An Bord Achomhairc Um Cheadúnais Dobharshaothraithe
Aquaculture Licences Appeals Board

Supplemental EIS submission

Salmon Watch Ireland

8 January 2019

OHara, Mary

From: John Murphy <caherdaniel1@gmail.com>
Sent: 08 January 2019 09:14
To: Alab, Info
Subject: Shot Head Appeal AP2/1-14/2015
Attachments: Gargan et al 2017 .pdf

Dear Sir,
Please find attached Gargan 2017 paper for your attention. This effectively demonstrates that the supplementary EIS model is not correct.
Regards

John Murphy
Director Salmon Watch Ireland
Mobile 086 3991074
www.salmon.ie

Sender notified by
Mailtrack

Assessment of the increased mortality risk and population regulating effect of sea lice (*Lepeophtheirus salmonis*) from marine salmon farms on wild sea trout in Ireland and Scotland

P.G. GARGAN[1], S. SHEPHARD[1] & C. MACINTYRE[2].

[1]*Inland Fisheries Ireland, 3044 Lake Drive, City West Business Campus, Dublin 24, Ireland.*
[2]Argyll Fisheries Trust, *Cherry Park, Inveraray PA32 8XE, Scotland.*

ABSTRACT

Infestation of wild sea trout with sea lice from marine salmon farms can result in mortality or premature return to freshwater and drive changes in population structure and population regulating effects. Sea trout with varying levels of sea lice infestation have been sampled in Ireland since 1991 and in Scotland since 1997. These sea trout time series are used to express observed sea lice infestation rates (number of lice per gram body mass (n g^{-1})) at local and national scales in relation to the mortality risk thresholds used to assess potential impacts on wild salmonids from salmon aquaculture in Norway. Analysis of a large international sea trout dataset from Ireland (N = 7,461) and Scotland (N = 16,758) reveals levels of lice infestation on sea trout that imply increased mortality risk in the early years of monitoring 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 or compromised seawater growth or reproduction, inferred from lice infestation rate, was estimated for individual sites. Results reveal that the likely sea trout population regulating effect of sea lice varies among locations; many sites recorded lice levels likely to result in strong regulating effects over a prolonged period, particularly in the west of Ireland. The Norwegian risk assessment framework for marine salmon aquaculture is discussed in relation to the results of lice infestation recorded on sea trout in Ireland and Scotland.

Keywords: sea trout, salmon farms, sea lice, mortality risk, population regulating effect.

INTRODUCTION

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 tonnes and 180,000 tonnes respectively in both countries. The scale of salmon farming has been much lower in Ireland with an estimated annual production in the range of 12-30,000 tons since the 1990's. The development of salmon aquaculture in all three countries coincided with observations of premature return of sea trout (*Salmo trutta*) to freshwater with heavy lice infestation, a marked reduction in sea trout rod catches and changes in sea trout population structure, (Anon., 1995; Birkeland, 1996; Birkeland & Jakobsen, 1997; Butler & Watt, 2002, Gargan *et al.*, 2003, Poole *et al.*, 1996). Soon after lice infested sea trout were observed returning to freshwater in Ireland, sampling of rivers began in 1991 to determine if this phenomenon was widespread; sea trout post-smolts were recorded in all rivers sampled with infestations of sea lice, predominantly juvenile lice, indicating recent transmission (Tully, Poole & Whelan, 1993). Monitoring programmes to assess the level of lice infestation on sea trout began in on the west coast of Scotland in 1997 and along the western coast of Norway in 1992 (Jakobsen *et al.*, 2002).

After migrating to sea, sea trout remain feeding and growing in coastal waters where salmon farms are situated and may therefore be especially vulnerable to salmon lice infestation (Thorstad *et al.*, 2015). Research has shown that in salmon aquaculture bays in springtime the majority of caligid copepod nauplii arise from ovigerous sea lice infesting farmed salmon (Tully & Whelan, 1993; Butler, 2002; Heuch & Mo, 2001). Gargan *et al.*, (2003) demonstrated a statistical relationship between lice infestation on sea trout and distance to the nearest salmon farm over a 10-year period, with highest infestations and variation in infestation seen close to fish farms. A similar relationship for lice infestation and distance to salmon farms was seen in Scottish (Butler & Watt, 2002; Mackenzie *et al.*, 1998) and Norwegian studies (Anon., 1997; Birkeland & Jakobsen, 1997; Bjørn *et al.*, 2001). Middlemas *et al.*, (2013) also demonstrated a link between salmon farms and sea lice burdens on sea trout in the west of Scotland, with the maximum range of effect of lice predicted by a critical threshold model at about 31 km. Gillibrand & Willis (2007) developed a sea lice dispersal model that showed that infective sea lice levels peaked 7–12 km seawards of the source and Serra-Llinares *et al.*, (2014, 2016) also found that wild fish seem unaffected by the direct lice infection pressure imposed by salmon farms at a distance >30km.

Previous studies in all three countries have described the level of lice infestation on sea trout in salmon aquaculture areas (e.g. Tully *et al.*, 1999; Gargan *et al.*, 2003; Birkeland & Jakobsen, 1997; Bjørn *et al.*, 2001; Bjørn & Finstad, 2002, Mackenzie *et al.*, 1998; Urquhart *et al.*, 2010) and some studies have undertaken an assessment of mortality risk of lice infestation. Gargan *et al.*, (2003) calculated the proportion of sea trout with lice loads indicative of causing physiological problems and osmoregulatory disturbances (Bjørn & Finstad, 1997) and found that the proportion of sea trout exceeding this threshold declined with distance from a salmon farm. Middlemas *et al.*, (2013) also developed a critical threshold model to examine the effect on sea trout of lice from salmon farms over a large special scale along the west coast of Scotland and used the critical lice threshold of 13 mobile lice per trout shown in laboratory studies (Wells *et al.*, 2006) to indicate the proportion of trout subject to physiological stress and potential death from sea lice infestation. They found a significant relationship between infestation and distance to the nearest farm, with the probability of sea trout having critical lice burdens being highest close to salmon farms.

More recently, Taranger *et al.*, (2014) developed a range of lice infestation rate indicators causing physiological stress in sea trout, and developed a first generation lice index that estimates increased sea trout mortality risk due to sea lice infestation. A risk spectrum like this provides an excellent context for evaluating both mortality risk and possible fitness impacts of lice infestation. In the present analysis, the effect of sea lice infestation rate of individual sea trout (number of lice per gram body mass (n g^{-1})) at local and national scales is expressed for the first time in relation to the mortality risk thresholds as proposed by Taranger *et al.*, (2014). The sum of the increased mortality risks of individual sea trout in different "*infection classes*" in a sample was then used to calculate a population-level increase in risk of mortality or compromised seawater growth or reproduction (reflecting the distribution of the intensity of salmon lice infections of the different individuals sampled, as described by Taranger *et al.*, 2014). The risk was further scored according to the system proposed by Taranger *et al.* (2012a) for assessment of lice-related increased mortality risk at the population level.

MATERIALS AND METHODS

SAMPLING

Annual monitoring of sea trout, primarily by gill netting in estuaries over the May/June period, was undertaken at 50 locations around the Irish coast over the period 1991-2015 (N= 7,461). A detailed description of the sampling strategy in Ireland is outlined in Gargan *et al.*, (2003). Gargan *et al.*, (2003) included only post-smolt sea trout (<26cm) in their analysis, whereas all sea trout available over the period have been included in the present analysis. The majority of sea trout sampling along the Scottish west coast used sweep nets at sea at 55 locations, primarily during the May/July period over the period 1997-2015 (N= 16,758). A detailed description of the sampling in Scotland is given by Middlemas *et al.*, (2013).

Sea trout lice load is calculated as the number of lice per gram body mass (n g^{-1}) for individual sea trout. There were some missing weight values (notably for Scottish data before 2010). Missing weight values were estimated from log-transformed length-weight relationships from the entire dataset for each country. Taranger *et al.*, (2014) developed a first generation salmon lice risk index based on post-smolt sea trout <150g and larger sea trout >150g. In the entire Irish and Scottish dataset, 83% of sea trout were <150g and so the lice-related mortality risk bands for sea trout <150g are used in the present analysis of the entire dataset. Were the

Taranger *et al.*, (2014) risk bands for sea trout >150g to be applied, the assessment of risk of mortality would apply at a lower lice level.

LICE INFESTATION RATES

The salmon lice risk index (Taranger *et al.* 2012) was applied. This index estimates the increased risk of individual mortality due to salmon lice infection (Table 1). This is referred to as a *"traffic-light system"* for sustainable salmon farming, using quantitative data on sea lice infection on wild salmonids as an indicator metric. The "traffic light system" described here is based on counting lice on salmon farms and modelling total emissions of lice larvae in a geographical area and is used as a warning indicator that predicts the risk of sea lice infestation on wild salmonids. Follow up assessment of sea lice on wild salmon and sea trout are used to verify and calibrate the system.

