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National Survey of Sea Lice (*Lepeophtheirus salmonis* Krøyer and *Caligus elongatus* Nordmann) on Fish Farms in Ireland - 2016

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http://www.marine.ie/Home/site-area/areas-activity/aquaculture/sea-lice

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INTRODUCTION

Sea lice are a naturally occurring parasite found on most fish, including salmonids. They are small ectoparasitic copepod crustaceans which occur on several species of fish. There are estimated to be approximately 559 species made up of 37 genera (Ahyong *et al*., 2011), including 162 *Lepeophtheirus* species (Chad & Goeff, 2011) and 268 *Caligus* species (Boxshall, 2011). The two main species found in Ireland are *Caligus elongatus* and *Lepeophtheirus salmonis*. *L. salmonis* infests only salmonids, while *C. elongatus* is known to parasitise over 80 different species of marine fish. *L. salmonis* is the larger of the two species and is regarded as the more damaging parasite. It is endemic at a high prevalence (>90%) within wild populations (Jackson *et al.,* 2013), and occurring frequently on farmed salmonids (Jackson & Minchin, 1992; Jackson *et al.,* 2005). There are two species of salmonids farmed in Ireland on a commercial basis, Atlantic salmon *Salmo salar* L. and rainbow trout *Oncorhynchus mykiss* Walbaum.

L. salmonis is an obligate parasite with a direct lifecycle, with 8 stages, comprising of nauplius 1 and 2, copepodid, chalimus 1 and 2, preadult 1 and 2 and the adult stages. The nauplius 1 stage hatches from paired egg-strings and is dispersed in the plankton. It moults to nauplius 2, also planktonic, which is followed by a copepodid, the infective stage where attachment to the host takes place. The copepodid then moults through the attached chalimus stages before becoming a mobile pre-adult. There are two pre-adult stages before maturing to the adult phase. The adult female can produce a number of batches of paired egg-strings, which in turn hatch into the water column to give rise to the next generation (Hamre, 2013; Kabata, 1979; Schram, 1993). The mean length for an adult female is 8mm-11mm and an adult male is 5mm-6mm (Schram, 1993). Under experimental conditions female *L. salmonis* survived up to 210 days, producing as many as 11 pairs of egg strings (Boxaspen, 2006). Jackson and Minchin (1992), in Ireland, found fecundity (mean eggs per pair of egg strings) on wild salmon to be 965 ±30, which was higher than for farmed salmon at 758 ±39. This contrasts to a lower fecundity recorded for wild and farmed salmon in Norway where mean egg numbers have been recorded as 304 ±32 with a range from 246 to 366 at 7.2°C (Heuch *et al*. 2000).

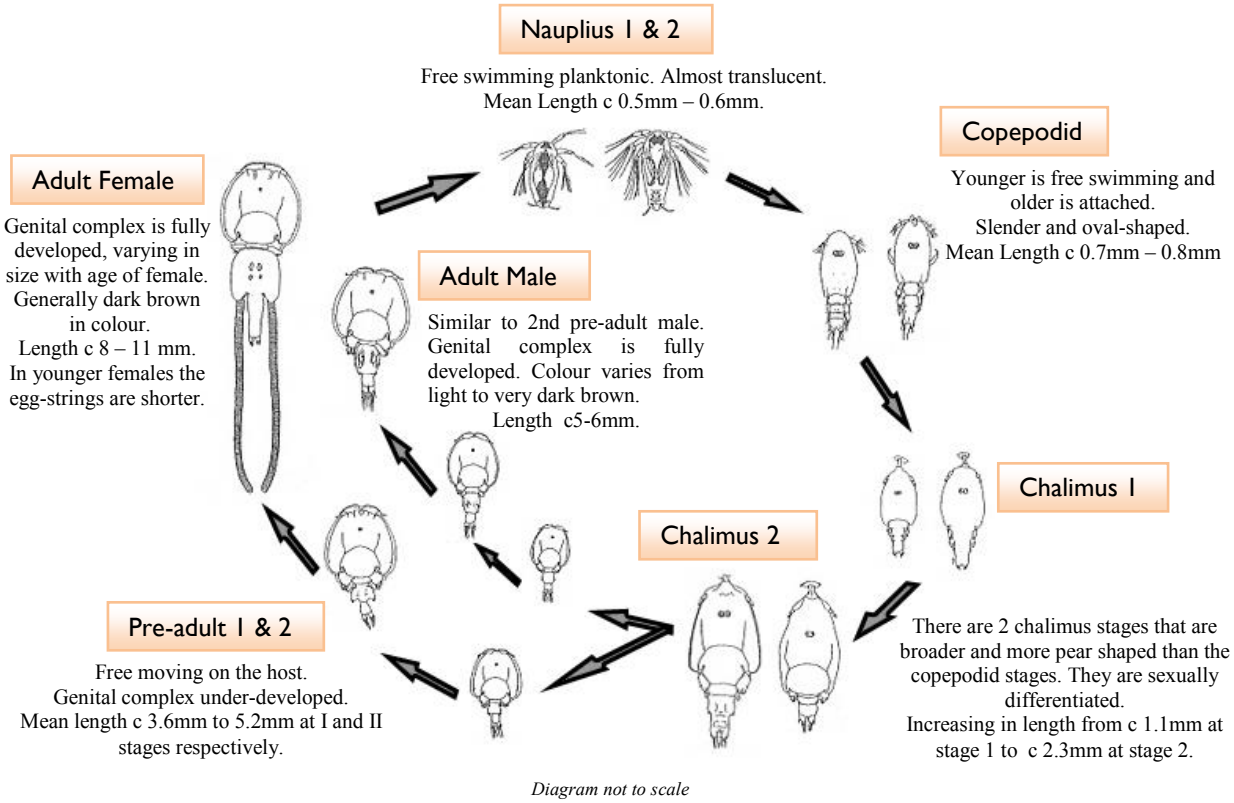

Figure 1. *Life cycle of Lepeophtheirus salmonis (after Schram 1993 & Hamre 2013).*

C. elongatus is smaller in size than *L. salmonis* averaging approximately 6-8mm in length (Hogans & Trudeau, 1989). The fact that *C. elongatus* is not as host specific as *L. salmonis* (Kabata, 1979) and that the hosts migrate widely is thought to be a factor in the highly variable levels on farmed salmonids at different times of the year.

History of Sea Lice Monitoring in Ireland

In 1991, the Department of the Marine instigated a Sea Lice Monitoring Programme for finfish farms in Ireland (Jackson & Minchin, 1993) and in 1993 monitoring was expanded nationwide (Jackson *et al.*, 2002; Jackson *et al.*, 2005). In May 2000 the protocol for sea lice monitoring was formally published (*Monitoring Protocol No.3 for Offshore Finfish Farms – Sea Lice Monitoring and Control*) by the Department of Marine and Natural Resources.

In 2008, the Department of Agriculture, Fisheries and Food (DAFF) published "*A strategy for the improved pest control on Irish salmon farms*". The strategy outlines a comprehensive range of measures to provide for enhanced sea lice control and was developed by a joint DAFF, Marine Institute and Bord Iascaigh Mhara workgroup in response to difficulties experienced by farms in achieving the low levels of infestation required by the national control programme. These measures draw on the on-going Single Bay Management (SBM)

process and, through a comprehensive action plan and list of recommendations, seek to advance the suite of tools necessary for improved sea lice control on farms.

The objectives of the National Sea Lice Monitoring Programme are:

- To provide an objective measurement of infestation levels on farms.
- To investigate the nature of infestations.
- To provide management information to drive the implementation of control and management strategies.
- To facilitate further development and refinement of this strategy.

