farming to enable abundant populations of wild salmon.

'"Even if we lose all wild salmon, it will be worth it". A quote from a Norwegian politician on salmon farming.'

'The pursuit of science alone in the false hope of some objective truth that will one day be placed before a politician. That will be the end of wild salmon.'

There are decades worth of data about wild salmon and salmon, and the single most important KPIs all remain firmly pointed in the wrong direction. Science hasn't saved wild salmon. More salmon farming, more sea lice, less wild salmon. Those are the only tests against which success can be measured and there are no and never will be brownie points for effort, just outcomes for wild salmon.

Salmon farming is the embodiment of a purely consumptive economic policy, no different from exploiting the Brazilian rainforest, and ignoring the hidden costs of so doing. The question we need to explore in campaigning is whether that economic policy is right for the coastal communities in Scotland, now and into the future? And regardless of the politics, it is also the case that only 5% of the gross value created from salmon farming remains in the communities that generate that income, while they continue to bear 100% of the cost of the pollution and environmental damage: it seems like the worst deal ever. Clearly, whatever solutions are found to these challenges they need to take account of the needs of local communities, and their sustainable futures ....

However, where we have science at one end of the scale, we have ideology at the other, and a balance needs to be found. Salmon & Trout Conservation, an organisation I consult for, strikes this balance better than most because it is committed to blending research with effective campaigning. And it recognises the onus is not on the public to learn about wild salmon to tell us, but on those who are paid to protect wild salmon to tell us about how important these fish are ecologically, economically, and culturally, and in terms that can be digested within our busy lives. You don't do that by constantly bombarding people with fry counts and raw data. Atlantic salmon's well-being is reliant on so many issues that are relevant to people's everyday lives. The abundance and quality of fresh water. Water flow and flood management. The management and protection of resources in the marine environment.

Presenting a much rounder picture of this iconic fish, with all its magic, both natural and cultural, can be a lightning conductor for all of society's concerns about resource depletion and environmental degradation. Only when the public equate wild Atlantic salmon numbers with their own wellbeing, do we really start to give salmon a fighting chance.

only

5%

of the **gross value** created from salmon farming r**emains in the communities** that generate that income

Artifishal – The Fight to Save Wild Salmon

Tony Juniper

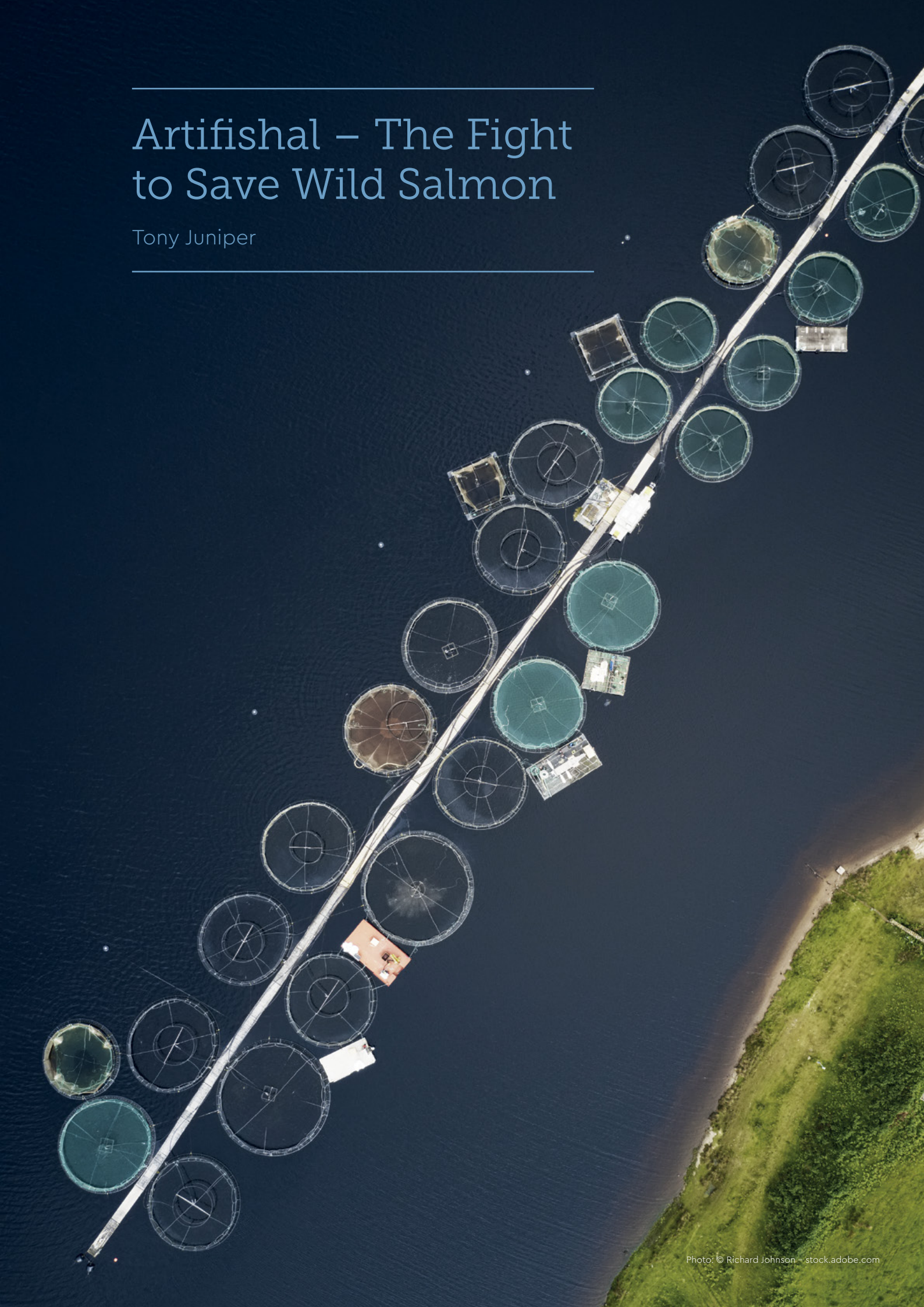


Photo: © Richard Johnson - stock.adobe.com

For anyone interested in Nature, and our relationship with the tapestry of life that sustains us, this is a must-see film.

Salmon are remarkable creatures. The complexities of their life cycles beggar belief. From the micro-scale of their genetic heritage to the macro-scale of the forest-clothed river catchments where they spawn, these magnificent fish are among Nature's most heroic superstars.

As a lifelong angler, the Salmon has always had a special place in my heart. Its size, long distance migratory movements and the spectacle of fish battling to the headwaters of cold clear rivers all capture the imagination. As time has gone by, however, my fascination for these wonderful animals has been increasingly replaced by concerns that they might soon disappear.

> 'Our default is to command and control natural systems, to seize their productivity for commercial bottom lines.'

Artifishal is an eye opener, vividly revealing the plight of salmon, both in the Pacific and Atlantic Oceans. Assailed by major dams, river pollution, over-fishing, changed genetics caused by mixing with fish farm escapees, low flows as river water is taken for farming and the effects of billions of fish released from hatcheries, it is no longer only fast flowing water against which the salmon must run an increasingly perilous gauntlet.

What is perhaps even more important than the story of the salmon is how our modern relationship with these fish is a microcosm of how we see our broader place in Nature. The 'take, take, take' mentality of the industrial approach to Nature leads to declines in wildlife, which, if addressed at all, are generally approached with technology.

Following centuries of technological advancement, mainstream culture in many western countries sees the natural world as a set of commodities and resources to exploit, to be managed for maximum output, with little to no regard for the consequences. Our default is to command and control natural systems, to seize their productivity for commercial bottom lines. In the case of decimated salmon populations, the technological response is

in part manifest in intensive fish hatcheries, that often have the opposite impact to that which is intended, leading to further declines in wild populations, not least through changes in the wild fish gene pool.

While the modern narrative will point to the benefits of our industrialized and technological mindset as the basis of human wellbeing, less often seen are the vast costs that accompany our present direction of travel. But in truth these costs are all too visible: in the destruction of the very resources that were initially regarded as so valuable, but also in the destruction of entire human cultures, whose philosophical foundations were built on deep relationships with the cycles of wild Nature.

The story of the salmon confirms the vital truth of how human health and wellbeing are directly dependent on the health and wellbeing of natural systems, including keystone animals like these fish, that enable those systems to function. While in many western societies this basic fact of life is often invisible, it is still at the philosophical heart of cultures that seek a different and more harmonious approach.

To this extent, the story of the Salmon is – at its most basic – one of competing world views. One view that sees Nature as a resource to be exploited with technology, and another that regards human existence as but one element in the infinitely complex web of wild cycles that sustain the biosphere upon which all life depends.

What is ever clearer to me is that the near-term future of humans on Earth will be determined by the extent to which we can relearn the wisdom of a worldview that has all but disappeared from many spheres of our lives, including technology, policy and popular culture.

Hope does appear in this wonderful film though, in visibly changing attitudes and demand for a different way. Protests have led to major dams being removed, rivers being rewilded and more intelligent fish management, not least due to the positive role played by savvy campaigns run by indigenous and first nation groups.

The message *Artifishal* film is powerful. It leaves the viewer seeing more clearly than ever how the next stages for the battle to save life on Earth will not only be about science and rational policies, but also about healing the crisis of perception that has so damaged how we see our place in the world. I have no doubt this brilliant film will be part of that process.

Artifishal: The road to extinction is paved with good intentions (Patagonia Films, 2019. 1 hr 15 m. Director Josh Murphy, Producers Yvonne Chouinard, Laura Wagner)

'The story of the salmon confirms the vital truth of how human health and wellbeing are directly dependent on the health and wellbeing of natural systems.'

Photo: © Richard Johnson – stock.adobe.com

Photo: © Peter – stock.adobe.com

The history, science and future of stocking

Kyle A. Young

We have been stocking salmon for a long time. From the middle of the nineteenth century salmon managers have been collecting adults from rivers, breeding them in hatcheries, rearing their offspring to some age, then releasing those offspring back into rivers to interact with wild-born fish. When we started stocking Darwin and Wallace were still developing their ideas about how natural selection drives adaptive evolution. Mendel was breeding peas to uncover the simplest principles of inheritance. By breeding and rearing salmon in hatcheries, we were driving maladaptation by artificial selection before we even understood adaptation by natural selection.

During the first half of the twentieth century paleontologists, evolutionists, ecologists, and geneticists drew upon the ideas of the early naturalists to study everything from fruit flies to dinosaurs. By the middle of the twentieth century this collective effort culminated in a period known as the Evolutionary Modern Synthesis. The goal of naturalists changed from naming and counting organisms to understanding how animals came to be, and not to be.

Salmon managers were not paying attention. They were busy refining and industrializing hatchery technology, resulting in the first collateral catastrophe of stocking: the damming of many of the world's great salmon rivers. Had we not been able to build huge hatcheries to replace fish lost by building dams, surely fewer would have been built— public outrage and commercial fishers wouldn't have allowed it. But when hatcheries offered society the promise of electricity, water for irrigation and drinking, *and* salmon, destroying river ecosystems was easy.

Not content with domesticating the freshwater phase of the salmon life cycle, salmon managers then applied hatchery technology to the saltwater phase. The result was the second collateral catastrophe of stocking: salmon aquaculture. The industry emerged during the golden age of ecology. Methodological and technological advances helped test and expand the ideas of the Modern Synthesis. At universities, departments of zoology and botany became departments of ecology, evolutionary biology, and environmental management. The field of conservation biology emerged to inspire early environmental legislation. Ecology now stood next to chemistry and physics as a world-changing science.

