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National Survey of Sea Lice (*Lepeophtheirus salmonis* Krøyer and *Caligus elongatus* Nordmann) on Fish Farms in Ireland - 2019

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NATIONAL SURVEY OF SEA LICE (*LEPEOPHTHEIRUS SALMONIS* KRØYER AND *CALIGUS ELONGATUS* NORDMANN) ON FISH FARMS IN IRELAND – 2019

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INTRODUCTION

Sea lice are a naturally occurring parasite found on marine fish, including salmonids. They are small ecto-parasitic copepod crustaceans and there are approximately 559 species, made up of 37 genera (Ahyong *et al*., 2011), including 268 *Caligus* species (Boxshall, 2011) and 162 *Lepeophtheirus* species (Chad & Goeff, 2011). The two main species found in Ireland are *Caligus elongatus* and *Lepeophtheirus salmonis*. *C. elongatus* is known to parasitise over 80 different species of marine fish while *L. salmonis* infests only salmonids. *L. salmonis* is endemic at a high prevalence (>90%) within wild populations (Jackson *et al.,* 2013), and occurs frequently on farmed salmonids (Jackson & Minchin, 1992; Jackson *et al.,* 2005). There is one species of salmonid farmed at sea in Ireland on a commercial basis, namely, Atlantic salmon *Salmo salar* (Linnaeus, 1758).

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 stage. 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 (Figure 1). The rate of this development through the different stages is dependent upon sea water temperature (Figure 2). The adult female can produce batches of paired egg-strings, which in turn hatch into the water column to give rise to the next generation (Hamre *et al*., 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).

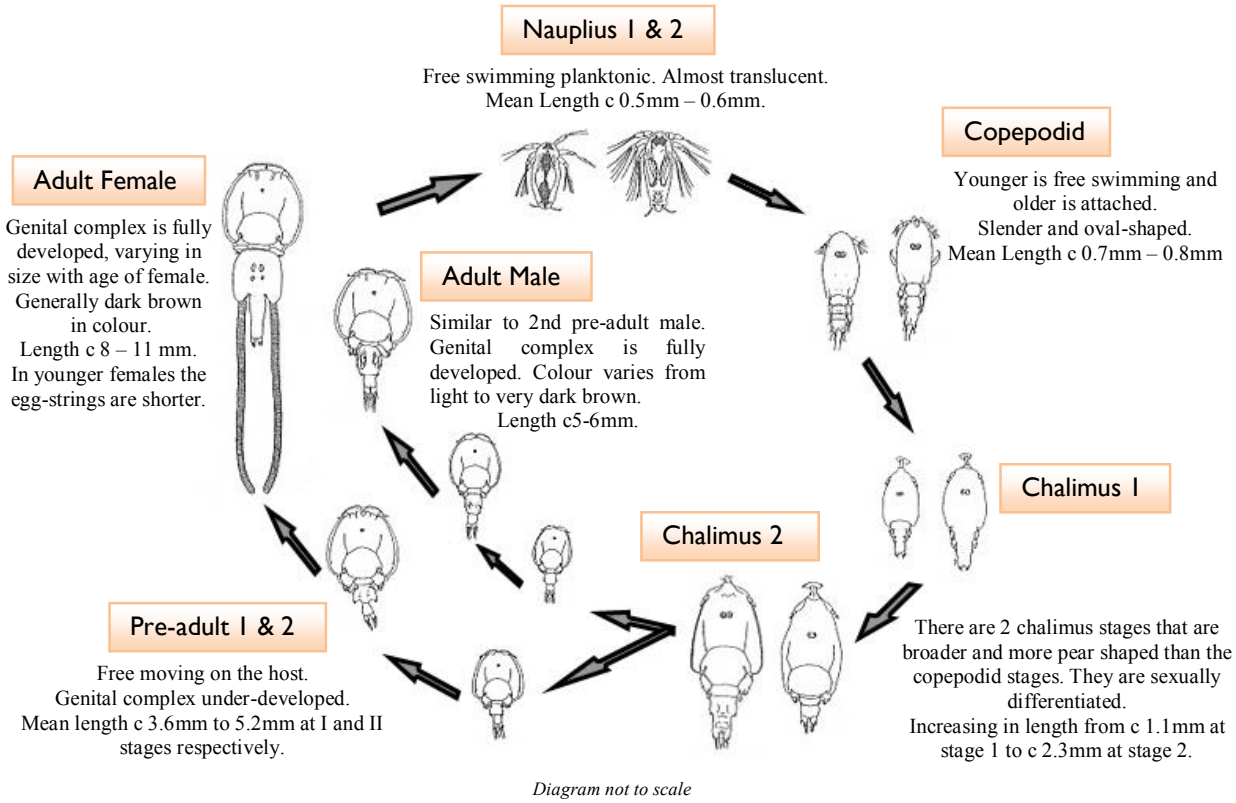

Figure 1 *Life cycle of Lepeophtheirus salmonis (after Schram, 1993 & Hamre et al., 2013).*

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.

