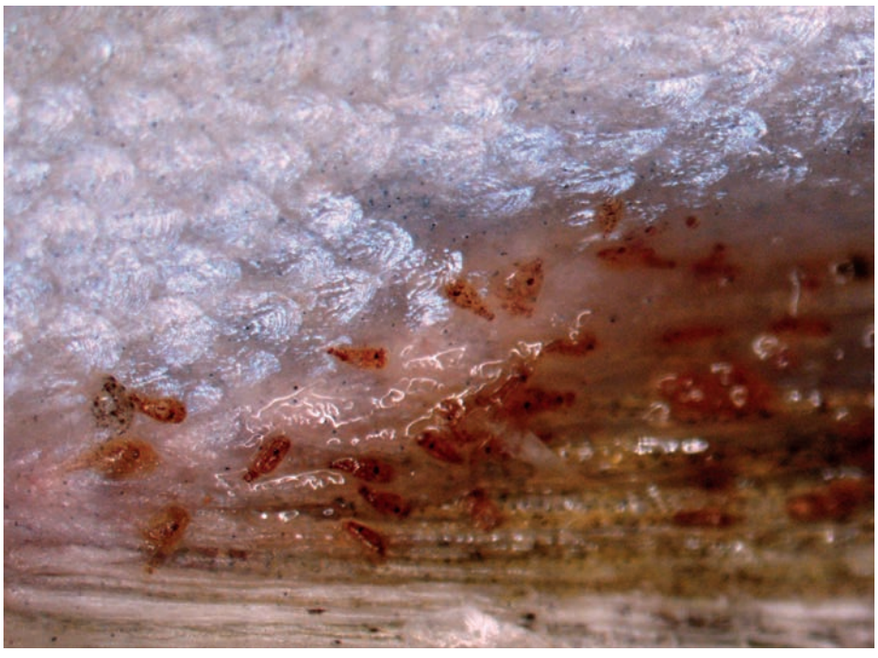
# The impact of sea lice

## A review of recent scientific evidence of the impact of sea lice from salmon farms on wild salmon and sea trout stocks.

DR PADDY GARGAN, INLAND FISHERIES IRELAND

For almost three decades, concern has been raised with regards to the potential impact of sea lice *(Lepeophtheirus salmonis)* from salmon farming on wild salmon and sea trout stocks. In the late 1980s, when salmon farming began to expand, little was known about the potential damage that lice from local salmon farms could cause to wild salmonids. Before the advent of salmon farming, wild fish — primarily spring salmon and some sea trout— returned to native rivers carrying natural levels of lice at the same time as salmon and sea trout smolts migrated to sea in spring, and these smolts encountered low levels of juvenile lice in estuaries. This natural phenomenon was altered dramatically when hundreds of thousands of farmed salmon were reared in estuaries increasing the production of sea lice larvae by orders of magnitude in springtime. Marine salmon farming has expanded significantly over the past two decades, particularly along the west coast of Norway and Scotland, and annual production has now reached 1.3 million tons and 180,000 tons respectively in both countries. The scale of salmon farming has been lower in Ireland with annual production in the range of 12,000 — 30,000 tonnes since the 1990s.

The first evidence of sea lice from marine salmon farms impacting on sea trout stocks occurred in the west of Ireland the late 1980s, when the Connemara sea trout rod catch suffered a collapse, falling from over 7,085 in 1987 to 240 in 1990. In late May 1989, sea trout were observed for the first time in the Delphi River in Connemara with heavy infestations of juvenile sea lice. These sea trout were post-smolts which had recently migrated to sea and had returned prematurely after only two or three weeks, with little or no sea growth on their scales. Similarly, lice-infested post-smolts and some sea trout kelts were recorded returning to rivers in all bays with salmon farming in western Ireland in 1990. At this time there were no regulations in place to limit lice levels on farms, and sampling of lice levels on farms did not begin until 1991. The unregulated proliferation of sea lice from salmon farms increased mortality of sea trout, and resulted in premature return of sea trout to rivers and a collapse in their stock. During the 90s, monitoring of rivers began in Scotland and Norway and similar evidence of heavily lice-infested sea trout and premature return to freshwater was apparent.



