

# Salmon Farms, Sea Lice and Migrating Wild Salmonids

## Introduction

This paper supplements the document *Complaint to the Commission of the European Communities on the Government of Ireland's failure to comply with Community law as regards the Habitats Directive and the Environmental Impact Assessment Directive for the species Atlantic Salmon for and on behalf of the Delphi Fishery, the Newport Fishery and the Ballynahinch Fishery*<sup>1</sup> submitted to DG Environment by Salmon Watch Ireland on 9 February 2009.

The extremely negative impact of sea lice (*Lepeophtheirus salmonis*) on migrating juvenile salmonids is well known based on research that originally concentrated on sea trout and more recently on salmon. This paper summarises the extensive research into these issues that has been conducted by scientists in Ireland, Scotland, Norway and Canada and highlights the established measures that can mitigate the negative effects of salmon farming on wild migrating salmonids.

There is a legal obligation by EU member states (including Ireland) to comply with the Habitats Directive. It is clear from this paper that Ireland is failing in its obligation to protect Atlantic salmon (*Salmo salar*) (an Annex II species within the Directive) during their migration to and from their native rivers. An “appropriate assessment” of all possible negative effects on salmon migrating to and from designated salmonid SACs by operations such as salmon farming needs to be carried out during the licensing process to conform with the terms of Article 6 of the Directive.

## Associated Background

Salmon aquaculture began to develop in bays in the West of Ireland in the early 1980's and by the late 1980's approximately 7,000 tonnes of farmed salmon was being produced per annum. Simultaneous with the development of salmon farming in Western bays, heavy sea lice infestation were observed on sea trout returning to rivers.

In 1989, sea trout were first observed in the lower pools of the Delphi Fishery in late May with heavy infestations of juvenile sea lice.<sup>2</sup> Sampling of rivers began in 1990 to determine if this phenomenon was widespread and prematurely returning sea trout post-smolts and some sea trout kelts were recorded in all rivers sampled with infestations of sea lice, predominantly juvenile lice<sup>3</sup> indicating recent transmission.<sup>4</sup>

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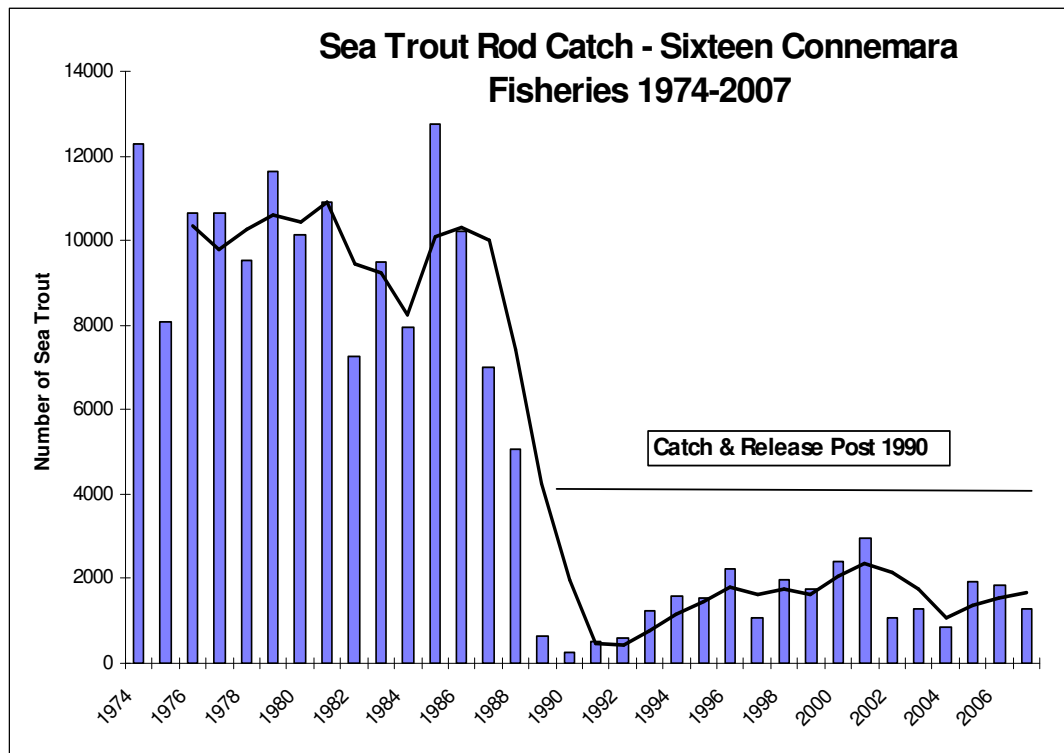
<sup>1</sup> Legal Complaint Reference Number 2006/4652 SG (2006) A/6058

<sup>2</sup> Anonymous (1992) *Report of the Sea Trout Working Group, 1991*. Department of the Marine, 1-49, Dublin.

<sup>3</sup> Anonymous (1992) *Report of the Sea Trout Working Group, 1991*. Department of the Marine, 1-49, Dublin.