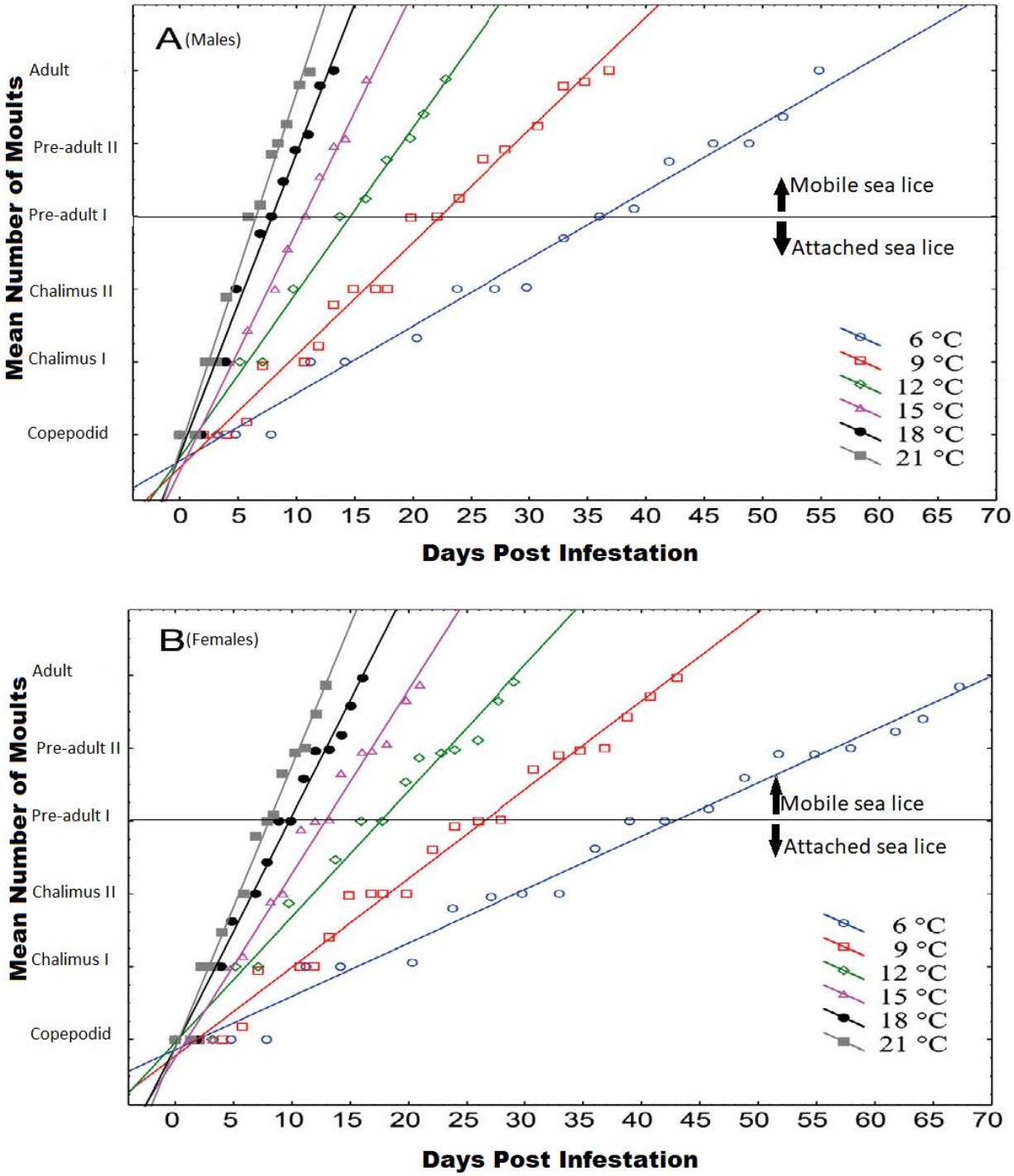

Figure 2 Mean number of moults vs. days post infestation for *L. salmonis* (A) males and (B) females.

Adapted from Hamre, et al., 2019

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 monitoring 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 practices.

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 synchronised 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 the 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 (Figure 2). 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 infestation. 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 is 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.*, 2003-2019).

Sea Lice Management

The sea lice management strategy includes the use of husbandry, management practises, veterinary medicines and non-medicinal measures to control sea lice infestation on farms. Table 1 shows a list of the veterinary medicines authorised to assist in the control of sea lice in Ireland. These are either 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 using well-boats or tarpaulins/skirts to enclose the salmon net-pens. 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 result in reduced efficacy in the short term and lead to development of resistance over time. For this and other reasons, current management practices are migrating away from veterinary medicines and moving toward non-medicinal removal of sea lice. A multi-pronged approach to sea lice control is considered more effective in the long-term and may combine biological, mechanical, thermal and hyposaline measures.

