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Review

Challenges in the conservation, rehabilitation and recovery of native stream salmonid populations: beyond the 2010 Luarca symposium

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Abstract – In May 2010, I chaired a session on challenges to salmonid conservation at the international symposium 'Advances in the population ecology of stream salmonids' in Luarca, Spain. I suggested that in addition to scientific challenges, a major challenge will be improving the links between ecologists, conservationists and policy makers. Because the Luarca symposium focused mainly on ecological research, little time was explicitly devoted to conservation. My objective in this paper is to further discuss the role of ecological research in informing salmonid conservation. I begin with a brief overview of research highlights from the symposium. I then use selected examples to show that ecological research has already contributed much towards informing salmonid conservation, but that ecologists will always be faced with limitations in their predictive ability. I suggest that conservation will need to move forward regardless of these limitations, and I call attention to some recent efforts wherein ecological research has played a crucial role. I conclude that ecologists should take urgent action to ensure that their results are available to inform resource managers, conservation organisations and policy makers regarding past losses and present threats to native, locally-adapted salmonid stocks.

Key words: salmon and trout; ecology; management; conservation; local adaptation

Introduction

In May 2010, approximately 100 salmonid ecologists from over 15 countries from around the globe gathered in Luarca, Asturias, Spain for the international symposium 'Advances in the population ecology of stream salmonids'. Attendees were from both academic and management institutions. The symposium consisted of four days of presentations; topics ranged from individual behaviour and life history to genetics and population dynamics, covering multiple scales from microhabiat- to ecosystem-level. Also discussed were conservation and restoration of native salmonids, human impacts and the impacts of invasive salmonids on endemic fauna. On the last day of the symposium, I chaired a session entitled 'Challenges in the conservation, rehabilitation and recovery of native stream salmonid populations' and I briefly introduced my interpretation of these challenges. I suggested that in addition to the challenges at the scientific level (i.e. an incomplete knowledge of salmonid ecology), another major challenge will be improving the links between ecologists, conservationists and policy makers. Because the Luarca symposium focused on ecological research, however, we devoted little time to explicitly discuss conservation. At the symposium's end, therefore, I was left with some uncertainty as to how ecological research might continue to inform conservation of these valuable fishes.

In this paper, I wish to capture the enthusiasm generated by the Luarca symposium to stimulate ecologists to think about the role of research for the future of salmonid conservation. I begin with some personal reflections of the symposium, but my main objective is to expand upon what was *not* explicitly discussed, i.e., linking ecology and conservation. I use

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selected examples, past and present, to show that ecological research has been crucial in informing salmonid conservation. I argue that regardless of scientific advances, however, ecologists will always be faced with limitations in their predictive ability and that conservation efforts will need to move forward despite these limitations. I call attention to some recent conservation efforts wherein ecological research has played a crucial role. I draw largely from examples from North America because I am most familiar with these; the principles I discuss, however, ought to be applicable throughout the native ranges of all stream salmonids. At the symposium, I proposed that we initiate an 'international society of stream salmonid ecologists'. In drawing links between ecology and conservation, this paper might serve as a first step towards developing a 'conservation statement' of such a society. Despite a wealth of salmonid conservation efforts being undertaken around the globe, I am unaware of any international statement to this effect. In this spirit, I welcome responses to this paper.

Personal reflections on the 2010 Luarca symposium

An important highlight of the symposium, in my opinion, was that a wealth of new methods and technologies, ranging from fish sampling to computing, have come to fruition over the past 20 years. Since the publication of the proceedings of the first Luarca stream fish symposium held in 1998, these methods have made it possible, in principle at least, to address some of the research challenges identified at that time (see Utter 1999; Rincón et al. 2000; Wootton et al. 2000). For example, we now have the ability to track movements, growth and survival of individual fish throughout their entire life, identify their parentage and better understand how their individual life history influences the entire population. Taken together with the encouraging assemblage of a number of long-term data sets across geographical regions (e.g. Lobón-Cerviá 2007; Vøllestad & Olsen 2008; Xu et al. 2010), ecologists have an unprecedented opportunity to understand the general patterns that govern behaviour, populations and evolution of stream salmonids. Elliott (1994) noted the importance of long-term research efforts in identifying patterns in salmonid ecology, but I wonder if he could foresee just how detailed these data sets would become in regard to genetics, growth, movements and survival of individual fish. Of particular research interest will be using these data sets to link temporal and spatial scales, from individuals to populations (including genetic structure), both within and among long-term data sets.

Of course, the Luarca symposium consisted of much more than new methods and technologies. I realise, however, that researchers from each sub-field of salmonid ecology (e.g. behaviour, genetics, populations, ecosystems) are aware of the most fruitful areas for future research, and it is beyond my scope to review these here. The question that I wish to address is how will the advances in ecological research influence future salmonid conservation efforts?

