

WHAT SCIENCE HAS TO SAY ABOUT THE INTERACTION OF SEA LICE AND WILD FISHES

SOME KEY QUOTATIONS

“Can farmed and wild salmon coexist? A global survey of wild salmon and trout populations reveals substantially reduced survival among those populations that migrate past salmon farms as juveniles on their way to the ocean.”

– Gross, 2008.¹

“The impact of salmon farming on wild salmon and trout is a hotly debated issue in all countries where salmon farms and wild salmon coexist. Studies have clearly shown that escaped farm salmon breed with wild populations to the detriment of the wild stocks, and that diseases and parasites are passed from farm to wild salmon. An understanding of the importance of these impacts at the population level, however, has been lacking [exhaustively addressed by Krkošek *et al.* in subsequent research].” – Ford & Myers, 2008²

“We show that recurrent louse infestations of wild juvenile pink salmon (*Oncorhynchus gorbuscha*), all associated with salmon farms, have depressed wild pink salmon populations and placed them on a trajectory toward rapid local extinction.” – Krkošek *et al.*, 2007³

“In sum, the combined knowledge from the [300] reviewed studies provides evidence of a general and pervasive negative effect of salmon lice on sea trout populations in intensively farmed areas of Ireland, Norway and Scotland.” – Thorstad *et al.*, 2014⁴

- Are salmon farms a significant source of lice? Yes,
- Is there an association between levels of lice on salmon farms and in the surrounding environment? Yes,
- Is there an association between levels of lice on salmon farms and on sea trout? Yes,
- Is there an effect of sea lice on wild trout at the individual level? Yes,
- Is there an effect of sea lice on wild salmon at the population level? Experiments undertaken in Norway and Ireland have shown that sea lice caused a loss of on average 39% of adult salmon recruitment (Krkošek *et al.* in press).

– Marine Scotland Science⁵

Spectacularly contradicted by: “Currently there is no information on the impact of sea lice from aquaculture on wild salmon in Scotland, however, Marine Scotland has started a ten-year programme of research to investigate any potential risk to wild salmon from sea lice in the Scottish coastal environment.” – The Scottish Government⁶

ALL THE REST

“Scottish Salmon and sea trout are under constant threat. We are here to protect them. The problems facing our migratory fish are real, present and increasing. Marine survival for salmon remains at historically low levels – now for every 100 juvenile fish that go to sea, no more than five will return. It is vital that we do everything to ensure that the maximum number of wild smolts leave our rivers and reach the open ocean safely, and that as many returning adults as possible reach their natal rivers.

- Salmon abundance (adults returning to our coasts) is now less than 20% of that seen 50 years ago
- Fish farming is destroying west Highland and Hebridean wild salmon and sea trout stocks and iconic sea trout fisheries ...” – Salmon & Trout Association⁷

“There is overwhelming scientific evidence that salmon farms pose a threat to wild salmon and sea trout. Salmon are currently farmed in open-net cages, which mean that only the netting separates farmed fish from wild. This allows parasites, disease, waste products and pesticides to flow freely into the wild and impact wild fish. And many fish farms are located close to estuaries important for wild salmon and sea trout, making interaction between farmed and wild fish inevitable.” – Salmon & Trout Association⁸

“Salmon farming industry figures reveal Scottish regions where sea-lice are out of control on fish-farms salmon & trout association (Scotland) demands answers of SSPO and Scottish government. In June 2013 over one third of salmon farms (47

¹ Gross, L. (2008). Can Farmed and Wild Salmon Coexist? *PLoS Biol* 6(2): e46. doi:10.1371/journal.pbio.0060046 <http://journals.plos.org/plosbiology/article/file?id=10.1371/journal.pbio.0060046&type=printable>

² Ford, J. S. & Myers, R. A. (2008). A global assessment of salmon aquaculture impacts on wild salmonids. *PLoS Biol* 6(2): e33. doi:10.1371/journal.pbio.0060033 <http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.0060033>

³ Krkošek, M., Ford, S.J., Morton, A., Lele, S., Myers, R.A. & Lewis, M.A. (2007). Declining Wild Salmon Populations in Relation to Parasites from Farm Salmon. *Science*, 318(5857): 1772-1775.

⁴ Thorstad, E.B., Todd, C.D., Bjørn, P.A., Gargan, P.G., Vollset, K.W., Halttunen, E., Kålås, S., Uglem, I., Berg, M. & Finstad, B. 2014. Effects of salmon lice on sea trout - a literature review. NINA Report 1044, 1-162. <http://www.fisheriesireland.ie/fisheries-research-1/459-effects-of-salmon-lice-on-sea-trout-a-literature-review-nina-report-1044-september-2014>

⁵ <http://www.gov.scot/Topics/marine/Salmon-Trout-Coarse/Freshwater/Research/Aqint/troutandlice> In full from page 3 of this document.