The first scientific papers documenting a clear link between lice emanating from salmon farms causing lice infestation on local sea trout stocks were from studies in the west of Ireland in the early 1990s. A large number of scientific papers have since been published on the subject and, in 2015, the Norwegian Institute for Nature Research (NINA) undertook a literature review of the effects of salmon lice on sea trout, examining over 300 scientific publications[1].

The general conclusions of this review show that salmon lice feed on the host fish's mucus, skin and muscle — causing tissue erosion — and laboratory and field studies demonstrated that salmon lice may induce osmoregulatory dysfunction, physiological stress, reduced feeding and growth, increased susceptibility to secondary infections, reduced disease resistance and mortality in individual sea trout. The review found that laboratory studies have demonstrated that infestations of 0.75 lice per gram of fish, or approximately 11 sea lice per fish, can kill a recently emigrated wild salmon smolt of about 15g if all the sea lice develop into pre-adult and adult stages.

Several studies have shown elevated salmon lice levels in wild sea trout adjacent to fish farms, particularly within 30km of the nearest farms. Amongst salmonids, sea trout are especially vulnerable to salmon lice infestation because they typically remain in coastal waters during their marine residence, and coastal waters are the areas where open-net cage Atlantic salmon farms are typically situated. Based on the reviewed studies, the NINA report 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. However, the resulting reduction of wild sea trout populations cannot, in


**Juvenile lice infestation on sea trout pelvic and anal fins**

most cases, be quantified because of a lack of suitably comprehensive field data and studies of population-level effects of salmon lice.

Such studies of population-level effects of lice were possible in a recent long-term study of the impact of a local salmon farm on the Erriff sea trout stock in western Ireland. After the commencement of salmon farming in the local estuary, there were significant decreases in the number and length of sea trout kelts, the estimated number of eggs deposited, the rod catch, the proportion of older fish, and the frequency of repeat spawners. There was also a significant positive relationship between the number of salmon lice on fish in the local salmon farm and the number of lice found on sea trout collected contemporaneously in local rivers. Results of this long-term monitoring programme demonstrated that significant changes in sea trout population structure can occur over a relatively short time period, and indicate that the introduction of salmon farming into the local estuary contributed to the changes in sea trout population observed.

More recently, scientists at the Institute of Marine Research in Norway initiated a risk assessment of Norwegian salmon farming where a salmon lice risk index was developed, that estimates increased sea trout mortality risk due to sea lice infestation. During the period 2010–2013, salmon lice infections — mainly resulting from salmon farming — were estimated at a total of 109 stations along the Norwegian coastline using wild sea trout as a proxy for local infection pressure on wild salmonids. Twenty-seven of these stations indicated moderate or high likelihood of mortality for wild migrating salmon smolts. For wild sea trout later in the season, 67 of the stations indicated moderate or high likelihood of mortality. This lice risk index has recently been applied to Irish and Scottish sea lice data and results reveal levels of lice infestation on sea trout that imply increased mortality risk throughout the 1990s in both countries. Lice loads on sea trout have reduced in recent years, likely reflecting improved lice control and changes in salmon farming practice. Population-level increase in risk of mortality, inferred from lice infestation rate, was estimated for individual sites.

> "The impact of sea lice from marine salmon farming on local sea trout stocks has been extensively studied but it is more difficult to assess the lice impact on salmon."

Results reveal that the likely sea trout population-regulating effect of sea lice varies among locations, with many sites recording lice levels likely to result in strong regulating effects over a prolonged period, particularly in the west of Ireland. The development of this sea lice risk index has allowed, for the first time, an estimate of the impact of salmon farming on the sea trout populations and has clearly shown that lice from farmed salmon can result in population-regulating effects on local sea trout stocks.