The link between salmonid ecology and conservation

A common definition of ecology is the scientific study of the distributions and abundances of organisms (e.g. Begon et al. 2006). Because ecologists are in the business of predicting the distribution and abundance of organisms, it is no surprise that they are commonly prevailed upon to assist resource managers in understanding the effects of proposed (or past) management activities, habitat change, etc. Populations of exploited species like salmonids are regulated by both direct management activities (e.g. fishing) and by natural or human-induced disturbance. In general, things have not gone well for the majority of salmonid populations worldwide over the past 100–200 years; large-scale declines have occurred in both the distribution and abundance of native stocks (Nehlsen et al. 1991; Parrish et al. 1998), and I am unaware of any evidence that this trend has stabilised or reversed. Ecologists, therefore, are now taxed with the task of informing managers and policy makers as to how to predict the distribution and abundance of the remaining salmonid stocks (i.e. conserve them) and how to rebuild depleted stocks. This task is urgent, because native stocks continue to be extirpated, and the task is difficult for two reasons: first, ecologists are limited in their ability to predict salmonid distributions and abundances, and second, even if we were not, it is far from certain that policy makers would listen to us anyway (see Hartman et al. 2000).

Limitations of predictions and the 'illusion of technique and fisheries management'

The short essay of this title by Behnke (1987) demonstrates why ecological models are limited in their predictive abilities, and more importantly, the danger that this may post to conservation. Behnke (1987) uses the phrase '*illusion of technique*' in reference to, as he writes, '*the common phenomenon whereby the human mind is highly susceptible to indoctrination with the naïve belief that chaotic systems of nature can be neatly ordered for predictive purposes if only modern technology, such as a computer simulation model, can be applied to a problem*'. He contrasts highly predictive natural phenomena (e.g. sunrise, sunset and tides), with biological systems, wherein inherent and stochastic variability (e.g. weather) limits predictive ability. The

danger arises when decision-makers delay critical management action because of a lack of conclusive data. Behnke (1987, 2002) provides examples of the illusion of technique from various areas of salmonid ecology, from instream flow regulation to genetic stock identification. Perhaps the best-known recent example from science in general, however, was the Bush Administration's insistence that more studies were needed to 'prove' global warming (see 'Why Bush Bailed on Global Warming Pact', *Time Magazine*, 29 March 2001). Coincidentally, the author of the article says that Bush was considered a 'flat-earther' – Behnke's (1987) thesis is summarised by the quote that ancient societies could '*compile the essential data on which accurate forecasts of sunrise, sunset, and the tides could be made, while accepting the theory that the earth is flat*'. My point here is that salmonid conservation, like efforts to stem global warming, will need move forward in spite of a lack of perfect knowledge.

During the revision of this paper, I had the privilege of seeing renowned ecologist J. Wiens give a presentation about the future of conservation, during which he called attention to the limitations of ecological predictions (see Wiens 2008). His argument that conservation decisions must often be made in the face of uncertainty bears much resemblance to that of Behnke (1987). Below, I discuss a relevant example from salmonid ecology, i.e. the role of ecological research in demonstrating the importance of local adaption. Although this is an area of research in which we are likely to always have imperfect knowledge, I contend that ecology has already shed considerable light on how local adaptation relates to salmonid conservation.

Local adaptation in salmonids

'*… successful programs for preserving biodiversity will rely on biologists who have some fundamental understanding of how evolution by natural selection works...*'Behnke (1992)

Salmonid populations evolve local adaptations to specific environmental conditions through natural selection. Although the extent of local adaptation versus the role of phenotypic plasticity may be a fruitful area for research (Elliott 1994; Adkison 1995; Leaniz et al. 2007), in terms of conservation, ecologists might do well remember, as Dawkins (2009) succinctly states, that 'evolution is a fact'. I know this seems self-evident, but it is surprising to see how much research effort is currently being directed towards understanding salmonid evolution, with an almost tacit implication that we are uncertain to what extent local adaptation exists. Ecologists in the past communicated far less uncertainty as to the role of natural selection in shaping salmonid populations. Consider the title of an early paper from Mathisen (1966), one of the founders of salmonid ecology in Alaska: '*Some adaptations of sockeye salmon races to limnological features of Iliamna Lake, Alaska*', and the following quote from the paper: '*The racial differences in a run of salmon to a watershed are a manifestation of the evolutionary adaptations of the fish to the various environments encountered during their life span*'. Mathisen (1966) states the minimum age of Lake Iliamna as 8520 ± 350 years and writes with confidence about how different 'races' (i.e. populations) of sockeye salmon (*Oncorhynchus nerka*) have evolved (i.e. locally adapted) during this time to utilise different spawning areas in the lake and tributaries. The Mathisen (1966) paper demonstrates that ecologists have recognised the importance of local adaption for a long time. But in a recent letter to the preeminent journal *Nature*, Schindler et al. (2010) echoed similar sentiments, clearly noting the importance of local adaption for salmonid conservation: '*Each river stock contains tens to hundreds of locally adapted populations distributed among tributaries and lakes…This remarkable diversity in sockeye reflects their ability to thrive in a wide range of habitat conditions, the reproductive isolation of populations by precise homing to natal spawning sites, and their capacity for microevolution*'. Schindler et al. (2010) use the results of a series of ecological studies to show that intraspecific diversity of sockeye in Bristol Bay, Alaska has a 'portfolio effect' (Figge 2004), by dampening the variance in ecosystem services (i.e. fisheries catch, prey for wildlife) provided by the salmon populations.

