Cyfoeth Naturiol Cymru
Natural Resources Wales

Bibliography of papers relevant to review of hatcheries and stocking

This is a developing bibliography that we are using as our evidence basis for the NRW salmon stocking, third party salmon stocking and future of NRW hatcheries consultation

v.4: 10.3.14

AUTHORS	TITLE OF PAPER / REFERENCE / SPECIES	KEY CONCLUSION
Anon (2000)	**Salmon and Freshwater Fisheries review** Ministry of Agriculture, Fisheries and Food The National Assembly for Wales Legislative review	Guidelines on stocking, embodying the following principles, should be established: • Stocking should be allowed only where there is no significant risk of ecological detriment to donor waters or receiving waters and where there is a demonstrable environmental, economic or recreational advantage; • Stocking should not normally be permitted in waters with established fish populations where it is not currently practised and has not been practised in recent years. However, stocking may be justified in such fisheries if it is needed in order to restore depleted populations or mitigate the effects of, for example, loss of spawning habitat; • Where recreational pressures justify stocking to sustain exploitation rates by anglers or losses due to predation higher than could be sustained naturally, decisions on consent applications should take account of the carrying capacity of the water involved and the management regime proposed for that water body;

<table>
<tr><td></td><td></td><td>Fish should not normally be introduced into water outside the existing range of the species concerned or into new catchments within their existing ranges;
Reintroduction of fish species which are no longer present in a catchment should be permitted only after an assessment of the likely environmental effect of the reintroduction.</td></tr>
<tr><td>Anon (2001)</td><td>Review of Salmon and Freshwater Fisheries
Government Response
Ministry of Agriculture, Fisheries and Food

Also,

Review of Salmon and Freshwater Fisheries
Response of National Assembly for Wales</td><td>46. Introductions of fish for stocking purposes should continue to be regulated and stocking should be permitted only where it can be justified taking account of the benefits and disadvantages.

47. Guidelines on stocking, embodying the following principles should be established:
stocking should be allowed only where there is no significant risk of ecological detriment to donor waters or receiving waters and where there is a demonstrable environmental, economic or recreational advantage;
stocking should not normally be permitted in waters with established fish populations where it is not currently practised and has not been practised in recent years. However, stocking may be justified in such fisheries if it is needed in order to restore depleted populations or
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fish should not normally be introduced into waters outside the existing natural range of the species concerned or into new catchments within their existing ranges;
reintroduction of fish species which are no longer present in a catchment should be permitted only after an assessment of the likely environmental effect of the reintroduction.
49. Stocking with salmon should be employed only to address a decline in stocks where:</td></tr>
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		• alternative methods to solve the problem have been fully evaluated and the need for stocking has been clearly identified and justified; • the programme is appropriate and conforms to agreed guidelines/criteria (including the use of appropriate stock and the adoption of best hatchery practices). **The Government agrees that there is a continuing need to regulate stocking. It also agrees in principle with the provisions on stocking proposed by the Review Group, including those on salmon, and looks to the Environment Agency, after consulting interested parties, to establish appropriate guidelines.**
Anon (2003)	National Trout and Grayling Fisheries Strategy Environment Agency, September 2003 **Review**	Policy 15 In considering whether or not to consent a stocking, we will adopt the guiding principles that: Fish introduction should not be allowed to jeopardise the well-being of naturally established ecosystems; and There should be no overall detriment to the fisheries (stock, habitat, performance) of the donor water or the receiving water, or to the variability of the fish involved in transfer and introduction.
Anon (2006)	Resolution by the Parties to the Convention for the Conservation of Salmon in the North Atlantic Ocean to Minimise Impacts from Aquaculture, Introductions and Transfers, and Transgenics on the Wild Salmon Stocks The Williamsburg Resolution NASCO Council CNL(06)48 **Policy**	ARTICLE 5 Measures to Minimise Impacts of Aquaculture and Introductions and Transfers Each Party shall take measures, in accordance with Annexes 2, 3 and 4 to this Resolution, to: • minimise escapes of farmed salmon to a level that is as close as practicable to zero • through the development and implementation of action plans as envisaged under the • Guidelines on Containment of Farm Salmon (CNL(01)53); • minimise impacts of ranched salmon by utilizing local stocks and developing and • applying appropriate release and harvest strategies; • minimise the adverse genetic and other biological interactions from salmon • enhancement activities, including introductions and transfers; • minimise the risk of disease and parasite transmission between all

		aquaculture • activities, introductions and transfers, and wild salmon stocks.
Anon (2009)	Hatchery fish may hurt efforts to sustain wild salmon runs. See 'Hatchery Fish May Hurt Efforts To Sustain Wild Salmon Runs' - ScienceDaily Website **Steelhead trout**	Captive breeding for reintroduction or supplementation can have a serious, long-term downside in some taxa, and so should not be considered as a panacea for the recovery of all endangered populations.
Anon (2010)	State of the Salmon 2010 Conference. Ecological interactions between wild and hatchery salmon. May 4-7,2010. Hilton, Portland, Oregon **Onchorynchus spp**	Bibliography
Anon (2011)	Schemes to stock rivers with salmon, sea trout and brown trout form locally sourced broodstock. Environment Agency Operational Instruction 570_11 **Review and policy**	Review, including bibliography.
Anon (2011)	Bibliography in Support of Supplementation Science. Compiled by: Yakam Nation Fisheries – Yakima Klickitat Fisheries project Columbia River Inter-Tribal Fish Commission **Onchorynchus spp**	Bibliography. The primary purpose of this bibliography is to present publications or studies that support the theory that supplementation (as defined by RASP 1992) techniques can be used to maintain or increase natural production, while maintaining the long-term fitness of the wild and native salmonid populations and keeping adverse genetic and ecological impacts within acceptable limits.
Anon (2013)	Sad end to Connecticut River Restoration Effort. Atlantic Salmon Federation. **Atlantic salmon**	The federal government is ending its conservation effort to restore Atlantic salmon in the Connecticut River basin because the nearly half-century old program is not working well enough o justify the continued cost – and a similar program in the Merrimack River may also be in jeopardy.
Araki,H. et al (2007)	Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild.	To supplement declining wild populations, therefore, repeat use of captive-reared organisms for reproduction of captive-reared progenies should be carefully reconsidered.

	Science 318:100-103. **Steelhead trout**	
Araki,H. et al (2007)	Reproductive Success of Captive-Bred Steelhead Trout in the Wild: Evaluation of Three Hatchery Programs in the Hood River Conservation Biology Volume 21, No. 1, 181–190 **Steelhead trout**	Thus, there was no sign that supplementation fish drag down the fitness of wild fish by breeding with them for a single generation. On the other hand, crosses between hatchery fish of either type (traditional or supplementation) were less fit than expected, suggesting a possible interaction effect.
Araki,H. et al (2007)	Effective population size of steelhead trout: influence of variance in reproductive success, hatchery programs, and genetic compensation between life-history forms. *Molecular Ecology* **16**, 953-966. **Steelhead trout**	We found high levels of reproductive contribution of nonanadromous parents to anadromous offspring when anadromous run size is small, suggesting a genetic compensation between life-history forms (anadromous and nonanadromous). This is the first study showing that reproductive interaction between different life-history forms can buffer the genetic impact of fluctuating census size on *Ne*.
Araki,H. et al (2008)	Fitness of hatchery-reared salmonids in the wild Evolutionary Applications. doi:10.1111/j.1752-4571.2008.00026.x **Pacific salmonids**	The summary of studies to date suggests: nonlocal hatchery stocks consistently reproduce very poorly in the wild; hatchery stocks that use wild, local fish for captive propagation generally perform better than nonlocal stocks, but often worse than wild fish. If selection acts on multiple traits throughout the life cycle, rapid fitness declines are plausible.
Araki,H. et al (2009)	Carry-over effect of captive breeding reduces reproductive fitness ofwild-born descendants in the wild. Biol. Lett. doi:10.1098/rsbl.2009.0315 **Steelhead trout**	Our results suggest a significant carry-over effect of captive breeding, which has negative influence on the size of the wild population in the generation after supplementation.
Araki,H. and Schmid,C. (2010)	Is hatchery stocking a help or harm? Evidence, limitations and future directions in ecological and genetic surveys.	These results suggest that negative effects of hatchery rearing are not just a concern but undeniably present in many aquaculture species. In a few cases, however, no obvious effect of hatchery rearing was observed, and a positive contribution of hatchery stock to the abundance of fish populations was

	Aquaculture (2010), doi:10.1016/j.aquaculture.2010.05.036. **Review**	indicated.
Ayllon,D. et al (2012)	Modelling carrying capacity dynamics for the conservation and management of territorial salmonids. Fisheries Research 134– 136 (2012) 95–103 **Brown trout**	Such results suggest that restoration measures attempting to increase population abundance through stocking, increased breeding dispersion or cohort survival may reduce the performance of both the enhanced and competing cohorts. Further, high exploitation rates may lead populations occurring at low carrying capacities to extinction.
Barnett-Johnson, R et al 2007	Identifying the contribution of wild and hatchery Chinook salmon (*Oncorhynchus tshawytscha*) to the ocean fishery using otolith microstructure as natural tags *Canadian Journal of Fisheries and Aquatic Sciences*, 2007, 64(12): 1683-1692, 10.1139/f07-129	Results from our mixed-stock model estimated that the contribution of wild fish was 10% ± 6%, indicating hatchery supplementation may be playing a larger role in supporting the central California coastal fishery than previously assumed.
Bartron, M.L. and Scribner, K.T. (2004)	Temporal comparisons of genetic diversity in Lake Michigan steelhead, Oncorhynchus mykiss, populations effects of hatchery supplementation. Environmental Biology of Fishes ch; 69(1-4): 395-407 **Steelhead trout**	We examined the effects of changes in stocking practices on straying rates of hatchery steelhead and to temporal changes in levels of genetic diversity and relationships among populations. Increased numbers of alleles in spawning adults from populations can be attributed to alleles specific to recently introduced hatchery strains.
Baumsteiger,J. et al (2008)	Use of Parentage analysis to Determine Reproductive Success of Hatchery-	This study shows that, under the right conditions, outplanted adult hatchery fish taken from localized hatchery stocks can contribute to the overall juvenile

	Origin Spring Chinook Salmon Outplanted into Shitike Creek, Oregon. North American Journal of Fisheries Management, 28:1472-1485. **Chinook salmon**	production in a natural stream.
Berejikian,B.A. et al (2000)	Social dominance, growth, and habitat use of age-0 steelhead (*Oncorhynchus mykiss*) grown in enriched and conventional hatchery rearing environments. Canadian Journal of Fisheries and Aquatic Sciences, 57:628-636.	Steelhead juveniles from the two rearing environments exhibited very similar use of woody structure in the quasi-natural stream, both in the presence and in the absence of mutual competition. Rearing steelhead in more naturalistic environments could result in hatchery fish that behave and integrate into the post release (natural) environment in a manner more similar to wild fish.
Berejikian,B.A. et al (2008)	Increases in steelhead (Oncorhynchus mykiss) redd abundance resulting from two conservation hatchery strategies in the Hamma River, Washington. *Canadian Journal of Fisheries and Aquatic Sciences* **65**, 754-764. **Steelhead trout**	Because stocking is only one of several management options for this species, it is critical to learn additional information about factors limiting hatchery production and natural recruitment processes. In addition, information on the effect of rearing technique, size and physiological status of stocked fish, propensity of stocked fish to residualize, and genetic contribution is needed to optimize use of hatchery produced fish while simultaneously conserving wild stocks. Collectively given the 2007 and 2008 data our results do not support the suggestion that there is a possible selective advantage for residualizing (against anadromy) among hatchery fish, but again there are relatively few data for comparison.
Berejikian,B.A. et al (2009)	Reproductive behavior and relative reproductive success of natural- and hatchery-origin Hood Canal summer chum salmon (*Oncorhynchus keta*) Can. J. Fish. Aquat. Sci. 66: 781–789 **Chum salmon**	Estimates of the relative fitness of hatchery- and natural-origin salmon can help determine the value of hatchery stocks in contributing to recovery efforts. This study compared the adult to fry reproductive success of natural-origin summer chum salmon (*Oncorhynchus keta*) with that of first- to third-generation hatchery-origin salmon in an experiment that included four replicate breeding groups. Hatchery- and natural-origin chum salmon exhibited similar reproductive success. Hatchery- and natural-origin males obtained similar access to nesting females, and females of both types exhibited similar breeding behaviors and durations.