The sea lice control and management strategy has five principal components:

- Separation of generations.
- Annual fallowing of sites.
- Early harvest of two-sea-winter fish.
- Targeted treatment regimes, including synchronous treatments.
- Agreed husbandry practises.

These components combine to reduce the development of sea lice infestations and to ensure the most effective treatment of sea lice. They seek to minimise sea lice levels whilst decreasing reliance on, and reducing the use of, veterinary medicines. Separation of generations and annual fallowing prevent the transmission of infestations from one generation to the next. The early harvest of two-sea-winter fish removes a potential reservoir of sea lice, while the agreed husbandry practises and targeted treatments enhance the efficacy of treatment regimes. One important aspect of targeted treatments is carrying out of synchronized autumn/winter treatments to reduce sea lice burdens to as close to zero as practicable, on all fish which are to be over-wintered. This is fundamental to achieving near zero egg-bearing sea lice in spring. The agreed husbandry practises cover a range of related fish health, quality and environmental issues in addition to those specifically related to sea lice control. The Single Bay Management Programme serves to facilitate this and provides a forum for exchange of information between farmers.

In late winter and early spring seawater temperatures are at a minimum and the development rate of sea lice is slower. Rising water temperatures in spring tend to synchronise the development of sea lice larvae. A strategic treatment at this time can break the cycle of infection. Ovigerous female sea lice are those which produce the infective larvae and treatments are timed to remove adult females before they can release larvae. Setting the treatment trigger at 0.5 ovigerous *L. salmonis* per fish in spring ensures that treatments are carried out when a maximum of half of the fish examined have one ovigerous sea louse. This is a practical time to interrupt sea lice development. Later in the

year, the development of new generations are not as synchronised and automatic intervention at a sea lice level of 0.5 ovigerous by way of treatment is not justified. A level of 2.0 ovigerous sea lice per fish has been shown to be a pragmatic level at which intervention by way of treatment is advisable. Levels of mobile and juvenile sea lice are important in advising fish health professionals in developing a sea lice control strategy. However, they are not of themselves appropriate measures upon which to trigger mandatory treatments.

Results of the monitoring programme are sent to the relevant farm within 5-10 days of each inspection. A monthly report of results is circulated to relevant parties and the data is published annually (www.marine.ie; Copley *et al.*, 2001; McCarney *et al.*, 2002; O'Donohoe *et al.*, 2003-2016).

Sea Lice Control Methods

The sea lice control and management strategy process includes the use of husbandry, management practises, and chemotherapeutants to control the numbers of sea lice on farms. Table 1 shows a list of the veterinary medicines authorised to assist in the control of sea lice in Ireland in 2016. These can either be administered topically or incorporated into the diet. Topical treatments are administered by bathing the fish in specified concentrations of the medicine. Bath treatments can be conducted by using tarpaulins or skirts to enclose the salmon net-pens, or by use of well-boats. Medicines incorporated into the diet are a very efficient way to get the required dose to the fish. An over-reliance on any one technique can act as a source of re-infestation in the short term and lead to development of resistance in time. A multi-pronged approach to sea lice control is considered more effective in the long-term.

The use of cleaner fish for the control of sea lice is being pursued in Ireland. Various wrasse species were used on salmon farms in the 1990s but recent interest has mainly been in stocking ballan wrasse *Labrus bergylta* (Treasurer, 2013). Studies in Norway also indicate that lumpfish *Cyclopterus lumpus* is a suitable cold-water option for biological delousing of Atlantic salmon (Imsland, 2014). Lumpfish are currently being trialled on farms in Ireland as part of a sea lice management plan, with positive results reported.

The use of filtration methods at harvest sites has also proven to be a very successful method for removing all stages of sea lice, including egg-strings; preventing sea lice from

re-entering the water column and potentially re-infecting stocks adjacent to the harvest area (O'Donohoe & McDermott, 2014).

Table 1. *Veterinary medicines authorized to assist in the control of sea lice on salmonids in Ireland (www.hpra.ie).*

Compound	*Group*	*Licensing status*	*Delivery Method*	*Mode of action*	*Stages targeted*	*Withdrawal period*
Animal medicines						
Deltamethrin	Pyrethroid	Full MA	Bath	Interferes with nerve transmission by blocking sodium channels in nerve cells	Adults, Preadults. Chalimus unknown	5 degree-days
Emamectin benzoate	Avermectin	Full MA	In-feed	Interferes with neurotranmission disrupting nerve cells causing paralysis and death	All stages	Zero
Teflubenzuron	Insect Growth Regulator	Full MA	In-feed	Inhibits chitin synthesis preventing moulting and growth. Limited efficacy beyond medication period. Not authorized for use below 9°C	Moulting stages - Chalimus, Preadults only	45 degree-days
Hydrogen peroxide	Oxidizer	Full MA	Bath	Gas embolism	Adults, Preadults	Zero

MA - marketing authorisation from the Health Products Regulatory Authority.

METHODOLOGY

Farmed stocks of Atlantic salmon in Ireland are inspected on 14 occasions throughout the year to monitor sea lice levels as part of a national programme. Additional follow-up inspections may be carried out when it is deemed appropriate. Sea lice inspections take place twice per month in March, April and May (the spring period) and then monthly for the remainder of the year. December and January are combined and only one inspection is carried out.

At each inspection two samples are taken for each generation of fish on site, a sample from a standard cage, which is sampled at each subsequent inspection, and a sample from a random cage, which is chosen on the day of the inspection. Thirty fish are examined for each sample after anaesthetising using tricaine methane sulfonate in seawater. The seawater is sieved for any detached lice at the end of each sample. Each fish is examined individually for all mobile sea lice. Sea lice are removed and preserved in 70% ethanol. In the laboratory the species, quantity and life-stage of the sea lice are determined and recorded. The mean number of sea lice per fish is calculated (including the number of detached sea lice from the sieved seawater). Results presented are mean ovigerous sea lice levels and mean total mobile sea lice levels for *L. salmonis* and *C. elongatus* per fish.

Ovigerous sea lice levels estimate the breeding female population and total mobile levels estimate successful infestation levels. The information gathered aims to evaluate the level of sea lice on the fish and to inform the farmer on a sea lice management strategy. Effective parasite control is characterised by a drop in sea lice levels on the subsequent inspection.

In 2016, salmonid farms were producing three different stocks of fish: 2015 Atlantic salmon (one-sea-winter salmon), 2016 Atlantic salmon (smolts), and 2014 Atlantic salmon (two-sea-winter salmon). Rainbow trout were not stocked in this period.

There are three distinct regions in Ireland where salmonid farming is carried out; the Southwest (Counties Cork and Kerry), the West (Counties Mayo and Galway) and the Northwest (Co. Donegal). These regions are geographically separate from each other with distances between regions of *c.*160 km from Northwest to West and *c.*200 km from West to Southwest. In 2016 a total number of 22 sites were inspected around Ireland, see Figure 2.