'The field of conservation biology emerged to inspire early environmental legislation. Ecology now stood next to chemistry and physics as a world-changing science.'

Still, salmon managers paid no attention. Until 1977. That year Reginald Reisenbichler and John McIntyre published the results of a simple experiment. They put eggs from wild and hatchery steelhead together in stream enclosures and hatchery ponds and asked which survived better where. Wild fish survived better in the stream enclosures and hatchery fish survived better in the hatchery ponds. The result offered a simple conclusion that should have been obvious for over a century: if wild salmon are put in a hatchery and exposed to artificial selection, they will become adapted to the hatchery environment and thus maladapted to the wild. This conclusion, in turn, supported two predictions. The first was that if a wild population is supplemented with hatchery fish, the per-capita number of smolts the population's adults produce is reduced and, as a result, the number of returning adults is reduced. Stocking reduces a population's productivity. The second prediction was that this damage could be ameliorated if only local, wild-born fish are used as brood stock.

It is hard to overstate the importance of these two predictions. They have guided hatchery management and stocking science ever since. For hatchery proponents it was a win-win. Where wild salmon don't matter, we can stock. We can establish domesticated hatchery populations, clip the adipose fins of stocked juveniles, and offer commercial and sport fishers salmon to harvest. Where wild salmon do matter, we can still stock. We can use wild broodstock and integrated hatchery populations, and get more adults without damaging the wild population.

The first prediction is really just the fundamental principles of evolutionary and population ecology reworded: adding maladapted individuals to a population reduces population productivity. Five decades of research suggests the second prediction turns out to be false. Whether domesticated hatchery fish or wild brood stock are used to produce juveniles for stocking, returning hatchery adults reduce population productivity by the same per-capita amount. But the mechanisms are different. Stocking with juveniles from domesticated hatchery populations reduces population productivity mainly because the fish are so maladapted (think aquaculture escapees) that hatchery adults produce only about 10% as many offspring as wild adults. Stocking with juveniles from wild brood stock reduces population productivity in part for the same reason — salmon become maladapted after a single generation in the hatchery, and first-generation hatchery adults will produce only half as many offspring as wild fish. But there is also another mechanism. Because they are relatively fit, such hatchery adults (or their offspring) will also interbreed with wild fish, making their offspring maladapted as well!

There is one scenario where it *might* be rational to *consider* imposing stocking on a wild salmon population: when a population is so small that it is at risk of imminent extirpation from "demographic stochasticity". When there are tens (not hundreds) of adults, a population may disappear due to simple bad luck. If, by chance, all the adults fail to reproduce at the same time, then poof, the population is gone. This is only a concern for very small populations that cannot be "rescued" by immigrants from neighbouring populations. Two things happen when such a population is stocked. First, to meaningfully increase adult population size, the ratio of hatchery fish to wild fish must be large, so the evolutionary damage inflicted through genetic introgression is severe and population productivity declines rapidly and dramatically. Second, the wild-born offspring of the hatchery adults and hybrids of hatchery-wild crosses will have adipose fins, and thus be available for use as "wild" brood stock. Such serial intergenerational exposure to artificial selection results in a toxic evolutionary cascade: a small, increasingly maladapted and decreasingly productive wild population. In many regards the worst possible thing that managers can do to a small wild salmon population is to subject it to a demographically meaningful wild broodstock conservation stocking programme.

'In many regards the worst possible thing that managers can do to a small wild salmon population is to subject it to a demographically meaningful wild broodstock conservation stocking programme.'

So what do we do when confronted with an unequivocal evidence-based scientific consensus that stocking compromises the evolutionary integrity and ecological status of wild salmon populations? We keep stocking.

The glaring disconnect between scientific consensus and management practice reveals that the "stocking problem" is a social, political and economic one. We thus need to identify, understand and challenge the pathologies that compel and perpetuate irrational management interventions. I offer a few reasons why we stock when we know we should not. Embracing alliteration, my "Seven Hs" elaborate on the "Four Hs" threatening wild salmon more generally: Habitat, Harvest, Hydropower, Hatcheries.

Habit. We stock mostly because we stock. It is far easier to build a hatchery than close a hatchery. Hatcheries bloat agency budgets and provide jobs. Bad habits are hard to break.

High. People love fish like drugs: the more the better. Salmon hatcheries engage, inspire and inform. For anglers, school children, tourists and politicians, a salmon hatchery can't possibly be bad for salmon.

Hubris. Gary Meffe's original description of large, industrial hatcheries as manifestations of "techno-arrogance" applies to all stocking. We cannot resist using technological interventions to "solve" ecological problems.

Honour. No one likes to admit being wrong. Agencies, corporations, organisations and individuals have staked their reputations and resources on hatcheries. Intransigent pride can compel otherwise rational actors to behave irrationally.

Hope. Blind faith sees no evidence. No matter how much evidence we compile demonstrating stocking harms wild populations, people will hope — that *their* stocking programme or river or salmon are somehow different, immune from the fundamental rules of evolutionary and population ecology.

Heresy. If hope is understandable, the cynical dismissal of evidence-based scientific consensus is indefensible. Science denial afflicts society more generally, making it acceptable, even admirable, to dismiss scientific consensus as no more valid than a personal opinion.

h-index. Salmon biologists share the blame. We are judged in part by our papers. Increasing our Google Scholar *h-index* (the number of papers *h* with at least *h* citations) requires publishing more, and more interesting, papers. We are trained to seize any funding, amplify uncertainty, and state our conclusions cautiously and objectively. At best, we tacitly support stocking just to do our jobs. If offered money to study stocking, we don't say "No, you dummies, stop!" We take the money, joke about the dummies spending it, and write the best papers we can. At worst, we amplify managerially irrelevant uncertainty ("I can never be certain") in betrayal of the precautionary principle, or refuse to forcefully articulate the scientific consensus in the name of apolitical objectivity ("It is not a scientist's place to judge management"). Stocking science is political. Scientists who study stocking have a responsibility to be so too.

Photo: © Cindy Creighton – stock.adobe.com

Despite these challenges, there is reason for hope. The citizens of most nations lucky enough to have native wild salmon have decided that the evolutionary integrity and ecological status of wild salmon matter. The majority of native wild salmon populations are officially protected by potentially powerful environmental legislation. Furthermore, every nation (except of course the United States) has signed the Convention on Biological Diversity, and has thus committed to managing wild salmon through the rational, evidence-based application of the precautionary principle.

So how do we reduce the future threat of stocking to wild salmon?

We need to be rational. The scientific evidence is clear: stocking is punitive not mitigative. Many stocking programmes are initiated

because a dam is built, or habitat is lost or degraded, or chemicals are spilled, or a population is overfished, or marine survival is low. We need to honestly acknowledge our mistakes, accept environmental variation and climate change, then address those threats we can. Subjecting what wild fish remain to stocking is almost always some combination of dumb, wasteful and damaging.

We need to be precautionary. The North Atlantic Salmon Conservation Organization (and its member states) *still* lists stocking as a tool of rebuilding programmes for wild salmon populations below their "Conservation Limit". But populations below their Conservation Limit will rarely be at risk of imminent extirpation. Conservation Limits are aligned to the carrying capacity of a population's river. A population with tens of thousands of adults can be below its river's carrying capacity and thus fail to meet its Conservation Limit. Those salmon need stocking less than they need bicycles.

We need to be realistic. We will not quit stocking any sooner than we will quit burning coal. But we can at least admit that when we do it, we don't care about wild salmon. So if we want a fish farm on Iceland's Ronga so people can fly from around the world to catch and kill salmon, that is ok. And when Oregon (USA) decides to manage some rivers for harvesting hatchery fish, and others for catching and releasing wild fish, that is ok too.

We need to be brave. It is possible to stop stocking. In 2014 Natural Resources Wales ended salmon and sea trout stocking across the entire country of Wales despite an overwhelming majority of consultees wanting stocking to continue. The angling community was outraged. Just as when people were told they had to wear seatbelts or couldn't smoke in pubs, the clamour fades.

We need to be grateful. For all the direct and indirect damage that hatcheries and stocking have inflicted upon wild salmon, we now have the technology to create salmon zoos. Complete life-cycle captive breeding programmes have, and will have, a place in maintaining live gene banks, saving populations from extirpation, and preserving unique evolutionary lineages. Be it Sockeye salmon from remote Idaho (USA) lakes that have been decimated by hydropower, or Atlantic salmon in the Bay Fundy (Canada) disappearing due to aquaculture, we can now maintain those populations in captivity. It may not always be rational to do so, but we can do so.

We need to be optimistic. Salmon are ecologically resilient and evolutionarily adaptable and have huge native ranges in the world's richest nations. Across most of those ranges we have done everything in our power to get rid of them. And we have mostly failed. Large populations of all species exist, and viable populations remain throughout much of their historic ranges. Left alone salmon will colonize habitat made available and their populations will grow. Even with the climate emergency, there is reason to believe the 21st century will be better for salmon than the 20th. Ranges will expand North, where freshwater habitat is least damaged. We will build fewer dams than we remove, we will manage our land and rivers better, we will kill fewer wild adults at sea, and aquaculture will transition to closed-containment production. And we will stock less.

Wild salmon will be with us forever. As thanks, we owe them better.

Further Reading:

R.R.Reisenbichler and J.D.McIntyre, 'Genetic Differences in Growth and Survival of Juvenile Hatchery and Wild Steelhead Trout, *Salmo gairdneri*, Journal of the Fisheries Research Board of Canada 34.1 (January 1977), pp.123–8.
cdnsciencepub.com/doi/abs/10.1139/f77-015

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A note and two poems

Harry Clifton

Distinguished Irish poet Harry Clifton reflects on fishing and introduces two recent salmon poems.