		Male body size was positively correlated with access to nesting females and reproductive success. The estimates of relative reproductive success (hatchery/natural = 0.83) in this study were similar to those in other studies of other anadromous salmonids in which the hatchery population was founded from the local natural population and much higher than those in studies that evaluated the lifetime relative reproductive success of nonlocal hatchery populations.
Bland MD. 2003	Assessing the impact of historical stocking with brown trout (*Salmo trutta* L.) in Llyn Idwal, North Wales, using microsatellite and mtDNA markers (M.Sc. Thesis) **Brown trout**	Genetic signal of 19th century stocking with Loch Leven trout was still detectable in Llyn Idwal trout population.
Blanchet,S. et al (2008)	An integrated comparison of captive-bred and wild Atlantic salmon (Salmo salar): implications for supportive breeding programs. Biological Conservation 141:1989-1999. **Atlantic salmon**	Overall, our results showed that both phenotypic and genetic changes can arise even if genitors share a common brood-stock and after only a few months if rearing in a controlled environment. We conclude that the progeny produced in such supportive breeding programs does not meet the criteria necessary to ensure preserving the genetic and ecological integrity of wild populations.
Blouin et al 2003	Hood River Steelhead Genetics Study; Relative Reproductive Success of Hatchery and Wild Steelhead in the Hood River", 2002-2003 Final Report, Project No. 198805312, 27 electronic pages, (BPA Report DOE/BP-00009245-1)	Our analyses of samples from fish that bred in the early to mid 1990's show that fish of "old" hatchery stocks have much lower total fitness than wild fish (17% to 54% of wild fitness), but that "new"stocks have fitness that is similar to that of wild fish (ranging from 85% to 108% of wild fitness, depending on parental gender and run year). Therefore, our results show that the decision to phase out the old, out-of-basin stocks and replace them with new, conservation hatchery stocks was well founded. We also conclude that the Hnew fish are leaving behind substantial numbers of wild-born offspring. The similar fitnesses of Hnew and W fish suggests that wild-born offspring of Hnew fish are unlikely to have negative genetic effects on the population when they in turn spawn in the wild.
Blouin 2009	No evidence for large differences in genomic methylation between wild and hatchery steelhead (Oncorhynchus	Hatchery and wild adult steelhead from the Hood River do not appear to differ substantially in overall levels of genomic methylation. Genomic methylation is the silencing of genomes as a result of epigenetic or environmental conditions

	mykiss) *Canadian Journal of Fisheries and Aquatic Sciences*, 2010, 67(2): 217-224, 10.1139/F09-174	surrounding parents. The hatchery environment does not appear to cause a global hypo- or hypermethylation of the genome or create a large number of sites that are differentially methylated.
Branon 2005	The Controversy about Salmon Hatcheries. Fisheries, vol 29, issue 9, 2004	The progeny of hatchery fish from the local stock performing in the wild will be indistinguishable from their native counterparts if management addresses the biological requirements needed in the wild. Natural production in the habitat remaining is not sufficient to provide the recreational and commercial harvest fisheries that are important to the fishing public. The challenges of multiple water uses means that we have to manage smarter, and smarter means that we don't limit our options to use artificial propagation as a tool for the betterment of the salmon and steelhead resources.
Brannon,E.L. (2009)	The Controversy about Salmon Hatcheries **Review**	Recently, the controversy has been epitomized by the recommendations to fisheries management agencies that excess hatchery fish should not be allowed to spawn in the wild, and hatchery fish should be excluded from salmon populations listed under the Endangered Species Act. The authors of the present article disagree with those recommendations and conclude that hatchery fish have an important role in recovery and supplementation of wild stocks. The present article is an attempt to help give balance to the discussion by providing a different perspective on hatchery fish and the literature pertaining to artificial propagation.
Brockmark, S.(2009).	Environmental influences on the behavioural ecology of juvenile salmonids – the importance of rearing density. Published by the Department of Zoology/Animal Ecology, University of Gothenburg, Sweden **Review**	In summary, my results show that conventional rearing methods in supplementary hatcheries do not prepare fish adequately for life in the wild and could be improved considerably, with density reduction as one key factor. Incorporating behavioural aspects in supplementary rearing methods is also important from an ethical point of view. However, there is a limit to what can be accomplished with improving supplementary hatchery rearing methods. Hatchery rearing should therefore be viewed as a complement rather than an alternative to habitat restoration.
Brunner,P.C. (1998)	Microsatellite and mitochondrial DNA assessment of population structure and stocking effects in Arctic charr *Salvelinus alpinus* (Teleostei:	…results suggest that long-term stocking practices did not generally alter natural genetic partitioning, and stress the importance of considering genetic diversity of Arctic charr in the Alpine region for sound management. The results also refute the general view of Arctic charr being a genetically depauperate species and show

	Salmonidae) from central Alpine lakes. *Molecular Ecology*, **7**, 209-223. **Arctic char**	the potential usefulness of microsatellite DNAs in addressing evolutionary and conservation issues in this species.
Busack,C. and Knudsen,C.M. (2007)	Using factorial mating designs to increase the effective number of breeders in fish hatcheries Aquaculture 273, 24-32. **Review**	Under assumptions of additive combination of fitness values, full-factorial mating resulted in an average *N*b increase of 33%. Partial-factorial designs as small as 2×2 achieved on average 45% of the *N*b advantage attainable under full-factorial mating. The proportionate incremental *N*b benefit from partial-factorial designs diminishes rapidly as the size of the design increases, but designs as small as 10×10 may attain such a large proportion of the full-factorial benefit as to render larger designs unnecessary.
Carrofino,D.C. et al (2008)	Stocking success of local origin fry and impact of hatchery ancestry: monitoring a new steelhead (*Oncorhyncus mykiss)* stocking programme in a Minnesota tributary to Lake Superior. Can. J. Fish.Aquat.Sci, 65, 309-318. **Steelhead trout**	Through genetic monitoring of two year classes we determined that hatchery adults produced 1.3-6.2 times as many age 2 juveniles as natural spawning fish. Survival of stocked fry of parents born in the hatchery relative to those born in the wild was 70% in paired stocking comparisons. These results suggest that stocking local origin fry can increase short term abundance of depleted populations and that fish with no hatchery ancestry are the best source for supplementation.
CCW (2008)	Core Management Plan, including conservation objectives, for River Usk Special Area of Conservation **Policy**	There is currently no stocking of salmon into the Usk. The management objectives for SAC salmon populations are to maintain naturally self-sustaining populations. Salmon stocking should not be routinely used as a management measure. Salmon stocking represents a loss of naturalness and, if successful, obscures the underlying causes of poor performance (potentially allowing these risks to perpetuate).
CCW (2008)	Core Management Plan, including conservation objectives, for River Wye Special Area of Conservation **Policy**	The management objectives for SAC salmon populations are to maintain naturally self-sustaining populations. Salmon stocking should not be routinely used as a management measure. Salmon stocking represents a loss of naturalness and, if successful, obscures the underlying causes of poor performance (potentially allowing these risks to perpetuate).
Chiasson 2013	Enhancement methods and results obtained over a thirty-plus year	Based on normal returns, this indicates a +10% survival from marked fry to smolts. Number of broodstock females = 220; ie., return of 6225 fish = 28

	program on the Nepisiguit River Poster presentation What Works? A Workshop on Wild Atlantic Salmon Recovery Programs. Atlantic Salmon Federation Workshop, Sept. 18 - 19, 2013 New Brunswick	returns per female. Natural spawning escapement for same time frame = 34 million eggs; minimum 3400 females. For the 14,879 unmarked return, this = 4.4 fish per female, which indicates the advantage of the hatchery process, over six times the return per female. To put this in perspective, in a river receiving only 50 % of required spawning escapement, removing 10% of these for a hatchery/incubation box process (5% of total) could yield the equivalent of an additional 30% to returns -, the same as a natural 75% of required spawning escapement- and over time, if performed each year, is cumulative to some extent, as shown by Nepisiguit returns.
Chilcote,M.W. et al (2011)	Reduced recruitment performance in natural populations of anadromous salmonids associated with hatchery-reared fish. Can.J.Fish.Aquat.Sci. 68:511-522. **Onchoryhnchus spp.**	In most cases, measures that minimize the interactions between wild and hatchery fish will be the best long-term conservation strategy for wild populations.
Chilcote,M.W. (2003)	Relationship between natural productivityand the frequency of wild fish in mixed spawning populations of wild and hatchery steelhead (O. mykiss). Can.J.Fish.Aquat.Sci. 60:1057-1067. **Steelhead trout**	For natural populations, removal rather than addition of hatchery fish may be the most effective strategy to improve productivity and resilience.
Christie,M.R. et al (2011)	Genetic adaptation to captivity can occur in a single generation. PNAS early edition. Steelehad trout, Hood River, Oregon.	These results demonstrate that a single generation in captivity can result in a substantial response to selection on traits that are beneficial in captivity but severely maladaptive in the wild.
Christie,M.R.et al (2012)	Effective size of a wild salmonid population is greatly reduced by hatchery supplementation Heredity (2012) 00, 1–7 **Steelhead trout**	The low Nb caused hatchery fish to have decreased allelic richness, increased average relatedness, more loci in linkage disequilibrium and substantial levels of genetic drift in comparison with their wild-born counterparts. We also documented a substantial Ryman–Laikre effect whereby the additional hatchery fish doubled the total number of adult fish on the spawning grounds each year,

		but cut the effective population size of the total population (wild and hatchery fish combined) by nearly two-thirds. These results emphasize the trade-offs that arise when supplementation programs attempt to balance disparate goals (increasing production while maintaining genetic diversity and fitness).
Ciborowski,K.L. et al (2007)	Stocking may increase mitochondrial DNA diversity but fails to halt the decline of endangered Atlantic salmon populations. Concer.Genet. 8:1355-1367. **Atlantic salmon**	Our results suggest that stocking with non-native fish may increase genetic diversity in the short-term, but may not reverse population declines.
Consuegra,S. and Garcia de Leaniz,C (2008).	MHC-mediated mate choice increases parasite resistance in salmon. Proc.Roy.Soc.London (B)275:1397-1403 **Atlantic salmon**	We found that the offspring of artificially-bred salmon had higher parasite loads and were almost 4 times more likely to be infected than free-mating salmon. Therefore, artificial breeding programmes that negate the potential genetic benefits of mate choice may result in inherently inferior offspring, regardless of population size, rearing conditions, or genetic diversity.
Cowx IG, Gerdeaux D. (2004)	The effects of fisheries management practises on freshwater ecosystems. *Fisheries Management and Ecology*, **11**, 145-151. **Review**	The principal mechanisms of inland fisheries management concentrate on four categories: fish stock enhancement (stocking and introductions); rehabilitation and habitat manipulation for fisheries purposes, including biomanipulation; fisheries regulations; and conservation and protection of fish and fisheries. The negative and beneficial impacts of these activities are summarised and options for improving the outputs of fisheries management practices to accrue wider benefits to society are discussed. Wider stakeholder participation and a shift from traditional fisheries towards ecosystem-based management approaches are the main mechanism proposed. This calls for new management tools to cater for legitimate human demand for water abstraction, hydropower generation and effluent disposal, as well as alternative commercial use of water bodies such as bathing, boating and tourism, in addition to fisheries exploitation and conservation needs
Dahl et al (2006)	No difference in survival, growth and morphology between offspring of wild-born, hatchery and hybrid brown trout (*Salmo trutta*).	In the laboratory experiment, we compared only the offspring of hatchery and wild-born trout with respect to growth, dominance, aggressiveness, feeding and activity. We found small differences between the offspring of hatchery and wild-born fish with respect to growth but this effect was not found in the field

	Ecology of Freshwater Fish 15:388-397 **Brown trout**	experiment. Our result suggests that the offspring of hatchery trout and hybrids between hatchery and wild-born trout performed equally well to the offspring of wild-born trout
Dannewitz et al (2003)	Effects of sea-ranching and family background on fitness traits in brown trout *Salmo trutta* reared under near-natural conditions. Journal of Applied Ecology 40:241-250	Synthesis and applications. Our results suggest that wild-born trout of sea-ranched origin can successfully compete with trout of wild origin under semi-natural conditions. This indicates that the impact of hatchery selection on the performance of sea-ranched fish in the wild may not be as pronounced as previously thought. It is suggested that for salmonid populations that depend on supplemental stocking, more effort should be paid to minimizing negative environmental effects during hatchery rearing.
Davidson,W.S. (2012)	Adaptation genomics: next generation sequencing reveals a shared haplotype for rapid early development in geographically and genetically distant populations of rainbow trout. Molecular Ecology 21:219-222 **Rainbow trout**	Identifying the genetic basis for local adaptation has major implications for the management, conservation and potential restoration of salmonid populations.
De Mestral,L.G. et al (2013)	Preliminary assessment of the environmental and selective effects of a captive breeding and rearing programme for endangered Atlantic salmon, Salmo salar. Fish Mgmt.Ecol. 20:75-89 **Atlantic salmon**	The ratio of effective-to-census number of breeders that produced the captive-origin smolts was higher than that of the wild-origin smolts due to successful captive breeding management practices. These results have direct implications for captive breeding and rearing programmes for salmonids and wider implications for understanding the rates of evolutionary and environmentally induced change that can occur in captivity.
Dittman,A.H. et al (2010)	Homing and spawning site selection by supplemented hatchery- and natural-origin Yakima River spring Chinook salmon. Transactions of the American Fisheries	While homing was clearly evident, the majority (55.1%) of the hatchery fish were recovered more than 25 km from their release sites, often in spawning areas used by wild conspecifics. Hatchery and wild fish displayed remarkably similar spawning distributions despite very different imprinting histories, and the highest spawning densities of both hatchery and wild fish occurred in the same river sections. These results suggest that genetics, environmental and social factors, or