Cleaner fish as a control method of sea lice continue to be used in Ireland. Farms typically stock the five species of wrasse most common in Irish waters, namely, Ballan wrasse *Labrus bergylta* (Ascanius, 1767); Goldsinny wrasse *Ctenolabrus rupestris* (L., 1758); Rock cook wrasse *Centrolabrus exoletus* (L., 1758); Corkwing wrasse *Crenilabrus melops* (L., 1758); Cuckoo wrasse *Labrus mixtus* (L., 1758). Lumpfish *Cyclopterus lumpus* (L., 1758) are a more suitable cold-water option for biological delousing of Atlantic salmon (Imsland *et al.*, 2014) and continue to be deployed with positive effects on farms in Ireland as part of a sea lice management plan.

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-infesting stocks adjacent to the harvest area (O'Donohoe & McDermott, 2014).

In addition to mechanical de-lousing methods which were observed in previous years, thermal de-lousing was used on several farms for the first time in Ireland in 2019, with high levels of clearance being reported. Additionally, the use of hyposaline water to reduce harmful amoeba has had the added benefit of reducing sea lice numbers, particularly during the warmer summer months.

Table 1 *Veterinary medicines authorised 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
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 the 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 sea 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 are a measure of the breeding female population and total mobile levels provide an indication of current 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 reduction in sea lice levels on the subsequent inspection.

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 (Figure 3).