<sup>4</sup> Tully, O., Poole, W.R., Whelan, K.F. & Merigoux, S. (1993b) *Parameters and possible causes of Lepeophtheirus salmonis (Krøyer) infesting sea trout (Salmo trutta L.) off the west coast of Ireland*. In: Pathogens of Wild and Farmed Fish: Sea Lice (eds. G.A. Boxhall & D. Defaye), pp. 202-213. Ellis Horwood, Chichester, UK.

The occurrence of heavy sea lice infestation on sea trout in rivers entering aquaculture bays in the west in the late 1980's also coincided with a sea trout stock collapse in these rivers. Annual sea trout rod catches for the period 1985 to 2003 for twenty two western fisheries display an overall trend for the period of catches decreasing until 1988, followed by a stock collapse in 1989/1990.<sup>5 6</sup> The rod catch of the sixteen rivers of the Connemara District, which constitutes a large proportion of the Western region (Fig.1), fell from an average of 9,570 sea trout over the 1974 - 1988 periods to 646 sea trout in 1989 and 240 sea trout in 1990. The history of the Western sea trout stock collapse and subsequent events has been well documented.<sup>7 8 9</sup>



**Figure 1.** Sea Trout Rod Catch, Sixteen Connemara Fisheries, 1974 – 2007.

Salmon aquaculture also developed in Donegal and in Kerry by the late 1980's. In the early 1990's premature returning lice infested sea trout were also recorded in rivers entering salmon aquaculture bays in Donegal and south Kerry.<sup>10</sup>

<sup>5</sup> Anonymous (1995) *Report of the Sea Trout Working Group, 1994*. Department of the Marine, 1-254, Dublin.

<sup>6</sup> Gargan, P.G., Poole, W.R., & Forde, G. (2004a) *A Review of the Status of Irish Sea Trout Stocks*. In: *Sea Trout: Biology, Conservation and Management* (eds. G.S. Harris & N.J. Milner). pp. 25-44. News Books, Blackwells Scientific Publications, Oxford.

<sup>7</sup> Poole, W.R., Whelan, K.F., Dillane, M.G., Cooke, D.J. & Matthews, M. (1996) *The performance of sea trout, Salmo trutta L., stocks from the Burrishoole system western Ireland, 1970-1994*. *Fisheries Management and Ecology* 3 (1), 73-92.

<sup>8</sup> Whelan, K.F. (1993) *Historic overview of the sea trout collapse in the west of Ireland*. In: *Aquaculture in Ireland - towards sustainability* (ed. J. Meldon). pp.51-53. Proceedings of a Conference held at Furbo, Co. Galway. 30th April - 1 May, 1993. An Taisce, Dublin.

<sup>9</sup> Gargan, P.G. (2000) *The impact of the salmon louse (Lepeophtheirus salmonis) on wild salmonids in Europe and recommendations for effective management of sea lice on marine salmon farms*. In: *Aquaculture and the Protection of Wild Salmon* (eds P. Gallagher & C. Orr). pp. 37-46. Workshop Proceedings, July 2000, Simon Fraser University, Vancouver, British Columbia, Canada.

<sup>10</sup> Tully, O., Gargan, P., Poole, W.R. & Whelan, K.F. (1999) *Spatial and temporal variation in*

Salmon rod catch data for a number of western rivers has also shown large reductions in one sea winter (grilse) catches one year after high sea lice levels on nearby marine salmon farms suggesting a link between salmon smolt migration and an impact from sea lice infestation on marine survival. The annual salmon catch on the Ballynahinch River in Connemara dropped from 328 in 1989 to 23 in 1990 coinciding with the development of salmon farming in its estuary and the collapse of its sea trout stocks.

### **The Relationship between Salmon Farms, Wild Salmonids and Sea Lice Infestation**

The sea louse, *Lepeophtheirus salmonis*, is an obligate parasite of salmonids; hence, sympatric fishes that are not salmonids cannot be the cause of *L. salmonis* epidemics on wild salmon and sea trout.

Tully and Whelan<sup>11</sup> studied the production of nauplii (larvae) of *L. salmonis* from farmed salmon and wild sources and its relation to infestation of wild sea trout off the west coast of Ireland. The study concluded that at least 95% of sea lice emanated from farmed salmon. Similar results have been found in Scotland<sup>12</sup> and Norway.<sup>13</sup> Tully *et al.*<sup>14</sup> have demonstrated that the presence of salmon farms significantly increased the level of sea lice infestation on sea trout post-smolts. Again, similar findings have been reported from Norway<sup>15</sup> and Scotland.<sup>16 17</sup>

Gargan *et al.*<sup>18</sup> discovered a significant relationship between the number of ovigerous lice (farmed and wild) in Killary Harbour and Clew Bay and the mean abundance of lice on sea trout over a period 1992-2001 (Fig.2). Such evidence makes it imperative that sea lice monitoring takes into account the total number of fish in each bay (farmed and wild) when controlling lice levels. This system has been recommended

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*the infestation of sea trout (Salmo trutta L.) by the caligid copepod Lepeophtheirus salmonis (Kroyer) in relation to sources of infection in Ireland. Parasitology* **119**, 41-51.