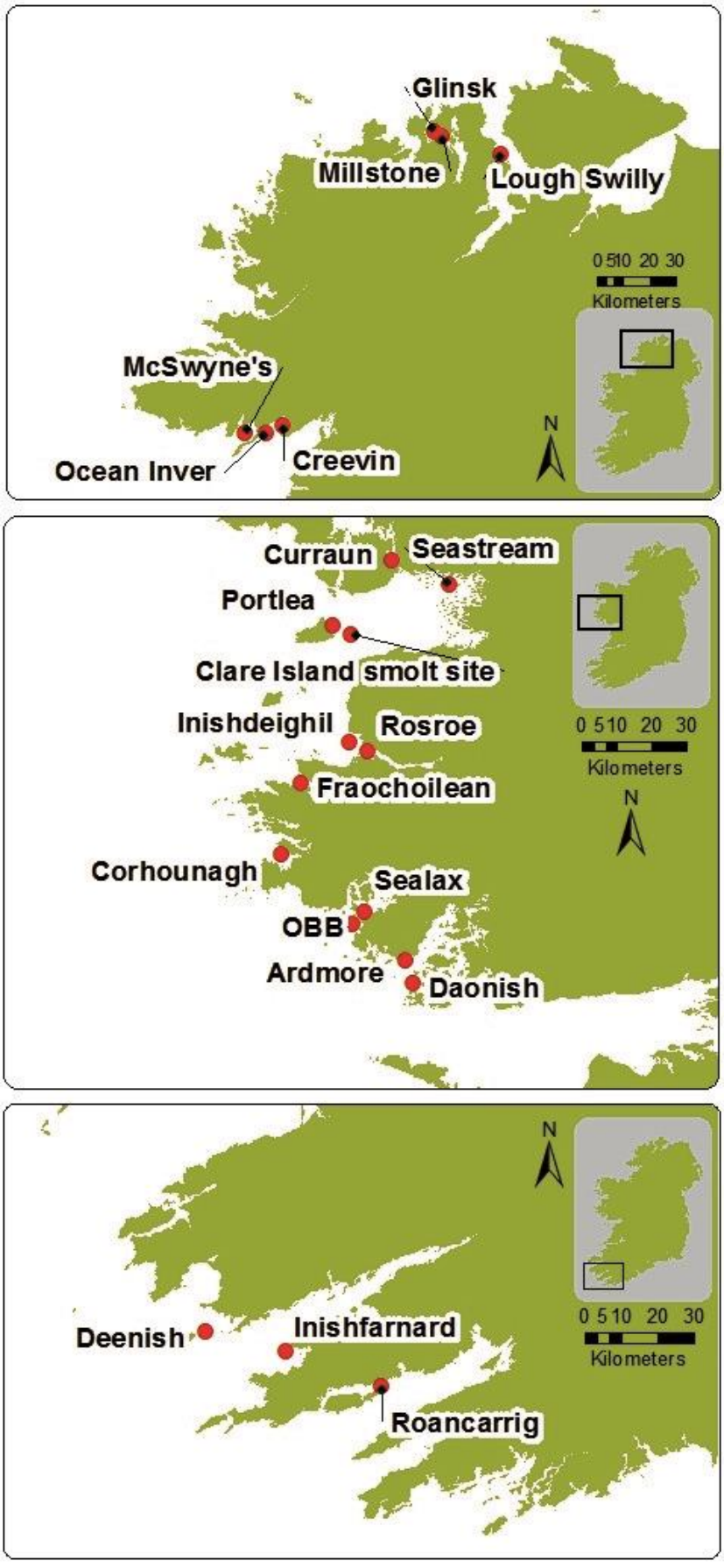

Figure 2. *Locations of fish farm sites.*

RESULTS

During 2016 a total of 207 sea lice inspections were carried out on the 22 active farm sites. Over 92.8% of Atlantic salmon samples were below the Treatment Trigger Levels (TTL) as outlined in the *Monitoring Protocol No.3 for Offshore Finfish Farms – Sea Lice Monitoring and Control,* Department of Marine and Natural Resources (2000). All Of the 115 inspections carried out on salmon smolts were below the TTL and 84% of the 91 inspections carried out on one-sea-winter salmon were below TTL. A single inspection was carried out on two-sea-winter salmon and this was below the TTL. Rainbow trout were not stocked in 2016.

Results of 2016 sea lice inspections of all active salmonid sites for each month are presented in Appendix 1.

Atlantic salmon 2014 (two-sea-winter salmon)

At the beginning of 2016, two-sea-winter salmon were inspected at 1 site: Seastream Inner (Inishcoragh), Clew Bay. Table 2 contains the number of inspections and number of inspections exceeding the treatment trigger levels.

Table 2. *Summary of inspections for two-sea-winter salmon on fish farm sites in 2016.*

Company	Site	Samples in Spring	Over in Spring	Samples outside Spring	Over outside Spring	Total Samples	Total Over	% over in Spring	% over outside Spring	% over total
Clare Island Seafarms Ltd.	Seastream Inner (Inishcoragh)	0	0	1	0	1	0	0%	0%	0%
West		0	0	1	0	1	0	0%	0%	0%
National Totals		0	0	1	0	1	0	0%	0%	0%

Atlantic salmon 2015 (one-sea-winter salmon)

One-sea-winter salmon were stocked in a total of 11 sites in 10 bays in 2016. Ninety one visits were undertaken to this generation of fish. Two sites continued to stock one-sea-winter salmon in November 2016.

Ovigerous *L. salmonis* levels greater than the TTL were recorded in a total of 15 inspections (16%) on one-sea-winter fish (Table 3). Within the critical spring period sea lice levels were in excess of 0.5 ovigerous females per fish on 8 inspections (16%) and outside of the spring period 7 inspections (17%) were in excess of 2.0 ovigerous female *L. salmonis* per fish.

Table 3. *Summary of inspections results on one-sea-winter salmon nationally in 2016.*

	Samples in Spring	Over in Spring	Samples outside Spring	Over outside Spring	Total Samples	Total Over	% over in Spring	% over outside Spring	% over total
National Totals	49	8	42	7	91	15	16%	17%	16%

C. elongatus levels greater than 10 individuals per fish (1SW salmon) were recorded on 3 occasions at two different sites during the year.

Southwest Region

In the Southwest there were no recorded instances of *L. salmonis* levels greater than the treatment trigger levels (Table 4).

Table 4. *Summary of inspections results on one-sea-winter salmon in the Southwest in 2016.*

Company	Site	Samples in Spring	Over in Spring	Samples outside Spring	Over outside Spring	Total Samples	Total Over	% over in Spring	% over outside Spring	% over total
Marine Harvest Ireland	**Deenish**	6	0	6	0	12	0	0%	0%	0%
	Roancarraig- Ahabeg	6	0	3	0	9	0	0%	0%	0%
Southwest	**Totals**	12	0	9	0	21	0	0%	0%	0%

West Region

In the West, *L. salmonis* infestation levels greater than the treatment trigger were recorded on 7 out of 26 inspections (27%) in the spring period and on 7 out of 23 inspections (30%) outside the spring period (Table 5).

Table 5. *Summary of inspections results on one-sea-winter salmon in the West in 2016.*

Company	Site	Samples in Spring	Over in Spring	Samples outside Spring	Over outside Spring	Total Samples	Total Over	% over in Spring	% over outside Spring	% over total
Bradan Beo Teo.	**Daonish**	6	0	3	0	9	0	0%	0%	0%
Bifand Ltd.	**Fraochoilean**	0	0	3	2	3	2	0%	67%	67%
	Corhounagh	4	2	1	1	5	3	50%	100%	60%
Comhlucht Bradain Chonamara Teo.	**Sealax**	6	1	6	0	12	1	17%	0%	8%
Clare Island Seafarms Ltd.	**Portlea**	1	1	2	1	3	2	100%	50%	67%
	Smolt site	5	3	6	2	11	5	60%	33%	45%
Curraun Blue Ltd.	**Curraun**	4	0	2	1	6	1	0%	50%	17%
West	**Totals**	26	7	23	7	49	14	27%	30%	29%

The Clare Island Smolt Site exceeded TTLs for 3 of the 5 inspections in the spring period and 2 of the 6 inspections outside spring. At Corhounagh, Mannin Bay, TTLs were exceeded for 2 of the 4 inspections in the spring and one of the inspections outside the spring period.

Northwest Region

The treatment trigger levels were exceeded on 1 of the 11 inspections in the spring and none of the 10 inspections outside the spring period in the Northwest (Table 6).