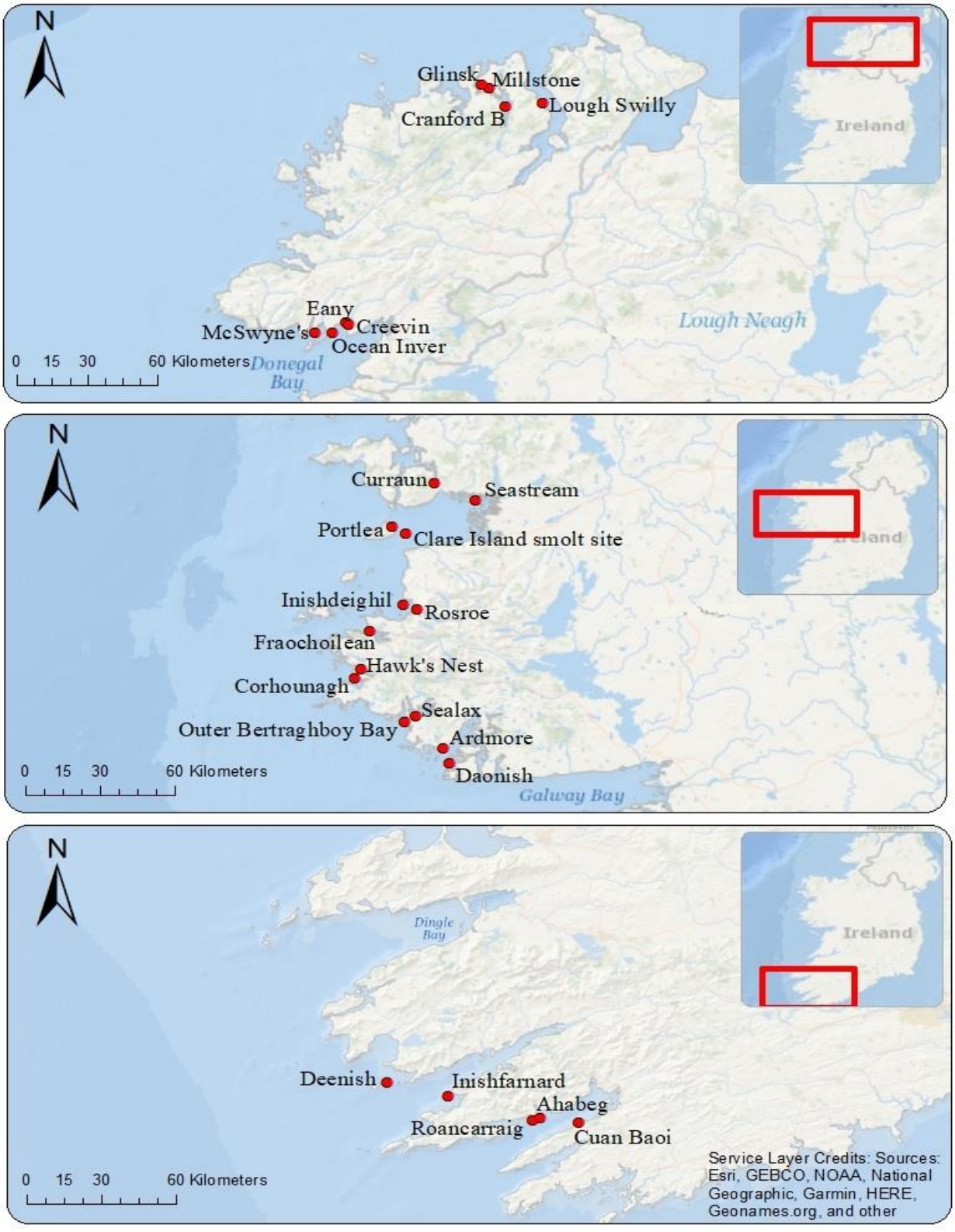

Figure 3 *Locations of fish farm sites active in 2019*

RESULTS

During 2019 a total of 210 sea lice inspections were carried out on the 24 active farm sites. Over 91% 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). Of the 122 inspections carried out on salmon smolts 96% were below the TTL and 84% of the 87 inspections carried out on one-sea-winter salmon were below the TTL.

Results of monthly sea lice inspections of all active salmonid sites for 2019 are presented in Appendix 1.

Atlantic salmon 2018 (one-sea-winter salmon)

One-sea-winter salmon were stocked in a total of 13 sites in 9 bays in 2019. Eighty-seven inspections were undertaken with this generation of fish.

Ovigerous *L. salmonis* levels greater than the TTL were recorded for a total of 14 out of 87 inspections (16%) on one-sea-winter fish (Table 2). Within the critical spring period sea lice levels were in excess of 0.5 ovigerous females per fish on twelve out of 51 inspections (24%) and outside of the spring period two out of 36 inspections (6%) were in excess of 2.0 ovigerous female *L. salmonis* per fish.

C. elongatus levels greater than 10 individuals per fish were recorded on two occasions during the year.

Table 2 *Summary of inspection results on one-sea-winter salmon nationally in 2019.*

	Samples in Spring	Ovigerous > TTL in Spring	Samples outside Spring	Ovigerous > TTL outside Spring	Total Samples	Total Ovigerous > TTL	% over in Spring	% over outside Spring	% over total
National Totals	51	12	36	2	87	14	24%	6%	16%

Southwest Region

In the Southwest there were no recorded instances of *L. salmonis* levels greater than the TTL (Table 3).

Table 3 *Summary of inspection results on one-sea-winter salmon in the Southwest in 2019*

Company	Site	Samples in Spring	Ovigerous > TTL in Spring	Samples outside Spring	Ovigerous > TTL outside Spring	Total Samples	Total Ovigerous > TTL	% over in Spring	% over outside Spring	% over total
Marine Harvest Ireland	**Inishfarnard**	6	0	4	0	10	0	0%	0%	0%
Southwest	**Totals**	6	0	4	0	10	0	0%	0%	0%

West Region

In the West, *L. salmonis* infestation levels greater than the TTL were recorded on one out of 24 inspections (4%) in the spring period and on one out of 17 inspections (6%) outside the spring period (Table 4).

Table 4 *Summary of inspection results on one-sea-winter salmon in the West in 2019.*

Company	Site	Samples in Spring	Ovigerous > TTL in Spring	Samples outside Spring	Ovigerous > TTL outside Spring	Total Samples	Total Ovigerous> TTL	% over in Spring	% over outside Spring	% over total
Bradan Beo Teo.	**Ardmore**	2	0	2	0	4	0	0%	0%	0%
Bifând Ltd./Marine Harvest Ireland	**Outer Bertraghboy Bay**	6	0	3	0	9	0	0%	0%	0%
	Sealax	5	0	2	0	7	0	0%	0%	0%
Rosroe Salmon Ltd.	**Fraochoilean**	1	1	2	1	3	2	100%	50%	67%
	Rosroe	4	0	2	0	6	0	0%	0%	0%
Clare Island Seafarms Ltd.	**Clare Island Portlea**	6	0	6	0	12	0	0%	0%	0%
West	**Totals**	24	1	17	1	41	2	4%	6%	5%

Northwest Region

The TTL were exceeded on 11 out of 21 inspections (52%) in the spring period. The TTL were exceeded on one of the 15 inspections (7%) outside the spring period in the Northwest (Table 5).