<sup>11</sup> Tully, O. & Whelan, K.F. (1993) *Production of nauplii of Lepeophtheirus salmonis (Kroyer) (copepoda: caligidae) from farmed and wild Atlantic salmon (Salmo salar L) on the west coast of Ireland during 1991 and its relation to infestation levels on wild sea trout (Salmo trutta L).* Fisheries Research **17**, 187-200.

<sup>12</sup> Butler, J.R.A. (2002) *Wild salmonids and sea louse infestations on the west coast of Scotland: sources of infection and implications for the management of marine salmon farms.* Pest Management Science **58**, 595-608.

<sup>13</sup> Heuch, P.A. & Mo, T.A. (2001) *A model of salmon louse production in Norway: Effects of increasing salmon production and public management measures.* Diseases of Aquatic Organisms **45**, 145-152.

<sup>14</sup> Tully, O., Gargan, P., Poole, W.R. & Whelan, K.F. (1999) *Spatial and temporal variation in the infestation of sea trout (Salmo trutta L.) by the caligid copepod Lepeophtheirus salmonis (Kroyer) in relation to sources of infection in Ireland.* Parasitology **119**, 41-51.

<sup>15</sup> Grimnes, A., Finstad, B. & Bjørn, P.A. (2000) *Registrations of salmon lice on Atlantic salmon, sea trout and Arctic charr in 1999.* NINA Oppdragsmelding **634**, 1-34, Trondheim.

<sup>16</sup> MacKenzie, K., Longshaw, M., Begg, G.S. & McVicar, A.H. (1998) *Sea lice (Copepoda: Caligidae) on wild sea trout (Salmo trutta L.) in Scotland.* ICES Journal of Marine Science **55**, 151-162.

<sup>17</sup> Butler, J.R.A. (2002) *Wild salmonids and sea louse infestations on the west coast of Scotland: sources of infection and implications for the management of marine salmon farms.* Pest Management Science **58**, 595-608.

<sup>18</sup> Gargan, P.G., Tully, O., & Poole, W.R. (2003) *The Relationship Between Sea Lice Infestation, Sea Lice Production and Sea Trout Survival in Ireland, 1992-2001.* In: Salmon on the Edge (ed D. Mills), 119-135. Blackwell Science, Oxford.

by the North Atlantic salmon farming industry and NASCO Liaison Group (ATF(09)5)

In Scotland, the early results of plankton surveys of larval sea lice showed peaks in abundances that coincided with the second year of salmon production in local farms, and a virtual absence of larvae during the first year of production.<sup>19 20</sup> Subsequent surveys affirmed the established “on-off” biennial pattern and showed consistently that copepodids (juveniles) were more widely dispersed in the sealoch (fjord) than nauplii (larvae) and that the greatest abundances of nauplii were found adjacent to the farm cages.<sup>21 22</sup>

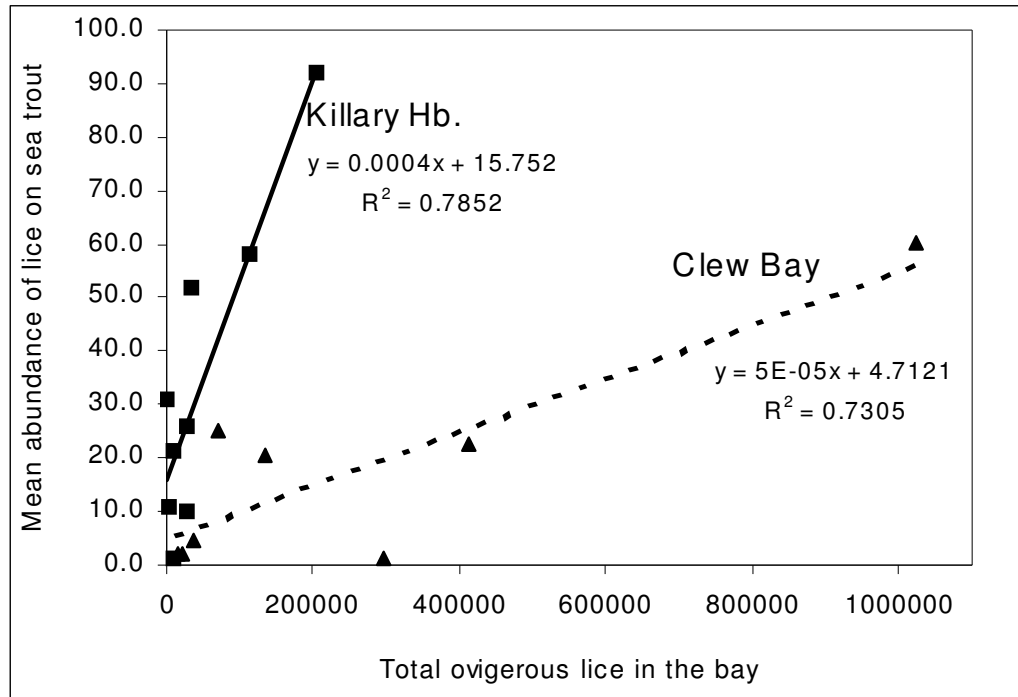


Figure 2. Relationship between the number of ovigerous lice (farmed and wild) in Killary Harbour and Clew Bay and the mean abundance of lice on sea trout, 1992-2001. (Gargan et al. 2003)