Table 1. Risk categories of sea lice-related sea trout mortality (number of lice per gram body mass (n g^{-1}) for individual sea trout) from Taranger *et al.*, (2012).

Lice/g sea trout	*Risk Category*	*Lice related sea trout mortality*
>0.3 lice g^{-1}	High	100%
0.2 – 0.3 lice g^{-1}	Medium	50%
0.1 – 0.2 lice g^{-1}	Low	20%
<0.1 lice g^{-1}		0%

The sum of the increased mortalities of individual sea trout for the different "infection classes" in a sample was then used to calculate the population-level increase in mortality risk, or compromised seawater growth and/or reproduction, reflecting the distribution of the intensity of salmon lice infections for the individuals sampled (Taranger *et al.*, (2014). The risk was further scored according to the system proposed by Taranger *et al.*, (2012) to assess lice related increased mortality risk at the population level (Table 2): where there is a) a low probability of having a population regulating effect when <10% of fish have >0.1 lice per gram fish weight, b) an intermediate probability of between 10% – 30% of fish have more than 0.1 lice per gram of weight, and c) a high probability of a negative effect if >30% of the sample have 0.1 lice per gram of fish weight. At individual locations, sample size was N ≥ 3. However, 75% of Scottish samples had a sample size of ≥17 sea trout and 75% of Irish samples had a sample size of ≥ 7 sea trout.

Table 2. Regulating effect of mortality risk to population status at different levels of lice infestation.

Increased Mortality Risk at Population Level	*Population Regulating Effect*
>30%	High
10%-30%	Intermediate
<10%	Low

RESULTS

IRELAND:

Temporal trends in increased sea trout mortality risk.
In order to provide greater insight into lice infestation, the Irish dataset was separated into rivers <30km and >30km from salmon farms. Results show that the increased mortality risk due to salmon lice infections for sea trout within 30km of salmon farms was at the 100% risk level (Taranger *et. al.*, 2014) in every year over the period 1991-2005 except 1994 (Figure 1). The risk of increased mortality decreased over the period 2006-2010 but still remained at the 50% risk level. The lowest recorded risk of increased sea trout mortality was seen in 2011, after which the risk of increased mortality increased again to the 50% level. For sea trout sampled >30km from salmon farms there was no risk of increased mortality due to sea lice infection over the period 1991-2015, albeit with two exceptions when the risk rose to 20% (2002) and 50% (2014). Sampling of Irish rivers distant from salmon farms was generally discontinued in the early 2000's.

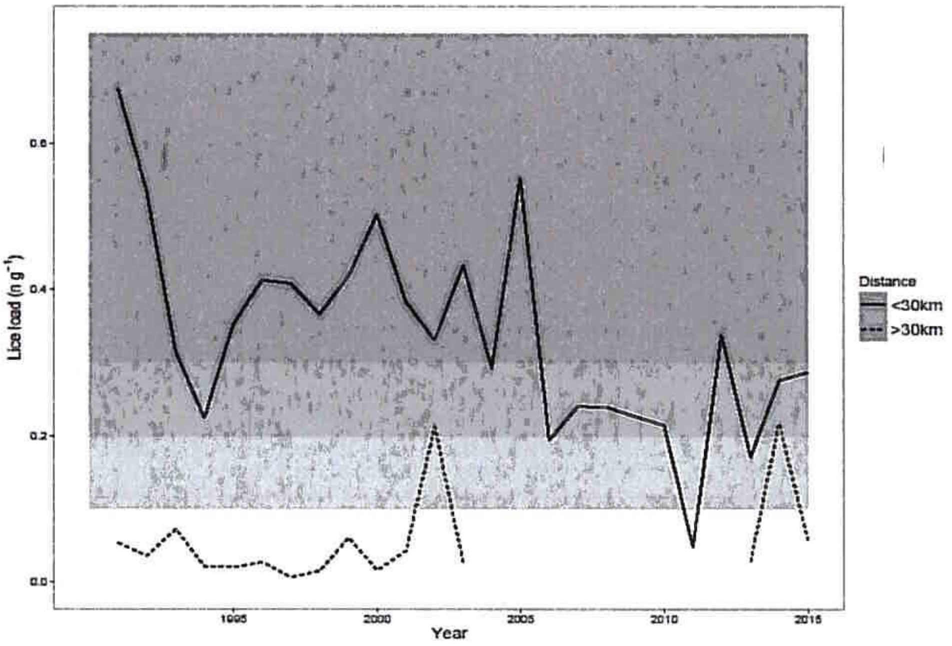


Figure 1. Lice infestation rates for sea trout in Irish rivers close to salmon farms (<30km) and distant from salmon farms (>30km). The risk bands are from Taranger *et al.*, (2014). The clear band is associated with 0% mortality, light grey band with 20% lice-related mortality, the medium grey band with 50% mortality and the dark grey band with 100% mortality.

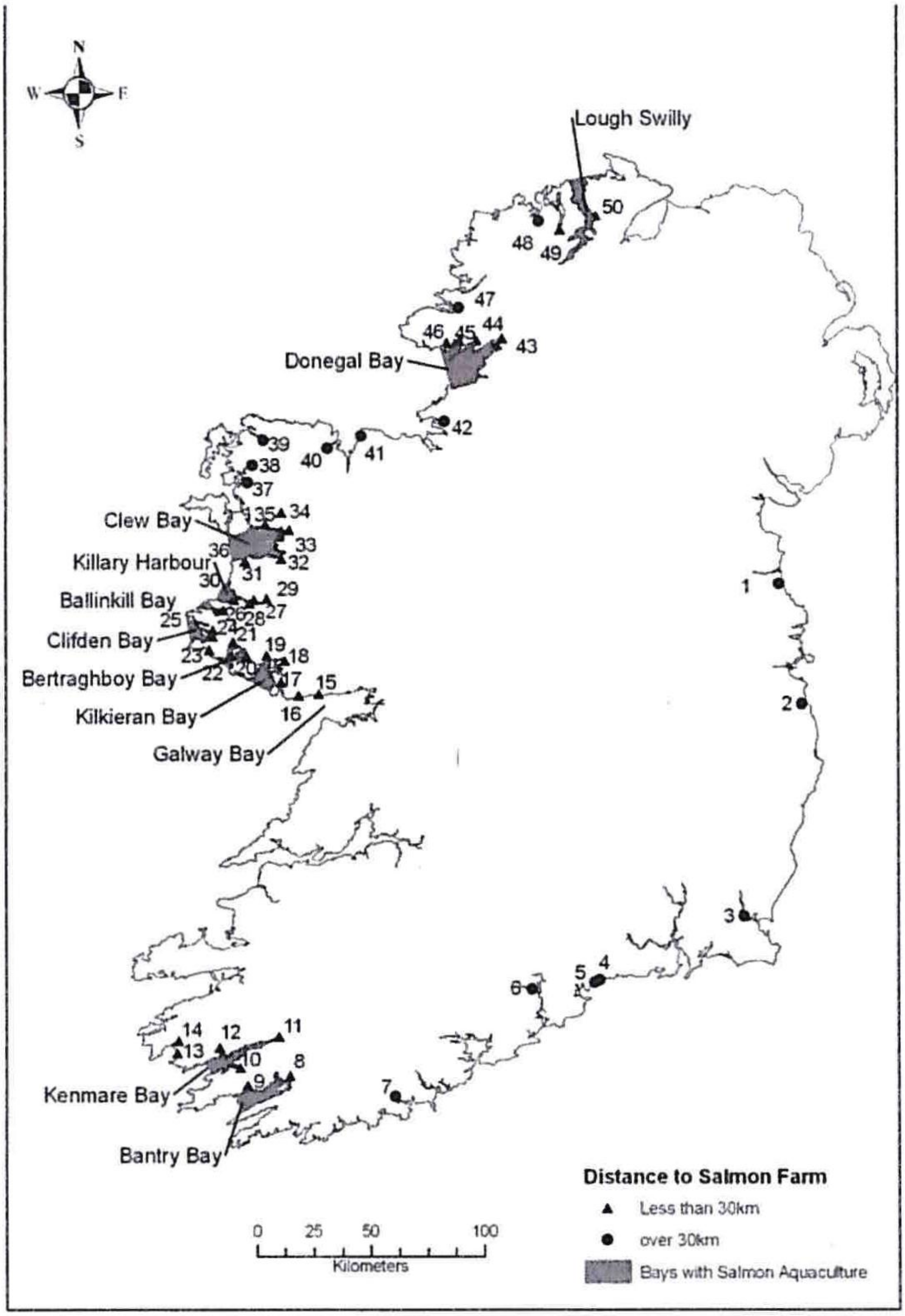


Figure 2. Location of rivers sampled for sea trout around the Irish coast. The general locations of bays with salmon aquaculture are shown.

Table 3. The population-level increase in mortality risk due to salmon lice infections at individual Irish locations. A <10% increase in mortality risk is described as low (= clear), a 10-30% increase in mortality risk is intermediate (= grey) and >30% increase in mortality risk is described as high (= black).