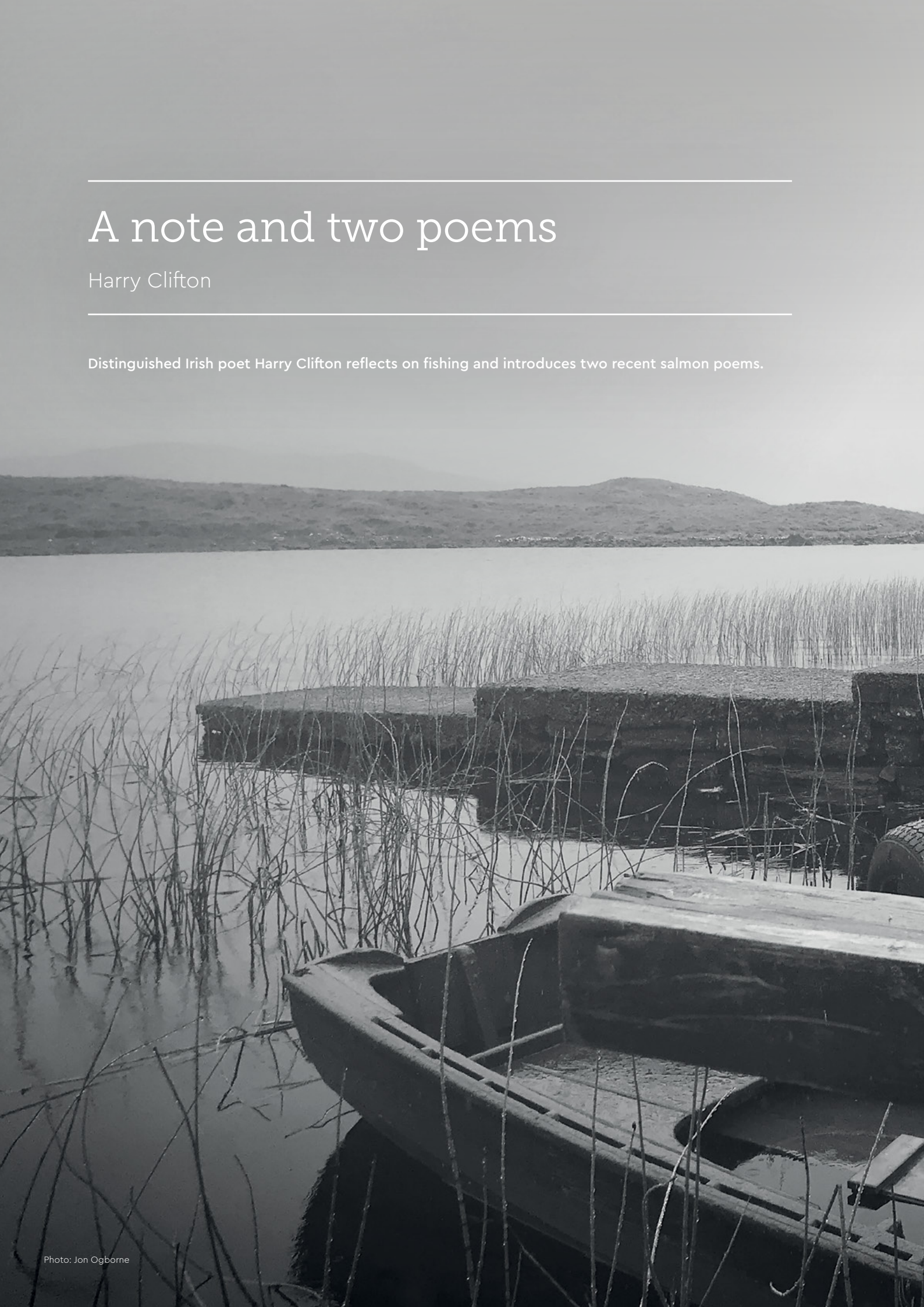


Photo: Jon Ogborne

Photo: Jon Ogborne

In childhood, I fished. Nowadays, I look at the waters. The soul-scape is the same, the mighty soul-scape of the west of Ireland, belonging to everyone and no-one. Or does it? Did it ever? I remember the Major, over from England at the beginning of each new season, adrift on his Spenserian dream of Irish otherness. And the Anglo-Irish landlord, his tumbledown house in its stand of pines up the valley, staring glumly through a front window, who 'did and did not' own the fishing, but who 'liked to be asked'. And last but not least, the local men in the Post Office by the bridge, with their immemorial birthright and entitlement, who went silent when one entered with a fish to be weighed, surprised perhaps that last night's netting in the estuary had left some still to be caught.

In those days, with the free fishing in the west of Ireland ('hundreds of eerie little lakes' as Ted Hughes once described them), it was still possible to believe, as a child, in an uncomplicated Eden. A few pounds changed hands at the door of a cottage on the top loughs of famous fisheries, a gate creaked, a field-path led to a boat half sunk in the rushes, and the rest – Englishman, Anglo-Irish man and Irishman – were the *dramatis personae* playing out their roles on the big loughs and river reaches down the system. God, somehow, had kept a little back from Caesar. At least until recently, when I retraced, fifty years later, those same waters, and heard instead of skylarks, the high electrified singing of history and politics, barbed wire fences.

I moved away from fishing, and poetry came to me. One form of pure attentiveness outgrowing itself into another. Not without ambivalence. My liberal self (the well-meaning interventionists on the night-river of 'The Pure Source') always accompanied by a shadow-self darkened by old politics of dispossession, working the fish-farm for a living ('The Salmon Cages'). I like to think, within a generation perhaps, of the two selves, poacher and gamekeeper, coalescing in the workable Eden of a fully-achieved republic, 'a future forbidden to no-one' as the poet Derek Mahon expresses it. Meanwhile I still fish, now and again – if fishing it can be called that is less for fish than for my own lost innocence.

THE PURE SOURCE

Beware of the pure source
Edward Said

Maura, Frank, myself and Paddy McCloskey
With his 150,000 salmon roe,
His marl and gravel for the man-made flow
Are interfering with nature
For its own good, sloshing about
In the shallows, where the hen-fish wallow
Steadying themselves, on tail and fin,
As the little males move in,
The gigolos, in their red striped livery,
Who never go to sea.
We are not alone
Up here, beyond our comfort zone,
Dungiven miles below us, and the lights of Kilrea –
A no-man's-land, adventured into
By lost souls, and the ghosts of the IRA.

Eyes are watching, from the barn owl's tree,
The otter's holt, by the hatchery.

Another shadow joins us. Why, I wonder,
Are we poking about after dark
On a pitch-black winter night of supernovae,
Constellations, Milky Way....
Night vision, I hear him say,
For what swims beneath our own reflection.
Paddy makes a joke about gender,
No-one laughs. It is late, too late
For all of that – for Frank with his photographs
That will never come out,
And Maura, with a miner's lamp
On her forehead, and me without gloves,
Dreaming hot toddy, lemon, honey and cloves...

Only the shadow, with his infinite patience
Beyond fish-kill, future of nation,
Slurry-pit of civilisation,
Flushes still, in deep December,
Guns and bootleg whiskey, organisations
Of which he was once a member.

THE SALMON CAGES

Remember me? I was left behind
Years ago, to farm the cages.
The rest of you went away
To greater things. My friends,
My brothers, there has come a day
When you sit here, like judges,

Looking me over. The mote in the eye
Of Ireland, the umpteenth son
Who minds the mother, stooks the hay
In summer...boredom
And horror, the lie of the country,
Everything can be laid at my door.

Look at them, out there on the water,
Hanging, fathoms deep,
The cages. And the million selves
I might have been, ripe for the slaughter,
Dreaming continental shelves
As the factory-ship

And the ice-plant on the drizzled pier
Digest them, year by year,
Like Jonah. Ptomaine
Dropping, like a slow rain
Of pellets, into the food-chain –
Tell me about it. I *live* here...

Mother is taken, once a week,
To the clinic. And John,
Arthritic from the cold of Spokane,
Is back with us now, half-witted.
The broken and the terminally sick,
We are growing again

To a kind of family. Grey days
Absorb us. The unbeautiful
Is our element – the way of duty.
No-one speaks of nationhood
Anymore. There is no taste
To the fish, but sales are good.

Photo: ©mark_gusev - stock.adobe.com


patagonia

Slutprodukt: Norwegian salmon farms and the impact on wild salmon

Few people in the world speak with such informed passion about wild salmon as the Swedish angler, conservationist and activist Mikael Frödin. When he gave a presentation in Cambridge last December, Mark Wormald had a front row seat.

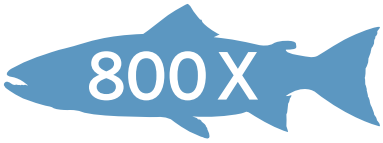
"I'm not a scientist, I'm not an expert on fish farming. I am just a fisherman." Since the early 1970s, Mikael Frödin has fished the world's finest salmon rivers, many of them in Norway, which has "been like my home country", and started guiding professionally on rivers there in 1983. Finding and catching "big Atlantic salmon in clear waters became an obsession", he says. And since the death of Orri Vigfusson, with whom Mikael fished in Iceland, no one speaks with more authority about the 1990s dramatic decline in the runs and quality of the wild Atlantic salmon. "Stocks have been going down since I started, in the early 70s. More and more of my time has been spent with conservation, trying to make sure there are some fish for us and our kids to fish for."

Acknowledging that "the situation could have been a lot worse than it is today," he credits the buy outs of driftnetting operations in the Atlantic negotiated by Orri Vigfusson, and Norway's decision to stop drift netting. But it is still "pretty terrible", he says. "Today there are less than half the number of fish entering the rivers than when I started guiding. The Tana is the largest of all the Scandinavian rivers and the biggest producer of smolts in the world – or it should be." Evidence of decline there is graphic: "the peak years in each seven-year salmon cycle now barely reach the bottom of equivalent data from twenty years ago. This shows us exactly where we are going."

Mikael may not be a scientist, but he recognizes the evidence Norwegian scientists present. "The Norwegian Scientific Council tells us that there are a few reasons for the stocks going down the way they do. All come from fish farming. It's the sea lice problem, it's genetic pollution, and it's the spreading of disease."

The numbers are frightening. "There are about 500,000 wild salmon entering Norwegian rivers. And in the fish pens of Norway there are 400 million individuals. Eight hundred times as many farmed fish as wild. Scientists, the sport fishing community, and myself, have been seeing the changes. We have been catching farmed fish in the rivers, seeing the effect of sea lice and trying to tell the politicians that the total collapse of all wild stocks is right around the corner. If we don't do something now, ALL Norwegian wild salmon stocks will be extinct in just a couple of decades."

'More and more of my time has been spent with conservation, trying to make sure there are some fish for us and our kids to fish for.'



as many farmed fish as wild

In 2017 Mikael was asked to take part in the documentary *Artifishal* (reviewed here by Tony Juniper). Having fished it for thirty years, he has long had "a history on the Alta, probably the best river for big salmon in the world," and has witnessed radical change. "I have seen the average size of wild fish go down, and effects of sea lice throughout that wild population."

Mikael took the *Artifishal* crew to Alta. He wanted to "get inside and have a look at how it was in the pen. We knew that we would have to break the law." It is illegal to go within twenty meters of any pen, but he regards it as a "moral obligation to break this law" and to try to gain information and spread it to the public. "I got on the pen and … it was worse than I expected. There were more sick than healthy fish. It was terrible." Unable to wait for the 2019 film release to share the horrors he'd seen, Mikael posted some photographs to his social media accounts; "it created a lot of noise. It took me to court".

'In a way the authorities were saying: 'There is no chance to rescue the Norwegian salmon.'

Revealingly, the case against him "was brought not by the company but by the fishing authorities of Norway. They saw me on the pen, found out what the company was, and told the company to prosecute me. I didn't understand how stupid the fish farming industry could be," Mikael reflects. "How could they be creating this opportunity for me to get all this media attention? The Alta Courthouse is small. There have never been so many people in the courthouse before." Hundreds of people came to show their support for him.

Mikael was duly convicted for trespassing, and received a 1500 Euro fine. He set out to appeal the conviction on the grounds that what he and the film crew had done was "a rescue action: we are trying to rescue the wild salmon of Norway." But the Supreme Court disallowed the appeal. Mikael summarizes the Court's response: "If you are going to be allowed an appeal for rescuing, you need to have a chance of rescuing something. In a way the authorities were saying: 'There is no chance to rescue the Norwegian salmon.'"

But the international media interest his case provoked did give him a second chance, "to educate the public on the situation surrounding fish farming. I did about a hundred and fifty interviews – normally I do interviews for fishing magazines." Education meant detailing more than the visible injury done to the salmon in that pen, itself a combination of sea-lice infestation in huge concentrations, and the warm water treatment developed in response to the immunity sea lice have developed to the toxins used to treat them. It meant describing the infestation billions of penned sea lice create for wild fish swimming nearby, a problem all the more acute in those farms positioned in long narrow fjords. It meant being open about the 24% mortality rates in Norwegian salmon farms. 53 million Norwegian salmon died in salmon farms in 2017. "If you think about it, 53 million salmon is about 100 million kilos of salmon," which in turns means "300 million kilos of food from the wild to produce this that are dying in the fish farms. It is a pretty awful situation."