Wells et al.<sup>23</sup> have concluded that 13 preadult/adult lice per fish was the critical

<sup>19</sup> McKibben, M.A. & Hay, D.W. (2004) Distributions of planktonic lice larvae *Lepeophtheirus salmonis* in the inter-tidal zone in Loch Torridon, Western Scotland in relation to salmon farm production cycles. *Aquaculture Research* **35**, 742-750.

<sup>20</sup> Penston, M.J., McKibben, M., Hay, D.W. & Gillibrand, P.A. (2004) Observations on openwater densities of sea lice larvae in Loch Shieldaig, Western Scotland. *Aquaculture Research* **35**, 793-805.

<sup>21</sup> Penston, M.J., Millar, C.P. & Davies, I.M. (2008a) Reduced *Lepeophtheirus salmonis* larval abundance in a sea loch on the west coast of Scotland between 2002 and 2006. *Diseases of Aquatic Organisms* **81**, 109-117.

<sup>22</sup> Penston, M.J., Millar, C.P., Zuur, A. & Davies, I.M. (2008b) Spatial and temporal distribution of *Lepeophtheirus salmonis* (Krøyer) larvae in a sea loch containing Atlantic salmon, *Salmo salar* L., farms on the north-west coast of Scotland. *Journal of Fish Diseases* **31**, 361-371.

<sup>23</sup> Wells, A., Grierson, C.E., MacKenzie, M., Russon, I.J., Reinardy, H., Middlemiss, C., Bjørn, P., Finstad, B., Wendelaar Bonga, S.E., Todd C.D. & Hazon, N. (2006) The physiological effects of simultaneous, abrupt seawater entry and sea lice (*Lepeophtheirus salmonis*) infestation of wild, sea-run brown trout (*Salmo trutta*) smolts. *Canadian Journal of Fisheries and Aquatic Sciences* **63**, 2809-2821.

abundance, which induced sub-lethal stress responses in post smolt sea trout. In an earlier study Bjørn & Finstad<sup>24</sup> had shown that infection intensities above 90 juvenile salmon lice or 50 pre-adult/adult lice may result in mortality of small sea trout post smolts (60 gram). Based on this evidence a critical level of less than 10 mobile lice per fish is considered to be imperative for the survival of juvenile sea trout in their first year.

In areas with sea lice epidemics, lice have been implicated in the mortality of 48-86% of wild salmon smolts.<sup>25</sup> Given the presence of a significant source of sea lice infestation from marine salmon farms, increased mortality of salmon smolts can be expected where sea lice levels are not maintained at near zero levels in spring (immediately prior to and during the salmon smolt migration to sea).

Studies of the lethal limits of sea lice for Atlantic salmon have shown that over 30 chalimus larvae (juvenile lice) can kill a 40 g salmon post smolt once the larvae have developed into the pre-adult stages and that only 11.3 chalimus larvae may have a detrimental effect on a wild smolt of 15 g.<sup>26</sup> This has also been shown by Holst *et al.*<sup>27</sup> where more than 3000 wild salmon smolts were examined for lice, but no fish carrying more than 10 adult lice was found. Wagner *et al.*<sup>28 29</sup> investigated sub-lethal levels of salmon lice on adult Atlantic salmon and found that the swimming performance of salmon was significantly reduced in fish with higher salmon lice numbers, thus impairing the salmon's ability to return to its native river.

In Norway, where the impacts of salmon farming on migrating wild salmon and trout is recognised by the government, a number of National Salmon Fjords have been created where no salmon farming is permitted. Initial reports from Norway relating to the National Fjords by Bjørn *et al.*<sup>30</sup> suggest that it is necessary to both reduce even further the lice level on each farmed fish and to optimise delousing strategies if the management aim of less than 10 lice per wild sea trout and even lower levels on Atlantic salmon postsmolts,<sup>31 32</sup> and thus no negative effects, is to be achieved.

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<sup>24</sup> Bjørn, P.A & Finstad, B. (1997) *The physiological effects of salmon lice infection on sea trout post smolts*. Nordic Journal of Freshwater Research **73**, 60-72.

<sup>25</sup> Holst, J.C. & Jakobsen, P.J. (1998) *Dødelighet hos utvandrende postsmolt av laks som følge av lakselusinfeksjon (Mortality in Atlantic salmon postsmolts due to salmon lice infections)*. Fiskets Gang **8**, 13-15.