A. Rivers located <30km from salmon farms

Bay	No.	River	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Bantry Bay	8	Coomhola			10			0																			
Bantry Bay	9	Adrigole			50	75	77	0			66																
Kenmare Bay	10	Owenshaugh			82	39	34	64	4		20		75	23		52											
Kenmare Bay	11	Roughty			52	28	1	3	0		1																
Kenmare Bay	12	Sneem			49	39	5	9	0		12		64			8											
Kenmare Bay	13	Currane	64	15	6	1	1		5	0		0															
Kenmare Bay	14	Inny		55	13	6	0			1		0															
Galway Bay	15	Spiddal			39	17	0																				
Galway Bay	16	Crumlin				14	5		33																		
Cashla Bay	17	Costello	44	37	65	0		33	44	33	40	0	0			7			19		0						
Kilkieran Bay	18	Furnace				75	37	80	51	62	73	83	0	18	0												
Kilkieran Bay	19	Invermore			77	94	59	85	82	86	82	95	75		55	11		28	80	67	83		20		25		
Bertraghboy Bay	20	Gowla	83	15	92	20			29	73	76	43	0		40	75	0		66		14					33	
Bertraghboy Bay	21	Ballynahinch	88	7	50				66	80		18				25	8										
Bertraghboy Bay	22	Bertraghboy Bay														90	0										
Bertraghboy Bay	23	Carna			0	38																					
Clifden Bay	24	Ardbear					17	46	67	38	38	23															
Clifden Bay	25	Clifden	55	70		59	0	39	17	16																	
Ballinakill Bay	26	Dawros	60	53	35	29	38	10	46	31	38	18	28	40	19	27	53	16	21	50		69	0		29	56	75
Killary Harbour	27	Killary	67	34				64								30	21	34									100
Killary Harbour	28	Culfin				0	46	89	3	13																	
Killary Harbour	29	Erriff	56		53	25	44	88	38	22	45	37	1		46	15	87	64	32	100			0		12		23
Killary Harbour	30	Delphi			22	12	54	60			100	54			53	65	100			91					44		
Clew Bay	31	Bunowen	33				24	9																			
Clew Bay	32	Belclare	10			6	31																				
Clew Bay	33	Newport		75	0		0			53	44			54		46	72	38	46	34		33			46		
Clew Bay	34	Burrishoole		79						95	0						96										
Clew Bay	35	Owengarve	0	65	75	7	57	40	12	46	32	2				34	54	40	70								
Clew Bay	36	Inner Clew Bay									21																
Donegal Bay	43	Eske			21	0	71	14	16	24	47	19	33	52	35	26			38	29	12	8	0			28	0
Donegal Bay	44	Eany			9	5	32	13	75	45	44	64	49	67	67	8		0	0	14	23	18			0	46	
Donegal Bay	45	Oily			65	6																					
Donegal Bay	46	Stragar			41	1	15																				
Lough Swilly	49	Leannan			15			26	29		0	0	14		43		36	10	7	9	48	5	0	13		36	5
Lough Swilly	50	Crana			33		45	25	61	5	69	30	54	37	52				38	15	85	30	29	53	1	53	7

B. Rivers located >30km from salmon farms

Bay	No.	River	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
East / South Coast	1	Nanny			12																						
East / South Coast	2	Dargle			22		40	24																			
East / South Coast	3	Slaney			0																						
East / South Coast	4	Tay			0		2			0																	
East / South Coast	5	Colligan			0					5	0		5		0												
East / South Coast	6	Bride			0		0																				
East / South Coast	7	Argideen		3	7		0	0	1	4																	
Tullaghan Bay	37	Owenduff					9	10	0		8	1		26	1												
Tullaghan Bay	38	Owenmore		33		0	0		0	1	23	6		0													
North Mayo/Sligo	39	Glenamoy			0					0	0	1															
North Mayo/Sligo	40	Palmerstown			0	0	0	0		0	0																
North Mayo/Sligo	41	Bunree			0																						
North Mayo/Sligo	42	Drumcliffe	8	0	24			0	0		26																
Loughros More Bay	47	Owenea			7	0	0	0	1			0	0		14		0										
Sheep Haven Bay	48	Lackagh			0	0		2	0	0		3															

Increased mortality risk at the population level in individual rivers / bays.

The location of rivers sampled for sea trout lice infestation around the Irish coast is shown in Figure 2. The increased mortality risk due to salmon lice infections at the population level in individual Irish bays is given in Table 3. For Bantry Bay and Kenmore Bay, there was a high risk of sea trout mortality at many sites in the early 1990s. In the south Connemara region, the estimated increase in sea trout mortality due to lice infestation was high for most years in the 1990s in Cashla Bay, Kilkieran Bay and Bertraghboy Bay. From 2000, the increased risk of mortality generally was low in Cashla Bay, and generally alternated between moderate and high for Kilkieran and Bertraghboy Bays. For three bays in north Connemara (Clifden, Ballinakill and Killary), the risk of increased mortality was generally moderate to high over the 1991 to 2000 period, after which the risk of high mortality fluctuated in Ballinakill Bay and remained high in Killary harbour up to 2008. The risk of increased mortality in Clew Bay rivers was generally high for all years. For two bays with salmon aquaculture in Donegal (Donegal Bay and Lough Swilly), risk of increased mortality from lice infection was generally high over the 1995-2002 period after which risk in increased mortality decreased in Donegal Bay. For the rivers sampled in bays distant from salmon aquaculture (East/South coast, Tullaghan Bay, North Mayo/Sligo, Loughros More Bay and Sheep Haven Bay), the risk of increased mortality due to sea lice infestation was predominantly low, with a small number of samples in the intermediate category and two sites in the high risk category. After 2003, sea trout sampling was largely confined to rivers close to salmon farms and the risk of high mortality was generally less evident than during the early period of sampling in the 1990s.

SCOTLAND:

Temporal trends in increased sea trout mortality risk

For the Scottish dataset, there were insufficient rivers located >30km from salmon farms to separate the data as undertaken for the Irish data. The increased mortality risk of sea trout due to salmon lice infections was in the 50-100% risk category (Taranger *et. al.*, 2014) for much of the 1997-2001 period (Figure 3). Over the period 2002-2008, the risk of lice-related sea trout mortality decreased and generally was in the 20% risk category, after which the risk of lice-related mortality further decreased.

Increased mortality risk at the population level in individual rivers/bays.

The locations of sweep netting sites sampled for sea trout on the Scottish west coast are shown in Figure 4. Although the overall risk of mortality to sea trout reduced over time, the data demonstrate that certain areas had moderate to high risk of mortality (Table 4). The estimated increase in mortality at the population level due to lice infestation was generally low to moderate for West Southerland locations (Table 4). For marine sampling locations in Wester Ross, some sweep netting sites (Dondonnell) recorded a high risk of mortality at the population levels for the majority of years while other locations recorded high risk in individual years. Sampling in Skye began only in 2011 and mortality risk varied across all three categories. Locations in Lochaber recorded a varying risk of mortality from lice infection, with Camus na Gaul recording the highest risk of mortality. Marine locations in Argyll exhibited all three categories of increased mortality risk, with a trend towards greater risk in mortality in rivers sampled since 2011. Locations sampled in the Outer Hebrides reflected all three risk categories up to 2010, after which marine netting sites generally were in the low to intermediate risk category.

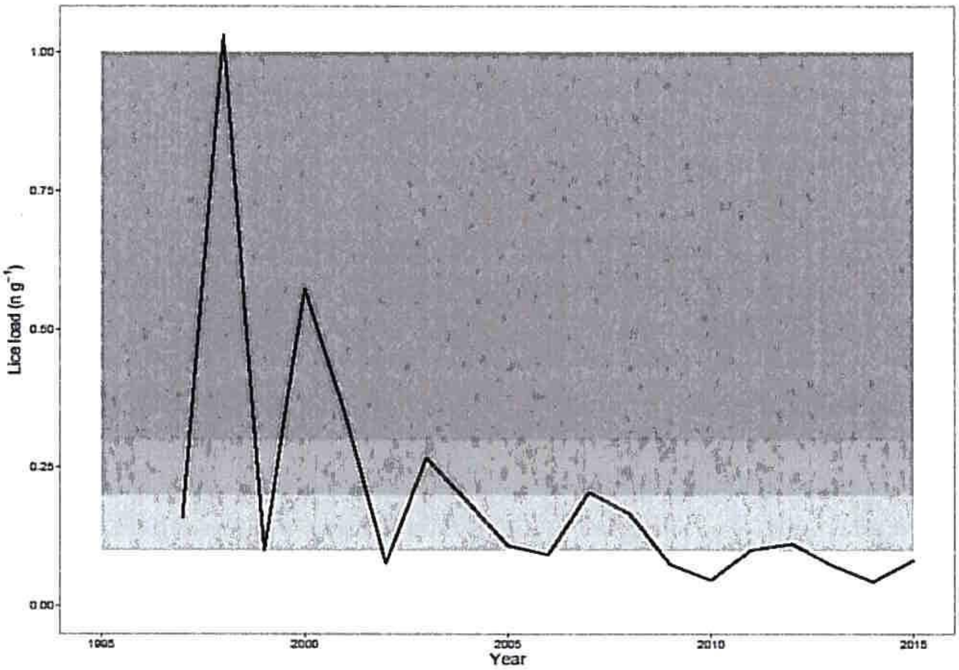


Figure 3. Lice infestation rate for sea trout in Scotland. The risk bands are from Taranger *et al.*, (2014). The clear band is associated with 0% mortality, the light grey band with 20% lice-related mortality, the medium grey band with 50% mortality and the dark grey band with 100% mortality.