Table 6. *Summary of inspections results on one-sea-winter salmon in the Northwest in 2016.*

Company	Site	Samples in Spring	Over in Spring	Samples outside Spring	Over outside Spring	Total Samples	Total Over	% over in Spring	% over outside Spring	% over total
Ocean Farm Ltd.	**McSwynes**	6	1	2	0	8	1	17%	0%	13%
Marine Harvest Ireland	**Lough Swilly**	5	0	8	0	13	0	0%	0%	0%
Northwest	**Totals**	11	1	10	0	21	1	9%	0%	5%

Atlantic salmon 2016 (smolts)

A total of 115 inspections were made to 12 sites stocking Atlantic salmon 2016 S1 and S½ smolts during the year 2016. *L. salmonis* levels were below the TTL of ovigerous female lice per fish for all of the inspections (100%) throughout the year (Table 7).

Table 7. *Summary of inspections results on salmon smolts nationally in 2016.*

Company	Site	Samples in Spring	Over in Spring	Samples outside Spring	Over outside Spring	Total Samples	Total Over	% over in Spring	% over outside Spring	% over total
Marine Harvest Ireland	**Roancarraig-Ahabeg**	6	0	8	0	14	0	0%	0%	0%
	Inishfarnard	2	0	6	0	8	0	0%	0%	0%
Southwest	**Totals**	8	0	14	0	22	0	0%	0%	0%
Bradan Beo Teo.	**Ardmore**	6	0	8	0	14	0	0%	0%	0%
Comhlucht Bradain Chonamara Teo.	**Outer Bertraghboy Bay**	2	0	5	0	7	0	0%	0%	0%
	Sealax	0	0	1	0	1	0	0%	0%	0%
Rosroe Salmon Ltd.	**Inishdeighil**	6	0	10	0	16	0	0%	0%	0%
	Rosroe	0	0	1	0	1	0	0%	0%	0%
Clare Island Seafarms Ltd.	**Clare Island Portlea**	1	0	6	0	7	0	0%	0%	0%
West	**Totals**	15	0	31	0	46	0	0%	0%	0%
Ocean Farm Ltd.	**Ocean Inver**	6	0	8	0	14	0	0%	0%	0%
Marine Harvest Ireland	**Creevin**	6	0	8	0	14	0	0%	0%	0%
	Glinsk	3	0	6	0	9	0	0%	0%	0%
	Millstone	4	0	6	0	10	0	0%	0%	0%
Northwest	**Totals**	19	0	28	0	47	0	0%	0%	0%
National Totals		42	0	73	0	115	0	0%	0%	0%

The maximum *C. elongatus* level recorded was 6.07 at Roancarrig-Ahabeg in September in 2016.

Sampling record

Two samples were missed due to poor weather conditions in the 2016 sampling year (Deenish in January and Lough Swilly in April).

One-sea-winter salmon monthly trend by bay

Bay mean ovigerous and mean mobile *L. salmonis* and *C. elongatus* levels for each bay are shown in Table 8 for one-sea-winter salmon throughout the year. Monthly ovigerous *L. salmonis* levels greater than the spring TTL of 0.5 ovigerous sea lice per fish were recorded on 4 of the 25 occasions. Of these, 2 were in Clew Bay and there was 1 each in Mannin Bay and Donegal Bay.

Bay mean ovigerous levels of 2.0 ovigerous females per fish or greater were recorded on 7 out of 42 occasions, outside of the spring period. These occurred in Clew Bay on 3 occasions, Ballinakill Harbour on 2 occasions, and once each at Mannin Bay and Bealacragher Bay.

Mean mobile levels per bay in excess of 10 *L. salmonis* per fish were recorded on 6 occasions, 3 of these instances had means of greater than 20 mobile lice per fish. The maximum bay mean level recorded was 37.6 mobile sea lice per fish, in Ballinakill Harbour in January.

Table 8. *Mean ovigerous and mean mobile Lepeophtheirus salmonis and Caligus elongatus levels per month, for one-sea-winter salmon, for each bay inspected in the year 2016.*

Mean ovigerous *L. salmonis*

	Dec/ Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Bantry Bay	0.24	0.29	0.13	0.10	0.19	0.00	HO				
Kenmare Bay		0.11	0.03	0.10	0.08	0.00	0.04	0.32	0.03	0.48	HO
Kilkieran Bay	0.02	0.02	0.11	0.01	0.03	0.03	HO				
Bertraghboy Bay	0.00	0.02	0.11	0.09	0.36	0.55	0.95	0.37	1.38	HO	
Mannin Bay			0.42	7.52	HO			4.43	HO		
Ballinakill Harbour	8.34	10.76	HO							0.39	HO
Clew Bay	0.02	4.46	0.97	0.29	1.28	1.11	0.25	1.97	1.96	3.85	4.41
Bealacragher Bay	0.16	2.72	0.29	0.11	HO						
Donegal Bay	0.54	0.65	0.30	0.30	0.94	HO					
Lough Swilly	0.05	0.00	0.01	0.00	0.26	0.57	1.60	0.19	0.00	0.00	0.06

Mean mobile *L. salmonis*

	Dec/ Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Bantry Bay	0.72	2.40	0.39	2.02	1.52	0.17	HO				
Kenmare Bay		0.62	0.08	0.30	0.38	0.15	0.06	0.87	0.10	1.05	HO
Kilkieran Bay	0.14	0.58	0.47	0.35	1.10	0.33	HO				
Bertraghboy Bay	0.02	0.22	0.31	0.77	1.57	1.46	10.79	18.22	1.98	HO	
Mannin Bay			4.33	14.70	HO			6.86	HO		
Ballinakill Harbour	37.58	33.46	HO							3.40	HO
Clew Bay	3.22	24.04	5.21	1.77	4.38	2.28	1.83	5.23	5.33	9.28	7.55
Bealacragher Bay	9.48	7.20	1.21	9.83	HO						
Donegal Bay	2.51	2.79	1.39	3.18	6.62	HO					
Lough Swilly	0.13	0.06	0.13	0.18	2.08	1.42	5.14	4.52	4.54	1.42	0.18

Mean ovigerous *C. elongatus*

	Dec/ Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Bantry Bay	0.38	0.23	0.05	0.20	0.09	0.00	HO				
Kenmare Bay		0.00	0.00	0.01	0.03	0.00	0.36	3.81	0.00	4.43	HO
Kilkieran Bay	0.42	0.50	0.10	0.03	1.18	1.13	HO				
Bertraghboy Bay	0.40	1.09	1.04	0.51	0.19	0.00	1.02	0.24	0.00	HO	
Mannin Bay			0.01	0.00	HO			0.00	HO		
Ballinakill Harbour	0.05	0.00	HO							0.06	HO
Clew Bay	0.04	0.00	0.00	0.00	0.08	0.13	0.34	0.99	3.54	1.87	0.62
Bealacragher Bay	0.00	0.00	0.00	0.00	HO						
Donegal Bay	0.74	0.00	0.03	0.01	0.07	HO					
Lough Swilly	0.15	0.00	0.00	0.00	0.00	0.02	0.13	0.00	0.00	0.12	7.12

Mean mobile *C. elongatus*

	Dec/ Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Bantry Bay	0.43	0.52	0.06	0.44	0.65	0.00	HO				
Kenmare Bay		0.00	0.02	0.03	0.10	0.00	0.94	10.63	0.03	11.43	HO
Kilkieran Bay	0.59	0.77	0.13	0.10	2.00	2.60	HO				
Bertraghboy Bay	0.73	1.74	1.22	0.82	0.41	0.25	2.69	1.10	0.00	HO	
Mannin Bay			0.01	0.00	HO			0.00	HO		
Ballinakill Harbour	0.05	0.03	HO							0.09	HO
Clew Bay	0.13	0.00	0.00	0.00	0.21	0.35	0.61	1.96	5.84	3.10	0.76
Bealacragher Bay	0.00	0.00	0.00	0.00	HO						
Donegal Bay	1.38	0.04	0.03	0.04	0.08	HO					
Lough Swilly	0.21	0.00	0.00	0.00	0.07	0.02	0.17	0.05	0.00	0.14	16.29

HO = Harvested out

Regional monthly means for one-sea-winter salmon

L. salmonis ovigerous and mobile monthly mean levels per fish for one-sea-winter salmon regionally are shown in Figures 3 and 4. In the spring period of 2016 the ovigerous mean sea lice levels per fish exceeded TTLs for April and May in the West, and for May in the Northwest.