53 million

Norwegian salmon **died in salmon farms** in 2017

It also meant enumerating the collateral casualties of industrial salmonid aquaculture. In a recent report Mikael cites, 50 million cleaner fish — wrasse and other species brought in as organic alternatives to chemical treatment of sea lice — are dying in

Norwegian fish farms every year. "That is 150,000 cleaner fish every day, and 150,000 salmon every day, meaning there are 300,000 animals dying every day." He applauds Corin Smith's sickening images of dumped salmon carcasses on North Uist. And then there are the shellfish in the fjords, the destruction of complex and delicate marine ecosystems by the concentrated discharges of salmon faeces and chemicals from the pens. Add to that the carbon dioxide emissions involved in transporting farmed salmon and, Mikael observes, "It is a pretty filthy industry."

Finally, it meant sharing research undertaken at the University of Bergen into the nutritional impact on the flesh of farmed fish that eventually reaches the consumer in any one of the countries that depend on Norwegian exports. Mikael summarizes: "if a kid weighing thirty kilos eats 70 grammes of farmed Norwegian salmon, he will reach his weekly limit on toxins in one half portion." In English, that farmed steak is 'the final product'; but the original Norwegian is the more powerful: 'Slutprodukt'.

In Sweden, 97% of consumed farmed salmon comes from Norway. Confronted with this evidence, the Swedish community of Åre committed to trying to stop serving farmed salmon. "Then all hell broke loose again." *Fish Farmer*, the industry journal, reported the international incident in July 2019: 'Norway hits back over Swedish salmon ban.' The stakes are high.

It isn't just fish or information that crosses borders. Disease does too, as a consequence of human interference in, and movement of, naturally discrete fish populations. The parasite *Gyrodactylus salaris* [known as salmon fluke] is indigenous to Swedish rivers where salmon have acquired immunity. It has already hit a number of Norwegian salmon rivers like the Laerdal, Rauma, and Vefsna, where wild salmon were not resistant and have been saved by the Genetic Bank.

Mikael supports regular genetic status mapping and gene banks for river salmon – where samples can be preserved as a proof against future disasters. He agrees with Kyle Young and Jamie Stevens that in all but the most severe environmental catastrophes local populations will recover, so long as a few wild salmon survive. Failing that, wild fish can be removed, a river sterilized, left a few years to recover, and then the wild stock can be reintroduced. 25 Norwegian rivers have already undergone this process.

An insidious and potentially irreversible threat getting more serious by the year is the genetic pollution of local sub-populations by interbreeding with escapees from salmon farms. The first analysis of the genetic purity of the wild salmon in Norway's rivers was undertaken in 2016: some 20% of rivers were already estimated as beyond genetic repair, and three years later it had risen to 30%. Such rapid deterioration underlies the Norwegian Supreme Court's argument about the futility of Mikael's film evidence from that Alta fjord salmon pen. Without rapid intervention, Mikael observes, "All of the sub-populations will be extinct." Wild salmon will disappear. It is why he believes "Fish farming is the biggest threat" to wild salmon. "This is how fish farming looks today."

Today matters because of what it means for tomorrow for all of us, and for wild salmon. Norway and Norwegian-owned companies

"...if a kid weighing thirty kilos eats 70 grammes of farmed Norwegian salmon, he will reach his weekly limit on toxins in one half portion."

have operated farms in Scotland, Ireland and around Europe for decades, and are already the biggest producers of farmed salmon. They have plans for radical, five-fold expansion in the near future, arguing that farmed salmon can feed the world.

Certainly, Mikael acknowledges that "Atlantic salmon is the species on the planet that has got the biggest market potential, and that is why it is the species where fish farmers really are doing the business."

But doing the business has appalling costs, and Mikael does not apologies for using strong language. "I would say Norwegian fish farming companies have been raping the coastline of our country, the fjords of Norway, the Chilean coast, parts of DC, Washington State, the West coast of the UK, Ireland: it is the same companies. Now they are going to Iceland. They want to increase the production of fish in Icelandic water now."

Here too, numbers tell a graphic story. "A total of around 50,000 wild salmon return to Icelandic rivers. One cage normally contains between 200,000 and 400,000 fish. A normal farm is between six and eight pens. So one farm contains forty and fifty times as many fish as the total amount of wild fish entering Icelandic rivers. It is not a question of if this is going to ruin Iceland. It is just a matter of time. It will be one or two decades. If they keep going like this the population of Iceland will be gone." What is this but ethnic cleansing?

Commercial interests can feel inexorable, irresistible in the simplicity of their logic, and they have no compunction invoking the imperatives of local employment and feeding the world to support their case. Mikael is not convinced. "They want to make as much money as possible. They don't care about sustainability, ecosystems, or wild fish. They want to earn money." Challenging rapacious ambitions needs equally urgent defenders and Mikael is sure what is needed: "I think it is important to show the public these photos, and to spread this around the world, so people can know what they buy in the food store.

'It is not a question of if this is going to ruin Iceland. It is just a matter of time.'

Photo: © mariusltu - stock.adobe.com

"I have been called fish farming's enemy number one", he goes on. "But I am not really an enemy of fish farming. I am an enemy of the way they are doing this. A solution is there, and we will get there. The work with *Artifishal*, the work around the trial, everything, perhaps will speed this up a bit." It needs to. With extinction of wild fish stocks in particular rivers already a reality, there is no time to lose. "If we can make this happen in five years, or a shorter time, it is worth the fight, because we will save the stocks of wild fish."

So what is this solution? In brief, land-based closed containment aquaculture. The first generation of closed containment systems were located in the sea, but Mikael much prefers land-based farms. "What happens when you get to the storm of the decade? Can you build a farm that maybe contains hundreds of millions of fish? The pollution, the genetic pollution when one of those breaks will be just as bad as ten other farms. Doing this in closed containments means you end up with very good quality fish. You can control everything." The horrors of salmon in pens or swimming past them being eaten alive by sea lice will disappear; so will the toxins or warm water treatments that blight open net pens. And you can site near major population centres, reducing transport costs and CO2 emissions.

"I believe in this," says Mikael. "We need to go this way. And the industry knows that they will end up here. They are fighting it because here they have to take care of the waste. And it is going to cost them more money. But if the price for the consumer is going to rise a bit, what's the price of an ecosystem? How should we compare this?"

"consumers can see that they can choose to do something that is not bad for the ecosystems and for the wild fish. Supporting land-based sustainable farming."

Governments and markets do have a choice. Mikael acknowledges the irony of the Norwegian government's massive sovereign wealth fund, derived from North Sea Oil, which it chooses to deploy in moral investment. Why isn't the state cleaning up its own back garden and ensure the genuine sustainability of both farmed and wild salmon stocks?

But until it does, individuals have a choice too. Mikael shares an initiative he has developed with some of Sweden's leading chefs and restaurants, where "consumers can see that they can choose to do something that is not bad for the ecosystems and for the wild fish. Supporting land-based sustainable farming. When we walk into our food store, we can ask for proper sustainable salmon. If we do, we can speed up the closed containment industry, and when that starts, and gets going, we won't have to do anything more. Because at that point the closed containment industry will kill the open pens."

In the meantime, Mikael thinks we should look elsewhere, shop seasonally, eat wild omega-3 rich mackerel rather than soya-fed farmed salmon. And he thinks that Norwegian aquaculture's current huge investment in local communities and cultural endeavours, and against activists like him, is a short-sighted mistake in defence of their monopoly. In a decade or two, he predicts that the Norwegian market share will have halved.

Let's hope – let's work together to ensure – that he is right.

From Polar Salmon to Ubiquitous Pacific Icon: The triumph and tragedy of steelhead

Ehor Boyanowsky

But the steelhead, with the brightness of the sea still on him, is livest of all the river's life. When you have made your cast for him, you are no longer a careless observer. As you mend the cast and work your fly well down to him through the cold water, your whole mind is with it, picturing its drift, guiding its swing, holding it where you know he will be. And when the shock of his take jars through to your forearms and you lift the rod to its bend, you know that in a moment the strength of his leaping body will shatter the water to brilliance, however dark the day.

Roderick Haig-Brown, *A River Never Sleeps* (1948)

Ehor Boyanowsky (left) and Ted Hughes, Dean River, British Columbia, 1987.
Photo: Ron Cordes

‘The fishing in the Thompson, every man’s river as it flows alongside Highway 1, was unparalleled, drawing anglers from the world over. Then numbers began to decline precipitously.’

I grew up in Northern Ontario progressing from snagging suckers to spinning for pike, walleyes, lake trout and muskellunge. I experienced steelhead only as a mystical creature through the books of Roderick Haig-Brown.

But then I moved to British Columbia in 1975. I saw that reverence wasn't enough. The steelhead was under threat, and the species needed all the help it could get, in an era of bureaucratic misjudgment, policy failure, commercial interests and scientific misunderstanding. So in 1976 I joined the Board of the Steelhead Society of British Columbia (SSBC), remaining a member for thirty years, and serving as its President in the early 1990s. As an angler and conservationist I want to tell their story.

For too much of the century, the steelhead has been disenfranchised. Long regarded as a rainbow trout, an interdepartmental memo turned over management from the federal Department of Fisheries and Oceans (DFO), the agency normally responsible for the conservation of all sea life, to the much smaller and less influential British Columbia fisheries department. From thereon steelhead were disregarded by DFO management. The effect on steelhead was distressing, especially for the Thompson River run of BC's fabled, most powerful steelhead. In the mid 1980s up to 40,000 rounded the corner of Vancouver Island before being pounded by gillnetters and seiners. Nevertheless, up to 10,000 still made it to the spawning beds. The fishing in the Thompson, every man's river as it flows alongside Highway 1, was unparalleled, drawing anglers from the world over. Then numbers began to decline precipitously.

In 1992, during my time as President of the SSBC, DNA analyses undertaken by Robert Behnke and others led steelhead to be reclassified as Pacific salmon. And when, five years later, a BC man and former Secretary of SSBC, David Anderson, became Federal Minister of Fisheries and Oceans and head of the Department (DFO), he instituted conservation measures to save steelhead from those mixed stock fisheries. Numbers of steelead rose again, by several thousands. But this brief window of hope closed again when Anderson moved on. Steelhead numbers again steadily declined as DFO resumed its role as the handmaiden of commercial fishing rather than conservation. Responsibility for conservation remained with the provincial fish and wildlife department, who continued to be ignored by DFO.