DISCUSSION

Analysis of this large Irish data set of sea lice levels on sea trout (N=7,461) over a 25-year period provides evidence of increased mortality risk for sea trout within 30km of salmon farms due to salmon lice infections. This risk of increased mortality was at the 100% level for the first fifteen years of monitoring, though this risk subsequently decreased over the most recent decade. Increased mortality risk, or compromised seawater growth or reproduction, at the population level was recorded at the majority of sites close to salmon farms in Ireland during the early 1990s. Embayments with the highest risk of mortality included Kilkieran Bay, Bertraghboy Bay, Killary harbour and Ballinakill Bay. These findings contrasted with Irish sites sampled for lice infestation >30km from salmon farms, where little risk of increased mortality due to lice infestation was estimated. Gargan *et al*., (2003) also recorded a significant negative relationship between sea trout survival and the level of lice infestation and concluded that it was reasonable to assume that infections of sea lice were a major contributor to increased marine mortality of sea trout observed since the late 1980's in the west of Ireland. This conclusion is supported by the results of the present analysis. Marine survival of Burrishoole sea trout between 1971-1987 ranged from 11.4% to 32.4% (Poole *et al*., 1996). Gargan *et al*., (2003) showed marine survival to have fallen markedly below these historical levels and to be negatively related to mean lice abundance on sea trout. The present findings of a high risk of sea trout mortality close to marine salmon farms in Ireland for the first fifteen years of sea lice monitoring on wild sea trout also is consistent with the observed collapse in sea trout rod catches in the Irish Connemara district around 1989-1990 (Whelan & Poole, 1996; Gargan *et al.*, 2006), which coincided with the development of salmon aquaculture in estuaries during the mid-1980s, and was linked to salmon lice infestation on sea trout (Tully & Whelan, 1993; Tully *et al.*, 1999; Gargan *et al.*, 2003).

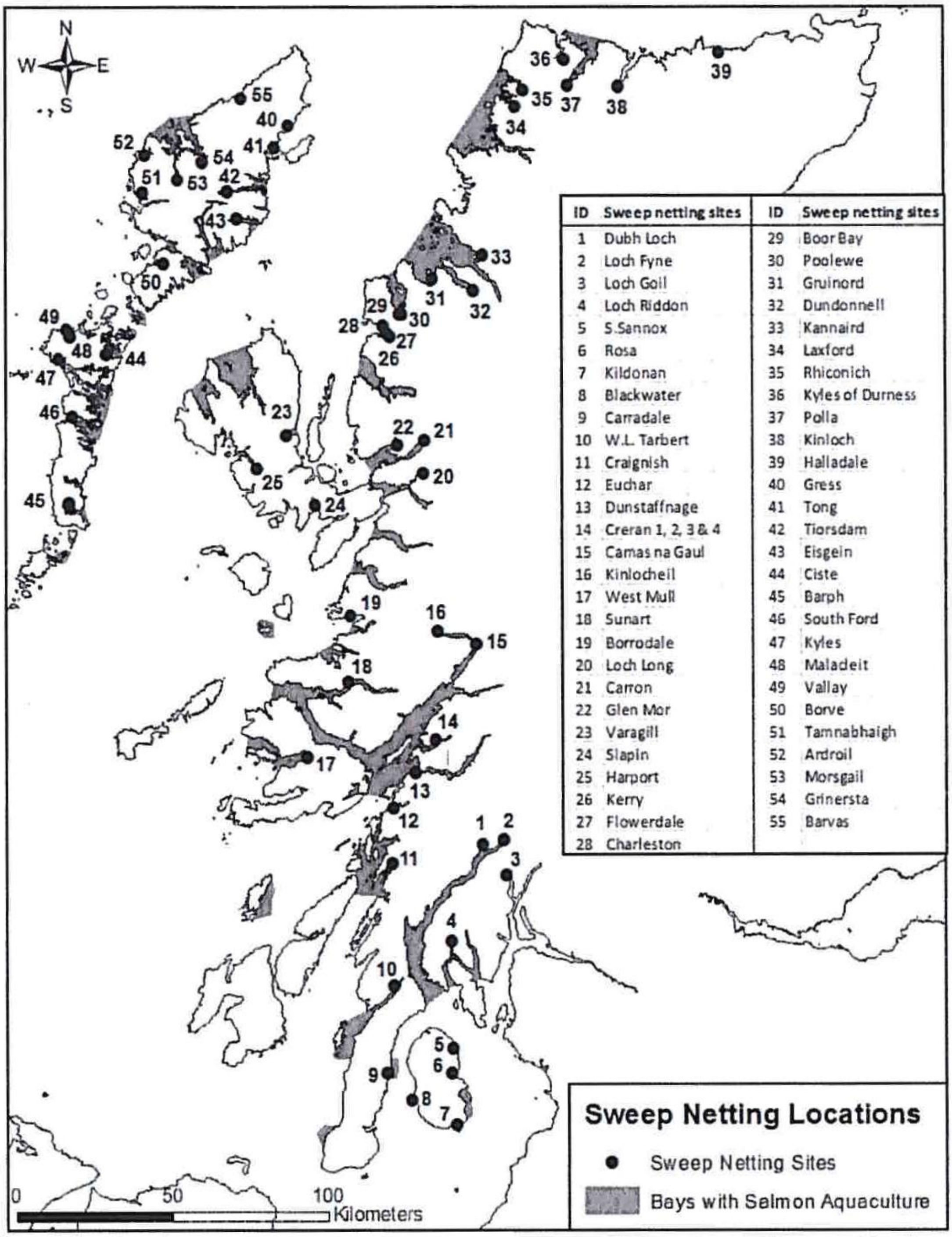
It is apparent from the present results that there was not sufficient control of sea lice on marine salmon farms in Ireland to prevent lice infestation and a high risk of sea trout mortality at many sites over the period when monitoring of sea trout began in 1991 until the mid-2000's. While the extent of sampling was more restricted after 2006, the data indicate that the increased mortality risk for individual sea trout and at the population level fell over the most recent decade. The establishment of sea lice protocol limits on salmon farms in Ireland from 2001, a change in salmon farm practice of moving to single generation sites in the mid 2000's and a general reduction in lice levels on farms over recent years is likely to have contributed to this result. However, results for a small number of individual sites continued to show high risk of sea trout mortality in certain years.

The increase in mortality risk of sea trout (N= 16,758) due to salmon lice infections in Scotland was moderate to high for the first five years of monitoring and decreased subsequently. Fewer sites were sampled prior to 2002, constraining the assessment of the increased mortality risk at the population level, but a high risk was recorded at approximately 50% of monitored sites. The increased risk of sea trout mortality in the early years of sampling in Scotland is consistent with studies on sea trout decline linked to sea lice infestation from salmon farms. In Scotland, unprecedented declines in sea trout rod fisheries were recorded throughout the west coast region during the late 1980's (Walker, 1994; Northcott & Walker, 1996) and the collapse in sea trout rod catch and a change in population structure of the River Ewe sea trout rod catch reported from 1988 was linked to salmon lice epizootics following the establishment of marine salmon farms near the river mouth (Butler & Walker, 2006). Middlemas *et al.*, (2013) found a significant relationship between lice infestation on sea trout and distance to the nearest farm along the Scottish West coast, with the probability of sea trout having critical lice burdens being greatest close to salmon farms. Over the most recent decade, the risk of lice-related sea trout mortality at the individual and population level generally has decreased at Scottish sites. The introduction of single generation sites in Scotland has been in place since 2001 and likely contributed to the more recent reduction in risk of lice-induced sea trout mortality.