	Society 139:1014-1028. **Chinook salmon**	requirements for specific spawning habitat may ultimately override the instinct to home to the site of rearing or release.
Eldridge,W.H. and Killebrew,K. (2008).	Genetic diversity over multiple generations of supplementation: an example form Chinook salmon using microsatellite and demographic data. Conserv.Genet 9:13-28 **Chinook salmon**	Based on these results we conclude that: Returning hatchery fish comprised 10-60% of the run from 1985-2001 Effective population size increased over time. Genetic diversity has been maintained over multiple generations of supplementation Supplementation has not contributed to a loss of genetic diversity
Environment Agency (2014)	The ecological impacts of fish stocking EA LitResponse Review	The question of the ecological impacts of stocking needs more research, particularly through the integration of classical and molecular approaches (Fraser etal, 2011; Ayllaon et al, 2012).
Finnegan,A.K. and Stevens,J.R, (2008)	Assessing the long-term genetic impact of historical stocking events on contemporary populations of Atlantic salmon, *Salmo salar* . Fisheries Management and Ecology 15 (4, August 2008): 315-326	Microsatellite loci were used to assess the current level of population admixture between samples taken from the source location of the stocked fish during the 1960s and contemporary Dart populations. After allowances were made for natural genetic relationships between donor and recipient populations, the long-term impact of the historical stocking events on a catchment scale appears minimal. However, one tributary consistently reflected closer genetic relationships with the donor populations, indicating a possible long-term impact on a localised scale.
Ford,M.J. (2002)	Selection in Captivity during Supportive Breeding May Reduce Fitness in the Wild Conservation Biology Volume 16, Issue 3, pages 815–825 **Review**	The rate of gene flow between the two environments, and hence the outcome of the model, is sensitive to the wild environment's carrying capacity and the population growth rate it can support. The results have two important implications for conservation efforts. First, they show that selection in captivity may significantly reduce a wild population's fitness during supportive breeding and that even continually introducing wild individuals into the captive population will not eliminate this effect entirely. Second, the sensitivity of the model's outcome to the wild environment's quality suggests that conserving or restoring a population's habitat is important for preventing fitness loss during supportive breeding.

Ford,M.J. et al (2006)	Changes in run timing and natural smolt production in a naturally spawning coho salmon (*Oncorhynchus kisutch*) population after 60 years of intensive hatchery supplementation *Canadian Journal of Fisheries and Aquatic Sciences*, 2006, 63(10): 2343-2355 **Coho salmon**	We found no significant difference in relative fitness between hatchery and natural fish, probably because the natural population consists largely of fish produced from the hatchery a generation or two previously. There has been a long-term trend for adults to return to the stream earlier in the spawning season. We estimated standardized selection differentials on run timing, with results indicating stabilizing selection with an optimum run timing later than the mean contemporary run timing but earlier than the historical mean run timing.
Ford,M.J. et al (2008)	Estimates of Natural Selection in a Salmon Population in Captive and Natural Environments Conservation Biology Volume 22, Issue 3, pages 783–794 **Onchorynchus spp**	Our goal was to determine whether natural selection acting on the traits we measured differed significantly between the captive and natural environments. For males, larger individuals were favored in both the captive and natural environments in all years of the study, indicating that selection on these traits in captivity was similar to that in the wild. For females, selection on weight was significantly stronger in the natural environment than in the captive environment in 1 year and similar in the 2 environments in 2 other years. In both environments, there was evidence of selection for later time of return for both males and females. Selection on measured traits other than weight and run timing was relatively weak. Our results are a concrete example of how estimates of natural selection during captivity can be used to evaluate this common risk of captive breeding programs.
Fraser,D.J. (2008)	How well can captive breeding programs conserve biodiversity? A review of salmonids. Evolutionary Applications. Doi:10.1111/j.1752-4571.2008.00036.x **Review**	Owing to several confounding factors, there is also currently little evidence that captive-bred lines of salmonids can or cannot be reintroduced as self-sustaining populations. Most notably, the root causes of salmonid declines have not been mitigated where captive breeding programs exist.
Fraser,D.J. et al (2008)	Mixed evidence for reduced local adaptation in wild salmon resulting from interbreeding with escaped farmed salmon: complexities in hybrid fitness Evolutionary Applications ISSN 1752-	Thus, for acid tolerance and the stages examined, we found some evidence both for and against the theory that repeated farmed-wild interbreeding may reduce adaptive genetic variation in the wild and thereby negatively affect the persistence of depleted wild populations.

	4571 doi:10.1111/j.1752-4571.2008.00037.x **Atlantic salmon**	
Fraser,D.J. et al (2010)	Consequences of farmed–wild hybridization across divergent wild populations and multiple traits in salmon Ecological Applications, 20(4), 2010, pp. 935–953 **Atlantic salmon**	Combined with ecological data on the rate of farmed escapes and wild population trends, we thus suggest that the greatest utility of hybridization data for risk assessment may be through their incorporation into demographic modeling of the short- and long-term consequences to wild population persistence. In this regard, our work demonstrates that detailed hybridization data are essential to account for life-stage-specific changes in phenotype or fitness within divergent but interrelated groups of wild populations.
Fraser,D.J. et al (2010)	Potential for domesticated–wild interbreeding to induce maladaptive phenology across multiple populations of wild Atlantic salmon (*Salmo salar*) Can. J. Fish. Aquat. Sci. 67: 1768–1775 (2010) **Atlantic salmon**	In certain cases, our data suggest that hybrid developmental rates are sufficiently mismatched to prevailing environmental conditions that they would have reduced survival in the wild. This implies that repeated farmed–wild interbreeding could adversely affect wild populations. Our results therefore reaffirm previous recommendations that based on the precautionary principle, improved strategies are needed to prevent, or to substantially minimize, escapes of aquaculture fishes into wild environments.
Fraser,D.J. et al (2011)	Extent and scale of local adaptation in salmonid fishes: review and meta-analysis. Heredity (2011) 106, 404–420 **Review**	A key research direction will continue to be the assessment of the extent and the scale of potential human-induced maladaptation (through climate and habitat alternations, fisheries, aquaculture, hatcheries, captive breeding and so on), as well as its consequences for salmonid evolution and persistence. Clarifying the magnitude of LA and fitness trade-offs in relation to geographic scale could also be very useful for optimising future species restoration efforts, including reintroductions and the maintenance of genetic variation within captive populations through artificial gene flow.
Fritts,A.L. et al (2007)	The effects of domestication on the relative vulnerability of hatchery and wild origin spring Chinook salmon (*Oncorhynchus tshawytscha*) to predation. *Canadian Journal of Fisheries and*	The most important findings of this study are (i) domestication can affect the susceptibility to predators after only one generation of state-of-the-art hatchery culture practices, and 9ii) the domestication effect was very small.

	Aquatic Sciences **64**, 813-818. **Chinook salmon**	
Garcia-Marin J. et al 1999)	Erosion of the native genetic resources of brown trout in Spain. *Ecology of Freshwater Fish*, **8**, 151-158. **Brown trout**	We analyzed the introduction of hatchery-reared trout in the Riutort Creek, a small stream in the eastern Spanish Pyrennees. In only two years the amount of introgression rose to 10%, indicating that 5% of the native ancestry is lost each year as a result of the stocking program. Based on these results, we review the present understandings on the genetic impact of hatchery fish on indigenous Spanish brown trout populations. The stocking of these populations involves a non-native broodstock widespread through the Spanish hatcheries, but successful stockings appear to be limited to wild populations subjected to occasional releases in protected or unfished areas. Surprisingly, extensive stocking in fished areas result in a more limited genetic impact on the recipient native population.
Garcia de Leaniz,C. et al (2007)	A critical review of adaptive genetic variation in Atlantic salmon: implications for conservation. Biol.Rev. 82:173-211 **Atlantic salmon**	As such an evolutionary approach to salmon conservation is required, aimed at maintaining the conditions necessary for natural selection to operate most efficiently and unhindered.
Garner.S.R. et al (2009)	Sexual conflict inhibits female mate choice for major histocompatibility complex dissimilarity in Chinook salmon. Proc. R. Soc. B 2010 **277**, 885-894	Males' aggression was positively correlated with their reproductive success, and it appeared to overcome female aversion to mating with MHC-similar males, as females who were the target of high levels of male aggression had lower than expected MHC divergence in their offspring. Indeed, offspring MHC divergence was highest when the sex ratio was female-biased and male harassment was likely to be less intense. These data suggest that male harassment can reduce female effectiveness in selecting MHC-compatible mates, and sexual conflict can thus have an indirect cost to females.
Gow,J.L. et al (2011)	Little impact of hatchery supplementation that uses native broodstock on the genetic structure and diversity of steelhead trout revealed by a large-scale spatio-temporal	These samples were collected over 58 years, a time period that spanned the initiation of native steelhead trout broodstock hatchery supplementation in these rivers. We detected no changes in estimates of effective population size, genetic variation or temporal genetic structure within any population, nor of altered genetic structure among them. Genetic interactions with non-migratory *O. mykiss*, the use of substantial numbers of primarily native broodstock with an

	microsatellite survey. Evol Appl. 2011 November; 4(6): 763–782. **Steelhead trout**	approximate 1:1 male-to-female ratio, and/or poor survival and reproductive success of hatchery fish may have minimized potential genetic changes. Although no genetic changes were detected, ecological effects of hatchery programs still may influence wild population productivity and abundance. Their effects await the design and implementation of a more comprehensive evaluation program.
Grandjean,F. et al (2009)	Fine-scale genetic structure of Atlantic salmon (Salmo salar) using microsatellite markers: effects of restocking and natural recolonization. Freshwat.Biol. 54:417-433 **Atlantic salmon**	Hatchery stocks used for restocking of the two rivers were genetically distinct form native stocks. From a management perspective, our study revealed that restoration of habitat is very effective to recreate new populations in rivers from which salmon have disappeared and that natural recolonization can be fast and effective in terms of genetic diversity.
Grant,W.S. (2012)	Understanding the adaptive consequences of hatchery-wild interaction in Alaska salmon. Environ.Biol.Fish 94:325-342 **Pacific salmon**	The preservation of adaptive potential in wild populations is an important buffer against disease and climate variability and, hence, should be considered in planning hatchery production levels and release locations. The protection of wild populations is the foundation for achieving sustained harvests of salmon in Alaska.
Gray M, Mee D. (2002)	Inventory of Trout Stocks and Fisheries in England and Wales. W2--062/TR. 2002. Bristol, Environment Agency.	
Griffiths,A.M. et al (2009)	Comparison of patterns of genetic variability in wild and supportively bred stocks of brown trout, Salmo trutta. Fish.Mgmt.Ecol. 16:514-519 **Brown trout**	The results of this study demonstrate that the SB stock of trout (NB - hatchery trout derived from wild parents) is highly differentiated from, and shows highly significant differences in allele frequencies form, any of the wild trout collected across the River Dart. This suggests that the hatchery process may have altered the genetic composition of the stock, leading to inflated values if genetic differentiation.
Hansen,M.M. et al (2009)	Sixty years of anthropogenic pressure: a spatio-temporal genetic analysis of brown trout populations subject to stocking and population declines. Molecular Ecology (2009) 18, 2549–2562 **Brown trout**	Based on theoretical considerations, we argue that population declines have had limited negative effects for the persistence of adaptive variation, but admixture with hatchery trout may have resulted in reduced local adaptation.