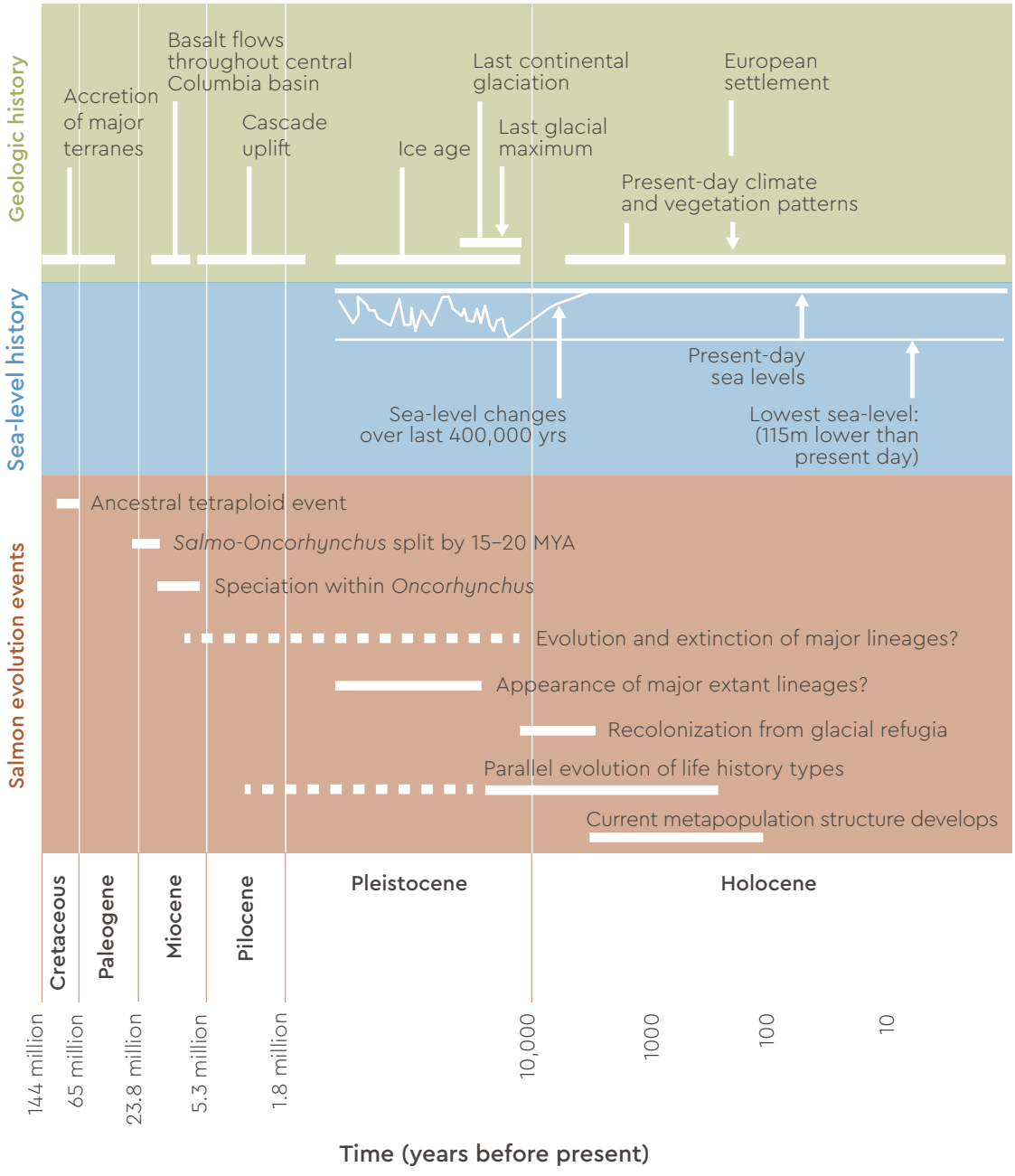
Alexei Boyanowsky

The consequence was one of the major crimes against the environment ever to have occurred in BC. Now, fewer than 200 wild steelhead are expected to return to spawn and the river is closed. A tragic mistake.

As Roderick Haig-Brown wrote: "A river without anglers is a river without friends."

Historically, steelhead were regarded as the Pacific counterpart of the Atlantic salmon. In the narrative I favour there was an ancient polar salmon that bifurcated into two branches: *Salmo salar* or Atlantic salmon to the east and *Oncorhynchus* to the west.

From Waples, RS, Pess, GR and Beechie, T. Evolutionary history of Pacific salmon in dynamic environments. Evolutionary Applications, 2008, May;1(2), 189–206



'The consequence was one of the major crimes against the environment ever to have occurred in BC. Now, fewer than 200 wild steelhead are expected to return to spawn and the river is closed.'

The steelhead is the most 'primitive' (least specialized in required habitat) *Oncorhynchus* species, and many forms enter rivers of all sizes from Alaska south, some anadromous, some patamodromous (that is, moving from river to river, not to the sea). Its habits of residency or migration have many iterations. One generation, or even only some individuals may shift strategy so an anadromous mother gives birth to some non-anadromous offspring and some anadromous offspring and vice versa. It is the only Pacific salmon that doesn't die upon spawning. And it enters streams as far south as Baja California in Mexico as they become briefly watered, to spawn and return to sea instantly.

The other descendants of that ancient polar salmon, *Oncorhynchus* — chinook, then coho, then chum, pink and sockeye (the last three salmon in the emergent sequence already confirmed through research according to Waples *et al*) – emerged as increasingly specialized species requiring special conditions and living an increasingly rigid life pattern, dependent on factors such as size of stream, a lake to be reared in. Sockeye are the most specialized and the most numerous, sometimes historically reaching tens of millions in a single run.

The steelhead, by contrast, remains on its own, the rarest, a lone shape-shifting wolf, usually numbering only in the hundreds or thousands. The exception used to be the Central Valley of California, where obviously conditions were optimal, even ideal. In those California rivers runs had reached one or two million where the habitat was undisturbed and intact among the redwoods. That was a paradise on earth combining perfect climate with perfect rivers for steelhead, until logging and water extraction ravaged the rivers, and cataclysmic floods in the mid 1950s and again a decade later completed the destruction.

Range of Steelhead – Waples et al.

Beyond their fascinating natural history, why are they held in such esteem? As Haig-Brown pointed out, their greatest ally is the angler.

Steelhead, especially summer fish who ascend the rivers in spring, summer and fall possessing immature gonads and are not about to spawn for sometimes up to nearly a year, feel like the angler's friend. They rise freely, even to the dry fly. Indeed, Thompson steelhead often prefer a waking dry

fly even in December water temperatures. I have taken them on the surface on New Year's Eve when the water temperature is one or two degrees Celsius. But this responsiveness has had its dangers: anglers and even early fish biologists overestimated the numbers of steelhead in each river and even believed angling alone could not wipe out a run. How wrong they were.

Moreover, biologists often added to the misapprehension of the effects of logging. They assumed, for example, that exposure of a spawning stream to the sun caused by logging actually accelerated fry growth. In fact, any benefits were temporary; with the denuded stream becoming desiccated, and the lack of living tree roots lowering the water table. Such research was seized upon by loggers to justify clearing riversides where the largest and most profitable old growth trees had grown. Most are now gone.

Late 20th century loggers argued that their industry, bringing in nearly a billion dollars per annum in prosperity, must be allowed to clearcut old growth untrammelled, as the sports industry only brought in millions of dollars. It was a false economy. Outdoor wilderness recreation now is booming, logging is in steep decline.

As Canadian economist Harold Innis has recognised, the true cost of ruining a river, destroying the fish and insect and attendant wildlife especially bears, whose leavings fertilize the soil, and even birds, deer and elk, etc, is never computed. It took millions of years for those creatures to evolve and the harvest reaped from them annually without cost must be factored into the river's destruction. The logging cannot be repeated for many decades, and in the case of old growth, centuries, if ever. No company, no country can afford to recreate such an ecosystem once it is lost.

But it was anglers, and particularly those anglers who wrote, like Haig-Brown, those who plied the riverbanks for love not money and communicated that love to others, who sounded the alarm. In 1970, they founded the Steelhead Society of British Columbia as an offspring of the BC Wildlife Federation that has since been the clarion voice of river conservation in BC. When my friend, the prominent Atlantic salmon angler and author, Gary Anderson of Montreal witnessed bait fishermen releasing steelhead in the Vedder/Chilliwack, like all BC waters, a public river notorious for crowds, he was astounded. The conservation message was getting across. When you fished for salmon you fished to kill, a propensity favoured in the east and Europe for several more decades as I discovered on a day spent with the legendary Hugh Falkus in the early 90s. Ironically, in the 70s only UK coarse fishermen realized they largely fished for pleasure and released their catch.

Ted Hughes, whom I introduced to steelhead fishing in the mid 1980s, told me that the conservation struggle in the UK was then seen as a class war: the upper classes angled for salmon in the rivers, whereas the working class held the netting rights in many estuaries, and the public was loath to halt the honest labour of those lads. Ted claimed that at least until the mid-nineties, no fisheries minister had ever halted netting on the sea or in the estuaries for conservation of salmon runs.

‘But it was anglers, and particularly those anglers who wrote, like Haig-Brown, those who plied the riverbanks for love not money and communicated that love to others, who sounded the alarm.’

Photo: © Conrad ~ stock.adobe.com

Ironically the same was practically true in BC where anglers were not divided by class. It remains the case that the majority of anglers, even fly fishers, are working or merchant men, while commercial gillnetters and many seiners are often very wealthy and these boats and operations are now corporately owned by a local billionaire.

Ted Hughes on the Dean River with Steelhead.
Photo: Ehor Boyanowsky

The major exception was the truly Honourable David Anderson. Keenly aware of the conservation concerns, and despite criticism from the commercial and aboriginal sectors, Anderson forced his DFO managers to hone their schedule of net fishing days to allow the safe passage of Thompson steelhead. The result, for a few years from the late 1990s, was an embarrassment of riches with anglers visiting the homely little desert hamlet of Spences Bridge from many countries including Japan, USA, France and the UK. Just to hook one or two mighty steelhead in a week.

But both marine and riverine denizens faced another threat: pulp mill effluent. A new test of effluent from mills that used chlorine for delignification of the wood (breaking down the fibres) revealed the production of dioxins and furans, substances so deadly that only a few hundred parts per billion (eg 100 grains of sand in an Olympic sized pool) could kill fin fish and contaminate shellfish such as clams and crab. Smokestack emissions from the mills released gases that were deeply implicated in human cancer especially lung cancer.

I had recently moved to West Vancouver, one of the most scenic and affluent cities in Canada, and the most conservative politically. As a miserable academic, I could only afford a house in darkest West Vancouver, its outskirts on the Squamish Highway, but it was

situated right over Hole in the Wall, the prime location for chinook and coho fishing in Howe Sound and spot prawn trapping. It was paradise, or should have been. But the populace was alarmed when epidemiological studies revealed higher than normal cancer rates for women living downstream of two pulp mills miles away.

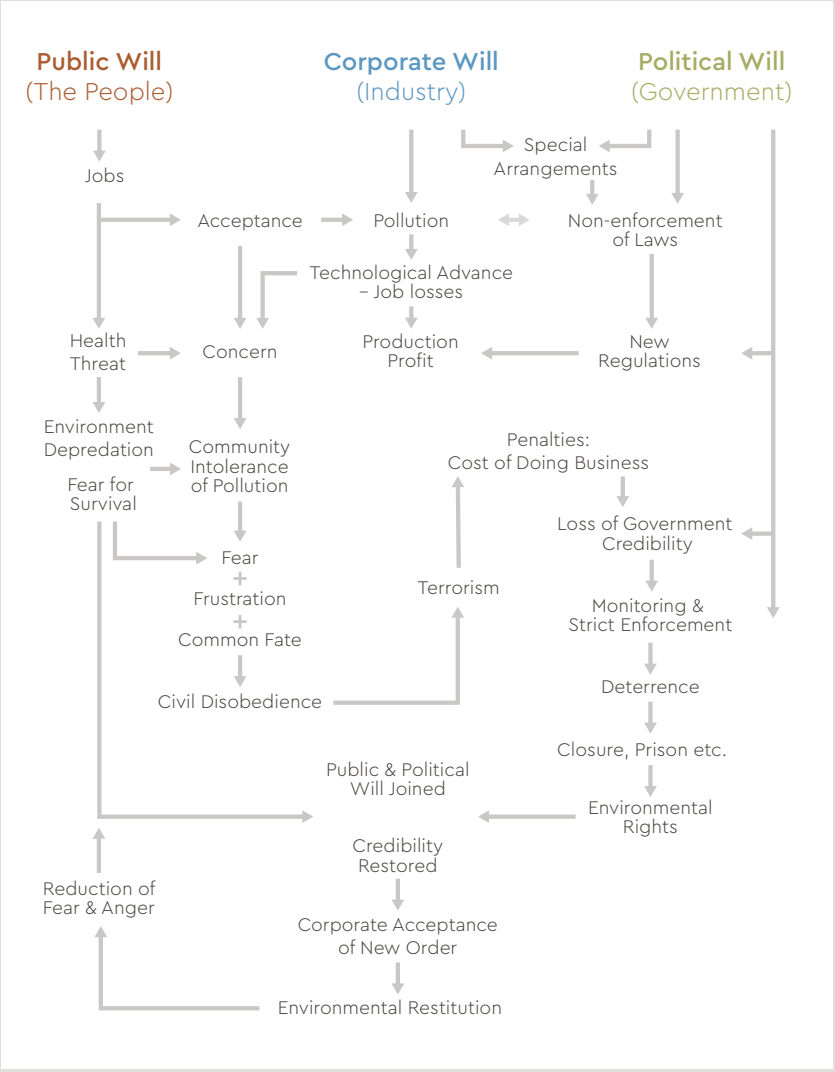
Our organization, Save Howe Sound, was mounting a campaign to stop pulp from those mills being used to manufacture paper milk cartons as the paper was dioxin-contaminated. As we gathered material for a press conference, I stumbled upon a study by DFO showing furans, many times above the lethal level for fish, in the flesh of prawns and crabs. I was familiar with scientific methodology, and recognized the significance of this study. The main focus of our campaign was immediately changed to dioxin and furan contamination in the previously assumed pristine waters of Howe Sound.