Overall, there was a lower lice-related mortality risk for sea trout sampled in Scotland in comparison to fish sampled in Ireland. This difference may be partly explained by sampling location and sampling method. Irish sea trout were captured in inner estuaries or river mouths and had returned prematurely from the sea, whereas the majority of sea trout in the Scottish samples were captured in sweep nets at sea. Premature return of lice infested sea trout to freshwater has been reported in Ireland since lice epizootics have been recorded (Whelan, 1991; Tully & Whelan, 1993) and subsequently also in Scotland (Butler & Walker, 2006; Hatton-Ellis *et al.*, 2006). Bjørn *et al.*, (2001) found that sea trout and arctic char that returned prematurely to freshwater had higher relative infection intensities than fish caught at sea at the same time, and commented that premature return to freshwater of the most heavily infected fish may therefore be triggered to ameliorate the physiological consequences of the infection (Bjørn & Finstad, 1997; Finstad *et al.*, 2000). Bjørn *et al.*, (2001) further comment that most records of sea lice on sea trout are for fish returning prematurely to hyposaline or freshwater conditions (Tully *et al.*, 1993; Birkeland, & Jakobsen, 1997; Tully *et al.*, 1999). This may confer a biased indication of the lice infestation in the total sea-going population because it presumed that the most heavily infested fish return to freshwater (Birkeland & Jakobsen, 1997) and these fish may die before being sampled. If this is so, sampling methods targeting fish at sea alone might reduce observations of the highest intensity infestation levels (Lester *et al.*, 1984). While sampling location may explain to some degree the lower lice related mortality risk observed for sea trout sampled in Scotland, this is not the case for all Scottish samples as some fish were captured in more estuarine locations.

The majority of west of Ireland sea trout populations are dominated by immature finnock (Went, 1962; Fahy, 1985) followed by one sea winter fish and then smaller numbers of maiden sea age groups and previous spawners. O'Farrell *et al.*, (1989) assessed the contribution of the various sea age groups to egg deposition in a west of Ireland catchment and demonstrated that sea trout ≥ 35cm (one and two sea-age fish) make the greatest contribution (76% of all ova) to egg deposition. Butler & Walker (2006) concluded that the combination of reduced abundance, size, longevity and hence frequency of spawning probably had a major influence on total egg deposition of sea trout in the Ewe catchment in western Scotland. The moderate to high risk of increased marine mortality of sea trout at the population level from sea lice infestation observed on the west coasts of Ireland and Scotland seen in the present study is likely to have resulted in loss of older sea age groups and typical population age-structure over time and a reduction in overall egg deposition. Studies in both countries (Poole *et al.*, 1996; Gargan *et al.*, 2006; Butler & Walker, 2006) have documented such changes which emphasise the need for adequate lice control on salmon farms for maintenance of viable sea trout populations.

The "Strategy for an environmentally sustainable aquaculture industry" in Norway (Anon, 2009) states that no disease, including lice, should have a regulatory effect on wild fish. The monitoring of salmon lice infection of wild salmonids is an important verification of whether this goal is achieved, and whether the measures taken are appropriate and sufficient (Taranger *et al.*, 2014). The "traffic light system" described here is used as a warning indicator that predicts the risk of sea lice infestation on wild salmonids based on counting lice on salmon farms and modelling total emissions of lice larvae in a geographical area. Subsequent census of sea lice on wild salmon and sea trout are used to verify and calibrate the model. This first generation measurement of risk assessment of salmon lice and wild salmonids (Taranger *et al.*, 2012b) and further presented in a recent report (Karlsen *et al.*, 2016) will be used as a starting point for the Norwegian Government for controlling and regulating salmon farming. While this management structure is still under development in Norway, the "traffic-light system" will offer a measure for estimating sustainability in salmon farming that could also be applied to Ireland and Scotland in the coming years.



ID	Sweep netting sites	ID	Sweep netting sites
1	Dubh Loch	29	Boor Bay
2	Loch Fyne	30	Poolewe
3	Loch Goil	31	Gruinord
4	Loch Riddon	32	Dundonnell
5	S.Sannox	33	Kannaird
6	Rosa	34	Laxford
7	Kildonan	35	Rhiconich
8	Blackwater	36	Kyles of Durness
9	Carradale	37	Polla
10	W.L. Tarbert	38	Kinloch
11	Craignish	39	Halladale
12	Euchar	40	Gress
13	Dunstaffnage	41	Tong
14	Creran 1, 2, 3 & 4	42	Tiorsdam
15	Camas na Gaul	43	Eisgein
16	Kinlocheil	44	Ciste
17	West Mull	45	Barph
18	Sunart	46	South Ford
19	Borrodale	47	Kyles
20	Loch Long	48	Maladeit
21	Carron	49	Vallay
22	Glen Mor	50	Borve
23	Varagill	51	Tamnabhaigh
24	Slapin	52	Ardroil
25	Harport	53	Morsgail
26	Kerry	54	Grinersta
27	Flowerdale	55	Barvas
28	Charleston		

Figure 4. Location of sweep netting sites sampled for sea trout on the Scottish west coast. The general locations of bays with salmon aquaculture are shown.

Table 4. The population-level increase in mortality risk due to salmon lice infections at individual Scottish locations. A <10% increase in mortality risk is described as low (= clear), a 10-30% increase in mortality risk is intermediate (= grey) and >30% increase in mortality risk is described as high (= black).

Region		Location	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Argyll	1	Dubh Loch					[illegible]	5	9	1	4	0	3	6	5						
Argyll	2	Loch Fyne									3	0	4	4	2			1	1	0	0
Argyll	3	Loch Gail																[illegible]	1	[illegible]	
Argyll	4	Loch Riddon									[illegible]	2	8	1	7			[illegible]	0	[illegible]	0
Arran	5	S.Sannox											10	0							
Arran	6	Rosa											0		[illegible]						
Argyll	7	Kildonan	[illegible]	[illegible]	[illegible]	[illegible]	8							0							
Arran	8	Blackwater							[illegible]	[illegible]		0	[illegible]								
Argyll	9	Carradale											6	0	6			0	0	1	0
Argyll	10	W.Tarbert											24	[illegible]	17						
Argyll	11	Craignish												[illegible]	0						
Argyll	12	Euchar								[illegible]		1	16	19	3						
Argyll	13	Dunstaffnage						[illegible]	[illegible]	17	17	19	[illegible]	10	[illegible]		18	3	54	0	41
Argyll	14	Creran1									2										
Argyll	14	Creran2							5	0	13	2	[illegible]		7						
Argyll	14	Creran3									[illegible]			0							
Argyll	14	Creran4							28	0	17	2	[illegible]	9	[illegible]						
Lochaber	15	Camas na Gaul							[illegible]	1	[illegible]	0	[illegible]	2	[illegible]	6	[illegible]	0	[illegible]	0	23
Lochaber	16	Kinlocheil			27	0	26		[illegible]	0	[illegible]	0	13	0	1	6	9	18	12	0	0
Argyll	17	West Mull							8	3	1	0	[illegible]	0	16						
Lochaber	18	Sunart										[illegible]		[illegible]	0	19					
Lochaber	19	Borrodale																10	0	3	0
Wester Ross	20	Loch Long												[illegible]							
Wester Ross	21	Carron												[illegible]	0	4					
Wester Ross	22	Glen Mor					[illegible]	[illegible]	4	3		22									
Skye	23	Varragill																			0
Skye	24	Slapin															14		16	[illegible]	0
Skye	25	Harport															11		5		
Wester Ross	26	Kerry												[illegible]	28	7					
Wester Ross	27	Flowerdale														6	21	0	0	0	[illegible]
Wester Ross	28	Charleston													7						
Wester Ross	29	Broom Bay	26	6	27	0			[illegible]		15		[illegible]	0	19	11	0	22	0		3
Wester Ross	30	Poolewe						14	[illegible]	0	0	0	[illegible]								
Wester Ross	31	Gruinard	[illegible]	34	22	8															
Wester Ross	32	Dundonnell	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	0	6	[illegible]	[illegible]		[illegible]					
Wester Ross	33	Kanaird	[illegible]		0								[illegible]	21			47	[illegible]	47	24	
West Sutherland	34	Laxford	5		3	12	2	1	7	6	1	13	3	[illegible]	1	1	[illegible]	1	[illegible]	0	[illegible]
West Sutherland	35	Rhiconich			0	6															
West Sutherland	36	Kyle of Durness									[illegible]			1	2	1				0	
West Sutherland	37	Polla			5	7	0	0	3	[illegible]	1	21	0	5	4	2	4	0	0	0	19
West Sutherland	38	Kinloch																	0	1	
West Sutherland	39	Halladale											[illegible]		47						
Outer Hebrides	40	Gress									0	0	0	0							
Outer Hebrides	41	Tong													0		0	0	9	9	2
Outer Hebrides	42	Tiorsdam								[illegible]		[illegible]	[illegible]	100	16						
Outer Hebrides	43	Eisgein													24		0	14	19	12	22
Outer Hebrides	44	Cate										[illegible]	[illegible]		17						
Outer Hebrides	45	Borgh										[illegible]	[illegible]		[illegible]						
Outer Hebrides	46	South Ford																			[illegible]
Outer Hebrides	47	Kyles											21				[illegible]	0	0	16	5
Outer Hebrides	48	Malaclait															10	5	11	14	12
Outer Hebrides	49	Valley										5									
Outer Hebrides	50	Borve							0			10	9	0	0		7	[illegible]	5	2	12
Outer Hebrides	51	Tamnabhaigh											1								
Outer Hebrides	52	Ardroil											0		0						
Outer Hebrides	53	Morsgail											[illegible]								27
Outer Hebrides	54	Grimersta						[illegible]	25	[illegible]		[illegible]	[illegible]	0	0						
Outer Hebrides	55	Barvas											27	0	[illegible]						

ACKNOWLEDGEMENTS

The Irish sea trout samples were provided by the staff of Inland Fisheries Ireland River Basin Districts (formerly the Central and Regional Fishery Boards). Samples were also provided by Dr Russell Poole, Marine Institute. Scottish sea trout samples were collected by the Fishery Trusts & Boards, namely Argyll Fisheries Trust, Lochaber Fisheries Trust, Wester Ross Fisheries Trust, Skye Fisheries Trust, West Sutherland Fisheries Trust, Outer Hebrides Fisheries Trust. We are grateful to Dr Bengt Finstad, Norwegian Institute for Nature Research, for helpful contributions to the overall manuscript.