<sup>26</sup> Finstad, B., Bjørn, P.A., Grimnes, A. & Hvidsten, N.A. (2000) *Laboratory and field investigations of salmon lice (Lepeophtheirus salmonis, Krøyer) infestation on Atlantic salmon (Salmo salar L.) post-smolts*. Aquaculture Research **31**, 795-803.

<sup>27</sup> Holst, J.C., Jakobsen, P., Nilsen, F., Holm, M., Asplin, L. & Aure, J. (2003) *Mortality of seaward-migrating post-smolts of Atlantic salmon due to salmon lice infection in Norwegian salmon stocks*. In: Salmon at the edge (ed D. Mills), 136-137. Blackwell Science, Oxford.

<sup>28</sup> Wagner, G.N., McKinley, R.S., Bjørn, P.A. & Finstad, B. (2003) *Physiological impact of sea lice on swimming performance of Atlantic salmon*. Journal of Fish Biology **62**, 1000- 1009.

<sup>29</sup> Wagner, G. N., McKinley, R.S., Bjørn, P.A., & Finstad, B. (2004) *Short-term freshwater exposure benefits sea lice-infected Atlantic salmon*. Journal of Fish Biology **64**, 1593- 1604.

<sup>30</sup> Bjørn, P.A., Finstad, B., Nilsen, R., Asplin, L., Uglem, I., Skaala, Ø., Boxaspen, K.K. & Øverland, T. (2008) *Nasjonal overvåking av lakselusinfeksjon på ville bestander av laks, sjøørret og sjørøye i forbindelse med nasjonale laksevassdrag og laksefjorder (Norwegian national surveillance of salmon lice epidemics on wild Atlantic salmon, sea trout and Arctic char in connection with Norwegian national salmon rivers and fjords)*. NINA Rapport **377**, 1-33, Trondheim.

<sup>31</sup> Finstad, B., Bjørn, P.A., Grimnes, A. & Hvidsten, N.A. (2000) *Laboratory and field investigations of salmon lice (Lepeophtheirus salmonis, Krøyer) infestation on Atlantic salmon (Salmo salar L.) post-smolts*. Aquaculture Research **31**, 795-803.

<sup>32</sup> Heuch, P.A., Bjørn, P.A., Finstad, B., Holst, J.C., Asplin, L. & Nilsen, F. (2005) *A review of*

## Studies into the Effect of Sea Lice on Migrating Wild Salmon

Preliminary data supporting a possible link between salmon farms and wild salmon declines in Ireland became available when survey netting for sea trout in Killary Harbour recorded salmon smolts with low numbers of juvenile sea lice,<sup>33</sup> the first record of sea lice on salmon smolt in Ireland. This salmon smolt phenomenon was slower to emerge than that of the sea trout because, whereas affected sea trout have a tendency to return to their native river once they are infected, salmon appear in the main to attempt to continue their migration and the impact becomes evident from higher mortality levels at sea.

The first Irish study to investigate the potential impact of sea lice from marine salmon farms on migrating salmon smolts in three aquaculture bays in the Western region<sup>34</sup> took place over the 2003 – 2005 period. Release of treated and control groups of hatchery-reared salmon smolts into aquaculture bays allowed assessment of the efficacy of the Slice® treatment to be tested. Results from the study reveal a significant difference in the return rate of Slice®-treated and control salmon smolts in six of the eight release groups. These data suggest reduced mortality of smolts in the treated groups and hence protection from sea lice infestation in aquaculture bays. (Obviously such treatment is not possible in the case of wild smolts).

Similar tests to investigate the effects of sea lice on populations of Atlantic salmon have been carried out in Norway where individually tagged salmon and sea trout smolts have been protected against sea lice by an in-feed medication (Slice® or bath treatment (Substance EX, Pharmaq). These fish were then released in the vicinity of their native rivers where similar unprotected groups were released simultaneously. Results on Atlantic salmon from Agdenes (middle Norway)<sup>35</sup> and Daleelva (South West Norway)<sup>36</sup> show that in years with high sea lice infection pressure, the returns of protected fish were higher than returns of unprotected control groups. These studies are also supported by Skilbrei & Vennevik<sup>37</sup> showing that in several release experiments with smolts treated with Slice® recapture rates were highest in the treated groups. Further Norwegian studies have been carried out in two rivers with permanent fish traps (Imsa and Talvik). Hazon *et al.*<sup>38</sup> reported that protected fish had a better growth rate than unprotected fish due to this in-feed medication.

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*the Norwegian 'national action plan against salmon lice on salmonids': the effect on wild salmonids.* Aquaculture **246**, 79-92.

<sup>33</sup> Anonymous (2004) *Infestation of sea trout by the salmon louse (Lepeophtheirus salmonis) in Ireland during spring 2004.* Central Fisheries Board, Dublin.