DFO, which had conducted the study, but let it idle on its shelves, immediately ended the harvesting of all shellfish and resident fish in Howe Sound. A coincidence? I think not. A case in point for why government scientists should not be prevented from publicly promulgating their findings. The headlines roused the ire of the public. Protests were mounted and militant groups planned direct action against the offending mills.

The Environment Minister, himself a West Vancouver man, resigned when the Premier would not ban chlorine delignification. As it transpired, that revelation contributed to the government's defeat and the incoming government insisted pulp mills use the much more expensive oxygen delignification process which satisfied European customers and removed dioxins from many waterways including the Thompson River. Some pulp mills recently modernized but not retrofitted for oxygen delignification were forced to shut down permanently, victims of corporate action that tried to save the bottom-line during renovation at the expense of nature and human health.

'The headlines roused the ire of the public. Protests were mounted and militant groups planned direct action against the offending mills.'

Photo: © Conrad - stock.adobe.com



Algorithm for calculating public reaction to environmental threat
Credit: Ehor Boyanowsky

Distilling the common elements from several such case studies, I developed an algorithm to predict the outcome of pollution and public reaction to environmental threat. My extraordinary graduate student, Omi Hodwitz, tested the hypotheses derived from it in North America, Asia and Europe and found to her dismay that people do not react to large, worldwide threats to the environment, but to those that occur most closely to where they live and affect them.

That may be why the plight of steelhead remains unassuaged: its identification as a sea-going trout lessened its stature, and concern for its wellbeing remained largely with angling groups. Not even aboriginal people have shown alarm until these past two years, despite many meetings on the subject of the imminent extirpation of Thompson steelhead. The relatively small numbers, the rarity of these fish, make them less a species of concern than the regular harvest of more numerous salmon, especially sockeye and chinook. Those types upon which they rely for food and commercial harvest. Despite representing only ca. 5% of the population, ca. 35% of commercial fishermen are natives, and their political clout has recently escalated through the Liberal federal governments campaign of reconciliation with aboriginal groups.

Public awareness of the crisis rose when in the early 90s there was a great deal of alarm over the high seas drift net fisheries – those fifty-mile long meshes of indiscriminate death operated by several nations that were roaming the high seas. A singular opportunity arose to confront the issue at a meeting in Vancouver preparing for the UN Conference on Highly Migratory and Straddling Stocks of the High Seas.

'Public awareness of the crisis rose when in the early 90s there was a great deal of alarm over the high seas drift net fisheries.'

Listening to the complaints of various commercial interests, it occurred to me that a natural solution existed. I buttonholed environmentalist/former commercial fisherman, Chris Chavasse, of Alaska, and eminent whale researcher Jon Lien, of Newfoundland, and proposed that fishing anadromous stocks should not be allowed on the high seas but only by the host country that had produced those stocks in its own rivers. Together we composed a proposition that went forward. Several years later I was gratified to learn that the idea had been adopted by the UN as Article 66.

> "The long-distance migrations of salmon expose them to capture in diverse fisheries, including in-river, coastal, and High Seas fisheries. High Seas fisheries are governed by the North Pacific Anadromous Fisheries Commission (NPAFC) whose member nations include Canada, Japan, the Republic of Korea, Russian Federation, and USA. Since 1992, directed fishing on salmon in the High Seas has been prohibited. However, enforcement over the vast North Pacific convention area is difficult. Beyond monitoring, there is a need for cooperative governance of other aspects of fisheries management (e.g., release of hatchery salmon) that influence feedbacks between the productivity of the High Seas commons and indigenous salmon fisheries." (Peterman *et al*. 2012).

Alas, according to a recent UBC study by Rashid Sumaila (reported in UBC News, June, 2017), the high seas interception continues, subsidized to the tune of billions of dollars, especially by China and its fleet of nearly 3,000 high seas commercial ships.

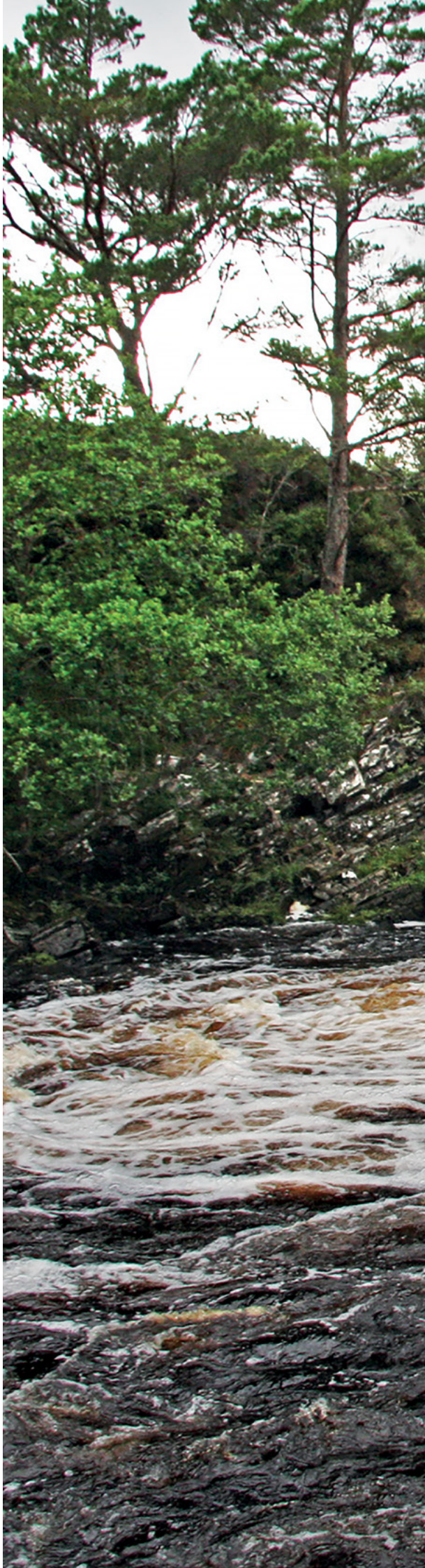
However, in 1994, buoyed by our recent victories we put together a multifaceted effort in favour of steelhead, headlined by Ted Hughes, that put this extraordinary species in the forefront of the public's awareness. For a time.

I will end with lines from 'The Bear', a poem drafted by Ted Hughes in 1987 as we sat, huddled under tarps and howling cold winds, beside the Dean River roaring in freshet, but like steelhead anglers everywhere, ever hopeful.

> The thousand-mile humping of mountains
> That looked immovable, was in a frenzy,
> Metabolism of stars, melt of snows—
> Was shivering to its ecstasy in the Steelhead.
> This actually was the love-act that had brought them
> Out of everywhere, squirming and leaping,
> And that had brought us too—besotted voyeurs—
> Trying to hook ourselves into it.

Salmon Conservation for Long-Term Sustainability – The Oykel Way

Steven Mackenzie



Steven Mackenzie, Fishery Manager on Sutherland's River Oykel, has worked on the river for almost 30 years. Here he shares his love of the river and describes the exciting initiatives a traditional fishery is taking to conserve and sustain its wild salmon, in partnership with the local community and visiting anglers.

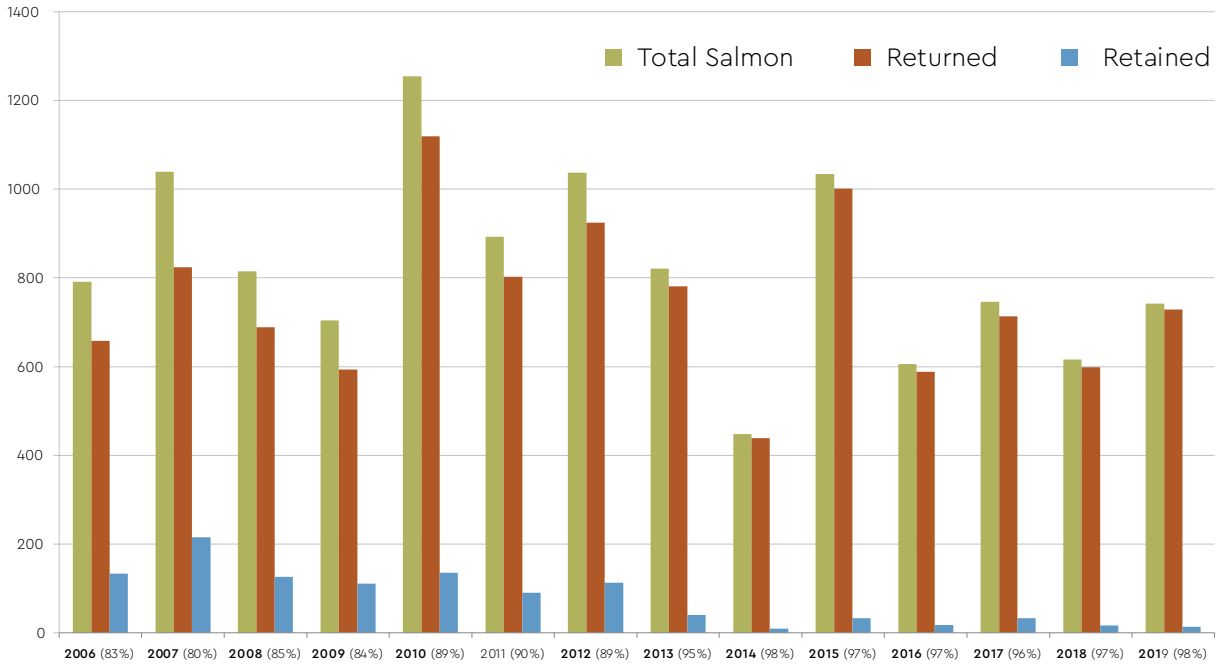
The Oykel system is a designated Special Area of Conservation (SAC) for the protection of Freshwater Pearl Mussels and Atlantic Salmon. I manage seven miles of river on the Lower Oykel and seven miles on the Upper, both consisting of four double banked beats. We allow three rods per beat and welcome our returning anglers year on year, both owners and some long-standing tenants – many of whom have fished the Oykel for over 50 years.

On the Oykel, we work hand in hand with the Kyle of Sutherland District Fishery Board, and I am a trustee of the Kyle of Sutherland Fisheries Trust. Working closely with the Fishery Board and Trust ensures that, as a company, we are able to make all our management and conservation decisions based on the best and most up to date scientific evidence. This partnership has developed and strengthened over the last 30 years, and has proved very effective. I am proud that George Ross MBE, my predecessor, and I have always managed the fishery for the fish and not the fishermen. If you keep this at the forefront of your mind when making sometimes tough management decisions, the results will speak for themselves in the years to come.