REFERENCES

Anon. (1995). Report of the Sea Trout Working Group, 1994, Department of the Marine, Dublin. 254 pp.

Anon. (1997). Report of the Workshop on the Interactions between Salmon Lice and Salmonids, Edinburgh, Scotland, UK. 11-15 November 1996. ICES CM 1997/M: 4, Ref. F. 204 pp.

Anon. (2009). Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry (*in Norwegian*). Ministry of Fisheries and Coastal Affairs, Oslo, Norway, 34 pp.

Birkeland, K. (1996). Consequences of premature return by sea trout (*Salmo trutta*) infested with the salmon louse (*Lepeophtheirus salmonis* Krøyer): migration, growth, and mortality. *Canadian Journal of Fisheries and Aquatic Sciences.* **53** 2808-2813.

Birkeland, K. & Jakobsen, P.J. (1997). Salmon lice, *Lepeophtheirus salmonis*, infestation as a causal agent of premature return to rivers and estuaries by sea trout, *Salmo trutta*, juveniles. *Environmental Biology of Fishes* **49**, 129-137.

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.

Bjørn. P.A. & Finstad, B. (2002). Salmon lice, *Lepeophtheirus salmonis* (Krøyer), infestation in sympatric populations of Arctic char, *Salvelinus alpinus* (L.), and sea trout, *Salmo trutta* (L.), in areas near and distant from salmon farms. *ICES Journal of Marine Science* **59**, 131-139.

Bjørn, P.A., Finstad, B. & Kristoffersen, R. (2001). Salmon lice infection of wild sea trout and Arctic char in marine and freshwaters: the effects of salmon farms. *Aquaculture Research* **32**, 947-962.

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.

Butler, J.R.A. & Watt, J (2003). Assessing and managing the impacts of marine salmon farms on wild Atlantic salmon in Western Scotland: Identifying priority rivers for conservation. In: *Salmon at the Edge* (D. Mills, *Ed*.). Proceedings of the 6th International Atlantic Salmon Symposium, Edinburgh, UK, July 2002. Atlantic Salmon Trust/Atlantic Salmon Federation. 93-118.

Butler, J.R.A. & Walker, A.F. (2006). Characteristics of the sea trout *Salmo trutta* (L.) stock collapse in the River Ewe (Wester Ross, Scotland), in 1988-2001. In: *Sea Trout Biology, Conservation & Management*. (Graeme Harris & Nigel Milner, *Eds*). Proceedings of the 1st International Sea Trout Symposium, July 2005, Cardiff, Wales, 45-59.

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 at the Edge*. (Mills, D. Ed.). Proceedings of the 6th International Atlantic Salmon Symposium, Edinburgh, UK, July 2002. Atlantic Salmon Trust/Atlantic Salmon Federation, 119-135.

Gargan, P.G., Poole, W.R. & Forde, G. (2006). A review of the status of Irish sea trout stocks. In: *Sea Trout Biology, Conservation & Management*. (Graeme Harris & Nigel Milner, N. *Eds*.). Proceedings of the 1st International Sea Trout Symposium, July 2005, Cardiff, Wales, 25-44.

Gillibrand, P.A. & Willis, K.J. (2007). Dispersal of sea louse larvae from salmon farms: modelling the influence of environmental conditions and larval behaviour. *Aquatic Biology*, 1, 63–75.

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.

Jakobsen, P.J. Birkeland, K., Grimnes, A., Nylund, A. & Urdal, K. (1992). Undersøkelser av lakselus-infeksjoner på sjøaure og laksesmolt i 1992. (Investigations of salmon lice infections on sea trout and salmon smolts in 1992). Report from the Zoological Museum, September. Department of Ecology, University of Bergen, Bergen. 38 pp.

Karlsen, Ø., Finstad, B., Ugedal., O. & Svåsand, T. (2016). Kunnskapsstatus som grunnlag for kapasitetsjustering innen produksjonsområder basert på lakselus som indikator (A status of knowledge as a basis for capacity adjustment in production areas based on sea lice as an indicator). Report from the Institute for Marine Research No.14-2016 (ISSN 1893-4536 online), 137 pp.

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.

Middlemas, S.J., Fryer, R.J., Tulett, D. & Armstrong, J.D. (2013). Relationship between sea lice levels on sea trout and fish farm activity in western Scotland. *Fisheries Management & Ecology*, **20**, 68-74

Northcott, S.J. & Walker, A.F. (1996). Farming salmon, saving sea trout: a cool look at a hot issue. In: *Aquaculture and sea lochs*. (Black, K.D. *Ed*.). The Scottish Association for Marine Science, Dunstaffnage, 72-81.

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 & Ecology,* **3**, 73-92.

Serra-Llinares, R.M., Bjørn, P.A., Finstad, B., Nilsen, R., Harbitz. A., Berg, M. & Asplin, L. (2014). Salmon lice infection on wild salmonids in marine protected areas: an evaluation of the Norwegian 'National Salmon Fjords'. *Aquaculture Environment Interactions* **5**, 1-16.

Serra-Llinares, RM., Bjørn, P.A., Finstad, B., Nilsen, R. & Asplin, L. (2016). Nearby farms are a source of lice for wild salmonids: a reply to Jansen *et al.*, 2016. *Aquaculture Environment Interactions* **8**, 351–356.

Taranger, G.L., Svåsand, T., Kvamme, B.O., Kristiansen, T.S. & Boxaspen, K.K. (2012a). Risk assessment of Norwegian aquaculture [Risikovurdering norsk fiskeoppdrett] (*In Norwegian*). Fisken og havet, særnummer 2-2012, 131 pp.

Taranger G. L., Boxaspen, K. K., Madhusn, A. S. & Svasand, T. (*Eds.*) (2012b). Suggested first generation method for environmental impact indicators with respect to genetic influences from farmed salmon to wild salmon and the impact of sea lice from farmed fish on wild salmon populations (*in Norwegian*). Fisken og Havet 13-2012.

Taranger, G.L., Karlsen, Ø., Bannister, R.J., Glover, K.A., Husa, V., Karlsbakk, E., Kvamme, B.O., Boxaspen, K.K., Bjørn, P.A., Finstad, B., Madhun, A.S., Craig Morton, H. & Svåsand, T. (2014). Risk assessment of the environmental impact of Norwegian Atlantic salmon farming. *ICES Journal of Marine Science* **72**, 997-1021.

Thorstad, E. B., Todd, C. D., Uglem, I., Bjørn P. A., Gargan, P. G., Vollset K. W., Halttunen, E., Kålås S., Berg, M. & Finstad, B. (2015). Effects of salmon lice *Lepeophtheirus salmonis* on wild sea trout *Salmo trutta*—a literature review. *Aquaculture Environment Interactions* **7**, 91–113.

Tully O, & Whelan, K.F. (1993). Production of nauplii of *Lepeophtheirus salmonis* (Krøyer) (Copepoda: Caligidae) from farmed and wild salmon and its relation to the infestation of wild sea trout (*Salmo trutta* L.) off the west coast of Ireland in 1991. *Fisheries Research* **17**, 187-200.

Tully, O., Poole, W.R. & Whelan, K.F. (1993). Infestation parameters for *Lepeophtheirus salmonis* (Krøyer) (Copepoda: Caligidae) parasitic on sea trout, *Salmo trutta* L., off the west coast of Ireland during 1990 and 1991. *Aquaculture and Fisheries Management* **24**, 545-557.

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* (Krøyer) in relation to sources of infection in Ireland. *Parasitology* **119**, 41-51.

Urquhart, K., Pert, C.C., Fryer, R.J., Cook, P., Weir, S., Kilburn, R., McCarthy, U., Simons, J., McBeath, S.J., Matejusova, I. & Bricknell, I.R. (2010). A survey of pathogens and metazoan parasites on wild sea trout (*Salmo trutta*) in Scottish waters. *ICES Journal of Marine Science* **67**, 444-453.

Walker A, F. (1994). Sea trout and salmon stocks in the Western Highlands. In: *Problems with sea trout and salmon in the Western Highlands*. Atlantic Salmon Trust, Pitlochry, Perthshire, 6-18.