Hansen,M.M., and Loeschcke V. (1994)	Effects of releasing hatchery-reared brown trout to wild trout populations. *Conservation Genetics*, **68**, 273-289. **Brown trout**	Hatchery-rearing may lead to domestication and loss of genetic variation, and if massive numbers of hatchery fish are stocked these may replace wild populations. Interbreeding of wild and domesticated populations or formerly reproductively isolated wild populations may result in a breakdown of the local genetic population structure, loss of genetic variation among stocks and loss of specific genotype combinations of potential adaptive value. Conservation and management efforts should primarily be aimed at individual stocks and priority should be given to improving environmental conditions. If stocking is inevitable the preferred option is to release offspring of local wild fish, and only in already heavily stocked populations is the use of exogenous hatchery fish justified.
Hansen, M.M. et al (2001)	Admixture analysis and stocking impact assessment with brown trout (Salmo trutta), estimated with incomplete baseline data. *Canadian Journal of Fisheries and Aquatic Sciences*, **58**, 1853-1860. **Brown trout**	The results showed almost complete absence of stocked, domesticated trout in samples of trout from the rivers. Consequently, stocking had little effect on improving fisheries. In one population, the genetic contribution by domesticated trout was small, whereas in the other population, some genetic impact was suggested. Admixture in this sample of anadromous trout despite absence of stocked domesticated trout could be because of introgression by domesticated trout adopting a resident life history.
Hay, D.W. and Hatton-Ellis, M. (2006)	Stocking sea trout (Salmo trutta L.) in the River Shieldaig, Scotland. Harris, G. and Milner, N. Sea Trout: Biology, Conservation and Management.Proceedings of the First International Sea Trout Symposium, Cardiff, July 2004, 349-355. **Brown (Sea) trout**	About 5% of stocked fry survived to emigrate as smolts. The number of emigrants rose each year since stocking started to over 1900 smolts in spring 2003, of which more than 90% were of stocked origin. Marine survival remains low with inadequate returns to allow a self-sustaining population (prob. due to sea lice). Early indications suggest that the return rates of stocked fish, though numerically higher, are proportionately inferior to wild fish.
Hayes,M.C. et al (2004)	Interactions between endangered wild and hatchery salmonids: can the pitfalls of artificial propagation be avoided in small coastal streams? Journal of Fish Biology 65 (Supplement	The return of hatchery steelhead was highly synchronized with that of wild steelhead, indicating that hatchery propagation had no adverse effects on the timing of the run. A disproportionate number of hatchery steelhead returned to the tributary where the hatchery was located, despite being planted throughout the watershed. Hatchery steelhead did not differ in mean age or size from wild steelhead. Observations of spawning indicated that hatchery and wild steelhead

	s1): 101–121, December 2004	interbreed. Competition for mates or spawning substratum was rarely observed between hatchery and wild steelhead. Many of the problems commonly associated with artificial propagation can be avoided in small coastal watersheds when wild broodstock are used and fish are released as smolts.
Hayes M.C. et al (2002)	Salmon restoration in the Umatilla River: A study of straying and risk containment. Fisheries 27: 10-19 **Chinook salmon**	The use of artificial propagation may produce unexpected results and the need for risk containment. Stray chinook salmon (Oncorhynchus tshawytscha) from Umatilla River captured or observed in the Snake River averaged more than 200 fish annually and comprised up to 26% of the escapement. Actions for the use of artificial propagation where straying or unexpected results are a concern include marking or tagging most or all fish, limiting the number of fish initially released, recognizing environmental variables that influence straying, ensuring that funding for risk containment is available when undesirable results occur, and recognizing that unexpected results may not be manifested or identified immediately.
Heard,W.R. et al 2003	Alaska salmon enhancement: A successful program for hatchery and wild Stocks. *Ecology of aquaculture species and enhancement of stocks* (pp. 149-169). Proceedings of the 30th U.S.-Japan Aquaculture Panel, 3-4 December 2001. Florida Sea Grant TP-128, Mote Marine Lab, Sarasota, FL. **Onchorynchus spp**	This salmon enhancement program has focused on protecting wild stock fitness and other unique stock characteristics through strict regulation by geneticists, pathologists, and managers for siting and capacity of hatcheries. The use of hatchery brood stocks has been restricted and controlled by policy and regulation. New mass-marking technologies have enabled harvest managers to better protect wild stocks in mixed-stock fisheries. A cornerstone of Alaska's successful salmon program has been the application of escapement-based, adaptive management for wild stocks and judicious use of technologies appropriate for enhancement. Salmon enhancement in Alaska is designed to supplement common property fisheries, not to supplement wild spawning populations or to rebuild depressed wild stocks with hatchery-origin fish
Heard,W.R. (2012)	Overview of salmon stock enhancement in southeast Alaska and compatibility with maintenance of hatchery and wild stocks	Although some interactions between hatchery salmon and wild salmon are unavoidable including increasing concerns over straying of hatchery fish into wild salmon streams, obvious adverse impacts from hatcheries on production of wild salmon populations in this region are not readily evident.

	Environ Biol Fish (2012) 94:273–283 **Onchorynchus spp**	
Hedrick,P.W. et al (2000)	Effective population size of winter-run chinook salmon based on microsatellite analysis of returning spawners. Canadian Journal of Fisheries and Aquatic Sciences, 57(12): 2368–2373.	These findings provide an optimistic outlook for the success of this supplementation program and suggest that the overall effective population size has not been greatly reduced, since returning spawners represent a broad sample of parents and not fish from only a few families.
Hedrick,P.W. et al (2000)	The impact of supplementation in winter run Chinook salmon on effective population size. Journal of Heredity, 2000: 91 (2) **Chinook salmon**	A breeding protocol, instituted in 1992, seeks to maximize the effective population size from the captive spawners by equaling their contributions to the released progeny. As a result, the releases in 1994 and 1995 appear not to have decreased the overall effective population size and may have increased it somewhat. However, mistaken use of non-winter-run chinook spawners resulted in artificial crosses between runs with a potential reduction in effective population size, and imprinting of the released fish on Battle Creek, the site of the hatchery, resulted in limiting the contribution of the released fish to the target mainstem population. Rapid genetic analysis of captured spawners and a new rearing facility on the Sacramento River should alleviate these problems and their negative effect on the effective population size in future years.
Heggenes,J. et al (2006)	Genetic Diversity in Steelhead before and after Conservation Hatchery Operation in a Coastal, Boreal River Transactions of the American Fisheries Society 135:251–267, **Steelhead trout**	We conclude that for the current management regime there is little apparent impact of hatchery practices on either the genetic structure or variation within the lower main-stem Kitimat River steelhead, but there may be a reduction in rare alleles. The practice of using substantial numbers of wild fish and multiple year-classes in the hatchery may have minimized genetic changes via genetic drift.
Heggens,J. et al (2011)	Estimation of Genetic Diversity within and among Populations of *Oncorhynchus mykiss* in a Coastal River Experiencing Spatially Variable Hatchery Augmentation.	We conclude that indigenous wild *O. mykiss* populations exist in the tributaries and the upper main-stem river and its tributaries. These upper-river populations appear to have retained genetic diversity and differentiation despite extensive releases of hatchery fish in the lower river

	Transactions of the American Fisheries Society 140:123-135 **Rainbow trout**	
Hess,M.A. et al (2012)	Supportive breeding boosts natural population abundance with minimal negative impacts on fitness of a wild population of Chinook salmon Molecular Ecology (2012) 21, 5236–5250 **Chinook salmon**	We conclude that fish chosen for hatchery rearing did not have a detectable negative impact on the fitness of wild fish by mating with them for a single generation. Results suggest that supplementation following similar management practices (e.g. 100% local, wild-origin brood stock) can successfully boost population size with minimal impacts on the fitness of salmon in the wild.
Hill, M.S 2006	Comparisons between hatchery and wild steelhead trout (*Oncorhynchus mykiss*) smolts: physiology and habitat use *Canadian Journal of Fisheries and Aquatic Sciences*, 2006, 63(7): 1627-1638, 10.1139/f06-061	Microhabitat use of PIT-tagged hatchery and wild individuals in a control (wild fish only) and effect (hatchery and wild fish) site were compared before and after the introduction of hatchery fish. No difference was detected in hatchery and wild smolt habitat use. Wild fish did not change their habitat use after the introduction of hatchery fish. Although hatchery and wild fish differed in smolt physiology, differences in short-term use of freshwater habitat were not detected, and hatchery fish did not appear to displace wild fish.
Holmlund, C.M. and Hammer M (1999)	Ecosystem services generated by fish populations. Ecological Economics 29: 253-268 **Review**	We review the role of fish populations in generating ecosystem services based on documented ecological functions and human demands of fish. Ecosystem services are here defined as fundamental services for maintaining ecosystem functioning and resilience, or demand-derived services based on human values. To secure the generation of ecosystem services from fish populations, management approaches need to address the fact that fish are embedded in ecosystems and that substitutions for declining populations and habitat losses, such as fish stocking and nature reserves, rarely replace losses of all services.
Holmlund, C.M. et al (2004)	Effects of fish stocking on ecosystem services: An overview and case study using the Stockholm archipelago. Environmental Management 33: 799-	We conclude that a more adaptive and cooperative management approach could benefit from a deeper analysis of where, when, and what species is released, by whom, which stakeholders that use the fish and those ecosystem services the fish generate, and of the role of formal and informal institutions for monitoring and

	820 **Review**	evaluating the success of releasing fish.
Horreo,J.L. et al (2009)	Identification of differential broodstock contribution affecting genetic variability in hatchery stocks of Atlantic salmon (Salmo salar) Aquaculture 280 (2008) 89–93 **Atlantic salmon**	The contribution of broodstock to this juvenile stock was examined by pedigree analysis. A restricted number of females contributing to the hatchery stock was identified as the main cause of loss in genetic variation, possibly due to overmaturity of some multi-sea-winter females.We suggest that better monitoring and control of parental contribution will help in solving the problem of loss of genetic diversity in hatchery populations.
Horreo,J.L. et al (2012)	Ecological and economic costs of supportive breeding: Atlantic salmon (Salmo salar) as a case study Aquaculture 356–357 (2012) 1–6 **Atlantic salmon**	Supportive breeding is a common management action carried out to enhance Atlantic salmon populations in the region of Asturias (northern Spain), but its real success is yet unknown despite the high effort expended in the last decades (since 1992). Identification of returning adult salmon as hatchery descendants was carried out with microsatellite loci and pedigree tests in two rivers of the region (Sella and Cares). High levels of straying between rivers and rates of return between 6% and 11% of Atlantic salmon hatchery descendants in sport fishing catches were found. The estimated cost of each salmon caught was higher than €4000.
Houde,A.L.S. et al (2009)	Fitness-related consequences of competitive interactions between farmed and wild Atlantic salmon at different proportional representations of wild–farmed hybrids Oxford Journals-ICES Journal of Marine Science **Atlantic salmon**	The results suggest that for the life stage examined and provided the rate of farmed intrusion and wild–farmed interbreeding remains low (i.e. _15% hybrids), the effects of competitive interaction with their farmed counterparts may have comparatively little effect on the mortality of wild populations.
Houde,A.L.S. et al (2010)	Reduced anti-predator responses in multi-generational hybrids of farmed and wild Atlantic salmon (Salmo salar L.) Conserv Genet (2010) 11:785–794 **Atlantic salmon**	Our study is consistent with the general hypothesis that continual farmed-wild interbreeding may have detrimental effects on the fitness of wild organisms.

Houde,A.L.S. et al (2011)	Relative risks of inbreeding and outbreeding depression in the wild in endangered salmon Evolutionary Applications ISSN 1752-4571 doi:10.1111/j.1752-4571.2011.00186.x **Atlantic salmon**	The results further suggested that outbreeding outcomes may be highly variable or unpredictable at small genetic distances. Our work highlights the necessity of evaluating the relative costs of inbreeding and outbreeding in the conservation and management of endangered species on a case-by-case basis.
Hyvärinen, P 2013	Enriched rearing improves survival of hatchery-reared Atlantic salmon smolts during migration in the River Tornionjoki *Canadian Journal of Fisheries and Aquatic Sciences*, 2013, 70(9): 1386-1395, 10.1139/cjfas-2013-0147	The results of this study show that enriching the rearing environment with methods easily applicable to large-scale production promotes smolt survival and migration speed during river migration, which is imperative for stocking success.
Jonsson, B. and Jonsson,N. (2006)	Cultured Atlantic salmon in nature: a review of their ecology and interaction with wild fish ICES Journal of Marine Science, 63: 1162e1181 **Atlantic salmon**	The lifetime reproductive success of farmed fish has been estimated at 17% that of similar-sized wild salmon. As a result of ecological interaction and through density-dependent mechanisms, cultured fish may displace wild conspecifics to some extent, increase their mortality, and decrease their growth rate, adult size, reproductive output, biomass, and production.
Jordan,W.C. et al (2005)	Allozyme variation in Atlantic salmon from the British Isles: associations with geography and the environment. J.Fish Biol. 67 (supplement A): 146-168 **Atlantic salmon**	There was some evidence for the existence of genetically-distinct celtic and boreal races of Atlantic salmon in the British Isles as previously has been suggested. Multiple regression analyses revealed associations between genetic variations and local environmental conditions providing evidence for adaptive population divergence in the species.
Kassler,T.W. and Dean,C.A. (2010)	Genetic Analysis of Natural-origin Spring Chinook and Comparison to Spring Chinook from an Integrated Supplementation Program and Captive Broodstock Program in the Tucannon	Factorial correspondence analysis identifies similarity among collections that are separated by four years and represent the genetic differences among primary brood years and not genetic changes to the natural-origin collection from 1986. The combination of all the results demonstrates that the genetic diversity of spring Chinook in the Tucannon River has not significantly changed as a result of