<sup>34</sup> [http://www.cfb.ie/fisheries\\_research/2007/2/lice.htm](http://www.cfb.ie/fisheries_research/2007/2/lice.htm)

<sup>35</sup> Hvidsten, N.A., Finstad, B., Kroglund, F., Johnsen, B.O., Strand, R. & Arnekleiv, J.V. (2007) *Does increased abundance of sea lice influence survival of wild Atlantic salmon postsmolt?* Journal of Fish Biology **71**, 1639-1648.

<sup>36</sup> Finstad, B. & Jonsson, N. (2001) *Factors influencing the yield of smolt releases in Norway.* Nordic Journal of Freshwater Research **75**, 37-55.

<sup>37</sup> Skilbrei, O.T. & Wennevik, V. (2006) *Survival and growth of sea-ranched Atlantic salmon treated against sea lice prior to release.* ICES Journal of Marine Science **63**, 1317-1325.

<sup>38</sup> Hazon, N., Todd, C., Whelan, B., Gargan, P., Finstad, B., Bjørn, P.A., Wendelaar Bonga, S.E. & Kristoffersen, R. (2006) *Sustainable management of interactions between aquaculture and wild salmonid fish.* Final report for the SUMBAWS EU project, 1-293, University of St. Andrews, St. Andrews.

In Canada Krkosek et al.<sup>39</sup> have shown that salmon farm-induced *L. salmonis* infestations of juvenile pink salmon have depressed wild pink salmon populations and may lead to their local extinction. The results from this study suggest that salmon farms can cause parasite outbreaks that erode the capacity of a coastal ecosystem to support wild salmon populations.

### **The Siting and Fallowing of Salmon Farms**

The annual marine monitoring of lice infestation on sea trout in spring was used to examine the relationship between sea lice infestation on sea trout in relation to distance to salmon aquaculture sites for a broad geographic range of Irish rivers.<sup>40</sup> Results revealed highest mean levels of total lice and juvenile lice were recorded at sites less than 20 km from salmon farms (Fig.3). The mean total lice infestation was lower at sites less than 30 km from farms and beyond 30 km, very low mean total lice levels were recorded. Juvenile lice dominated the sea lice population structure at distances <30 km, indicating a localised lice source. At distances <100 km chalimus (juvenile) and post chalimus (pre-adult/adult) stages were equally represented and at sites >100km post chalimus stages predominated (Fig. 4).

This study discovered furthermore that 29% of the infested trout had lice levels above the indicative stress level. For trout sampled in bays without farms, only 3.4% of the infested trout were above the indicative stress level while for fish captured in bays with farms this level rose to 30.8%. This evidence confirms that sea trout were picking up sea lice emanating from local salmon farms.

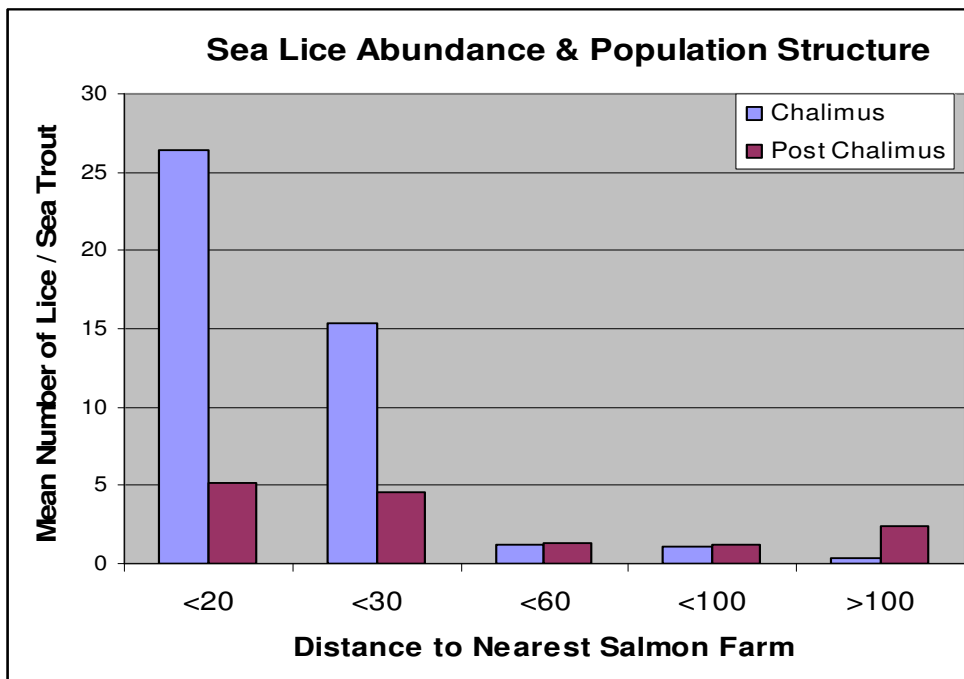
Gargan *et al*<sup>41</sup> also concluded that good sea trout marine survival was associated whole-bay fallowing (the simultaneous fallowing of all sites within the bay) during springtime by adjacent marine salmon farms in Bertraghboy Bay, Connemara. Marine survival returning sea trout was 19% in the year of whole-bay fallowing compared to an average of less than 2% in the ten years where no fallowing took place.