Table 5 *Summary of inspection results on one-sea-winter salmon in the Northwest in 2019.*

Company	Site	Samples in Spring	Ovigerous > TTL in Spring	Samples outside Spring	Ovigerous > TTL outside Spring	Total Samples	Total Ovigerous > TTL	% over in Spring	% over outside Spring	% over total
Ocean Farm Ltd.	**Ocean Inver**	6	4	3	0	9	4	67%	0%	44%
Marine Harvest Ireland	**Creevin**	4	2	2	1	6	3	50%	50%	50%
	Glinsk	0		2	0	2	0		0%	0%
	Millstone	0		1	0	1	0		0%	0%
	Cranford B	5	4	2	0	7	4	80%	0%	57%
	Lough Swilly	6	1	5	0	11	1	17%	0%	9%
Northwest	**Totals**	21	11	15	1	36	12	52%	7%	33%

Atlantic salmon 2019 (smolts)

A total of 122 inspections were made to 14 sites stocking Atlantic salmon 2019 S1 and S½ smolts during the year 2019. *L. salmonis* levels were below the TTL of 0.5 ovigerous female sea lice per fish for all the inspections (100%) during the spring period. Five out of 82 (6%) inspections outside the spring period were above the TTL of 2 ovigerous female sea lice per fish (Table 6). There were five occasions where the mean total mobile *L. salmonis* were greater than ten. These occurred outside the spring period in the West region on four occasions and once in the Northwest region.

Table 6 *Summary of inspection results on salmon smolts nationally in 2019*

Company	Site	Samples in Spring	Ovigerous > TTL in Spring	Samples outside Spring	Ovigerous > TTL outside Spring	Total Samples	Total Ovigerous > TTL	% over in Spring	% over outside Spring	% over total
Marine Harvest Ireland	**Ahabeg**	6	0	8	0	14	0	0%	0%	0%
	Roancarraig	6	0	8	0	14	0	0%	0%	0%
	Deenish	2	0	6	0	8	0	0%	0%	0%
Murphy's Irish Seafood Ltd.	**Cuan Baoi**	0		6	0	6	0		0%	0%
Southwest	**Totals**	14	0	28	0	42	0	0%	0%	0%
Bradan Beo Teo.	**Daonish**	6	0	8	1	14	1	0%	13%	7%
Bifand Ltd.	**Fraochoilean**	0		6	2	6	2		33%	33%
Mannin Bay Salmon Company Ltd.	**Corhounagh**	0		4	1	4	1		25%	25%
	Hawks Nest	6	0	2	0	8	0	0%	0%	0%
Clare Island Seafarms Ltd.	**Clare Island Smolt Site**	2	0	5	0	7	0	0%	0%	0%
	Seastream	0		1	0	1	0		0%	0%
Curraun Blue Ltd.	**Curraun**	6	0	8	0	14	0	0%	0%	0%
West	**Totals**	20	0	34	4	54	4	0%	12%	7%
Ocean Farm Ltd.	**Mc Swynes**	6	0	8	1	14	1	0%	13%	7%
Marine Harvest Ireland	**Glinsk**	0		6	0	6	0		0%	0%
	Millstone	0		6	0	6	0		0%	0%
Northwest	**Totals**	6	0	20	1	26	1	0%	5%	4%
National Totals		40	0	82	5	122	5	0%	6%	4%

Atlantic salmon 2020 (smolts)

One sea lice inspection was undertaken at Ardmore, in the West region in November 2019. Sea lice were below the TTL on these fish.

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 7 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 7 out of 22 occasions. Of these, three were in Donegal Bay, three were in Mulroy Bay and one was in Ballinakill Harbour.

Bay mean ovigerous levels of 2.0 ovigerous females per fish or greater were recorded on two out of 30 occasions, outside of the spring period. These occurred on one occasion each in Ballinakill Harbour and Donegal Bay.

Mean levels per bay in excess of ten mobile *L. salmonis* per fish were recorded on 12 occasions, six of these instances had a mean of greater than 20 mobile sea lice per fish. The maximum bay mean level recorded was 50.08 mobile sea lice per fish, in Ballinakill Harbour in February.

The maximum *C. elongatus* level recorded was 14.19 per fish in the West in December/January in 2018/19.

Table 7 *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 2019.*

Mean ovigerous *L. salmonis*											
	Dec/Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Kenmare Bay	0.00	0.00	0.06	0.09	0.08	0.15			1.73	HO	
Kilkieran Bay	0.63	1.29	0.19	HO							
Bertraghboy Bay	0.05	0.01	0.04	0.13	0.17	0.19	1.34	HO			
Ballinakill Harbour	0.67	2.15	0.77	HO							
Killary Harbour	0.71	0.63	0.07	0.05	HO						
Clew Bay	0.00	0.02	0.01	0.04	0.18	0.03	0.14	0.68	0.07	HO	
Donegal Bay	1.76	2.20	0.65	3.30	0.68	0.15	HO				
Mulroy Bay	0.25	0.24	2.84	1.07	0.53	HO					
Lough Swilly	0.03	0.07	0.15	0.41	0.12	1.20	1.79	0.97	HO		