	River. Report to BPA, Project No. 2000-019-00, Contract Number 40744. WDFW, Olympia, WA **Chinook salmon**	the supplementation or captive brood programs.
Kennedy,R.J. et al (2012)	The effect of stocking with 0+ year age-class Atlantic salmon Salmo salar fry: a case study from the River Bush, Northern Ireland. J Fish Biol. 2012 Oct;81(5):1730-46 **Atlantic salmon**	Stocking with unfed and fed fry contributed to increased smolt production and helped attain local management objectives between 2001 and 2005. Significant differences in biological characteristics were observed between wild and stocked-origin fish. Differences in run timing between wild smolts and smolts derived from stocked fry were also apparent with the stocked-origin fish tending to run earlier than wild fish. Although the stocking exercise was useful in terms of maximizing freshwater production, concerns over the quality of stocked-origin recruits and the long term consequences for productivity are highlighted.
Kawamura,K. et al (2012)	Effects of stocking hatchery fish on the phenotype of indigenous populations in the amago salmon Onchorynchus masou ishikawae in Japan J.Fish Biol. 81:94-109 **O. masou**	These results suggest the possibility that introgression by stocked fish causes a change of phenotype in indigenous populations.
Koljonen,M.L. et al (2002)	Maintenance of genetic diversity of Atlantic salmon (Salmo salar) by captive breeding programmes and the geographic distribution of microsatellite variation. Aquaculture 212:69-92 **Atlantic salmon** (in Finland)	In short-term breeding programmes, the average rate of loss of heterogeneity was 1.4% per generation and the average observed rate of loss of alleles was 4.7% per generation. Changes in present-day bottlenecks were not alarming and the Ne/Nc ratios were higher than in wild populations in general.
Knudsen et al 2008	Comparison of Female Reproductive Traits and Progeny of First-Generation Hatchery and Wild	Relative fecundity (the number of eggs per centimeter of body length) was on average 1.3% greater in hatchery females. We also compared **body size** at yolk absorption and egg-to-fry survival of the progeny from hatchery-by-

	Upper Yakima River Spring Chinook Salmon **Transactions of the American Fisheries Society** **Volume 137, Issue 5, 2008**	hatchery and wild-by-wild matings. After differences in **egg size** were accounted for, hatchery fry were on average 1.0% heavier than wild fry. Egg-to-fry survival rates varied among years, with no consistent difference between hatchery and wild fry. Our data support the idea that a single generation of state-of-the-art conservation hatchery propagation can produce fish with reproductive traits similar to those of wild fish, given comparable body size.
Kostow,K. (2009)	Factors that contribute to the ecological risks of salmon and steelhead hatchery programs and some mitigating strategies. Reviews in Fish Biology and Fisheries 2009 Vol. 19 No. 1 pp. 9-31 **Onchorynchus spp**	This paper reviews some of the factors that contribute to ecological risks. Important contributing factors include the relative abundance of hatchery and wild fish in natural production areas, hatchery programs that increase density-dependant mortality, residual hatchery fish, some physical advantages that hatchery fish can have over wild fish, and life history characteristics that may make some species especially vulnerable to the effects of ecological risks. Many of these risk factors can be mitigated by management activities that reduce the level of interactions between hatchery and wild fish.
Kumada,N. et al (2014)	The multi-scale aggregative response of cormorants to the mass stocking of fish in rivers. *Fisheries Research*, **137**, 81-87. **Ayu**	This study indicates that although cormorants altered their feeding areas in accordance with the mass stocking of ayu in a Japanese river, sufficient numbers of ayu were still maintained for anglers.
Laikre,L. et al (2010)	Compromising genetic diversity in the wild: unmonitored large-scale release of plants and animals. Trends in Ecology and Evolution 25:520-529. **Review**	While adverse genetic impacts are recognized and documented in fisheries, little effort is devoted to actually monitoring them.
Larsson,S. et al (2011)	Feeding of wild and hatchery reared Atlantic salmon (Salmo salar L.) smolts during downstream migration. Environ Biol Fish DOI 10.1007/s10641-011-9846-7 **Atlantic salmon**	In conclusion, this study suggests that stocked 2-year old smolts may enter sea with an inferior foraging behaviour and it is a possibility that this may contribute to the observed low post-smolt survival in the Baltic Sea.
Levin,P.S. et al (2001)	The road to extinction is paved with	Our results suggest that hatchery programmes that produce increasingly higher

	good intentions: negative association of fish hatcheries with threatened salmon. Proc.Royal Soc.London B 268:1153-1158 **Review**	numbers of fish may hinder the recovery of depleted wild populations.
Levin,P.S. and Williams,J.G. (2002)	Interspecific effects of artificially propagated fish: an addition conservation risk for salmon. Conservation Biology 16(6): 1581-1587 **Steelhead trout and chinook salmon**	Our results suggest that industrial-scale production of hatchery fish may hinder the recovery of some threatened salmonids and that the potential interspecific impact of hatcheries must be considered as agencies begin the process of hatchery reform.
Marie,A.D. et al (2010)	Loss of genetic integrity correlates with stocking intensity in brook charr (Salvelinus fontinalis) Molecular Ecology (2010) 19, 2025–2037 **Brook char**	In summary, this study clearly showed that the loss of genetic integrity of wild brook charr populations, both in terms of genetic diversity and population structure, is strongly associated with the extent of stocking intensity.
Marshall et al (1994)	Fish culture strategies in support of Atlantic salmon enhancement/colonization initiatives in the Scotia-Fundy Region, Nova Scotia and New Brunswick. *In* Proceedings of the New England Atlantic salmon management conference, Danvers, MA, USA, April 22-24: App. + 17	Recent stocking of age 0+ fall parr above dams on the Saint John River resulted in a return rate of 1.8*10-3 or about 10 recruits per MSW female equivalent spawner. Natural spawning, in very recent years, mostly above 3 dams, is yielding only about 3 recruits; hatchery smolts released above 3 dams yield about 25 recruits per MSW equivalent spawner. In all cases recruits exceeded "replacement" of two fish and complement a strategy of colonization/enhancement as opposed to mitigation.
Matala,A.P. et al (2012)	Influences of Hatchery Supplementation, Spawner Distribution, and Habitat on Genetic Structure of Chinook Salmon in the South Fork	Our results indicated variable abundances of SFSR hatchery spawners distributed spatially among the three main watersheds. Gene flow appears to be restricted and genetic differentiation to be relatively large despite substantial hatchery releases in the upper SFSR. Three historical aggregates of Chinook salmon appear to persist in the SFSR metapopulation, where variable hatchery influences are

	Salmon River, Idaho North American Journal of Fisheries Management 32:346–359, 2012 **Chinook salmon**	coincident with the distribution of suitable spawning habitat and watershed-specific management objectives.
May et al 2010	Effects of Supplementation on Spring Chinook Salmon Abundance and Distribution in the Yakima River Basin. Poster presentation, State of the Salmon Ecological Interactions between Wild & Hatchery Salmon, Portland, OR, May, 2010.	Redd survey totals for the upper Yakima R. and Naches R. (1981 to 2010) indicated that the number of spawners increased for both populations during the post-supplementation period (2001-2010) but the average number of redds increased 245% in the upper Yakima vs. 160% for the unsupplemented Naches River (see figure below). These results suggest that supplementation increased the number of spawners in the upper Yakima beyond the natural increases associated with improved ocean survival. The number of redds and natural origin spawners has increased in the targeted Teanaway River indicating this approach may be successful for reintroduction of salmonids into underutilized habitat
May L, Spears BM. (2012)	Managing ecosystem services at Loch Leven, Scotland, UK: actions, impacts and unintended consequences. *Hydrobiologia*, **681**, 117-130. **Review**	Rivers, lakes and wetlands are good examples of ecosystems that provide multiple, concurrent, services to mankind. Human society has often exploited these systems by enhancing one ecosystem service at the expense of another. Loch Leven, Scotland, UK, is a good example of this. Over the past 150 years, the lake has been subjected to hydrological modification, fish stocking and pollution control to improve the delivery of key goods and services. This study uses historical records to explore the results of these interventions on the ecosystem services that were targeted for improvement and the knock-on effects on other services provided by the lake. The results suggest that, when management changes are being considered to enhance particular ecosystem services, the potentially damaging effects on other ecosystem services should be taken into account. This requires a better understanding of the role of ecosystem function in delivering ecosystem services, and of the links between multiple ecosystem services, than is currently available. While further research is clearly needed, the value of long-term datasets in providing knowledge and understanding through 'hindsight' should not be underestimated. The study concludes that successful management actions are likely to be those that incorporate lessons learned from

		previous decisions.
McClure,M.M. et al (2008)	Evolutionary effects of alternative artificial propagation programs: implications for viability of endangered anadromous salmonids Evolutionary Applications Special Issue: Evolutionary perspectives on salmonid conservation and management Volume 1, Issue 2, pages 356–375, May 2008 **Onchorynchus spp**	We conclude that because of the evolutionary risks posed by artificial propagation programs, they should not be viewed as a substitute for addressing other limiting factors that prevent achieving viability. At the population level, artificial propagation programs that are implemented as a short-term approach to avoid imminent extinction are more likely to achieve long-term population viability than approaches that rely on long-term supplementation. In addition, artificial propagation programs can have out-of-population impacts that should be considered in conservation planning.
McCormick,S.D. et al (1998)	Movement, migration, and smolting of Atlantic salmon (*Salmo salar*) Can. J. Fish. Aquat. Sci. 55(Suppl. 1): 77–92 **Atlantic salmon**	Smolt development is adversely affected by acidity, pollutants, and improper rearing conditions, and is often more sensitive than other life stages.
McGinnity,P. et al (2003)	Fitness reduction and potential extinction of wild populations of Atlantic salmon, *Salmo salar*, as a result of interactions with escaped farm salmon Proc.Royal Soc. B. doi 10.1098/rspb.2003.2520 **Atlantic salmon**	We thus demonstrate that interaction of farm with wild salmon results in lowered fitness, with repeated escapes causing cumulative fitness depression and potentially an extinction vortex in vulnerable populations
McGinnity,P. et al (2009)	Impact of naturally spawning captive-bred Atlantic salmon on wild populations: de[pressed recruitment and increased risk of climate-mediated extinction. Proc.Royal Soc. B doi:10.1098/rspb.2009.0799 **Atlantic salmon**	Rather than imposing an additional genetic load on wild populations by releasing maladapted captive bred animals, we propose that conservation efforts should focus on optimizing conditions for adaptation to occur by reducing exploitation and protecting critical habitats.
Milner,N.J. et al (2004)	The role of stocking in recovery of the	The overall conclusion is that the dominant recovery process has always been

	River Tyne salmon fisheries. Environment Agency Fisheries technical report No. 2004/1. **Atlantic salmon**	natural recolonisation, but stocking was probably an important contributory factor in accelerating and stabilising recovery of the salmon stocks during the early years. Both recovery processes were crucially influenced by the time course of water quality improement.
Milot,E. et al (2012)	Reduced fitness of Atlantic salmon released in the wild after one generation of captive breeding. Evol. Applications ISSN 1752-4571. **Atlantic salmon**	Our results underline the potential fitness decrease, warn on long-term evolutionary consequences for the population of repeated stocking and support the adoption of more natural rearing conditions for captive juveniles and their release at a younger stage, such as unfed fry.
Molony,B.W. et al. (2003)	Stock enhancement as a fisheries management tool. Reviews in Fish Biology and Fisheries 13: 409-432 **Review**	Stock enhancement has been viewed as a positive fisheries management tool for over 100 years. To address these issues and consider stock enhancement in a broader ecosystem perspective, a new approach for stock enhancement is proposed. If stock enhancement is subsequently identified as the most-appropriate tool, then the stepwise progression will provide the best possible chance of a positive outcome for a stock enhancement project, while minimizing risks and costs. In this way, stock enhancement may advance as a science and develop as a useful fisheries management tool in appropriate situations.
Moore and Berejikian 2012	Variation in the early marine survival and behavior of natural and hatchery-reared Hood Canal steelhead. Plos One, 2012;7(11):e49645. doi: 10.1371/journal.pone.0049645. Epub 2012 Nov	The mean adult-to-adult return rate of hatchery-reared steelhead exceeded replacement and that of the naturally-spawning population. Although the smolt-to-adult survival rates of hatchery-reared fish fluctuate, salmonid escapement has increased in recent years, permitting steelhead and spring chinook harvest. Enumeration of potential spawners and observed redds reveals an increase in natural production of all supplemented species.
Morita,K. (2006)	A review of Pacific salmon hatchery programmes on Hokkaido Island, Japan ICES Journal of Marine Science, 63: 1353e1363 **Onchorynchus spp**	Future hatchery programmes should incorporate active, adaptive learning approaches to minimize the risks associated with artificial propagation and to promote sustainable salmon stocks.
NASCO (2004)	The Williamsburg Resolution. Resolution by the Parties to the	**ARTICLE 5** Measures to Minimise Impacts of Aquaculture and Introductions and Transfers

	Convention for the Conservation of Salmon in the North Atlantic Ocean To Minimise Impacts from Aquaculture, Introductions and Transfers, and Transgenics on the Wild Salmon Stocks. **Atlantic salmon**	Each Party shall take measures, in accordance with Annexes 2, 3 and 4 to this Resolution, to: • minimise escapes of farmed salmon to a level that is as close as practicable to zero through the development and implementation of action plans as envisaged under the Guidelines on Containment of Farm Salmon (CNL(01)53); • minimise impacts of ranched salmon by utilizing local stocks and developing and applying appropriate release and harvest strategies; • minimise the adverse genetic and other biological interactions from salmon enhancement activities, including introductions and transfers; • minimise the risk of disease and parasite transmission between all aquaculture activities, introductions and transfers, and wild salmon stocks.
Neff,B.D. et al (2011)	Conservation and enhancement of wild fish populations: preserving genetic quality versus genetic diversity. Can.J.Fish.Aquat.Sci. 68:1139-1154 Review – mainly salmonids **Review**	WE argue that most breeding programs do not maintain genetic adaptations and may consequently be ineffective at rehabilitating or enhancing wild populations. We suggest that artificial breeding programs must shift from solely preserving genetic diversity to preserving genetic adaptations.
Normandeau,E. et al (2009)	Population-specific gene expression responses to hybridization between farm and wild Atlantic salmon Evolutionary Applications ISSN 1752-4571 doi:10.1111/j.1752-4571.2009.00074.x **Atlantic salmon**	Hence, the consequences of introgression of farm genetic material on gene expression depended on population-specific genetic architectures. These results support the need to evaluate impacts of farm-wild genetic interactions at the population scale.
Palme,A. et al (2012)	Stopping compensatory releases of salmon in the Baltic Sea. Good or bad for Baltic salmon gene pools? Report from the Baltic Salmon 2012 Symposium and workshop, Stockholm University February 9-10, 2012.	Statements: Releases should not be performed in wild salmon rivers with viable populations. The need for conservation actions to protect and save weak salmon populations is recognized. Conservation releases can be used as one measure to support weak populations.