Wells, A., Grierson, C.E., MacKenzie, M., Russon, I.J., Reinardy, H., Middlemiss, C., Bjørn, P.A., Finstad, B., Wendelaar Bonga, S.E., Todd, C.D. & Hazon, N. (2006). 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 Fish and Aquatic Sciences* **63**, 2809-2821.

Whelan, K.F. & Poole, W.R. (1996). The sea trout stock collapse, 1989-1992. In: *The Conservation of Aquatic Systems*. (J. Reynolds. *Ed*.). Proceedings of a Seminar held on 18-19 February 1993. Royal Irish Academy, 101–110.

Comments by Salmon Watch Ireland on Supplementary EIS from Marine Harvest

Shot Head Bantry Bay

05 January 2019

Introduction

Salmon Watch Ireland would like to take this opportunity to address and comment on aspects which are of concern to us in relation to the supplementary EIS concerning the Shot Head application process.

The main issue which we would like to comment on is the risk (i.e. posed by the proposed salmon farm installation) of sea-lice infestation of wild salmonids migrating, from / to the Dromogowlane and Trafrask rivers, and any resulting implications for local freshwater pearl mussel (FPM) populations.

This is a very complex issue and our approach to this will be to extract areas from the supplemental EIS and comment on same. This approach is to address issues that we see as having a detrimental effect on salmonid populations in an informed and transparent way and to demonstrate how the EIS is flawed to the extent that the entire process must be abandoned.

In relation to the mention of the "natural infestation zone" the document would seem to suggest that the Bantry Bay Shot Head farm would not be capable of having a sea lice impact on the out migrating salmonids from the Dromogowlane and Trafrask rivers. This factor is underpinned by the model as presented in the supplementary EIS and as such is open to challenge as there appears to be fundamental errors in relation to the persistence of the applicant in stating that lice are neutrally buoyant and as such the model is flawed.

However there is a more pressing issue in relation to the model as described in the supplementary EIS. It can be comprehensively demonstrated that the larval lice and indeed more importantly the infective copepods can certainly reach the so called "natural infestation zone" or can be transferred in full marine waters which the EIS seems to comprehensively suggest this to be highly unlikely. This EIS essentially suggests that farm origin lice cannot infest wild salmonids in the open marine waters of Bantry Bay or marine waters outside the bay and that for infestation of migrating smolts would have reach the "natural infestation zone". This is not correct and extensive studies (Todd *et al*, 2006 and Gargan *et al*, 2016) are indicative of salmonids being infected both in full marine waters and indeed in the so called natural infestation zones. The advent of salmon farming has certainly changed infestation pressure on wild salmonids due to their location and the existence of large numbers of available hosts. It must be borne in mind that up to two million hosts for sea lice production will be available within Bantry Bay if Shot Head is licensed, while adult wild salmon returns to the bay would be in the region of less than two thousand potential hosts. Another factor is that the vast majority of wild salmon enter Bantry Bay in the summer months outside the critical smolt migration window so effectively the only source of lice are from farm sources during wild smolt migration period thus the EIS segment concerning natural lice production is irrelevant in this context and only serves to facilitate confusion.

With the near complete loss of sea trout populations within the rivers entering the bay it can be seen that the farmed population has the potential to cause persistent sea lice infestation rates to a very poor wild salmon smolt population and an ever dwindling and fragile sea trout resource.

We would like to draw attention to Figure 2.10 and 2.11 (Appendix 1) as contained in the supplementary EIS. This is purported to demonstrate the maximum and average plume envelope plot of dispersing copepod density resulting from 1 Ovigerous female lice per farmed fish on farms in Bantry Bay.

It is important to also important to draw your attention to Table 2.2 (Appendix 2) which outlines copepod densities at various distances from proposed Shot Head salmon farm.

As the models used to illustrate sea lice larvae and copepod dispersal for Shot Head and the other adjacent farms are using the same model it should be safe to assume that no salmon river estuary will be affected if data and model dispersion is correct. However this is not the case and Salmon Watch Ireland would like to illustrate that these models bear little resemblance to the physical and real time dispersion routes which exist in the bay.

A recent analysis of a large international sea trout database from Ireland and Scotland carried out by Gargan *et al.* (2017) is of particular interest to the Shot Head application. The data set reveals levels of lice infestation on sea trout that imply a high mortality risk. Bantry Bay was one of the locations where this analysis was undertaken with two rivers sampled through the period 1993 – 1999. The Adrigole and Coomhola Rivers were sampled with the Adrigole River (Close to salmon farms near Bere Island) demonstrating a consistently high risk status with levels of infestation high with juvenile lice dominant indicating localised infection.

This aspect is highly relevant in that models presented in EIS do not indicate that lice larvae or copepods enter the estuary of the Adrigole River. This leads to a question as to whether juvenile lice infested these sea trout in estuarine waters or full marine waters. Either way it disproves that fish farms (Ahabeg and Roancarrig) adjacent to the Adrigole River cannot have an effect on out-migrating or on resident feeding salmonids. This certainly calls into question the accuracy and veracity of the models presented.

In relation to the Trafask River it is highly probable that this river will certainly be affected by the Shot Head site and indeed the other sites within the Bay. It is highly relevant that the electro fishing survey carried out by Inland Fisheries Ireland indicated extremely low salmonid density levels (Appendix 3) which is not consistent with a Q 4-5 water quality designation.

It is further stated in the EIS that salmonid density of 0.2 to 0.3m^2 is a requirement for a healthy population of Freshwater Pearl Mussels (FPM) and as such the Trafask River falls well below this threshold. The Gargan *et al* (2017) paper does indicate a very high risk posed to sea trout at a population level in one river (Adrigole) within the bay and it is highly probable that this river (Trafask) has been affected to the same degree and that very few sea trout survive to spawn. The direct linkage to the poor density is in all probability linked to reduced sea trout spawning and indeed to reduced fecundity associated with poor growth at sea of sea trout (That survive to spawn) in bays with salmon aquaculture. The resident brown trout are in all probability unable to fully utilise the catchment recruitment potential due to their small body size which affects fecundity. All these streams and small rivers require sea trout with their larger body size to produce a large enough juvenile stock density to ensure survival of FPM.

This is demonstrated in a very effective study by Goodwin *et al* (2016).

"This study demonstrated using a novel combination of stable isotope analysis and microsatellite genotyping demonstrated the overwhelming contribution of anadromous parents (both female and male) to fry production and that offspring of anadromous females emerged earlier and at a larger body size than offspring of resident females. Overall, this study suggests that anadromous maternal traits provide offspring with an adaptive advantage and greater fitness in early ontogeny, and that a small number of anadromous females (six of 96 adults sampled) are the main drivers of reproduction in this system."

This effectively demonstrates that the lack of juveniles in the Trafask River is in all probability due to the apparent lack of sea trout in all systems in Bantry Bay. Anecdotal evidence suggests that there were large stocks of sea trout in all these rivers prior to the advent of salmon farming (Pers. Communication).

This is in all likelihood the result of sea lice infestation causing an ongoing population effect within the bay.

One further comment is that the absolute reliance on a very small amount of scientific papers regarding the effects of salmon aquaculture on wild salmonids by Marine Harvest and their agents suggests bias in the extreme which we would expect ALAB to strongly look at the wider more reliable sources available.

It is no longer appropriate to take at face value scientific literature associated with private or government sources which have a vested interest in allowing the expansion of an unsustainable industry in its present format.

References

Gargan, P.G., Shephard, S & MacIntyre, C. (2017). Assessment of the increased mortality risk and population regulating effect of sea lice (*Lepeophtheirus salmonis*) from marine salmon farms on wild sea trout in Ireland and Scotland. In: (Harris, G, Ed.) *Sea Trout: Science & Management. Proceedings of the 2nd International Sea Trout Symposium.* pp. 507-522

Gargan, P., Karlsbakk, E., Coyne, J., Davies, C., Roche, W (2016). Sea lice (Lepeophtheirus salmonis and Caligus elongatus) infestation levels on sea trout (Salmo trutta L.) around the Irish Sea, an area without salmon aquaculture. *ICES J Mar Sci (2016) 73 (9): 2395-2407.*

Goodwin, J., King, A., Jones, A., Ibbotson and Stevens, J. (2016) A small number of anadromous females drive reproduction in a brown trout (Salmo trutta) population in an English chalk stream. *Freshwater Biology*, pp.1075–1089. Available at: https://onlinelibrary.wiley.com/doi/pdf/10.1111/fwb.12768 [Accessed December 11, 2018]

Todd, CD, Whyte, BDM, MacLean, JC & Walker, AM 2006, 'Ectoparasitic sea lice (Lepeophtheirus salmonis and Caligus elongatus) infestations of wild, adult, one sea-winter Atlantic salmon Salmo salar returning to Scotland' *Marine Ecology Progress Series*, vol. 328, pp. 183-193. DOI: 10.3354/meps328183