Outside the spring regional mean ovigerous *L. salmonis* levels per fish were in excess of TTL in February, August, October and November in the West.

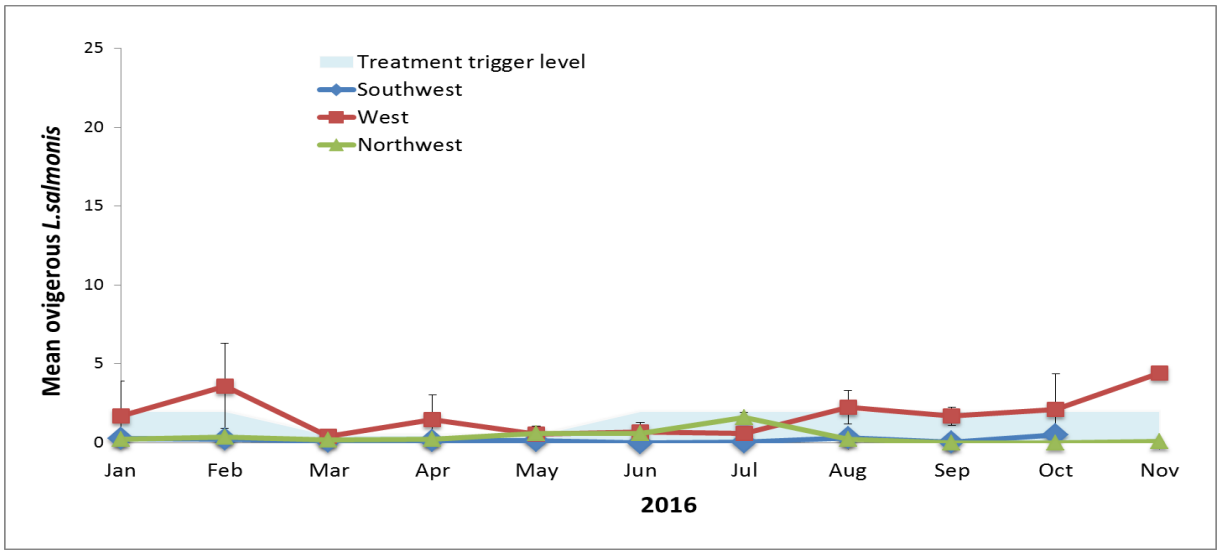

Figure 3. *Mean (SE) ovigerous L. salmonis per fish per month per region in 2016 on one-sea-winter salmon fish.*

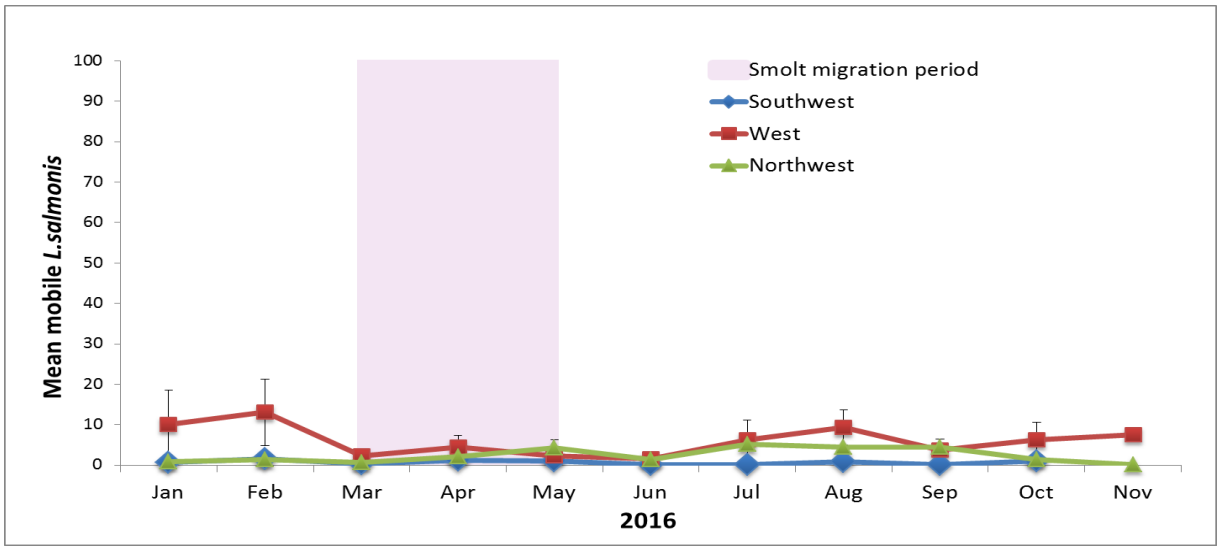

Figure 4. *Mean (SE) mobile L. salmonis per fish per month per region in 2016 on one-sea-winter salmon.*

Total mobile *L. salmonis* levels exceeded 10 sea lice per fish in January and February in the West, but neither the Southwest nor the Northwest reached this level. Total regional mean mobile *L. salmonis* levels peaked at 1.51 mobile sea lice per fish in the Southwest, 13.1 mobile sea lice per fish in the West and at 5.14 mobile sea lice per fish in the Northwest.

Annual trends

The annual trends of *L. salmonis* ovigerous and mobile sea lice levels are compared in Figures 5 and 6 for one-sea-winter salmon in the month of May from 1991 to 2016.

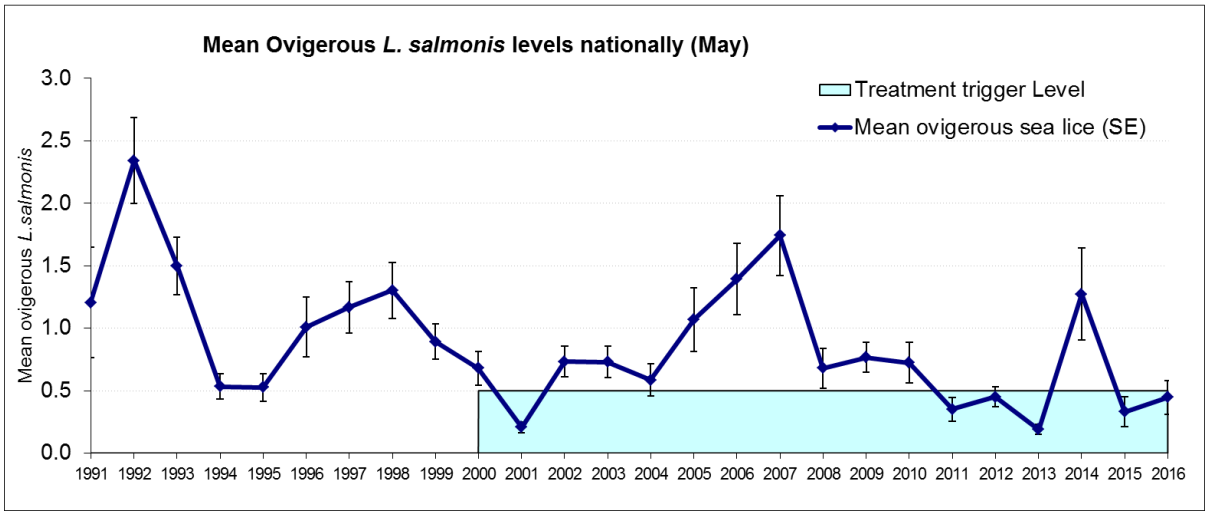

Figure 5. *Annual trend (May mean) (SE) ovigerous L. salmonis on one-sea-winter salmon.*