The Oykel Conservation Policy has evolved over the years with fantastic results. Very small changes in the way you word the rules for anglers, can help shift their attitude towards conservation and in turn, help them understand and be supportive of our efforts to protect the future of the salmon they catch.

We made the decision 25 years ago to return 100% of spring fish back to the river. To protect the multi-sea winter fish for the entire season, we introduced a no kill policy of any fish bigger than 65cm. At the time, we also adopted the policy of only using single hooks in flies or tubes to minimise the chance of fatally wounding any spring fish. Only single hooks are used until the 15th of June; from then on,

Photo: Andrew Graham-Stewart



Lower Oykel Salmon Return Rate, 2006–2019

both singles and doubles are permitted. Our Oykel records show that we have less than 1% mortality in the spring, which is exactly what we wanted to achieve. In 2004, we welcomed the decision by the Kyle of Sutherland District Fishery Board, through the Scottish Government (Salmon Conservation Act 2001), to make treble hooks illegal in the entire Kyle of Sutherland catchment area.

In 2009/10, we removed the rule that all hens must be returned after the 15th August. We wanted anglers to understand the importance of genetic diversity in the river: having high numbers of cock fish in the system is as important as high numbers of hen fish. This was a very subtle yet successful change in mind-set because anglers began to view cock fish as of equal value to hen fish, therefore were less likely to keep either. The graph demonstrates how as a result of this change in policy, return rates increased from just over 80% return to around 90%.

'This again demonstrated how very subtle change in policy can have an enormous effect on mind-set.'

In 2012/13, we went from allowing anglers to retain two fish, per rod, per week to *one* fish, per rod, per week. Immediately, our return rate reflected this, rising from 90% to 97%+. This again demonstrated how very subtle change in policy can have an enormous effect on mind-set, and we welcomed the support of our anglers to make the positive change. It seemed that no one was interested in killing these very precious fish anymore. The change in behaviour has been dramatic: we have come from 98% kill rate to 98% return rate in the last 30 years. In 2019, Oykel Fishings landed 1068 salmon and safely returned 1048. The 20 that were retained

'Having now carried out the technique of non-contact release on a daily basis for many years, I am keen to share with others how easy this is to carry out, either while helping another angler return a fish or when returning your own.'

were unfortunately fatally hooked but we believe that as a result of our conservation-centred policy, this is a good result. For the 2020 season, it was decided that we would introduce 100% catch and release on both the Upper and Lower Oykel.

As an angler, hooking a fish is one of the most exhilarating and memorable experiences in your life. Every time is as exciting as the one before but as we now know, it is best practice to minimise the impact of the catch on the fish. Often when you hear an angler say, 'My fish took a while to recover,' this suggests that they are recovering from being played. However, from evidence gathered on the Oykel, we believe the fish may well be recovering from being handled, rather than being played. Anyone who has lost a salmon within 2 feet from the net or beach will know that the fish does not hang around – it takes off and appears to '*recover*' instantly. In this situation, the fish hasn't been handled and appears to have escaped unharmed. On other occasions, when a fish is beached or removed from the water, on return they may take some time to recover and swim off. All this led us to consider the possible negative effects of handling a fish over not handling a fish.

George Ross and I were lucky enough to have been able to observe rod-caught salmon on a daily basis during our Spring Enhancement Project from 1996–2006. This involved catching spring fish (March/April) and keeping them in fresh water tanks through to spawning time in November when their eggs were stripped for the hatchery. We were able to observe changes in the salmon over the period of 9 months. It became very apparent which fish had been handled poorly during the catching process: secondary fungus would appear over time as a result of the removal of their protective mucus. We observed some fish with a complete white ring of fungus around the wrist of their tails where they had been held tightly by the angler, and on occasion four white spots on one side and one white spot on the other side (around the belly area) where the fish had clearly been picked up. These personal observations drove us to reconsider catch and release techniques and to develop new methods whereby we could release a fish after being caught, without any physical contact.

Having now carried out the technique of non-contact release on a daily basis for many years, I am keen to share with others how easy this is to carry out, either while helping another angler return a fish or when returning your own. The main priority is to be organised before you hook the fish by ensuring you have good forceps immediately to hand (clipped on your jacket or on a lanyard). When the fish has played out and you are bringing it in towards the bank or beach, take hold of the nylon leader rather than grabbing the fish by the tail. You then have the fish like a dog on a lead while it's still comfortable in the water. The vast majority of the time, when you're holding the fish by the nylon, the hook is visible and within reach. Then reach down and catch the hook with your forceps and with one confident twist it will come out. On the odd occasion when the hook is not visible and therefore not easily removed, cut the nylon as close to the fish's mouth as you can get, and the fish will swim away and expel the hook within a short time. We know this because during our observations with the Spring Enhancement Project, we'd sometimes find flies on the bottom of the tanks within a couple of days of the fish going in. This led us to conclude that any flies or hooks left in the fish would be expelled easily with no long term detrimental effect to the fish.

'As an angler, hooking a fish is one of the most exhilarating and memorable experiences in your life. Every time is as exciting as the one before but as we now know, it is best practice to minimise the impact of the catch on the fish.'

I am pleased to say that a short video demonstrating the technique is available here: **youtu.be/oswrsXw7ukU** and via the S&TC website.

If the option of using this method of non-contact release is not possible due to conditions, there are fantastic flat-bottomed rubber nets available, which are very fish-friendly. Unlike the now illegal knotted nets that used to split fins and remove mucus, these rubber nets are kinder to the fish, and are the only net we would ever consider using on the Oykel. When releasing the fish from the net, we would lie the net down in the water and allow the fish to swim out, untouched by human hands.

I would urge anyone reading this to find the confidence to try and adopt any of these techniques as soon as you can. As an old man on the river once said to me, 'The best time to plant a tree was 30 years ago, the second best time to plant a tree is today.' The same applies to catch and release.

October Salmon

Ted Hughes

Ted Hughes, the inspiration for 'Owned by everyone' and thus for this issue of *Wild Fish*, was asked in 1994 to conclude an interview with the Canadian magazine *Wild Steelhead & Salmon* by reading his favourite poem from his great collection *River* (Faber & Faber, 1983.) He chose 'October Salmon', making clear that he was inspired to write it by stopping by the town bridge over the River Taw on his way home from visiting his father, a Gallipoli veteran, in a nursing home.

In December 1982, Hughes recorded a selection of his poems, including several from *River*, for a Faber audio cassette of his work. Here is how he introduced 'October Salmon' then.

"If a salmon returns from the sea after one winter, he weighs about five pounds. If he stays abroad two winters, he might weigh twelve or thirteen. Three winters might bring him to twenty. I live close to a river that used to be famous for its salmon, and they used to spawn along below the village. In one long pool there fifteen years ago I counted nearly fifty salmon waiting to spawn. Now after nearly fifteen years of disease and immense commercial netting at sea it's rare enough to see. Here is one of those lonely survivors – a cock salmon, diseased, waiting: for a hen fish to appear, or to die, or both."

October Salmon

He's lying in poor water, a yard or so depth of poor safety,
Maybe only two feet under the no-protection of an outleaning small oak,
Half under a tangle of brambles.

After his two thousand miles, he rests,
Breathing in that lap of easy current
In his graveyard pool.

About six pounds weight,
Four years old at most, and hardly a winter at sea –
But already a veteran,
Already a death-patched hero. So quickly it's over!
So briefly he roamed the gallery of marvels!
Such sweet months, so richly embroidered into earth's beauty-dress,
Her life-robe –
Now worn out with her tirelessness, her insatiable quest,
Hangs in the flow, a frayed scarf –

An autumnal pod of his flower,
The mere hull of his prime, shrunk at shoulder and flank,

With the sea-going Aurora Borealis
Of his April power –
The primrose and violet of that first upfling in the estuary –
Ripened to muddy dregs,
The river reclaiming his sea-metals.

In the October light
He hangs there, patched with leper-cloths.

Death has already dressed him
In her clownish regimentals, her badges and decorations,
Mapping the completion of his service,
His face a ghoul-mask, a dinosaur of senility, and his whole body
A fungoid anemone of canker –

Can the caress of water ease him?
The flow will not let up for a minute.

What a change! from that covenant of polar light
To this shroud in a gutter!
What a death-in-life – to be his own spectre!
His living body become death's puppet,
Dolled by death in her crude paints and drapes
He haunts his own staring vigil
And suffers the subjection, and the dumbness,
And the humiliation of the role!

And that is how it is,
That is what is going on there, under the scrubby oak tree, hour after hour,
That is what the splendour of the sea has come down to,
And the eye of ravenous joy – king of infinite liberty
In the flashing expanse, the bloom of sea-life,

On the surge-ride of energy, weightless,
Body simply the armature of energy
In that earliest sea-freedom, the savage amazement of life,
The salt mouthful of actual existence
With strength like light –

Yet this was always with him. This was inscribed in his egg.
This chamber of horrors is also home.
He was probably hatched in this very pool.

And this was the only mother he ever had, this uneasy channel of minnows
Under the mill-wall, with bicycle wheels, car-tyres, bottles
And sunk sheets of corrugated iron.
People walking their dogs trail their evening shadows across him.
If boys see him they will try to kill him.

All this, too, is stitched into the torn richness,
The epic poise
That holds him so steady in his wounds, so loyal to his doom, so patient
In the machinery of heaven.

Afterword

John Fanshawe

***Owned by Everyone's* two days of talks unfolded in the University of Cambridge's renovated David Attenborough Building, home to the Cambridge Conservation Initiative (CCI), co-hosts of the meeting with Pembroke College. At the outset, we showed a short film Sir David had narrated for S&TC outlining the International Year of the Salmon, and his opening words, *'Salmon is the king of fish. Their journeys up rivers are some of the most thrilling spectacles in the natural world, and yet now their very survival is at risk'*, echoed throughout our discussions. Indeed, Sir David's story-telling voice has been a backdrop to the lives of all of us involved in conservation since his Zooquest programmes were broadcast in the 1950s.**

Naming the 'DAB' – as it is shorthanded by its inhabitants – in his honour made perfect sense, and the architects who renovated Sir Philip Dowson's iconic building were tasked with creating a light and dynamic space where people could forge a cohort, as CCI's mission states, to *'transform the global understanding and conservation of biodiversity.'* Since our move in early 2016, a community of 500 have been working along a continuum of research, education, policy, and practice, and the building has quickly become the hub of a conservation community that reaches 180 countries worldwide.

Like all the OBE contributors my CCI colleagues have personal stories, often rooted in encounters with charismatic species or key places, that lit their concern, and led them into careers that champion nature. For me, I confess it was really birds and I've worked for a CCI partner, BirdLife, since 1987; although for the past 5 years I've also been supporting CCIs's nascent Arts, Science and Conservation Programme (ASCP), which seeks to shape coalitions between artists and scientists that find new ways of tackling the biodiversity and climate crisis. It was in this capacity, that the collaboration between CCI, Pembroke and S&TC grew.

'Salmon is the king of fish. Their journeys up rivers are some of the most thrilling spectacles in the natural world, and yet now their very survival is at risk.'

In 2018, after an event with *Magma* magazine on poetry and climate activism, Mark and I fell into a conversation about Ted Hughes and environmentalism. Years ago, I'd clipped out an article Simon Armitage had written for the *Guardian* entitled, 'Ted Hughes ... Eco-warrior'. Armitage wrote of Hughes's role in forming The Westcountry Rivers Trust, and the impact of Rachel Carson's work, *Silent Spring*.