In fact, D. Schindler, R. Hillborn and their colleagues at the University of Washington, USA, have been leaders in linking ecological research with fisheries management and conservation through their work in Alaska and elsewhere; I think their work exemplifies the kind of efforts to link research and management that I mentioned above as being of particular importance. It is frustrating to me on some level, however, that it is necessary for leading ecologists today to publish ideas that probably would have seemed self-evident to O. Mathisen and others of his generation. According to Google scholar, I am only the second author to cite Mathisen (1966). More interestingly, the other was Ricker (1972), whose classic paper on the stock concept Behnke (2002) credits as having had a great influence on his thinking about local adaptation. Behnke (2002), however, states that he read Ricker's unpublished manuscript in 1959, when it was circulated among ecologists for review and comment – further evidence of how long ecologists have recognised the importance of local adaptation. Behnke (2002) also notes sadly that local

adaptation continues to be disregarded in many fisheries management decisions. This suggests to me that ecologists must do a better job of communicating our research results, so that management programs may make use of them.

Given the approximately 10,000 years of relatively isolated (i.e. some fish do stray, leading to gene flow) reproduction of Pacific salmon populations, a diverse array of locally adapted populations is no surprise. If one needs further evidence for local adaptation in the genus *Oncorhynchus,* one need look no further than the cutthroat trout (*Oncorhynchus clarki* spp.) complex of interior North America, where somewhat longer time periods of complete reproductive isolation have led to diversity at the subspecies level (Behnke 1992, 2002). Of course, there are innumerable other examples from all taxa in family *Salmonidae* (e.g. Klemetsen et al. 2003) – but how can ecologists bring information on such topics as local adaptation to the forefront of conservation efforts?

Ecology and salmonid conservation organisations

I first read of Schindler et al.s' (2010) paper on the website of Trout Unlimited (TU), (http://www.tu.org), the primary North American nonprofit trout conservation organisation. This raises an important point: within a week of its publication in the premier international peer-reviewed science journal, TU had notified its membership of 140,000 avid anglers (and voters) about the article. Thus, this broad public conservation base was able to read the latest scientific publication on salmon conservation, wherein Schindler et al. (2010) note the importance of local adaptation. Why do TU members care about local adaptation, and how do they know about its significance for salmonid conservation? One might reasonably argue that TU members' awareness of scientific research has been greatly influenced by the work of R. Behnke. In addition to his pioneering scientific work that led to the recognition of local adaptation in the trout of western North America (see Behnke 1992), he has written a quarterly article for TU's trout magazine every year beginning in 1983 (see Behnke (2007) for a collection of some of these essays). Over this time, a generation of trout fishers has been educated about the role of ecology and the importance of local adaptation in salmonid conservation.

Another example of ecological research on local adaption being linked to conservation, from 'across the pond' [i.e. Atlantic salmon (*Salmo salar*) in Europe], can be found on the website of the Atlantic Salmon Trust (http://www.atlanticsalmontrust.org/research/why-the-genes-should-fit.html). They write '*…the report of the SALGEN project… makes it clear to all fishery managers that (intraspecific) aspects of the species' genetics matter – indeed, taking on board the importance of genetic differences could make all the difference between saving a river's stock and losing it'*. They go on to discuss at length the importance of local adaption for Atlantic salmon conservation and 'why the genes should fit'.