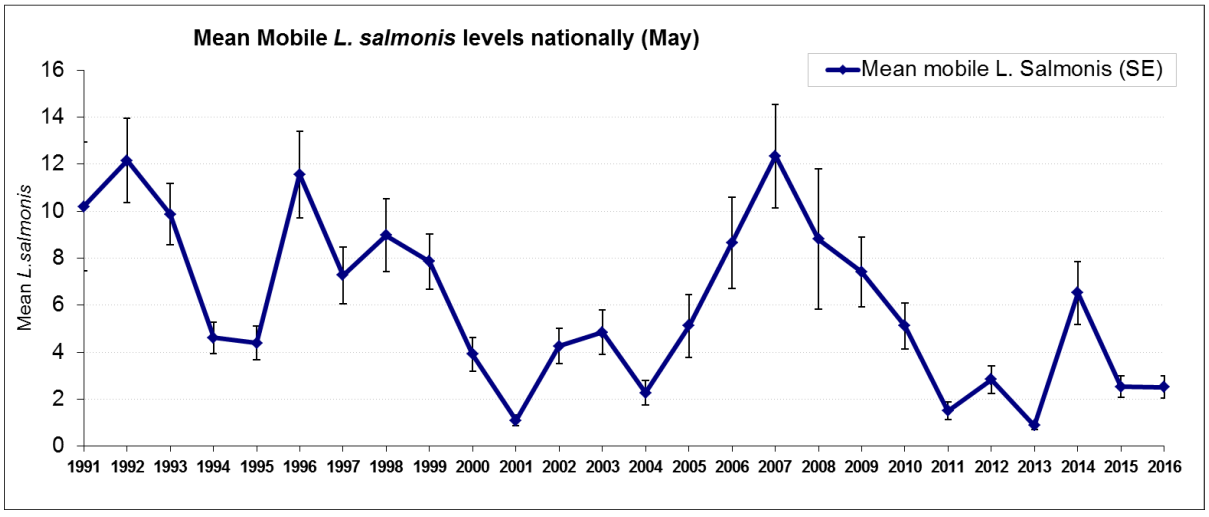

Figure 6. *Annual trend (May mean) (SE) mobile L. salmonis on one-sea-winter salmon.*

Mean ovigerous *L. salmonis* levels in May of 2016 increased to 0.45 sea lice per fish, compared to 0.33 in 2015 and 1.27 in 2014. Total mobile levels also of 2.52 are similar to May 2015 at 2.53 sea lice per fish.

DISCUSSION

Sea lice levels on smolts in 2016 were low. All of the sea lice inspections carried out on smolts were below the Treatment Trigger Levels (TTL); this compares with 97% in 2015 and 94% in 2014.

On one-sea-winter salmon sea lice levels decreased in 2016 compared to 2015. In 2016 84% of inspections were below TTL compared to 78% in 2015 and 71% in 2014. During the spring period in the Northwest 91% of inspections were below the TTL compared to 81% in 2015. In the West, for the same period, 73% were below TTL which is an increase from 63% on 2015. The Southwest again continued to have no breaches of protocol levels in 2016. All of the inspections on one-sea-winter salmon, done outside of the spring period, were below TTL in the Northwest and Southwest, while 70% were below in the West. These compare to 69% in the Northwest, 61% below in the West, and 100% in the Southwest during 2015.

Sea lice levels in excess of 10 *L. salmonis* mobiles per fish on one-sea-winter salmon nationally were recorded on 8 occasions, compared to 13 occasions in 2015 and 26 in 2014, four of these inspections had means of greater than 20 mobile *L. salmonis* per fish which was the same as 2015. The highest mean sea lice level recorded for one-sea-winter salmon was 37.6 mobile *L. salmonis* per fish, this compares to 71.5 mobile *L. salmonis* per fish in 2015 and 137.6 mobile *L. salmonis* per fish in 2014. There were no unusually high numbers of *Caligus elongatus* recorded in 2016.

During the spring period, the greatest improvement in sea lice numbers in 2016 was on grower fish in the West - the number of inspections below TTLs increased from 64% in 2015 to 73% in 2016. Outside the spring period, the greatest improvement in sea lice numbers in 2016 was recorded in the Northwest as the number of inspections below TTLs increased from 69% in 2015 to 100% in 2016. Inspections of salmon smolts, outside the spring period 2016, recorded no breaches of TTLs as compared with 3 nationally in 2015. The regional plots (Figure 3 & 4) show that sea lice numbers remained low throughout the year. There was no autumn increase in 2016 as there had been in 2015.

The pro-active approach of farms by carrying out regular on-farm sea lice checks has allowed efficient on-site management which facilitates early intervention resulting in better sea lice control generally. Notably, the Single Bay Management platform has helped to coordinate efforts to reduce lice levels among sites within bays.

Alternative approaches to complement medicinal treatments, coupled with a rigorous pro-active regulatory oversight, meant that sea lice levels in Ireland during 2016 have generally been managed well. There is a growing trend in the use of cleaner fish with anecdotal evidence to suggest they are working well at reducing numbers of ovigerous female lice. Their use is becoming more widespread in Ireland; in fact, their presence was noted at 50% of all salmon farm sites in Ireland in 2016.

GLOSSARY

Grower:	A fish which has been at sea for one complete year or longer.
Mobile lice:	All sea lice that are mobile – male and female (pre-adult and adult stages) sea lice that have developed beyond the attached larval stages.
n<10	Ten fish or less were inspected in one or both cages sampled.
Ovigerous lice:	An egg bearing adult female sea lice.
Random (Ran.) Cage:	A cage which is selected by the Inspector on the day of inspection.
Salmonids:	A fish of the family Salmonidae. It includes salmon, trout and charr.
Standard (Std.) Cage:	The selected cage which is sampled at each inspection.
S1 Smolt:	This pertains to a stage in the life cycle of the salmon when it changes from being a freshwater fish to a seawater fish, a process known as smoltification. These fish are transported to the saltwater environment in the spring, which is approximately 15 months after they were hatched.
S½ Smolt (also known as S0):	These fish are exposed to manipulated photoperiods to hasten the onset of smoltification. Hence an S½ smolt is ready to go to sea during the autumn/winter, approximately 11 months after hatching. They are sometimes referred to as S0 (S zero) smolts.
SE:	Standard error (error bars in the graphs) is the standard error of the mean of a sample from a population with a normal distribution, which is equal to the standard deviation of the normal distribution divided by the square root of the sample size.

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APPENDIX 1. MEAN SEA LICE LEVELS ON SALMONID FARMS IN 2016.