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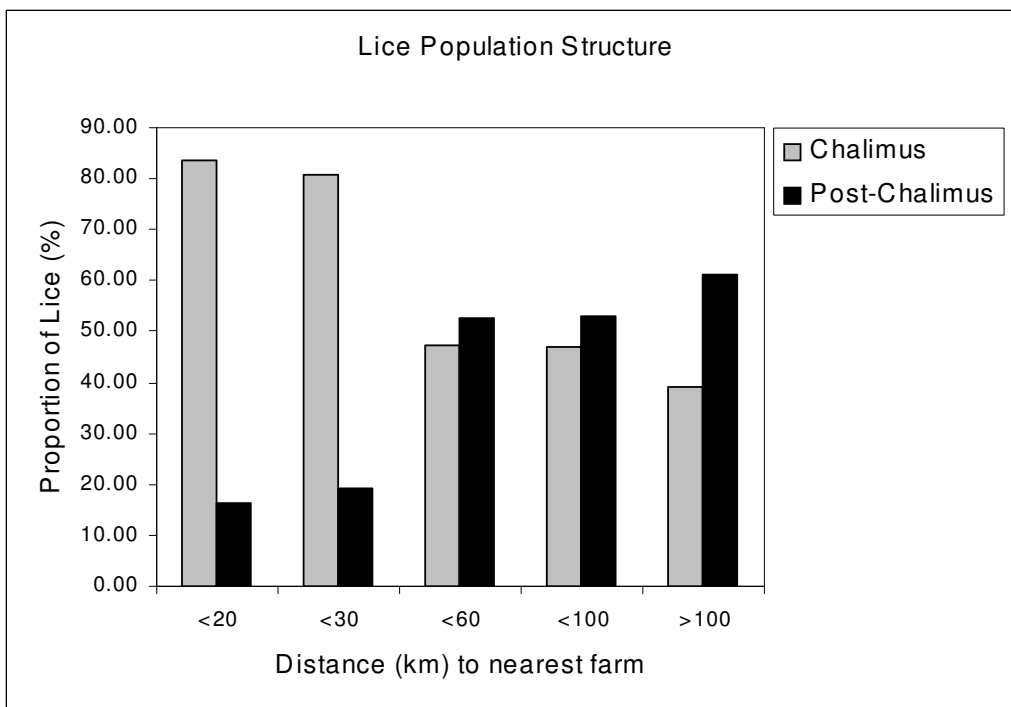
<sup>39</sup> Krkosek, M., J. Ford, A. Morton, S. Lele, R.A. Myers, M. Lewis, 2007. *Declining wild salmon populations in relation to parasites from farm salmon*. Science. **318**, 1772-1775.

<sup>40</sup> Gargan, P.G., Tully, O., & Poole, W.R. (2003) *The Relationship Between Sea Lice Infestation, Sea Lice Production and Sea Trout Survival in Ireland, 1992-2001*. In: Salmon on the Edge (ed D. Mills). pp. 119-135. Blackwell Science, Oxford.

<sup>41</sup> Gargan, P.G., Roche, W.K., Forde, G.P. & Ferguson, A. (2004) *Characteristics of sea trout (Salmo trutta L.) stocks from the Owengowla and Invermore Fisheries, Western Ireland, and Recent Trends in Marine Survival*. In: Sea Trout: Biology, Conservation and Management (eds. G.S. Harris & N.J. Milner). pp. 60-75. Fishing News Books, Blackwells Scientific Publications, Oxford.



**Figure 3.** Mean number of lice juveniles (*chalimus*) and adults (*post-chalimus*) infesting sea trout smolts in relation to distance categories to the nearest farm. (Gargan *et al.* 2003)



**Figure 4.** The proportion of *chalimus* (juveniles) in the lice population infesting sea trout as a function of distance to the nearest farm. (Gargan *et al.* 2003)

In Canada, Krkosek et al.<sup>42</sup> found that sea lice infestation pressure imposed by a single Atlantic salmon farm was four times greater than ambient levels. This resulted in a maximum infection pressure near the farm that was 73 times greater than ambient levels and exceeded ambient levels for 30 km along the two wild salmon migration corridors.

Fraser,<sup>43</sup> in a recent paper having modelled results from the most up-to-date science on the subject concluded that declines in wild salmonids can be avoided only by ensuring that wild fish do not share water with farmed fish, either by locating sea cages very far from wild fish or through the use of closed-containment aquaculture systems.

## **Advice from International Bodies**

### **NASCO Liaison Group:**

The North Atlantic salmon farming industry and the NASCO Liaison Group presented “Guidance on Best Management Practices to address impacts of sea lice and escaped farmed salmon on wild salmon stocks” (ATF(09)5) at NASCO’s annual conference in Norway in 2009.