	Davidsons Tryckeri, Vaxjo, Sweden. **Atlantic salmon**	
Pearsons,T.N. et al. (2007)	Impacts of early stages of salmon supplementation and reintroduction programs on three trout species. N Am J Fisheries Mgt 27: 1-20 **Chinook salmon, rainbow trout, cutthroat trout, bull trout**	No evidence on significant effect of chinook salmon juvenile stocking on abundance, size or biomass of any of the other 3 species.
Pedersen,S. et al (2006)	Comparison of survival, migration and growth in wild, offspring from wild (F1) and domesticated sea-run trout (Salmo trutta L.). Harris, G. and Milner, N. Sea Trout: Biology, Conservation and Management.Proceedings of the First International Sea Trout Symposium, Cardiff, July 2004 , 377-388. 2006. Oxford, Blackwell Publishing. 10-7-2004. **Brown (sea) trout**	Compared stocking of domesticated strain vs stocked from F1 wild. Wild strain showed normal migration behaviour and a higher recapture rate.
Perrier,C. et al (2011)	Determinants of hierarchical genetic structure in Atlantic salmon populations: environmental factors *vs.* anthropogenic influences. Molecular Ecology Volume 20, Issue 20, pages 4231–4245, **Atlantic salmon**	This study overall indicates that geological substrate and river length are major environmental factors influencing gene flow and potential local adaptation among Atlantic salmon populations but that stocking with non-native individuals may ultimately disrupt these natural patterns of gene flow among locally adapted populations.
Perrier,C. et al (2013)	Changes in the genetic structure of Atlantic salmon populations over four decades reveal substantial impacts of stocking and potential resiliency. *Ecology And Evolution*, 3(7), 2334-2349. Publisher's official version : Wiley Online Library - Changes in the genetic	Admixture rates among populations were highly variable, ranging from a nearly undetectable contribution from donor stocks to total replacement of the native gene pool, suggesting extremely variable impacts of stocking. Depending on population, admixture rates either increased, remained stable, or decreased in samples collected between 1998 and 2006 compared to samples from 1965 to 1987, suggesting either rising, long-lasting or short-term impacts of stocking. We discuss the potential mechanisms contributing to this variability, including the

	structure of Atlantic salmon populations over four decades reveal substantial impacts of stocking and potential resiliency Open Access version : Archimer - Changes in the genetic structure of Atlantic salmon populations over four decades reveal substantial impacts of stocking and potential resiliency **Atlantic salmon**	reduced fitness of stocked fish and persistence of wild locally adapted individuals.
Peters,M.B., and Turner,T.F. (2008)	Genetic variation of the MHC (MHC class IIb gene) in the threatened Gila trout, Onchoryhynchus gilae gilae. Conservation genetics 2008. **O. gilae**	Maintenance of diversity at MHC will require careful implementation of hatchery breeding protocols and continued protection of wild populations to prevent loss of allelic diversity due to drift.
Phillips,J.L. et al (2000)	Anadromous salmonid recovery in the Umatilla River Basin, Oregon: A case study. Journal of the American Water Resources Association, Vol. 36, no. 6, pp. 1287-1308. Dec 2000. **Steelhead trout**	The mean adult-to-adult return rate of hatchery-reared steelhead exceeded replacement and that of the naturally-spawning population. Although the smolt-to-adult survival rates of hatchery-reared fish fluctuate, salmonid escapement has increased in recent years, permitting steelhead and spring chinook harvest. Enumeration of potential spawners and observed redds reveals an increase in natural production of all supplemented species. Comparison of hatchery-reared and naturally-spawning steelhead populations revealed differences in life history characteristics (in age composition and sex ratios) though run timing and genetic stock compositions of the two components of the populations have not differed. Sustained monitoring is needed to determine benefits of integrating habitat restoration and artificial production in restoring salmonid populations.
Pister, E.P. (2001)	Wilderness fish stocking: History and perspective. Ecosystems 4: 279-286 **Review**	The necessity for wilderness fish stocking is now the subject of widespread debate, especially in view of changing social values and priorities. Options for future generations cannot be preserved if introductions continue to erode the biodiversity of mountain lake ecosystems.
Pitcher,T.E. and Neff,B.D.	Genetic quality and offspring	We also found no relationship between

(2007)	performance in Chinook salmon: implications for supportive breeding Conserv Genet (2007) 8:607–616 **Chinook salmon**	sire sexually selected characters and offspring survival or growth, which is inconsistent with a ''good genes'' hypothesis. Finally, we show that incorporation of genetic quality into supportive breeding programs can increase offspring growth or survival by between 3% and 19% during the endogenous feeding stage alone, and projections to adulthood suggest that survivorship could be over four fold higher.
Riley,S.C. et al (2009)	Behavior of steelhead fry in a laboratory stream is affected by fish density but not rearing environment. North American Journal of Fisheries Management, 29, 1806—1818. **Steelhead trout**	Overall, rearing environment had relatively little influence on the behavior of steelhead fry. Our results indicate that stocking hatchery-reared steelhead fry at low densities may have effects on similar-size wild fish comparable to an equivalent increase in the density of wild fish. We suggest that releasing hatchery-reared steelhead fry as a supplementation strategy may have few direct negative ecological effects on wild fry
Reisenbichler,R.R. and Rubin,S.P. (1999)	Genetic changes from artificial propagation of Pacific salmon the productivity and viability of supplemented populations. ICES J.Mar.Sci. 56:459-466 **Onchorhynchus spp**	When the published study and the three studies in progress are considered collectively, however, they provide strong evidence that the fitness for natural spawning and rearing can be rapidly and substantially reduced by artificial propagation.
Rogan,G. et al 2002	Ranching of Atlantic salmon (Salmo salar L.) to the rod from a native and non-native system. Marine Institute, Salmon Management Service Division, Newport, Co. Mayo, Ireland ICES CM 2002/T:05 **Atlantic salmon**	In summary the behaviour of the Burrishoole ranch strain in the non-native system was similar to that in the native system. Although reduced growth rate at the remote site following transfer suggests increased stress levels, the return of the fish to the remote site suggests that it did not interfere with the imprinting process. Adult Burrishoole fish returning to the remote site showed a similar pattern of migration along the Irish coast to fish returning to Burrishoole. The rod catch data shows that a higher rod catch of Burrishoole fish is attainable in a non-native system. Therefore the behaviour of the Burrishoole stock ranched from other locations could be predicted with a high degree of certainty if local factors are taken into consideration.
Ruzzante, D. E. et al	Stocking impact and migration pattern	These results suggest that stocked domestic brown trout that become

(2004)	in an anadromous brown trout (Salmo trutta) complex: where have all the stocked spawning sea trout gone? Mol Ecol. 2004 Jun;13(6):1433-45. **Salmo trutta**	anadromous experience high mortality at sea and are therefore largely absent among the larger, spawning individuals. We conclude that sea trout of domestic origin exhibit much reduced ability to reproduce and are unlikely to contribute significantly to the local gene pool largely because of a relatively high mortality at sea before the onset of maturity.
Ryman,N. et al (2002)	Supportive Breeding and Variance Effective Population Size Conservation Biology Volume 9, Issue 6, pages 1619–1628, December 1995 **Review**	We show that the effect of supportive breeding may be quite different on the inbreeding and the variance effective sizes. Whereas supportive breeding always results in a reduction of the inbreeding effective number, the variance effective number may either decrease, increase, or remain unchanged. We discuss these observations in relation to conservation management and suggest some general guidelines for supportive breeding situations. Our recommendations include making a distinction between inbreeding and variance effective numbers; taking particular care when dealing with organisms with high reproductive potential; assuring that the amount of drift be no larger than it would be without supportive breeding; and focusing primarily on the variance effective size of a population-that is, on the effective number directly related to the rate of loss of gene diversity.
Saltveit,S.J. (2006)	The effects of stocking Atlantic salmon, Salmo salar, in a Norwegian regulated river. Fish.Mgmt.Ecol 13:197-205 **Atlantic salmon**	The lack of positive response to stocking is possibly due to lesser age, smaller size and later migration of hatchery smolts, and that seawater tolerance of hatchery smolts is poorly developed, all factors increasing mortality at sea
Santos, N.P. (2006)	Genetic evidence for limited introgression between wild and stocked individuals in Portuguese brown trout, *Salmo trutta* populations *Folia Zool.* – 55(4): 433–443 **Brown trout**	It was confirmed the inefficiency of stocking practices in Portugal, as suggested by mtDNA haplotype distribution. From the management and conservation points of view, any kind of stocking with exogenous specimens should be avoided to allow preservation of the autochthonous genetic pools. As well as the stocking techniques and released fish density should be considered. Therefore new policies for stocking and monitoring hatchery fish are needed to preserve the gene pools of wild Portuguese trout populations.

Saura,M. et al (2006)	Genetic variation in restored Atlantic salmon (Salmo salar L.)populations in the Ulla and Le´rez rivers, Galicia, Spain. ICES Journal of Marine ScienceVolume 63, Issue 7Pp. 1290-1296 **Atlantic salmon**	The programme utilizes progeny of adults returning to the rivers and wild parr reared in fresh water until maturity. Five microsatellite loci were used to compare genetic variability in the restored populations with that in populations before their collapse in the 1950s. DNA samples were obtained from scale collections (old samples) and from tissue samples of live fish caught in the rivers (modern samples). Average heterozygosities and allelic richness are very similar in modern and old samples. Populations inhabiting the Ulla and Lérez rivers today are more similar than they were in the past, possibly because they originated in the same stock mixture.
Schilling, E.G. et al. (2009)	Effects of introduced fish on macroinvertebrate communities in historically fishless headwater and kettle lakes. Biological Conservation 142: 3030-3038 **Review**	Fish had significant effects on macroinvertebrate community structure in both lake types, with reduced species richness and abundances of taxa characteristic of fishless lakes. The effects of introduced fish were more pronounced in headwater lakes despite a less diverse fish assemblage than in kettle lakes. We attribute this to abundant submerged vegetation providing refuge from fish predation and reduced stocking frequency in kettle lakes. We assessed effects of stocking duration on macroinvertebrates in a subset of headwater lakes with known dates of trout introduction. Species richness and abundance of most taxa declined within 3 years following trout introduction; however, richness and abundance were least in lakes with long stocking histories (>= 40 years). Macroinvertebrates previously identified as fishless bioindicators were absent from all stocked lakes, indicating that trout rapidly eliminate these sensitive taxa. Conservation of this historically undervalued ecosystem requires protecting remaining fishless lakes and recovering those that have been stocked.
Schindler,D.E. et al (2012).	Population diversity and the portfolio effect in an exploited species. Nature 465:609-613. **Sockeye salmon (O. nerka)**	Our results demonstrate the critical importance of maintaining population diversity for stabilizing ecosystem services and securing the economies and livelihoods that depend on them. The reliability of ecosystem services will erode faster than indicated by species loss alone.
Schroder,S.L. et al (2008)	Breeding Success of Wild and First-Generation Hatchery Female Spring Chinook Salmon Spawning in an Artificial Stream.	Subtle differences between hatchery and wild females in redd abandonment, egg burial, and redd location choice may have been responsible for the difference observed. Body size did not affect the ability of females to spawn or the survival of their deposited eggs. How long a female lived was positively related to her