Although TU and the Atlantic Salmon Trust are two of the older and more established nonprofit conservation organisations, there are others and they appear to be growing in prominence. The Wild Trout Trust (http://www.wildtrout.org) and the Wild Salmon Center (http://www.wildsalmoncenter.org), for example, are two of the more prominent groups. All of these organisations rely on scientific research to inform their conservation policy, and they use research results to inform their membership. Their financial assets are considerable (their annual reports are public access), although these must represent only a tiny fraction of what government spends on salmonid research and management. I believe that these organisations have been of great influence in shaping public opinion and policy, especially over the past 20 years, and that this trend is likely to continue. Of particular interest are recent symposiums organised by the State of the Salmon organisation (http://www.stateofthesalmon.org) on wild salmon and wild/hatchery salmon interactions and one on instream flows by the Atlantic Salmon Trust. These three symposiums attracted large numbers of well-respected ecologists as well as conservation leaders. I think that they demonstrate some of the many aspects of ecological research that are important to these burgeoning organisations and the role that ecology will play in the future of salmonid conservation.

Conclusions: ecology and the future of salmonid conservation

'*The importance of theory (and experimentation) notwithstanding, the interpretation of …nature must rely heavily on professional judgment. So much must be done in so short a time to protect the remaining genetic diversity of these fishes that I cannot responsibly suspend judgments…in the hope that irrefutable data might one day be collected*'.Behnke (1992)

So, what *can* ecologists do to meet the 'Challenges in the conservation, rehabilitation and recovery of native salmonid populations'? Efforts will need to take a multitude of forms, and we will need to achieve a kind of 'portfolio effect for conservation' if I may borrow the term (Schindler et al. 2010). First of course, we must continue to build upon the long history of insightful research that has led to our current understanding of the ecology, life history and evolution of salmonids. I hope I have demonstrated above

that without this research, the current unprecedented efforts to conserve salmonid populations would not be possible. The 2010 Luarca symposium highlighted a representative sample of this work. I suggest to all attendees, and to others who read this, that we continue to hold similar symposiums at regular intervals, to foster the exchange of ideas and to develop new research collaborations.

But in my opinion, good science alone will not be enough. Ecologists will need to develop closer links with resource managers when possible and make a concerted effort to be sure their results are available to the public. On the former point, it will be critical that ecologists convey a clear understanding of what we do know, and a realistic assessment of the limitations of our predictive ability. In this way, management can be based on a precautionary approach, without delaying decisions until 'scientific proof' can be obtained. On this subject, Wiens (2008) nicely articulates that levels of uncertainty that may be unacceptable for peer review may, for practical purposes, need to be 'good enough' for making conservation decisions. On the later point, ecologists have a solid foundation upon which to build. Popular works by P. Ehrlich, E. O. Wilson, J. Diamond and R. Dawkins come immediately to mind, but there are many others who have written popular books or produced films linking ecology to conservation. Salmonid ecologists in their own right have achieved much on this front (e.g. Netboy 1974; Lichatowich 1999; Behnke 2002, 2007; Sutterby & Greenhalgh 2005). I do not think the value of this kind of popularisation of science can be overstated; the attendance of local policy makers and the presence of television cameras at the 2010 Luarca Symposium are examples of the kind of public outreach necessary to link science and management with policy making.

As I was finishing this review, I decided to take one last look at Google news to check out the latest salmon-related issue receiving international attention. I found that British Columbia's wild salmon, in particular the famous Fraser River sockeye stocks, will be the subject of intense scrutiny by a federal commission after dismal returns in 2009. According to the *BC Globe and Mail* (9 June 2010), the government has released a report noting that: '*The organizational structure of the Department of Fisheries and Oceans; the harvesting sector, which will include an examination of pre-season planning; and the methods for forecasting run sizes and conservation efforts, will all come under examination by the inquiry led by British Columbia Supreme Court… But the key focus of the commission appears to be on* ***fish biology and ecosystem issues*** *(boldface added) – a category in the discussion paper which includes numerous, lengthy sub-sections, including water pollution, salmon farms, logging, diseases and parasites, predators, nonretention fisheries, climate change, urbanization and agricultural activities and hydro*'. I could hardly wish for a more succinct summary of the conservation issues facing salmonid ecologists. But I found the following headline from the *Edmonton Journal* (10 June 2010) even more interesting: '*Capt. Kirk fights off alien salmon*' William Shatner, of Star Trek fame, has lent his efforts to saving BC's wild salmon. Perhaps, our 'portfolio effect for salmonid conservation' is going intergalactic?

Of final note, in doing the background reading for this letter, I came upon much work of W. E. Ricker, whose insights into both local adaption and quantitative science justify his place among the leading biologists of the 20th century. In his autobiographical essay, Ricker (2006) wrote: '*So it is as an ecologist that I would like to be remembered…*' and a characteristically pragmatic note of warning, very much to the point for salmonid conservation: '*But continual vigilance will be essential. Resource maintenance is under unremitting pressure from the standard business practice of estimating the present value of future supplies using a discount rate. Unfortunately this means that the fish to be caught 50 years from now, or even as little as 20 years from now are worth practically nothing today*'.

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