⁶ <http://www.gov.scot/Topics/marine/Salmon-Trout-Coarse/Freshwater/Research/Aqint/seallice>

⁷ <http://www.salmon-troutscotland.org>

⁸ <http://www.standupforwildsalmon.org/Problems.html>

farms) on the Scottish mainland and in the Hebrides were in areas where average sea-lice numbers exceeded the industry's own limit for sea lice. In each of the previous five months at least one quarter (35 farms) were in this category.” – Salmon & Trout Association⁹

“Just what is the issue with sea lice? As they migrate to sea, juvenile wild salmon and sea trout enter bays and sea lochs containing salmon farms that produce an abundance of juvenile sea lice many orders of magnitude above natural background levels. Young fish are not equipped to cope with sea lice and numerous studies have shown that high lice burdens can prove fatal. A recent exhaustive study¹⁰ concluded that lice were responsible for ‘a 39 per cent loss in salmon abundance’.” – Salmon & Trout Association (Scotland)¹¹

“The parasitic crustaceans were probably acquired during early marine migration in areas that host large aquaculture populations of domesticated salmon, which elevate local abundances of ectoparasitic copepods –particularly *Lepeophtheirus salmonis* [sea lice]. These results provide experimental evidence from a large marine ecosystem that parasites can have large impacts on fish recruitment, fisheries and conservation.” – Krkošek *et al.*, 2012¹²

“A wealth of scientific evidence points to a clear link between salmon farms and adverse impacts on wild salmon and sea trout, both from the transfer of disease and parasites, especially sea lice, and the interbreeding of escaped farmed salmon with wild stocks, thus potentially endangering gene pools. All initiatives over the last two decades to promote dialogue between wild fish interests and the fish farming industry have produced almost nothing of value to protect wild fish from farming impact. Consequently there has been a marked and disproportionate decline in rod catches in the west Highlands and Islands compared to the rest of Scotland.” – Salmon & Trout Association (Scotland)¹³

“A 10-week study in the Broughton Archipelago found sea lice were 8.8 times more abundant on wild fish near farms holding adult salmon and 5.0 times more abundant on wild fish near farms holding smolts than in areas distant from salmon farms. Sea lice abundance was near zero in all areas without salmon farms. The evidence from this control–impact study points to a relationship between salmon farms and sea lice on adjacent, wild, juvenile salmon.” – Morton *et al.*, 2004¹⁴

“Marine salmon farming has been correlated with parasitic sea lice infestations and concurrent declines of wild salmonids.” – Krkošek, Lewis & Volpe, 2005¹⁵

“We show that recurrent louse infestations of wild juvenile pink salmon (*Oncorhynchus gorbuscha*), all associated with salmon farms, have depressed wild pink salmon populations and placed them on a trajectory toward rapid local extinction.” – Krkošek *et al.*, 2007¹⁶

“Wild salmon stocks in Canadian coastal waters are being severely affected by parasites from fish farms. So intense are these infestations that some populations of salmon are at risk of extinction.” – Andrew A. Rosenberg, 2008¹⁷

“Fishes farmed in sea pens may become infested by parasites from wild fishes and in turn become point sources for parasites. Sea lice are the most significant parasitic pathogen in salmon farming in Europe and the Americas, are estimated to cost the world industry €300 million a year and may also be pathogenic to wild fishes under natural conditions.” – Mark J. Costello, 2009¹⁸

SALMON “The parasitic crustaceans were probably acquired during early marine migration in areas that host large aquaculture populations of domesticated salmon ...” – Krkošek *et al.*, 2012¹⁹

Full reference list (aquaculture vs sea lice) from the Krkošek lab:

<http://s3.spanglefish.com/s/35331/documents/krkosek-lab-publications.pdf>

SEA TROUT “Based on the reviewed studies, it can be concluded that salmon farming increases the abundance of lice in marine habitats and that, despite the control measures routinely applied by the salmon aquaculture industry, salmon lice in intensively farmed areas have negatively impacted wild sea trout populations by reducing growth and increasing marine mortality.” – Thorstad *et al.*, 2014²⁰

⁹ http://www.salmon-trout.org/news_item.asp?news_id=275

¹⁰ Krkošek *et al.*, 2012.

¹¹ http://www.salmon-troutscotland.org/fish_farming.asp

¹² Krkošek, M., Revie, C.W., Gargan, P.G., Skilbrei, O.T., Finstad, B & Todd, C.D. (2012). Impact of parasites on salmon recruitment in the Northeast Atlantic Ocean. *Proceedings of the Royal Society Biological Sciences*, 280(1750): 20122359.