	Transactions of the American Fisheries Society, 137:1475-1489. **Chinook salmon**	breeding success, but female origin did not affect longevity. The density of females spawning in portions of the stream affected both egg deposition and egg-to-fry survival. No difference, however, was found in the overall distribution patterns of the two types of females. Other studies that have examined the effects of a single generation of hatchery culture on upper Yakima River Chinook salmon have disclosed similar low-level effects on adult and juvenile traits. The cumulative effect of such differences will need to be considered when hatcheries are used to restore depressed populations of Chinook salmon.
Schroder et al 2010	Behavior and Breeding Success of Wild and First-Generation Hatchery Male Spring Chinook Salmon Spawning in an Artificial Stream Yakima/Klickitat Fisheries Project Monitoring and Evaluation Annual Report 2006 Performance Period: May 1, 2006-April 30, 2007 U.S. Department of Energy Bonneville Power Administration Division of Fish and Wildlife	Wild males exhibited higher attack rates and greater social dominance than did hatchery males. However, the observed inequalities in agonism and dominance appeared to be largely caused by differences in body weight between the two types of males: wild males were, on average, 9% heavier than hatchery males. Wild and hatchery males did not differ in the frequency of courting behaviors or in the number of mates. Pedigree analyses based on DNA showed that hatchery and wild males had comparable breeding success values. Consequently, a single generation of hatchery exposure appeared to have a low effect on spring Chinook salmon male breeding success in our experimental setting.
Scott,R.J. et al (2005)	Nest site selection and spawning by captive bred Atlantic salmon, Salmo salar, in a natural stream. Environmental Biology of Fishes, 74	Compared to random locations in the stream, the nest sites chosen were lower in the relative abundance of sediment size classes that are detrimental to embryo and juvenile survival. In addition, the process of nest construction by these captive bred fish further reduced the proportions of these detrimental sediments. Although captive breeding may have changed some aspects of the nest site

		selection and construction behaviour, it has not caused a complete loss or major alteration of the trait and thus does not preclude hatchery fish from restoration or reintroduction programs.
Sharma,R. et al (2006)	An evaluation of the Clearwater River supplementation program in western Washington. Canadian Journal of Fisheries and Aquatic Sciences, 63(2): 423-437.	The study, initiated in 1984, involves the collection of natural origin brood stock, rearing in a combination of hatchery and natural environments, and volitional releases, combined with marking and sampling of natural origin fish. Primary findings relative to five essential research questions of this study concluded that (*i*) smolts from supplementation returned at a lower rate than natural smolts; (*ii*) the reproductive efficiency (spawner to spawner) of fish taken for supplementation was higher than that for fish allowed to spawn naturally; (*iii*) supplemental fish successfully reproduced and the combined supplemental natural spawning population had a high productivity; (*iv*) supplementation did not appear to have affected the overall reproductive performance of the population for the duration of the project; and (*v*) supplementation increased the overall spawner return on the Clearwater River and is required to maximize adult production, unless conditions in both freshwater and ocean environments are optimal.
Sharpe,C.S. et al (2010)	Natural Reproductive Success of First-generation Hatchery Steelhead Spawning in the Kalama River: A Progress Report. Washington Department of Fish and Wildlife, Fish Program, Fish Science Division. 'Natural Reproductive Success of First-generation Hatchery Steelhead Spawning in the Kalama River:A Progress Report' **Steelhead trout**	We did not detect a difference in reproductive success of the wild broodstock hatchery spawners: the proportions of offspring from Hatchery × Hatchery (HH), Hatchery × Wild (HW), and Wild × Wild (WW) spawners closely approximated the proportions expected under the null hypothesis with reproductive success of hatchery spawners equal to that of wild spawners. Reproductive success of first-generation wild broodstock hatchery fish appeared to be similar to that of wild fish in the first replicate of our experiment.

Small,M.P. et al (2009)	Impacts of supplementation: genetic diversity in supplemented and unsupplemented populations of summer chum salmon (Oncorhynchus keta) in Puget Sound (Washington, USA) *Canadian Journal of Fisheries and Aquatic Sciences*, 2009, 66(8): 1216-1229, 10.1139/F09-068 **Chum salmon**	In supplementation programs, hatcheries employ wild-origin fish as brood stock and their offspring are allowed into wild spawning areas. Resource managers use supplementation to support imperiled salmonid populations, seeking to increase census size and possibly effective population size (N_e), while minimizing risks of genetic diversity loss and domestication from hatchery intervention. In most supplemented subpopulations, we detected no effects on diversity and N_e, but high variance in individual pairwise relatedness values indicated over-representation of family groups. In two subpopulations, hatchery impacts (decreased diversity and lower N_e) were confounded with extreme bottlenecks. Rebounds in census sizes in all subpopulations suggest that general survivorship has improved and that possible hatchery effects on genetic diversity will be overcome.
Snow,C. et al 2012	Monitoring the Reproductive Success of Naturally Spawning Hatchery- and Natural-Origin Steelhead in a Tributary of the Methow River Annual Progress Report for the Period: 1 August 2010 – 31July 2011. U.S. Department of Energy ,Bonneville Power Administration ,Division of Fish and Wildlife Portland OR Project Number: 2010-033-00 **Steelhead trout**	Juvenile samples were assigned a single parent (30.7%), two parents (38.4%), or no parents (30.9%). Of the single-parent assignments, most (66.1%) were assigned the maternal parent. Hatchery- and natural-origin mothers produced similar numbers of offspring (hatchery = 4.6 offspring per female; natural = 5.2 offspring per female). Hatchery males appeared to produce fewer offspring than natural-origin males (hatchery = 3.0 offspring per male; natural = 7.2 offspring per male). Although a slight difference was detected in the reproductive success of hatchery- and naturally-produced fish as measured by juveniles produced, this project is designed to evaluate reproductive success over multiple generations. These preliminary results are similar in some respects to those of other steelhead reproductive success studies, but drawing any major conclusions at this time would be premature.
Spidle,A.P. et al (2001)	Fine-scale population structure in Atlantic salmon from Maine's Penobscot River drainage. *Conservation*	We report a survey of microsatellite DNA variation in Atlantic salmon from the unimpounded lower reaches of Maine's Penobscot River. Our analysis indicates that Atlantic salmon in the Penobscot River are distinct from other populations

	Genetics, **2**, 11-24. **Atlantic salmon**	that have little or no history of human-mediated repopulation. Significant heterogeneity was detected in allele frequency among all three subpopulations sampled in the Penobscot drainage. The degree of population structure identified in the Penobscot drainage is noteworthy in light of its lengthy history of systematic restocking, the geographic proximity of the subpopulations, and the extent of the differentiation. Similar population structure on this extremely limited geographic scale could exist among Atlantic salmon runs elsewhere in Maine and throughout the species' range and should be taken into account for future management decisions.
Spidle,A.P. et al (2003)	Comparison of genetic diversity in the recently founded Connecticut River Atlantic salmon population to that of its primary donor stock, Maine's Penobscot River. Aquaculture 236:253-265 **Atlantic salmon**	Healthy ratios of Ne to N indicate that hatchery production has not resulted in excessive inbreeding to date.
Theriault,V. et al (2010)	Survival and life history characteristics among wild and hatchery coho salmon (*Oncorhyncius kisutch*) returns: how do unfed fry differ from smolt releases? Can. J. Fish. Aquat. Sci. 67, 486-497 **Coho salmon**	The relative reproductive success (RRS) of the fry release strategy to wild spawning was significantly greater for one of two cohorts, whereas the smolt release strategy to wild RRS was significantly greater for both cohorts. Fish released as smolts were significantly smaller upon returning as adults than either those released as unfed fry or wild returns. Mean run timing was also significantly biased towards an earlier run time for hatchery-released fish when compared with the wild component. The incidence of jacking (males maturing at age 2) was greater among fish stocked as smolts than for fish stocked as fry. Differences in survival, RRS, and life history appeared to be the result of hatchery practices and indicated that a fry stocking strategy produced fish more similar to the wild component of the population than to that of fish released as smolts.
Theriault,V. et al (2011)	Reduced reproductive success of hatchery coho salmon in the wild: insights into most likely mechanisms	Thus, we report three lines of evidence pointing to the absence of sexual selection in the hatchery as a contributing mechanism for fitness declines of hatchery fish in the wild

	Molecular Ecology (2011) doi: 10.1111/j.1365-294X.2011.05058.x **Coho salmon**	
Thrower,F.P. (2009)	Effects of a single event of close inbreeding on growthand survival in steelhead Conserv Genet (2009) 10:1299–1307 **Steelhead trout**	The results underscore the potential problems that can arise from using protective culture technologies, including captive broodstocks, to supplement endangered populations, and they highlight the genetic hazards that can be faced by small wild populations. This study demonstrates that high natural mortality or selection increases the amount of inbreeding depression detected in survival. Inbreeding effects on survival and growth in captivity can be poor indicators of survival and growth in a wild marine environment.
Tymchuk et al 2006	Growth and behavioral consequences of introgression of a domesticated aquaculture genotype into a native strain of coho salmon. Transactions of the American Fisheries Society 135:442-455. **Coho salmon**	As phenotypic differences between strains are largely a consequence of additive gene action, the phenotypic effects of domestication are largely diluted within two generations of backcrossing to wild salmon
Unwin 1997	Fry-to-adult survival of natural and hatchery-produced chinook salmon (Oncorhynchus tshawytscha) from a common origin *Canadian Journal of Fisheries and Aquatic Sciences*, 1997, 54(6): 1246-1254, 10.1139/f97-032	Survival rates for hatchery fish were four times higher than for naturally produced fry, but were extremely poor relative to their size at release. Survival rates for fish of natural and hatchery origin were positively correlated, suggesting that recruitment of both stocks is primarily controlled by common influences within the marine environment, probably during the first winter at sea
Van Cramon-Traubadel,N. et al (2005)	Determination of body shape variation in Irish hatchery-reared and wild Atlantic salmon. J.Fish Biol. 66:1471-1482	Rearing conditions had a significant impact on the production and growth of body shape. Th si turn may have affected adaptability and survivorship of ranched Atlantic salmon in the marine environment.

	Atlantic salmon	
Vandoornik,D.M. et al (2010)	The effect of a supplementation program on the genetic and life history characteristics of an *Oncorhynchus mykiss* population. Canadian Journal of Fisheries and Aquatic Sciences, 67(9): 1449-1458 **Steelhead trout**	We found that supplementation did not cause substantial changes in the genetic diversity or effective size of the population, most likely because a large proportion of all of the steelhead redds in the river each year were sampled to create the supplementation broodstock. Our data also showed that the captively reared fish released as adults successfully produced parr. Furthermore, we found that during supplementation, there was an increase in the proportion of *O. mykiss* with anadromous ancestry vs. resident ancestry.
Van Doornik,D.M. et al (2011)	Genetic Monitoring Reveals Genetic Stability within and among Threatened Chinook Salmon Populations in the Salmon River, Idaho. North American Journal of Fisheries Management 31:96-105.	Populations that had been supplemented with hatchery-reared fish showed genetic similarity to the within-basin hatchery source population, presumably because of the extensive use of native fish for hatchery brood stocks and minimal out-of-basin stock transfers.
Van Poorten, B.T. et al (2011)	Social-ecological interactions, management panaceas, and the future of wild fish populations. PNAS. 'Social-ecological interactions, management panaceas, and the future of wild fish populations' **Review**	The net result (of fish introductions) will be the preservation of a renewable resource through user-based incentives, but the once natural populations are likely to be altered and to host non-native genotypes.
Vasemaegi,A. et al (2001)	Identification of the origin of an Atlantic salmon (*Salmo salar* L.) population in a recently recolonized river in the Baltic Sea. *Molecular Ecology*, **10**, 2877-2882. **Atlantic salmon**	The founder event in a recently recolonized salmon population in the Baltic Sea (Gulf of Finland) was investigated. The results of assignment tests and factorial correspondence analysis suggest that the initial recolonizers of the river Selja originated from the geographically nearest (7 km) wild population (river Kunda) but as the result of stocking activities, interbreeding between recolonizers and hatchery individuals has occurred in subsequent years. Although the hatchery releases are outnumbering the wild salmon recruitment in the Baltic Sea at present, our results suggest that the native populations may still have an