Mean mobile *L. salmonis*											
	Dec/Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Kenmare Bay	0.02	0.07	0.32	0.74	1.12	0.97			24.07	HO	
Kilkieran Bay	25.36	25.07	2.07	HO							
Bertraghboy Bay	0.61	1.15	0.95	0.98	1.08	1.24	5.94	HO			
Ballinakill Harbour	9.44	50.08	24.36	HO							
Killary Harbour	4.87	15.99	2.43	5.02	HO						
Clew Bay	0.00	0.22	0.19	1.01	0.72	1.24	2.25	4.63	3.42	HO	
Donegal Bay	12.36	14.71	6.52	38.19	2.24	10.34	HO				
Mulroy Bay	2.72	2.32	18.69	4.05	14.41	HO					
Lough Swilly	0.31	0.37	2.46	2.11	5.73	4.09	4.93	2.29	HO		

Mean ovigerous *C. elongatus*											
	Dec/Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Kenmare Bay	0.39	0.25	0.53	0.13	0.31	0.08			2.07	HO	
Kilkieran Bay	0.64	0.66	0.03	HO							
Bertraghboy Bay	7.28	1.85	1.50	0.20	0.29	0.00	0.20	HO			
Ballinakill Harbour	0.03	0.18	0.11	HO							
Killary Harbour	0.05	0.18	0.03	0.00	HO						
Clew Bay	0.03	2.12	1.12	0.29	0.02	0.08	1.32	1.73	1.13	HO	
Donegal Bay	0.78	0.00	0.05	0.41	0.05	0.32	HO				
Mulroy Bay	0.15	0.20	0.54	0.02	0.08	HO					
Lough Swilly	1.39	4.70	0.14	0.04	0.15	0.00	0.09	0.00	HO		

Mean mobile *C. elongatus*											
	Dec/Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Kenmare Bay	0.62	0.60	1.82	0.38	0.46	0.94			7.13	HO	
Kilkieran Bay	1.53	1.40	0.06	HO							
Bertraghboy Bay	14.19	8.71	4.78	0.50	0.59	0.00	0.61	HO			
Ballinakill Harbour	0.39	0.85	0.86	HO							
Killary Harbour	0.23	0.30	0.07	0.00	HO						
Clew Bay	0.07	4.52	2.84	0.87	0.05	0.13	2.77	3.27	2.07	HO	
Donegal Bay	1.19	0.01	0.10	0.69	0.23	0.74	HO				
Mulroy Bay	0.21	0.39	0.75	0.03	0.30	HO					
Lough Swilly	10.48	8.33	0.25	0.12	0.46	0.02	0.14	0.00	HO		

HO = Harvested Out

Regional monthly means for one-sea-winter salmon

L. salmonis ovigerous and monthly mean mobile levels per fish for one-sea-winter salmon regionally are shown in Figure 4 & 5. In the spring period of 2019, the ovigerous mean sea lice levels per fish exceeded TTL for March and April, in the Northwest.

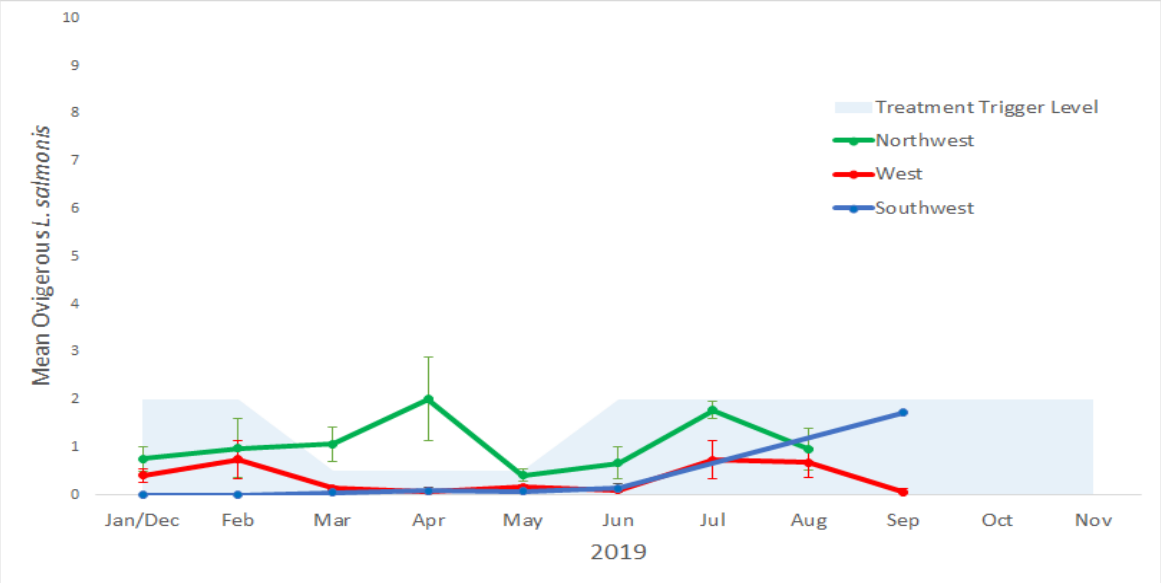

Figure 4 *Mean (±SE) ovigerous L. salmonis per fish per month per region in 2019 on one-sea-winter salmon*