The report reads that “...(The) most recent NASCO/ICES symposium held in Bergen in 2005 highlighted that sea lice and escapes were identified as continuing challenges both for the industry and the wild stocks and on which further progress was urgently needed. NASCO, therefore, decided that it would establish a Task Force comprising representatives of the Parties, the salmon farming industry and NASCO’s accredited NGOs with the aim of: identifying a series of best practice guidelines and standards to address the impacts of aquaculture on wild salmon stocks; to identify knowledge gaps and research requirements to address them. The guidance provides a range of measures from which those most appropriate to the local conditions should be put into place to safeguard the wild salmon stocks.”

Pertinent recommendations of the report include:

- 100% of farms to have effective sea lice management such that there is no increase in sea lice loads or lice-induced mortality of wild salmonids attributable to the farms.
- Area management, risk-based, integrated pest management (IPM) programmes that meet jurisdictional targets for lice loads at the most vulnerable life-history stage of wild salmonids.
- Lice control management programmes appropriate for the number of farmed salmon in the management area and sampling protocols effective in characterising the lice loads in the farms and wild salmonid populations.
- Monitoring lice loads on wild salmonids in salmon aquaculture areas compared to areas with no salmon farms.
- Research into lice-induced mortality of wild salmonids (e.g. as monitored using sentinel fish, fish-lift trawling, using batches of treated smolts)
- Monitoring of lice levels: in areas with and without farms; before, during and after a farm production cycle; and in plankton samples

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<sup>42</sup> Krkošek, M., Lewis, M.A., and Volpe, J.P. (2005) *Transmission dynamics of parasitic sea lice from farm to wild salmon*. Proceedings of the Royal Society of London [B] 272(1564): 689-696

<sup>43</sup> Fraser, L.N. (2008) *Sea-Cage Aquaculture, Sea Lice, and Declines of Wild Fish*. Conservation Biology, **23**, No. 3., pp. 599-607.

- Single year-class stocking
- Fallowing
- Adaptive management in response to monitoring results to meet the goal

### **Williamsburg Agreement**

In 2003 the NASCO membership, including the members of the salmon farming industry signed the Williamsburg Resolution (CNL(03)57). Excerpts from the agreement are described below.

Article 3, “Burden of Proof” states that: *“Each Party, in accordance with the Precautionary Approach, should require the proponent of an activity covered by this Resolution to provide all information necessary to demonstrate that the proposed activity will not have an adverse impact on wild salmon stocks or lead to irreversible change.”*. This article is similar to the “Appropriate Assessment” required under Article 6(3) of the Habitats Directive

Annex II of the Resolution refers to the *“Siting and Operation of Aquaculture Activities”*. The recommendations (listed below) mirror the conclusions of many of the articles cited in this paper:

- 1 *Salmon aquaculture facilities should only be located where hydrographical, epidemiological, biological and ecological standards can be met. Factors which may be taken into consideration include: availability of water supply and receiving waters for discharge; water quality and exchange; water depth; site protection; separation distances between aquaculture facilities; and distance from salmon rivers. Further guidance on containment is provided in Annex 3.*
- 2 *Consideration should be given to the establishment of “wild salmon protection areas” where salmon aquaculture is restricted or prohibited. Such protection areas may minimise genetic, disease, parasite and environmental impacts.*
- 3 *The designation of “aquaculture regions”, where all the steps in the production process are carried out and which are separated from similar regions by areas without aquaculture, should also be considered. Such regions could provide a framework for management of the aquaculture industry and could assist in controlling the spread of fish diseases and parasites.*

### **Conclusions**

The greatly increased production of sea lice by salmon farms in estuaries and the impact of sea lice infestation on migrating juvenile salmon and sea trout are now well understood. Research across sites in Ireland, Scotland, Norway and Canada is consistent in its findings that salmon farms located close to estuaries and migration routes of wild salmonids have severe deleterious effects on the survival of migrating salmon and trout. Poorly managed salmon farms leading to a further increase in sea lice numbers drastically increases the mortality rate of wild salmonids.

Some of the mitigation measures of sea lice production have been identified and are proven. The document, “*A strategy for improved pest control on Irish salmon farms*”<sup>44</sup> produced by DAFF in 2008 sets out a number of initiatives which need to be addressed to ensure effective sea lice management on Irish salmon farms. However, it is essential that this is accomplished within a regulatory framework that is consistent with the requirements of the Habitats Directive and in particular with the processes set out in Article 6 of the Directive.

Priority must now be given to establishing and implementing the standards of salmon farm management required ensuring that wild stocks are not further adversely impacted. The most effective initiative to protect wild salmonids from lice impacts in salmon aquaculture bays would be to establish wild salmon protection areas (similar to the National Salmon Fjords in Norway) where salmon aquaculture is restricted or prohibited as recommended in the Williamsburg Resolution. Remaining aquaculture areas need to have proper regulations and controls enshrined in law where tougher sanctions are employed for noncompliance. When such measures are implemented, wild salmon and salmon farming will move closer to a more sustainable coexistence.

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<sup>44</sup> Anon, *A strategy for improved pest control on Irish salmon farms*, Department of Agriculture, Fisheries and Food, Dublin (2008).