The impact of sea lice from marine salmon farming on local sea trout stocks has been extensively studied but it is more difficult to assess the lice impact on salmon. Whereas trout, after migrating to sea, spend long periods feeding in estuaries and coastal waters, salmon smolts migrate through estuaries more quickly to the open sea and offshore feeding grounds. This migration pattern would be expected to reduce sea lice infestation pressure on salmon smolts and result in lower impact, but is difficult to study as they do not return prematurely to freshwater to rid themselves of lice where they can be examined, as is the case with sea trout. Scientists have used hatchery salmon smolts to examine sea lice effects, by comparing survival of smolts chemically protected against sea lice infestation with un-treated control groups released in parallel. Results of these release experiments show that the potential levels of extra mortality attributable to salmon lice in farm-intensive areas is 12—44% fewer in returning adult salmon spawners. The level of increased mortality may depend on the length of estuaries/fjords, the level of lice production from local salmon farms, →

and the exposure time of salmon smolts to lice. Studies of Atlantic salmon likely represent minimum estimates for sea trout mortality at the same sites because salmon smolts migrate quickly through coastal waters and into the open ocean, whereas sea trout remain throughout in coastal or inshore waters.

The impact of sea lice and farm escapes on wild salmon stocks was recently investigated by ICES (the International Council for the Exploration of the Sea). ICES advised that there is substantial and growing evidence that salmon aquaculture activities can affect wild Atlantic salmon through the impacts of sea lice as well as farm escapees. Both factors can reduce the productivity of wild salmon populations, and there is marked temporal and spatial variability in the magnitude of reported effects. In some studies, the impact of sea lice has also been estimated as losses of returning adult salmon to rivers. These estimates indicate marked variability, with losses in individual experiments up to 39%. ICES concluded that these results suggest that sea lice-induced mortality has an impact on Atlantic salmon returns, which may influence the achievement of conservation requirements for affected stocks.

A range of strategies have been implemented on salmon farms aimed at reducing lice levels in spring. These include fallowing of sites in spring, single generation sites where only one year class of salmon are present, whole bay spring fallowing, harvesting carried out remote from the grower sites, annual synchronous 'winter' lice treatment for all adjacent sites. In addition, since the early 1990s, countries have put sea lice threshold levels in place below which lice levels should be maintained on salmon farms. These thresholds are lower in springtime when wild salmon and sea trout are migrating to sea. Sanctions are also in place for breaches of lice threshold levels. Monitoring indicates that lice infestation of wild salmon and sea trout stocks does not occur at every location each year. The level of infestation and potential impact on wild salmonids depends on a wide range of factors, including the stage of production of local farms (smolts or older), lice levels on farms in spring, salinity, temperature, rainfall, wind direction, the length of estuaries/fjords, single or multiple farm sites in estuaries, local topography, etc. There is no doubt that if a combination of factors exist, even in short coastal bays, there is potential for lice from farms to impact out-migrating wild salmonids.

> "An exciting new development being undertaken in northern Norway involves rearing what are called 'super smolts', salmon smolts reared on land in re-circulation systems to a larger size before they are stocked into sea cages."

Despite recent initiatives to reduce lice levels on salmon farms in spring, monitoring indicates that sea lice from salmon farms continue to impact local wild salmon and sea trout stocks at certain locations.

One solution to this ongoing problem would be to have no sea lice impact at the most vulnerable time period in late spring, when wild salmonids migrate to sea. This would require a farm production strategy where large grower fish were harvested before wild smolt runs in spring or where these grower fish had close to zero levels of adult female sea lice. Re-location of existing farms away from important salmon and sea trout rivers is

another possible strategy to reduce lice impact on wild stocks. An exciting new development being undertaken in northern Norway involves rearing what are called 'super smolts', salmon smolts reared on land in re-circulation systems to a larger size before they are stocked into sea cages. By stocking salmon of a larger size into sea cages, this results in a reduction in the duration of the production-cycle at sea by months, and potentially offers huge benefits in terms of sea lice impacts and greater flexibility with regard to timing of stocking sea cages and fallowing periods. It is also likely that the rearing of super smolts could be used as a stepping-stone towards full land-based production.