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
BANTRY BAY					
MARINE HARVEST IRL.					
Roancarraig-Ahabeg					
Atlantic Salmon, 2015 S1/2	27/01/2016	0.24	0.72	0.38	0.43
	03/02/2016	0.29	2.40	0.23	0.52
	14/03/2016	0.23	0.63	0.03	0.03
	23/03/2016	0.02	0.16	0.07	0.10
	12/04/2016	0.03	2.00	0.14	0.37
	25/04/2016	0.17	2.04	0.26	0.51
	10/05/2016	0.18	0.50	0.00	0.00
	25/05/2016	0.20	2.54	0.17	1.29
	08/06/2016	0.00	0.17	0.00	0.00
			Harvested Out		
Atlantic Salmon, 2016 S1/2	27/01/2016	0.00	0.06	0.02	0.02
	03/02/2016	0.00	2.21	0.03	0.37
	14/03/2016	0.00	0.22	0.02	0.04
	23/03/2016	0.00	0.32	0.00	0.06
	12/04/2016	0.00	0.01	0.00	0.01
	25/04/2016	0.00	0.02	0.08	0.19
	10/05/2016	0.02	0.31	0.34	1.02
	25/05/2016	0.00	1.69	1.17	2.79
	08/06/2016	0.00	1.45	0.17	0.23
	22/07/2016	0.04	0.54	0.60	1.07
	17/08/2016	0.00	3.15	1.11	1.95
	19/09/2016	0.00	0.29	3.48	6.07
	10/10/2016	0.00	0.29	1.09	2.68
	03/11/2016	0.02	0.12	0.44	0.79

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
KENMARE BAY					
Deenish					
Atlantic Salmon, 2015 S1/2	27/01/2016		Missed due to weather		
	03/02/2016	0.11	0.62	0.00	0.00
	14/03/2016	0.02	0.06	0.00	0.02
	23/03/2016	0.04	0.11	0.00	0.02
	12/04/2016	0.10	0.29	0.00	0.05
	25/04/2016	0.10	0.31	0.02	0.02
	11/05/2016	0.15	0.68	0.05	0.20
	25/05/2016	0.00	0.08	0.00	0.00
	09/06/2016	0.00	0.15	0.00	0.00
	21/07/2016	0.04	0.06	0.36	0.94
	18/08/2016	0.32	0.87	3.81	10.63
	19/09/2016	0.03	0.10	0.00	0.03
	19/10/2016	0.48	1.05	4.43	11.43
			Harvested out		
Inishfarnard					
Atlantic Salmon, 2014			Harvested Out		
Atlantic Salmon, 2016	10/05/2016	0.00	0.01	0.10	0.27
	25/05/2016	0.00	0.05	0.10	0.52
	08/06/2016	0.00	0.04	0.04	0.05
	22/07/2016	0.00	0.00	0.00	0.47
	17/08/2016	0.00	0.00	0.05	0.15
	19/09/2016	0.03	0.08	2.01	4.29
	10/10/2016	0.00	0.12	0.87	1.65
	03/11/2016	0.00	0.00	0.02	0.02

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
KILKIERAN BAY					
BRADAN BEO TEO.					
Ardmore					
Atlantic Salmon, 2016 S1/2	03/12/2015	0.00	0.02	0.08	0.10
	12/02/2016	0.05	0.45	0.22	0.39
	07/03/2016	0.02	0.18	0.36	0.46
	23/03/2016	0.02	0.20	0.14	0.28
	15/04/2016	0.00	0.25	0.02	0.04
	26/04/2016	0.00	0.25	0.00	0.00
	10/05/2016	0.00	0.08	0.00	0.02
	20/05/2016	0.02	0.11	0.00	0.00
	01/06/2016	0.03	0.14	0.00	0.02
	05/07/2016	0.05	0.10	0.02	0.02
	25/08/2016	0.00	0.05	0.00	0.00
	07/09/2016	0.00	0.06	0.02	0.02
	12/10/2016	0.00	0.02	0.79	1.47
	03/11/2016	0.00	0.04	0.33	1.04
Daonish					
Atlantic Salmon, 2015 S1/2	15/12/2015	0.02	0.14	0.42	0.59
	12/02/2016	0.02	0.58	0.50	0.77
	07/03/2016	0.14	0.59	0.20	0.25
	29/03/2016	0.08	0.35	0.00	0.00
	15/04/2016	0.02	0.19	0.00	0.05
	26/04/2016	0.00	0.52	0.05	0.15
	10/05/2016	0.00	0.73	0.32	0.77
	25/05/2016	0.05	1.47	2.05	3.23
	02/06/2016	0.03	0.33	1.13	2.60
				Harvested Out	

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
BERTRAGHBOY BAY					
COMHLUCHT BRADAIN CHONAMARA TEO.					
Outer Bertraghboy Bay					
Atlantic Salmon, 2016	09/05/2016	0.00	0.00	0.00	0.12
	24/05/2016	0.00	0.03	0.04	0.04
	02/06/2016	0.00	0.02	0.00	0.00
	06/07/2016	0.09	2.44	0.03	0.24
	09/08/2016	0.06	0.96	0.00	0.00
	13/09/2016	0.13	2.06	0.00	0.00
	21/10/2016	1.70	4.98	0.00	0.08
			Transferred to Sealax		
Sealax					
Atlantic Salmon, 2015	11/12/2015	0.00	0.02	0.40	0.73
	10/02/2016	0.02	0.22	1.09	1.74
	11/03/2016	0.10	0.35	1.25	1.54
	23/03/2016	0.12	0.27	0.82	0.91
	12/04/2016	0.15	0.77	0.84	1.31
	21/04/2016	0.03	0.77	0.19	0.34
	09/05/2016	0.10	1.76	0.37	0.81
	30/05/2016	0.62	1.39	0.02	0.02
	20/06/2016	0.55	1.46	0.00	0.25
	06/07/2016	0.95	10.79	1.02	2.69
	09/08/2016	0.37	18.22	0.24	1.10
	23/09/2016	1.38	1.98	0.00	0.00
			Transferred to Fraochoilean		
Atlantic Salmon, 2016	07/11/2016	0.60	1.16	0.00	0.14

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	**Total**	**F + eggs**	**Total**
BALLINAKILL HARBOUR					
BIFAND LTD.					
Fraochoilean					
Atlantic Salmon, 2015 S1/2	27/01/2016	8.34	37.58	0.05	0.05
	25/02/2016	10.76	33.46	0.00	0.03
		Transferred to Corhounagh, remainder harvested out			
Atlantic Salmon, 2015	21/10/2016	0.39	3.40	0.06	0.09
			Harvested out		
MANNIN BAY					
BIFAND LTD.					
Corhounagh					
Atlantic Salmon, 2015 S1/2	16/03/2016	0.40	3.29	0.00	0.00
	22/03/2016	0.45	5.38	0.02	0.02
	05/04/2016	5.35	11.67	0.00	0.00
	25/04/2016	11.87	20.77	0.00	0.00
			Harvested Out		
COMHLUCHT BRADAIN CHONAMARA TEO.					
Corhounagh					
Atlantic Salmon, 2015	25/08/2016	4.43	6.86	0.00	0.00
			Harvested Out		

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
KILLARY HARBOUR					
ROSROE SALMON LTD.					
Inishdeighil					
Atlantic Salmon, 2016 S1/2	25/01/2016	0.02	0.36	0.00	0.00
	11/02/2016	0.05	0.30	0.00	0.00
	10/03/2016	0.00	0.37	0.02	0.02
	31/03/2016	0.00	0.82	0.00	0.00
	13/04/2016	0.02	0.44	0.00	0.00
	27/04/2016	0.00	0.25	0.00	0.00
	11/05/2016	0.00	0.48	0.00	0.05
	25/05/2016	0.00	0.14	0.01	0.02
	27/06/2016	0.00	0.00	0.02	0.05
	14/07/2016	0.00	0.00	0.15	0.24
	19/08/2016	0.08	0.28	1.57	3.34
	06/09/2016	0.07	0.12	0.07	0.16
	19/10/2016	0.26	0.56	0.56	0.97
	14/11/2016	0.39	1.64	0.43	0.88
Atlantic Salmon, 2016	14/07/2016	0.00	0.03	0.03	0.07
	19/08/2016	Sampled Atlantic salmon 2016 S1/2			
	06/09/2016	Sampled Atlantic salmon 2016 S1/2			
	19/10/2016	0.04	0.23	0.23	0.46
	14/11/2016	Sampled Atlantic salmon 2016 S1/2			
Rosroe					
Atlantic Salmon, 2016	27/06/2016	0.00	0.00	0.00	0.00
		Transferred to Inishdeighil			