<http://rsob.royalsocietypublishing.org/content/280/1750/20122359.full.pdf>

¹³ http://www.salmon-troutscotland.org/fish_farming.asp

¹⁴ Morton, A., Routledge, R., Peet, C. & Ladwig, A. (2004). Sea lice (*Lepeophtheirus salmonis*) infection rates on juvenile pink (*Oncorhynchus gorbuscha*) and chum (*Oncorhynchus keta*) salmon in the nearshore marine environment of British Columbia, Canada. *Canadian Journal of Fisheries and Aquatic Sciences*, 61: 147–157.

¹⁵ Krkošek, Lewis, M.A. and Volpe, J.P. (2005). Transmission dynamics of parasitic sea lice from farm to wild salmon. *Proceedings of the Royal Society Biological Sciences*, 272(1564): 689–696.

¹⁶ Footnote 3.

¹⁷ Rosenberg, A.A. (2008). The price of lice. *Nature*, 451: 23–24

¹⁸ Costello, M.J. (2009). How sea lice from salmon farms may cause wild salmonid declines in Europe and North America and be a threat to fishes elsewhere. *Proceedings of the Royal Society Biological Sciences*, 276(1672): 3385–3394.

¹⁹ Krkošek, M., Revie, C.W., Gargan, P.G., Skilbrei, O.T., Finstad, B & Todd, C.D. (2012). Impact of parasites on salmon recruitment in the Northeast Atlantic Ocean. *Proceedings of the Royal Society Biological Sciences*, 280(1750): 20122359.

<http://rsob.royalsocietypublishing.org/content/280/1750/20122359.full.pdf>

²⁰ Footnote 4.

The Scottish Government (Marine Scotland Science)

Summary of information relating to impacts of salmon lice from fish farms on wild Scottish sea trout and salmon

The salmon louse is a native parasite that infests both farmed and wild salmonids to the potential detriment of aquaculture and angling interests (Torrissen *et al.* 2013). Recent reviews have considered information concerning interactions between salmon farms and wild salmonids (e.g. Taranger *et al.* 2015; Thorstad *et al.* 2015). Here, the evidence available to assess the likelihood and scale of impact of salmon lice from salmon farms on Scottish wild salmonids is summarised. The aim is not to repeat existing reviews but to focus on key issues relevant to locating fish farms in the Scottish coastal zone.

Are salmon farms a significant source of salmon lice?

Yes, salmon farms have been shown to be a more important contributor than wild fish to the total numbers of salmon lice in the environment (Morton *et al.* 2011; Penston & Davies, 2009).

Is there an association between levels of lice on salmon farms and in the surrounding environment?

Yes, environmental larval lice concentrations relate to local farm lice loads (Penston and Davies 2009). The distribution of lice depends on hydrodynamic conditions and so the relationship may be highly variable at any specific location (Salama *et al.* 2013).

Is there an association between levels of lice on salmon farms and on wild sea trout?

Yes, analysis of data from Norway highlights a significant relationship between infection potential from farms and settlement on wild sea trout (Hellend *et al.* 2015). Data collected throughout the west coast of Scotland shows that the proportion of individual sea trout with sea louse burdens above a level known to cause physiological stress increased with the mean weight of salmon on the nearest fish farm (a measure of where they are in their production cycle), and decreased with distance from that farm (Middlemas *et al.* 2013).

Is there an effect of salmon lice on wild sea trout at the individual level?

Individual wild sea trout sampled on the west coast of Scotland have been shown to have salmon louse infestations above a level known to cause physiological harm (Middlemas *et al.* 2010, 2013).

Is there evidence of an effect of salmon lice on wild sea trout at the population level?

No such direct evidence for a Scottish situation has been published.

An experiment in Norway, comparing survival of anti-lice treated sea trout smolts with non-treated smolts, indicated an increased survival rate of 3.41% over 1.76%, this is about a 50% reduction in the stock returning to the river, suggesting that salmon lice can negatively affect sea trout populations (Skaala *et al.* 2014).

Is there an association between levels of lice on salmon farms and on wild salmon?

No information is available for wild salmon in Scotland. However, an association between lice levels on farms with louse settlement on salmon held short distances away has been noted. However it is inconclusive as to whether it is possible to estimate infection pressure from salmon farms at specific points in time (Pert *et al.* 2014). In Scotland and Norway, salmon lice abundance on farmed fish is lowest in early spring and peaks during autumn, (Jansen *et al.* 2012; Murray 2016a). This seasonal change in lice infestation levels is comparable to those observed on wild salmonids in Norway (Serra-Llinares *et al.* 2014).