New developments are ongoing involving closed-containment farms at sea, and development of larger offshore sites. Land-based salmon farming is now believed to be close to being economically viable and a number of large-scale land-based farms have recently gone into production. The continued use of in-feed medical treatment for sea lice has begun to lead to resistance of lice to chemical treatment and there have been reports of treatment failures. This has led to greater use of non-medicinal lice control strategies such as 'cleaner fish' (wrasse and lumpfish) and the use of freshwater treatment for sea lice control.

Scientific work is ongoing to develop sea lice models using hydrodynamic modelling, environmental variables and sea lice production on salmon farms to support sustainable development of aquaculture and wild salmon stocks. These models simulate dispersal of larval sea lice based on farm production, hydrodynamics, water temperature and salinity, and are being used to identify the role of specific salmon farming sites as sources of sea lice. This will support assessment of the carrying capacity of the environment for aquaculture and potential for interaction with wild salmonids. This concept was implemented by the Norwegian Parliament in 2015, who introduced the concept that environmental impact should be the most important determining factor in the future growth of the salmon farming industry. The Parliament decided to use sea lice impacts on wild salmonid populations as the indicator when determining whether or not a salmon farm production area is suitable for an increase in production. A 'traffic light system' is used whereby if the indicator in a production area is green, (<10% of wild salmonids will die due to sea lice infestation) farm salmon production could be increased by 6%, if the indicator is yellow (10% — 30% of wild salmonids will die due to sea lice infestation) then production should remain unchanged; and red (if it is likely that >30% of wild salmonids will die due to sea lice infestation) the farmed salmon production level should be reduced. Monitoring will be done using a model-based system using data on juvenile sea lice emission from all salmon farms in a production area, and this will be related to the risk of unacceptable impacts on wild salmonids.

There is now a large body of scientific studies demonstrating that unregulated sea lice levels on salmon farms, particularly in spring when wild salmonids enter the sea, can lead to increased mortality of salmon and sea trout and impact conservation status. Despite the improvement of sea lice control and the new initiatives aimed at managing sea lice on farms, local salmon and sea trout stocks continue to be impacted at certain locations annually. Greater focus on implementing effective lice-control strategies needs to be implemented, particularly where salmonid stocks are vulnerable.

**Juvenile sea lice infestation on sea trout pelvic fin**

## BIBLIOGRAPHY

*1. Thorstad, E.B., et al. Effects of salmon lice Lepeophtheirus salmonis on wild sea trout Salmo trutta—a literature review. Aquacult Environ Interact Vol. 7: 91–113, 2015. www.int-res.com/articles/aei2015/7/q007p091.pdf.*

*Footnote: The publications below provide recent information on sea lice infestation of sea trout in Ireland and Scotland.*

*Shephard, S., MacIntyre, C., & Gargan, P.G. (2016) Aquaculture and environmental drivers of salmon lice Lepeophtheirus salmonis infestation and body condition in sea trout (Salmo trutta L.). Aquacult Environ Interact. Vol. 8: 597–610, doi: 10.3354/aei00201.*

*Gargan, P.G., Kelly, F.L., Shephard, S., and Whelan, K.F. (2016). Temporal variation in sea trout (Salmo trutta L.) life history traits in the Erriff river, Western Ireland. Aquacult Environ Interact. Vol. 8: 675–689, doi: 10.3354/ aei00211.*

# Action on Sea Lice

## Paul Knight of Salmon & Trout Conservation UK outlines what is being done.

**In 2016, Salmon & Trout Conservation UK made an official complaint to the EU under the Marine Strategy Framework Directive over Scottish Government's failure to regulate marine salmon farming sufficiently to protect wild salmonids. Further pressure was put on Scotland during a Special Aquaculture Session at the 2016 annual meeting of NASCO. Meanwhile, S&TC is challenging supermarkets sourcing farmed salmon from companies with poor sea lice control records – lice being a major danger to wild salmon and sea trout. The ultimate aim is for salmon farming to move to closed containment units, so creating a biological barrier between farmed and wild fish.**