		important role in colonization processes of the former salmon rivers.
Verspoor E. (1988)	Reduced genetic variability in first-generation hatchery populations of Atlantic salmon (*Salmo salar*). *Canadian Journal of Fisheries and Aquatic Sciences*, **45**, 1686-1690. **Atlantic salmon**	Levels of genetic variation were measured in first-generation Atlantic salmon (*Salmo salar*) cultured for stock enhancement programs in eastern Canada and compared with variation in wild stocks. One regulatory and 19 structural protein loci were screened of which 10 were polymorphic. Mean heterozygosity and number of alleles per locus were positively correlated with the effective number of adults (N) used to establish the hatchery groups and averaged 26 and 12% lower, respectively, than wild stocks. The observations are consistent with a loss of genetic variability in the hatchery salmon from random drift caused by using small numbers of salmon for broodstock.
Wang,J. and Ryman, N. (2001)	Genetic Effects of Multiple Generations of Supportive Breeding Conservation Biology Volume 15, Issue 6, pages 1619–1631 **Review**	Numerical examples indicate that supportive breeding, when carried out successfully over multiple generations, may increase not only the census but also the effective size of the supported population as a whole. If supportive breeding does not result in a substantial and continuous increase of the census size of the breeding population, however, it might be genetically harmful because of elevated rates of inbreeding and genetic drift.
Wang,S. et al (2001)	Salmonid inbreeding: a review Springer Link- ‘Reviews in Fish Biology and Fisheries’ 2001, Volume 11, Issue 4, pp 301-319 **Review**	We identify several sources of inbreeding in salmonids. Although inbreeding occurs naturally, much of the evidence for inbreeding stems from direct or indirect results of human activity. The potential consequences of inbreeding highlight the importance of maintaining genetic diversity in salmonid populations. Our weak understanding of genetic interactions between cultured and wild salmonids has allowed widespread practices that can reduce genetic variability in natural populations. Although studies have detected inbreeding depression in salmonids, its genetic basis has rarely been addressed in wild, anadromous salmon. The genetic basis of inbreeding depression is complex, and evaluating its effects over the entire lifecycle remains challenging. The experimental evidence nevertheless reinforces the importance of maintaining genetic variation within populations as a primary goal of conservation and management.
Wares,J.P. et al (2004)	A genetic perspective on management recovery of federally endangered trout (*Oncorhyncus*	Population managed for 80 years including hatychery propogation following strict mating protocols. Multilocus assessment of 19 populations strongly indicates that

	gilae) in the American Southwest. Can J. Fish. Aquat. Sci. 61: 1890-1899 (2004) **O. gilae**	management has maintained the genetic integrity of this species whilst restoring each species to a number of historically occupied streams.
Wertheimer,A.C. and Smoker,W.W. (2001)	A Review of the Hatchery Programs for Pink Salmon in Prince William Sound and Kodiak Island, Alaska. Transactions of the American Fisheries Society 130:712–720, 2001 **Pink salmon**	Pink salmon catches in PWS are currently at historic highs, averaging 27 million fish per year over the past decade. Over 85% of the harvest is from a system of large hatcheries. We, however, find compelling evidence that hatchery fish have greatly increased the total pink salmon harvest in PWS. Hatchery fish are not responsible for the apparent declines in wild fish escapement.
Whitlock, R. et al (2013)	A systematic review of phenotypic responses to between-population outbreeding. Env. Evidence 2:13 **Various animal and plant spp**	The translocation of plants or animals between populations has been used in conservation to reinforce populations of threatened species, and may be used in the future to buffer species' ranges from the anticipated effects of environmental change. This population admixture can result in outbreeding, and the resulting "hybrid" offspring can be either fitter (heterosis) or less fit (outbreeding depression) than their parents. Outbreeding depression has the potential to undermine conservation plans that mix populations of declining or threatened species.
Winfield IJ, Fletcher JM, James BJ. 2008.	A review of recent research and translocation activities concerned with the gwyniad of Llyn Tegid. CCW Contract Science Report No. 840. **Gwyniad**	Reviews the gwyniad translocation project. [various other reports are available on this subject]
Young, K.A. (2013)	The balancing act of captive breeding programmes: salmon stocking and angler catch statistics Fish Mgmt. Ecol. 2013 doi.10.1111/fme.12032 **Atlantic salmon**	For stocked rivers, there was no evidence for a generally positive relationship between annual stocking efforts and catch statistics. Those rivers for which stocking appeared to improve annual rod catches tended to have lower than expected mean rod catches. The results suggest the damage inflicted on wild salmon populations by stocking is not balanced by detectable benefits to rod fisheries.
Youngson,A.F. et al	Management of salmonid fisheries in	The evidence for structuring of Atlantic salmon (Salmo salar) and brown trout

(2003)	the British Isles: towards a practical approach based on population genetics. *Fisheries Research*, **62**, 193-209. **Atlantic salmon**	(Salmo trutta) into distinct reproductive populations and for genetic differentiation and local adaptation is compelling. The effect of genetic variation among populations is demonstrably a factor determining the economic value of salmonid fisheries in the British Isles. Genetic considerations are, therefore, a matter of self-interest for fisheries managers and a shared interest with those advocating more general approaches to the conservation of diversity and variation. The local population is the basic unit of production and, therefore, the preferred unit of management. However, salmonid populations are numerous and many are small. These factors limit practical possibilities for management at the population level. We suggest that this difficulty can be addressed by combining populations in fisheries-biased management units that comprise interchangeable, nested groupings of populations that are both genetically and biologically meaningful. This population-based approach addresses the necessity of managing the fisheries in ways that are consistent with the conservation of adaptive potential in relation to the dynamic aspects of populations, their capacity to respond to changing environmental conditions, and the likelihood that salmonids will remain a worthwhile resource for the future.
Van Doornik,D.M. (2010)	The effect of a supplementation program on the genetic and life history characteristics of an *Oncorhynchus mykiss* population Can. J. Fish. Aquat. Sci. 67: 1449–1458 **Steelhead trout**	We found that supplementation did not cause substantial changes in the genetic diversity or effective size of the population, most likely because a large proportion of all of the steelhead redds in the river each year were sampled to create the supplementation broodstock. Our data also showed that the captively reared fish released as adults successfully produced parr. Furthermore, we found that during supplementation, there was an increase in the proportion of *O. mykiss* with anadromous ancestry vs. resident ancestry.
Van Doornik,D.M. et al (2013)	Genetic Monitoring of Threatened Chinook Salmon Populations: Estimating Introgression of Nonnative Hatchery Stocks and Temporal Genetic Changes North American Journal of Fisheries Management Volume 33, Issue 4, DOI:10.1080/02755947.2013.790861 **Chinook salmon**	We found that introgression from the Rapid River Hatchery stock was particularly noticeable in the early 1990s but that it appears to have had a substantial effect on only two of the native populations (Lookingglass Creek and the upper Grande Ronde River) despite the ample opportunities for introgression to occur. All seven of the native populations sampled have maintained their levels of within-population genetic diversity throughout the sampling period. Overall, this region's supplementation efforts appear to have had a minimal effect on the genetic diversity of its Chinook Salmon populations.

OBSERVATIONS AND RESULTS FROM SCOTTISH DISTRICT SALMON BOARDS AND DEPT. AGRICULTURE NORTHERN IRELAND		
Dee Bulletin (2011)	Hatchery Stocking Assessment	Planting hatchery reared salmon into Dess burn above the waterfall has had little impact on smolt production, returning adult numbers and therefore on Dee rod catches. Although high densities of hatchery fry were found in some years, survival rates of these fish in their first year are very low, resulting in the low (or zero) parr densities found. Hatchery fry were stocked into habitat comparable to habitat in the burn below the waterfall, yet densities of wild parr are much higher below the waterfall. The poor survival of hatchery fry stocked above the waterfall may be due to a loss/reduction of their 'natural' behaviours during their hatchery-rearing. This can include behaviours involved in obtaining food, avoiding predators and interacting with other salmon (e.g. defending territories); all affect growth and survival of the fish once released into the wild. Furthermore, stocking fry out into the wild at high densities leads to high mortality rates due to stresses on feeding and use of habitat.
Don District Salmon Fishery Board (2012)	Open letter to fishery interests	The DDSFB received the evaluation 2 weeks ago. The evaluation concluded that the current rehabilitation type stocking should cease indefinitely and that any future stocking programmes undergo a strict assessment in terms of the criteria identified in ASFB/RAFTS policy. It is without doubt that the hatchery, which opened in the mid 60's, has played a pivotal role in the survival of salmon and sea trout stocks in the Don. With the success of the FMP, we are now confident that nature can do the job itself but it does need some help from us. To this end, the Board staff will embark on removal of many debris blockages and man-made obstacles and I encourage all proprietors to help the Don achieve a 90% Catch and Release target.
Rosell,R. (2000) Department of Agriculture and Rural development for	Habitat Enhancement Workshop To be held in Westport, Co. Mayo, Ireland September 16th - 19th, 2002	Atlantic salmon became extinct in the River Lagan, which enters the Irish Sea through the port of Belfast, Northern Ireland, between 1750 and 1800, the extinction coinciding with a period of major population growth, industrialisation and finally the construction of a navigable waterway based on the river.

Northern Ireland Agricultural and Environmental Science Division, (Aquatic Systems Group	RESTORATION OF A SELF SUSTAINING POPULATION OF SALMON TO THE RIVER LAGAN, BELFAST, NORTHERN IRELAND	From 1950 to 1990, water quality in the river improved as a result of improved sewage treatment, the Lagan Navigation was abandoned and fell into disuse, and many Industrial effluents were diverted to sewer. These changes led to a feasibility study on re-introducing the salmon to the river being considered. In 1991, the first of a series of plantings of unfed fry and smolts sourced from the river Bush hatchery took place. The first adult salmon returned to the Lagan in 1993. Since 1993, experimental stocking has continued, with annual planting of fry, leaving some areas unstocked each year to look for progeny of natural spawning activity. Adult runs have risen to hundreds each year with an increasing Lagan bred wild component. One tributary has not been stocked since 1997 and has had two generations of wild spawned fish. The best year for returns to date was 2000 when an estimated 800 fish ascended the Lagan, almost reaching the provisional spawning target of 1000 fish. An estimated 200 of these 800 were wild-bred fish.
Spey District Salmon Fishery Board:- Coulson et al (2013)	The use of genetic parentage analysis to assess hatchery contribution of Atlantic salmon on the River Spey Prepared as part of the Focusing Atlantic Salmon Management on Populations (FASMOP) Project	**Conclusion** Clearly, the effectiveness of Atlantic salmon stocking is variable and case-dependent. The characteristics of the catchment and river system being stocked, the origin of the broodstock used and the life stages of the juveniles or ova released or planted can all influence the effectiveness of such operations. This study demonstrates a limited contribution to the rod catch from stocking on the River Spey through the use of genetic parentage analysis. It also highlights the important contribution made by keeping detailed breeding records and broodstock genetic samples in order to allow the subsequent confirmation of genetic parentage results. Regardless of the reasons or practices employed in stocking operations, there is a clear benefit for taking genetic samples from broodstock fish in order to investigate the efficacy of the hatchery contribution in subsequent years. The results of this analysis will allow further consideration and review of hatchery management and stocking practices and activities undertaken by the Spey Salmon Fishery Board and Spey Foundation to take place. These reviews can take place on

		an increasingly informed basis having applied robust genetic analysis of the hatchery work to compliment other monitoring results and alongside other relevant considerations. These considerations are now able to review the biological contribution of the hatchery to the rod catch.
Tay District Salmon Fisheries Board (2011)	Frequently asked questions No.2 Could smolt stocking achieve similar results for the Tay as Iceland?	When smolts which had been reared in the wild in the River Braan were microtagged the recapture rate in Tay estuary nets was 5.14% compared to the 0.153% for hatchery smolts.
Tweed Foundation (2014 website) (NB – permission to reproduce this text currently being sought)	FREQUENTLY ASKED QUESTIONS ABOUT THE TWEED 1: Hatcheries & Salmon Management on the R. Tweed.	If there is a problem that is reducing fish stocks (over-fishing; poor habitat; restricted access; estuary pollution) then these cannot be solved by stocking. Stocking treats only the symptoms (lack of fish) not the underlying cause(s). In fact, stocking makes things worse because it uses up money that could otherwise be used to solve the real, underlying causes of problems. On the Tweed, we spend our money on: (1) the actual causes of problems, not on just treating symptoms. (2) finding out how the salmon populations of the catchment “work” in terms of numbers of adults and juveniles; distribution and quality of nursery areas; ages; run-timings etc. at this time of good catches, so if something does go wrong in future, it will be apparent where the problem is (3) Protecting the habitat of juveniles and making sure access to all parts of the catchment is open. The 19th century belief in the incapability of salmon to reproduce in the wild and the consequent need for artificial stocking has, however, persisted. If hatcheries worked in the real world as well as they “work” in the letters pages of angling magazines, the world would have been swamped with Salmon for the last 150 years!
WYE SALMON ASSOCIATION PAPERS		
Anon (2013)	Case for SNR (semi natural rearing) V.3	A presentation on works undertaken by the Wye Salmon Association and partners.

Anon (2013)	Issues from Hatchery and stocking meeting with Chris Uttley at NRW Offices, Hadnock Rd, Monmouth on 21st Nov 2013	Our project is not just about short term objectives and this headline target must be underpinned by genetic studies.
Tyler,W. et al (2011)	A Review of Semi-Natural Rearing Ponds for implementation on the River Wye catchment. Revision 14	Semi natural rearing [SNR] is different to traditional stocking. It combines the advantages of hatchery technology in achieving high survival to early juveniles with the “real life” experiences of a wild environment which is also protected from natural chance mortality.