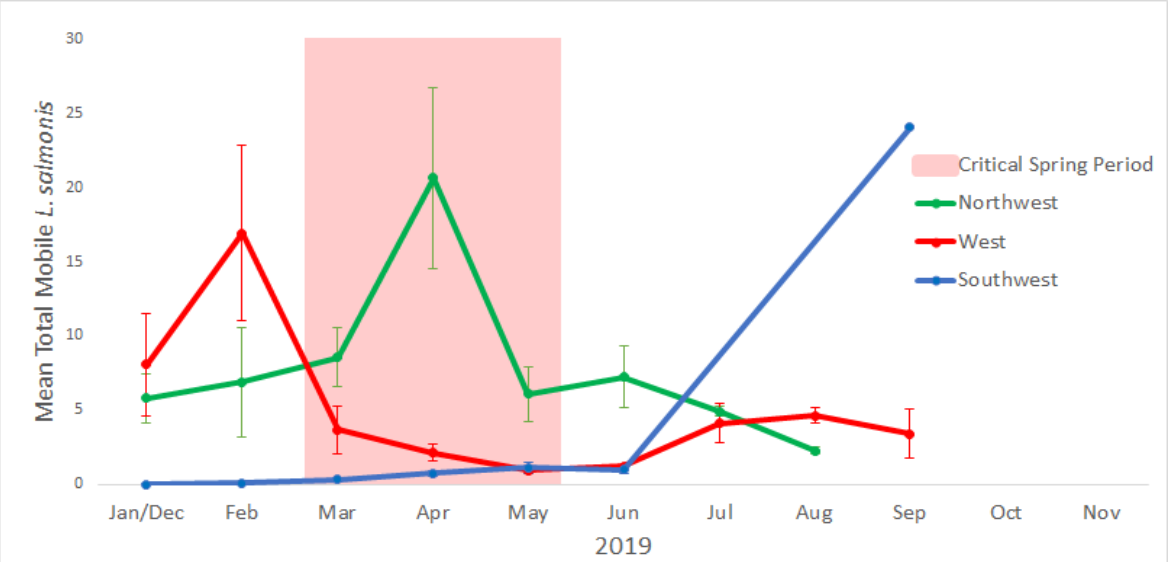

Figure 5 *Mean (±SE) mobile L. salmonis per fish per month per region in 2019 on one-sea-winter salmon.*

Total regional mean mobile *L. salmonis* levels peaked at 24.07 mobile sea lice per fish in the Southwest in September, 16.92 in the West in February and 20.63 in the Northwest in April.

Annual trends

The annual trends of *L. salmonis* ovigerous and mobile sea lice levels are compared in Figure 6 & 7 for one-sea-winter salmon for the month of May from 1991 to 2019.

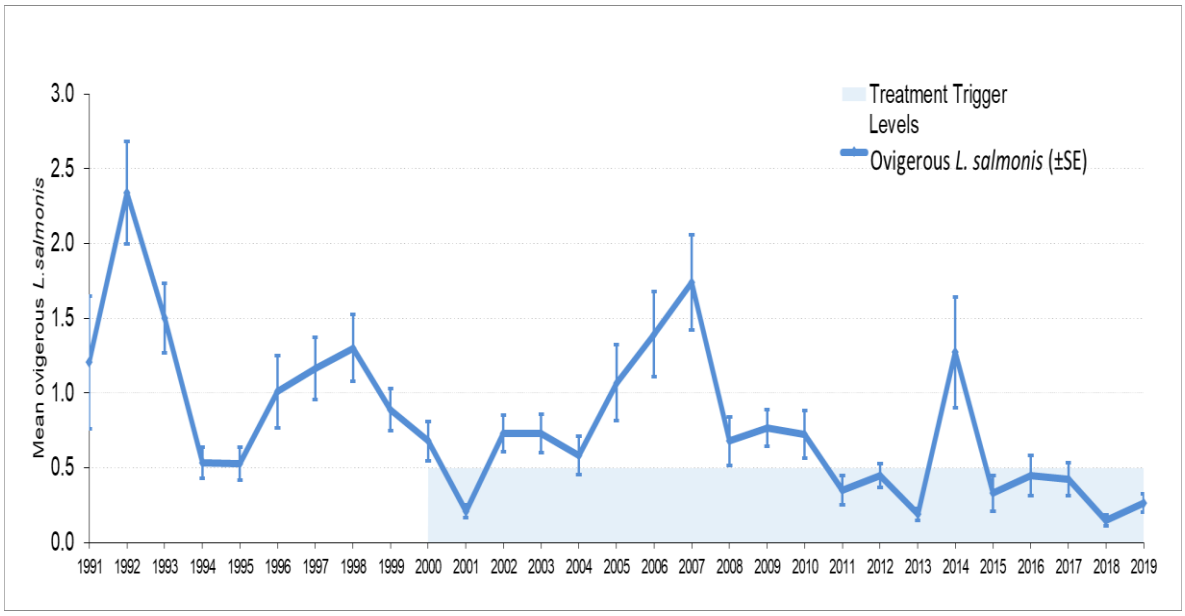

Figure 6 *Annual trend (May mean ±SE) ovigerous L. salmonis on one-sea-winter salmon.*