For me, like most other birders, it is his poem 'Swifts' that always comes to mind in mid-May, when those flying sickless return from Africa to rip up the sky over Cambridge – and countless other Eurasian towns and cities – with their screaming parties. I think then of Hughes's line: *'They've made it again, which means the globe's*

still working.' As the poet Martyn Crucefix notes, *'there is no better tribute to their speed, power, heroic journeying and the pleasure given by their return.'*

Like many other migratory birds, of course, swifts are in deep decline, with numbers more than halved in the UK since 1995, declines which parallel catastrophic collapse in insect numbers. A depressingly memorable study of flying insects describes the parlous state of nature reserves in Germany. In 1989, a strict method of recording with aptly named Malaise Traps was introduced. Results from 63 sites revealed a 79% decline overall by 2016. Covering the study in the *Guardian*, Damian Carrington noted anecdotal evidence from car journeys, with *'people remembering many more bugs squashed on their windscreens in the past.'*

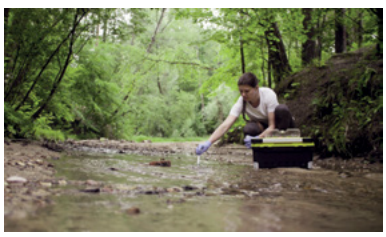
Crises facing migratory birds have uncanny parallels in the crisis facing migratory fish. Nick Measham has detailed the results of ST&C's landmark Riverfly Survey, and how it revealed radical declines in freshwater invertebrates like caddis, stone, dragon, damsel and may flies. In recent days a bleak analysis of the role of pet flea treatments has added to the litany of challenges fish face, with 20 rivers – from the Eden in Cumbria south to the Test – found to be contaminated by fiprinol and the neonicotinoid imidacloprid, with the former in 99% of samples. Both are banned in agriculture, but the consequence of their use in veterinary treatments has been overlooked, and there are ten million plus dogs in the UK, with more than 80% treated regularly. A co-author, the pioneering entomologist, Dave Goulson, said learning, *'our rivers are routinely and chronically contaminated with both of these chemicals and mixtures of their toxic breakdown products is deeply troubling.'*

In his paean for migratory birds, *Say Goodbye to the Cuckoo*, the former Independent environment editor, Mike McCarthy, opens one chapter 'Spring-Bringers' with a powerful image: *'If we could see it as a whole, if they arrived in a single flock, say, and they came in the day instead of at night. Work would stop, people would gather to watch [...] and the nation would celebrate, not only for the giant, scarcely credible journeys [...] but [...] that in coming, they have brought the spring.'*

Inspired by flyways conservation, a feasibility study led by the International Union for Conservation of Nature (IUCN) has been underway since 2019, to create a first global map of swimways. Along with colleagues from the university, UNEP's World Conservation Monitoring Centre, and the World Fish Migration Foundation, Will Darwall – who leads IUCN's Freshwater Unit, and spoke on the Red List at OBE – has being gathering the evidence. Of some 17,800 freshwater fish currently described, Will and his collaborators argue that the majority of species are likely to undertake some movements between feeding and spawning areas. Of these, 1,000 species are epic migrants and their survival hangs on completing long migrations between the freshwater and marine ecosystems. Among salmonids, many species fall into this category, so it is vital to map the routes, stopover, and non-breeding areas. The team's study has assessed biological, economic, and social criteria for swimways, acknowledging that the complex drivers of species decline are interwoven, and that a strong case needs to be built to ensure that migratory fish are no longer overlooked by

'...there is no better tribute to their speed, power, heroic journeying and the pleasure given by their return.'

Photo: © Chudakov – stock.adobe.com



mechanisms like the UN Convention on Migratory Species, which have hitherto largely focused on birds and mammals.

Another driving force behind OBE was work by Peter Rand and his colleagues, a Global Assessment of Extinction Risk to Populations of Sockeye Salmon *Oncorhynchus nerka* that was published in 2012. Treated as of "Least Concern', Rand was concerned that evaluating at species-level would mean the status of individual populations would be under-represented on IUCN's Red List. So it proved: they identified 98 separate Sockeye populations: five were extinct, and the risk status of a further 62 ran the full gamut of IUCN Red List categories, with 4 Critically Endangered (CR), 12 Endangered (EN), 3 Vulnerable (VU), and 2 Near-threatened (NT), and a further 32% were Data Deficient (DD). As the authors argued there, although sockeye salmon were not 'threatened' at the species level, a third of the sub-populations were seriously at risk or already extinct.

The Sockeye study was a sobering reminder how taxonomic boundaries can influence conservation decision-making. So as we have reflected on the success of *Owned by Everyone* and pondered next steps, the questions of species complexity, and swimways have been at the forefront of discussions with S&TC, IUCN and others.

Atlantic Salmon have not been formally assessed for the Red List since 1996 and languish in a stalled status as 'Least Concern'. Towards the end of his IYS/S&TC video, Sir David catalogued many of the threats salmon face as they battle, in every sense, upstream: *'Dams blocking their rivers; overexploitation; pollution of the water; the spread of parasites; diseases, and fish escaping from open-cage salmon farm ...'* All these and more featured in our discussions in Cambridge; all of them suggest how crucial it is to understand Atlantic Salmon populations throughout their range.

Indeed, Jamie Stevens's article on chalk streams, and a likely sub-species of salmon for which he offers the scientific name *Salmo salar calcariensis* drives home the point of the vulnerability of key taxa. In the imagination of most people, sparkling, constant, crystal clear chalk waters epitomise healthy fresh-waters, even if the reality of the threats they face, not least of abstraction, pollution and urbanisation, are grim. As Jamie argues, the presence of this unique taxon has much *'to tell us about the fate of salmon everywhere, and may even inspire hope for the future.'*

But it also reveals one more reason why we need to understand more, and do more to protect, the chalkstreams many of the readers of *Wild Fish* know and love. To anglers who only dream of fishing their waters, gin-clear and twice as expensive, chalkstreams may not seem so obviously 'owned by everyone'. But well-managed and cherished, they are a national, and an international resource. Britain is home to 85% of the world's limited supply of this precious commodity. Those in reasonably good health welcome sea trout and eels as well as salmon and, of course, brown trout, and the riverflies they need and the natural predators who need them; but many have been neglected, badly require restoration, even the protection of the law. All have a remarkable human and natural history. That's why we are planning a second international gathering in Cambridge from 31 March to 2 April 2022, with and around and beyond the science and culture of chalkstreams and all they represent.

Autumn sunrise on the River Itchen

Photo:© J H Gazzard 2018 - stock.adobe.com

Contributors

Nick Measham is CEO of Salmon & Trout Conservation, the UK's only wild fish campaigning charity. He is dedicated to putting more wild fins in rivers in the UK and beyond. A keen fisherman, he is increasingly content nowadays to know that the fish are still there.

Mark Wormald is Fellow in English at Pembroke College, Cambridge. He has coedited, with Terry Gifford and Neil Roberts, *Ted Hughes: from Cambridge to Collected* (2013), and *Ted Hughes, Nature and Collected* (2018), and chairs the Ted Hughes Society. *The Catch: Fishing for Ted Hughes* will be published in 2022.

Dr William Darwall is Head of the IUCN Global Species Programme's Freshwater Biodiversity Unit. He has over 30 years experience of the ecology and conservation of aquatic ecosystems. His current work with IUCN includes assessment of species threatened status for the IUCN Red List and the identification of Freshwater Key Biodiversity Areas (KBAs).

Dr Jamie Stevens is a molecular ecologist and evolutionary biologist. His research focuses on the application of population genetics to explore questions in ecology and conservation. He moved to Exeter in 1998 following the award of a Wellcome Trust Biodiversity Fellowship. Since then, his research has focused on the use of genetic methods to address applied questions in animal movements, e.g. genetic tracking of Atlantic salmon and sea trout.

Thomas F. Thornton holds a PhD in anthropology and has worked on North Pacific environmental governance issues, particularly concerning Alaska Natives, since 1989. Director of the Environmental Change & Management programme at Oxford from 2008–18, he now serves as Dean of the School of Arts & Sciences and Vice Provost for Research at the University of Alaska Southeast.

Over his career, **Ken Whelan** worked for several research organisations in Ireland. He specialises in the fields of fisheries science, migratory fish stocks, recreational fisheries and science communications. He is currently the Atlantic Salmon Trust's Research Director and an Adjunct Professor at University College Dublin. He is also a passionate angler.

Katherine Robinson is a PhD candidate at Pembroke College, Cambridge where she is researching Ted Hughes's engagement with early Welsh literature. Her poetry, fiction, and essays have appeared in The Ted Hughes Society Journal, The London Magazine, Poetry Wales, Poetry Ireland, The Hudson Review, The Kenyon Review, and elsewhere.

Poet and historian **Katrina Porteous** lives on the Northumberland coast and writes from a deep commitment to the ecology of place and local community. She has been an international visitor at the Fisherpoets' Gathering, Oregon USA, with poems from *The Lost Music* and *Two Countries* (Bloodaxe 1996 and 2014). www.katrinaporteous.co.uk

Arlin Rickard is Chief Policy Advisor at The Rivers Trust, and Chair of Catchment Based Approach, NSG. He recently stepped down as CEO of The Rivers Trust (the umbrella body of the Rivers Trust Movement) after 25 years of leadership, which began with the establishment of Westcountry Rivers Trust in 1994.

Corin Smith is a campaigning photographer most recognised for his work to document the inner workings of open cage salmon farms in Scotland. Whether four years old, or forty, his deep connections with wild things drives Corin to do whatever he can to resist the forces of industrialisation. He dreams of a future with wild places that will make our children smile.

Tony Juniper CBE is Chair of the official Nature conservation agency Natural England and a Fellow of the University of Cambridge Institute for Sustainability Leadership. He is a former Director of Friends of the Earth, Executive Director with WWF UK, President of the Royal Society of Wildlife Trusts and environment advisor to HRH the Prince of Wales. He is the author of many books, including the best-selling *What has Nature ever done for us?*

Kyle Young received his BSc from Brown University and PhD from the University of British Columbia. His salmonid research addresses topics ranging from riparian zone management, aquaculture and stocking to competition, life history and invasion biology. He regularly works with governments, NGOs, and anglers to improve fisheries and river ecosystem management. And he fishes for bass with his daughter.

Harry Clifton has published *The Holding Centre: Selected Poems 1974–2004* and *Herod's Dispensations*, both from Bloodaxe Books, in the United Kingdom. He was Ireland Professor of Poetry 2010–2013 and currently teaches at Trinity College Dublin.

Mikael Frödin is a Swedish-born professional fly fisherman, fly-tyer and environmental activist, who campaigns against overfishing, hatcheries and fish-farming problems. He appeared in Patagonia's film *Artifishal* (2019). Mikael has caught and released thousands of salmon. He is the author of the international best-seller *Classic Salmon Flies* and *My Salmon Flies*.

Steven Mackenzie is the Fishery Manager of the river Oykel. Steven has 30 years' experience in river management and enjoys developing his knowledge of current issues affecting Atlantic Salmon. He works closely with local and national Fishery organizations to support the long-term preservation and appreciation of the Atlantic Salmon.

John Fanshawe is curator of the arts, science and conservation programme for the Cambridge Conservation Initiative. After studying law, he completed doctoral research in Kenya with Oxford's Wildlife Conservation Research Unit, and has worked as a conservation practitioner, author and editor. He co-founded the annual arts-science collaboration, New Networks for Nature, in 2009.

Ted Hughes (1930–1998) was one of the twentieth century's greatest poets, and became Poet Laureate in 1984. He was also a passionate fisherman, environmentalist and activist, who loved the salmon and campaigned tirelessly for wild fish and water quality and against their exploitation. *River* (1983) contains many of his finest salmon poems.

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