Appendix 1

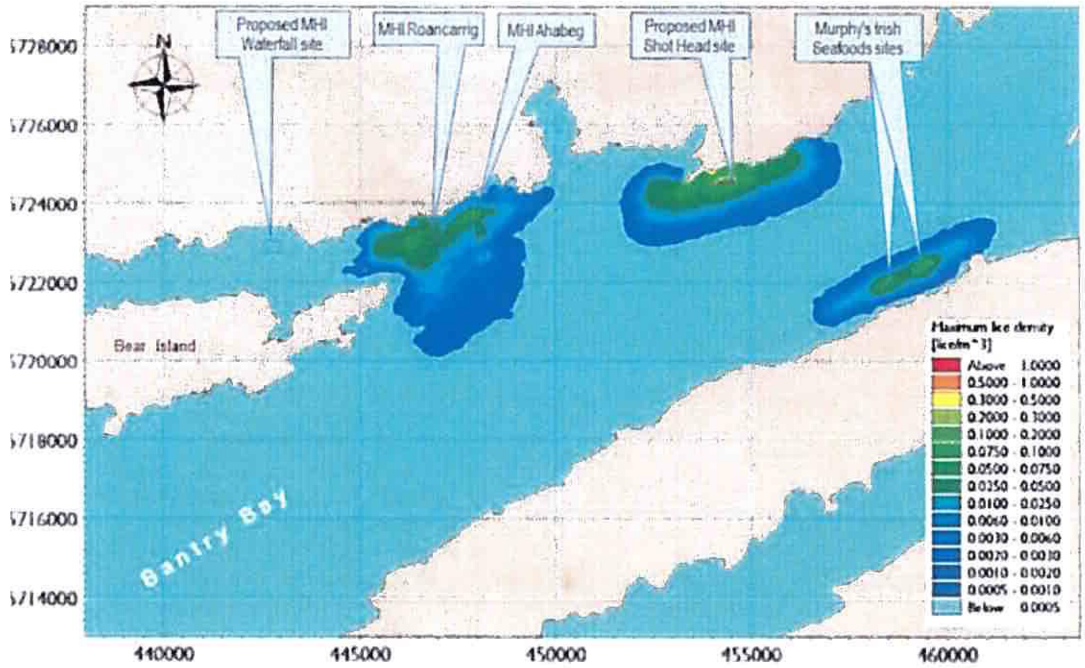


Figure 2.10
Maximum plume envelope plot of dispersing copepodid density, from 1 ovigerous louse per fish for all existing and proposed Bantry Bay salmon farm sites, Shot Head / Fastnet dominent.

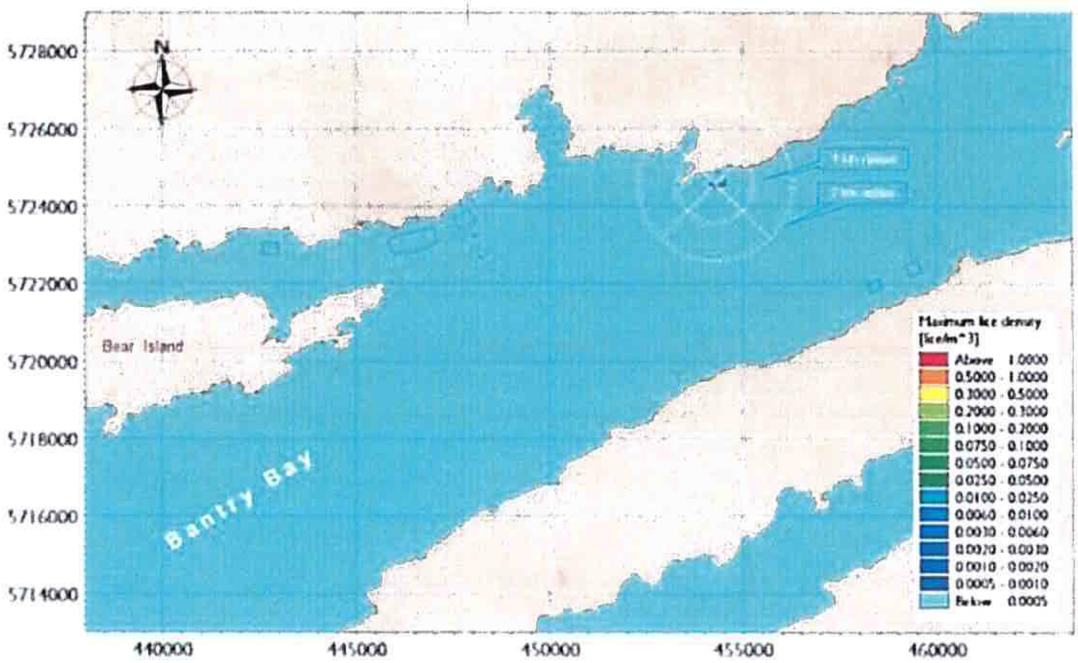


Figure 2.11
Average plume envelope plot of dispersing copepodid density, from 1 ovigerous louse per fish for all existing and proposed Bantry Bay salmon farm sites, Shot Head / Fastnet dominent.

Appendix 2

Table 2.2.
Estimates of grid cell value ranges in still weather and Force 5 wind in Typical and Time Series plots. See in particular Figures 2.13 and 2.14.

	Tidal state	Copepodids / m^3 mid-ebb tide		Copepodids / m^3 mid-flood tide		Comments
	Mean ovigerous female lice per farmed fish	0.3	1.0	0.3	1.0	
Still weather tidal ccurrents	Within site boundary	Zero to 0.050	Zero to 0.165	Zero to 0.040	Zero to 0.0132	Read from Figure 2.14.2. Highest values in individual pens, for few single timesteps only
	Offshore, within 1 km of site centre	Zero to 0.030	Zero to 0.100	Zero to 0.030	Zero to 0.100	0.3 levels from Figure 2.13.1, 2.13.2. 1.0 level = 0.3 levels * 3.3. Maximum cell values just west of site on ebb, just east of site on flood
	1-2km from site centre (open waters)	Zero to 0.0040	Zero to 0.0132	Zero to 0.0040	Zero to 0.0132	0.3 levels from Figure 2.13.1, 2.13.2. 1.0 level = 0.3 levels * 3.3. Maximum cell values west of site on ebb, just over 1km east of site on flood
	>2km from site centre (open waters)	Zero to 0.0002*	Zero to 0.0006*	Zero to 0.0001	Zero to 0.0003	* Applies to highest value in each case on ebb applies to one single grid cell just over 2km SW of site. Otherwise max as for flood current
	Outside plume axis (open waters)	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	
	In salmon river estuaries	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	As for all open waters except *. However line plots across nearest estuary (Trafrask) suggest estuary values at lower end of given range, if not zero.
Force 5 sustained SW wind	Within site boundary	Zero to 0.0300	Zero to 0.1000	Zero to 0.040	Zero to 0.132	Read from Figures 2.13.3 to 2.13.6. SW Plume. Slightly lower grid cell values in site area on mid-ebb tide than on mid-flood. High values intermittant.
	Offshore, within 1 km of site centre	Zero to 0.030	Zero to 0.100	Zero to 0.010	Zero to 0.033	Read from Figures 2.13.3 to 2.13.6. Higher grid cell values become more intemittant and dispersed with distance from site. Plume maintained to SW. No grid cell over minimum value beyond 5km from site. Overriding majority of grid cells <0.0001 Copepodidis /m^3 from 1km out, even from 1 ovigerous female per farmed fish.
	1-2km from site centre (open waters)	Zero to 0.0100	Zero to 0.0300	Zero to 0.0025	Zero to 0.010	
	>2km from site centre along axis of plume	Zero to 0.0006	Zero to 0.0025	Zero to 0.0015	Zero to 0.006	
	Outside plume axis (open waters)	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	
	In salmon river estuaries	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	Zero to 0.0001	Read from Figures 2.13.3 to 2.13.6. Effectively zero Copepodid density in all salmon river locations from all sites.

Appendix 3

Site	Site description	Number of Salmo salar (6-9cm)	Number of Salmo trutta (4-15cm)	Salmo salar density per m^2	Salmo trutta density per m^2
IFI 1	On Trafrask above R572, just below confluence with Leitrim More River. No FPM present.	2	4	0.018	0.035
IFI 2	On Trafrask further N, just below confluence with Curragh River. Good numbers of FPM (FPM Site 5).	1	9	0.009	0.086
IFI 3	On Leitrim More River. Not surveyed for FPM.	3	6	0.052	0.103
IFI 4	On Upper Trafrask; not surveyed for mussels.	0	11	0	0.076
IFI 5	On a tributary of the Curragh River, in the upper Trafrask catchment, in the foothills of the Caha Mountians . Not surveyed for FPM.	0	4	0	0.047
IFI 6	Further W along Leitrim More River than IFI Site 3. Not surveyed for FPM.	0	10	0	0.079