Is there an effect of salmon lice on wild salmon at the individual level?

No information is available for Scotland.

Is there an effect of salmon lice on wild salmon at the population level?

Declines in catches of wild salmon have been steeper on the Scottish west coast than elsewhere in Scotland and Norway (Vøllestad *et al.* 2009) although the authors stressed that this did not prove a causative link with aquaculture. Ford & Myers (2008) compared indices of salmon abundance on the East and West coasts of Scotland together with farm production data. They found a reduction in the catches and counts of salmon on the west coast correlating with increased production of farmed salmon. In addition Butler & Watt (2003) showed that rivers with farms had significantly lower abundances of juvenile salmon than those without farms.

Experiments comparing survival of smolts treated or untreated with anti-sea lice medicines have shown that sea lice adversely affect certain salmon populations in Norway and Ireland (e.g. Vollset *et al.* 2015). There is a great deal of year-to-year and site-to-site variability in the magnitude of such impacts and the reduction in numbers of returning salmon associated with lice infestations is in the range of 0-39% (Jackson *et al.* 2013; Krkošek *et al.* 2013; Skilbrei *et al.* 2013; Vollset *et al.* 2015). A meta-analysis of all available Norwegian studies showed anti-lice treatment increased returns of adult salmon by an average of 18% (Vollset *et al.* 2015). It is not clear in these studies how much of the estimated impact of lice is due to baseline natural levels in the environment and how much is associated with an additional effect caused by salmon aquaculture.

No information exists on impacts of lice on wild populations of salmon in Scotland. However, the estimated mean effect size of lice seen in other countries is of a similar magnitude to the difference between the aquaculture zone and east coast of

Scotland in the reduction in abundance of wild salmon determined using data from fish counters (Ford & Myers 2008). It is not clear how much of this regional variation may be due to factors besides aquaculture.

Over what distance do farms influence environmental lice levels?

Salmon lice transport modelling in a Scottish system reports that >97.5% of sea lice are transported within 15 km of fish farms (Salama *et al.* 2016). However, site specific factors such as prevailing wind and currents, and local topography can have a large impact on the direction and distance of lice dispersal (Salama *et al.* 2013; Adams *et al.* 2012).

Middlemas *et al.* (2013) found a significant relationship between sea lice infestations on sea trout and the distance to the nearest salmon farm. Infestation levels were highest when sea trout were sampled near to a salmon farm and reduced as the distance to the nearest farm increased. There is considerable scatter around the general relationship found by Middlemas *et al.* (2013) which likely reflects unknown site specific factors and unaccounted fish movements.

Do we understand the dispersal patterns of sea trout and salmon?

Salmon smolts depart rapidly from home rivers but there is no knowledge of their subsequent distribution in relation to the Scottish coast. In general sea trout remain near shore for their first two months at sea and then disperse more widely. There is no understanding of the scale of sea trout dispersal or whether it is uniform in direction relative to the home river (Middlemas *et al.* 2009).

Can fish farmers reduce numbers of lice released into the environment?

There are a number of control strategies that farms can use to reduce salmon lice infestation. These include chemical, physical and biological methods. Historically chemical treatments have been favoured, reduced efficacy of treatments has been documented (Lees *et al.* 2008; Aaen *et al.* 2015) as has increased frequency of treatment (Murray 2016b). This has encouraged alternative control methods to be investigated. One of these is the use of cleaner fish, such as wrasse, as a biological control. These fish are introduced into pens to directly eat lice off salmon (Leclercq *et al.* 2013). This adds an additional method to control sea lice as part of integrated pest management; other methods include functional feeds (Jensen *et al.* 2015), cage design to control salmon's depth (Stein *et al.* 2016), and selective breeding (Gharbi *et al.* 2015).

Summary

Salmon aquaculture can result in elevated numbers of sea lice in open water and hence is likely to increase the infestation potential on wild salmonids. This in turn could have an adverse effect on populations of wild salmonids in some circumstances. The magnitude of any such impact in relation to overall mortality levels is not known for Scotland. However, concerns that there may be a significant impact of aquaculture have been raised due to declines in catches of both salmon and sea trout on the Scottish west coast. There is scientific evidence that individual Scottish sea trout can experience physiological detrimental burdens of salmon lice in areas with salmon aquaculture but the effects on populations in different areas is not known. Scientific evidence from Norway and Ireland indicates that early protection against salmon lice parasitism results in reduced absolute marine mortality, increasing recapture rates of experimental salmon, and reduces the time spent at sea, indicating that salmon lice can influence the population status of wild salmon. Marine Scotland Science has recently commenced a [project to address this data gap for Scottish salmon](#). Further information on this project can be found [online](#) and [details of all references cited](#) are also available.

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