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
CLEW BAY					
CLARE ISLAND SEAFARMS LTD.					
Clare Island Smolt Site					
Atlantic Salmon, 2015			Transferred to Portlea		
Atlantic Salmon, 2015	31/03/2016	0.50	2.21	0.00	0.00
	12/04/2016	0.40	2.15	0.00	0.00
	22/04/2016	0.19	1.39	0.00	0.00
	13/05/2016	1.05	5.69	0.15	0.42
	31/05/2016	1.51	3.07	0.00	0.00
	17/06/2016	1.11	2.28	0.13	0.35
	18/07/2016	0.25	1.83	0.34	0.61
	18/08/2016	1.97	5.23	0.99	1.96
	19/09/2016	1.96	5.33	3.54	5.84
	13/10/2016	3.85	9.28	1.87	3.10
	04/11/2016	4.41	7.55	0.62	0.76
Portlea					
Atlantic Salmon, 2014			Transferred to Seastream		
Atlantic Salmon, 2015	15/12/2015	0.02	3.22	0.04	0.13
	23/02/2016	4.46	24.04	0.00	0.00
	10/03/2016	1.43	8.21	0.00	0.00
			Transferred to Clare Island Smolt Site		
Atlantic Salmon, 2016	31/05/2016	0.00	0.06	0.06	0.06
	17/06/2016	0.00	0.08	0.08	0.13
	18/07/2016	0.00	0.03	0.21	0.38
	18/08/2016	0.11	0.42	0.16	0.33
	19/09/2016	0.00	0.24	0.54	1.14
	13/10/2016	0.02	0.08	0.00	0.03
	04/11/2016	0.15	1.39	0.48	1.02
Seastream					
Atlantic Salmon, 2014	23/02/2016	0.45	4.30	0.00	0.00
			Harvested out		

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
BEALACRAGHER BAY					
CURRAUN BLUE LTD.					
Curraun					
Atlantic Salmon, 2015 S1/2	08/01/2016	0.16	9.48	0.00	0.00
	05/02/2016	2.72	7.20	0.00	0.00
	11/03/2016	0.41	1.43	0.00	0.00
	29/03/2016	0.18	0.99	0.00	0.00
	11/04/2016	0.22	9.26	0.00	0.00
	20/04/2016	0.00	10.40	0.00	0.00
			Harvested Out		
DONEGAL BAY					
MARINE HARVEST IRL.					
Creevin					
Atlantic Salmon, 2016 S1/2	12/01/2016	0.00	0.04	0.06	0.08
	10/02/2016	0.00	0.02	0.22	0.49
	07/03/2016	0.00	0.03	0.51	0.65
	23/03/2016	0.00	0.08	0.47	0.87
	08/04/2016	0.00	0.08	0.21	0.49
	25/04/2016	0.06	0.16	0.21	0.66
	11/05/2016	0.04	0.38	1.04	2.83
	24/05/2016	0.11	0.41	1.19	2.84
	22/06/2016	0.13	0.23	0.02	0.07
	12/07/2016	0.00	0.16	0.02	0.03
	16/08/2016	0.02	0.09	0.00	0.00
	07/09/2016	0.00	0.32	0.00	0.00
	11/10/2016	0.14	0.34	0.02	0.02
	23/11/2016	0.78	3.19	1.22	2.66

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
DONEGAL BAY					
OCEAN FARM LTD.					
Mc Swynes					
Atlantic Salmon, 2015	13/01/2016	0.54	2.51	0.74	1.38
	11/02/2016	0.65	2.79	0.00	0.04
	08/03/2016	0.31	0.95	0.02	0.02
	23/03/2016	0.30	1.84	0.04	0.04
	08/04/2016	0.22	4.82	0.02	0.05
	25/04/2016	0.39	1.54	0.00	0.03
	11/05/2016	0.42	5.57	0.04	0.04
	24/05/2016	1.46	7.67	0.11	0.13
			Harvested Out		
Ocean Inver					
Atlantic Salmon, 2016 S1/2	13/01/2016	0.00	0.00	0.02	0.02
	11/02/2016	0.00	0.00	0.00	0.19
	08/03/2016	0.00	0.00	0.23	0.43
	23/03/2016	0.00	0.06	0.06	0.28
	08/04/2016	0.02	0.05	0.09	0.24
	25/04/2016	0.02	0.28	0.89	1.66
	11/05/2016	0.03	0.20	0.86	2.53
	24/05/2016	0.00	0.22	0.89	2.00
	22/06/2016	0.00	0.19	0.58	1.02
	12/07/2016	0.04	0.09	0.00	0.06
	16/08/2016	0.37	0.50	0.12	0.19
	07/09/2016	0.05	0.30	0.00	0.00
	11/10/2016	0.48	0.70	0.00	0.02
	24/11/2016	0.31	2.01	0.37	0.66

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
MULROY BAY					
MARINE HARVEST IRL.					
Glinsk					
Atlantic Salmon, 2015			Transferred to Lough Swilly		
Atlantic Salmon, 2016	26/04/2016	0.00	0.00	0.00	0.06
	05/05/2016	0.00	0.02	0.02	0.10
	17/05/2016	0.00	0.04	0.06	0.19
	09/06/2016	0.00	0.00	0.14	0.26
	13/07/2016	0.00	0.00	0.00	0.00
	17/08/2016	0.00	0.00	0.00	0.00
	08/09/2016	0.00	0.00	0.00	0.00
	12/10/2016	0.00	0.02	0.00	0.00
	22/11/2016	0.00	0.02	0.03	0.11
Millstone					
Atlantic Salmon, 2016	12/04/2016	0.00	0.00	0.00	0.00
	26/04/2016	0.00	0.02	0.02	0.13
	05/05/2016	0.00	0.02	0.07	0.30
	17/05/2016	0.00	0.00	0.30	0.55
	09/06/2016	0.00	0.04	0.43	0.47
	13/07/2016	0.00	0.00	0.00	0.00
	17/08/2016	0.00	0.00	0.00	0.00
	08/09/2016	0.00	0.00	0.00	0.00
	12/10/2016	0.00	0.07	0.00	0.00
	22/11/2016	0.03	0.26	0.15	0.22

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
LOUGH SWILLY					
Lough Swilly					
Atlantic Salmon, 2015	11/01/2016	0.05	0.13	0.15	0.21
	10/02/2016	0.00	0.06	0.00	0.00
	07/03/2016	0.02	0.13	0.00	0.00
	24/03/2016	0.00	0.13	0.00	0.00
	12/04/2016	0.00	0.18	0.00	0.00
	28/04/2016		Missed due to weather		
	05/05/2016	0.06	0.96	0.00	0.14
	17/05/2016	0.47	3.20	0.00	0.00
	09/06/2016	0.57	1.42	0.02	0.02
	13/07/2016	1.60	5.14	0.13	0.17
	17/08/2016	0.19	4.52	0.00	0.05
	08/09/2016	0.00	4.54	0.00	0.00
	12/10/2016	0.00	1.42	0.12	0.14
	23/11/2016	0.06	0.18	7.12	16.29

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