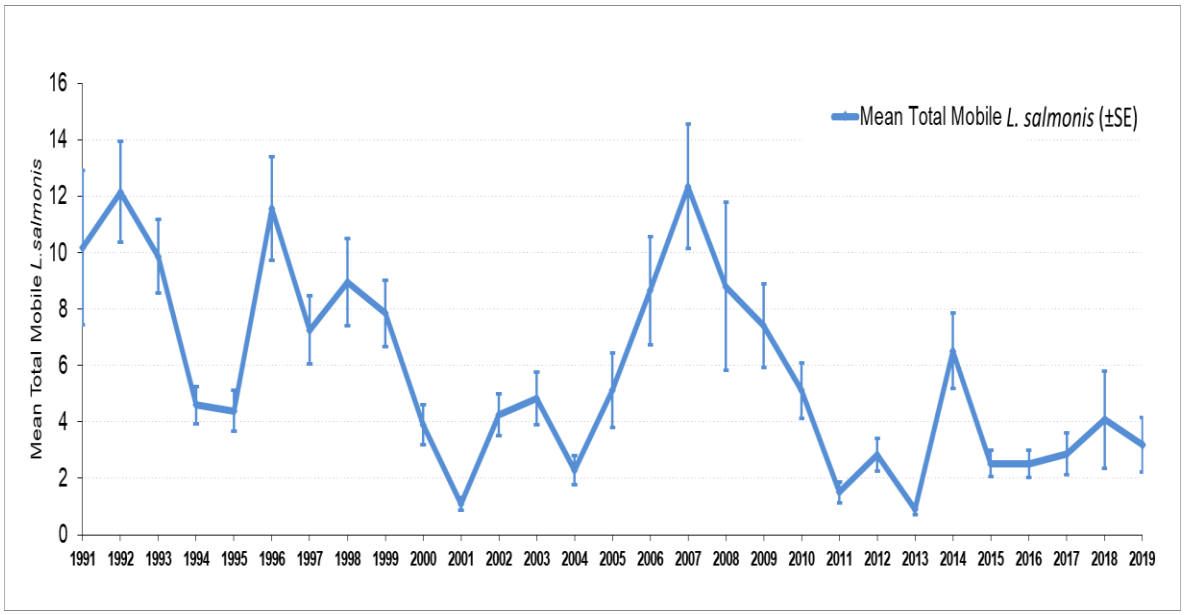

Figure 7 *Annual trend (May mean ±SE) mobile L. salmonis on one-sea-winter salmon.*

Mean ovigerous *L. salmonis* levels in May increased to 0.27 sea lice per fish in 2019, compared to 0.15 per fish in 2018, but remain below the TTL of 0.5. Total mobile *L. salmonis* levels decreased to 3.19 per fish compared to 4.08 per fish in May 2018.

DISCUSSION

Sea lice levels on smolts in 2019 were low. Most of the sea lice inspections (96%) carried out on smolts were below the TTL. These results indicate a slight decline compared to the results from 2018, where 100% of inspections were below the TTL.

Nationally, in 2019, 84% of all sea lice inspections on one-sea-winter salmon were below the TTL. The national mean ovigerous *L. salmonis* levels for one-sea-winter salmon in May increased to 0.27 per fish in 2019 compared to 0.15 per fish in 2018 which was the lowest levels on record. Conversely, the national total mobile *L. salmonis* levels for May decreased in 2019 to 3.19 following two consecutive increases from the previous two years. Overall, these May-mean sea lice levels have been steady for the past five years.

During the spring period, 48% of inspections on one-sea-winter-salmon were below the TTL in the Northwest compared to 100% in 2018. In the West, for the same period, 96% were below the TTL which is an increase from 70% in 2018. Most of the sea lice inspections of one-sea-winter salmon undertaken outside of the spring period were below the TTL in the Northwest (93%). Similarly, in the West, 94% of inspections on one-sea-winter-salmon were below the TTL outside the spring period. In the Southwest, 100% of inspections were below the TTL.

Sea lice levels in excess of ten mobile *L. salmonis* per fish on both one-sea-winter salmon and smolts were recorded on 23 occasions nationally, 11 of which had means greater than 20 mobile *L. salmonis* per fish. Fourteen of these occasions coincided with ovigerous *L. salmonis* levels in excess of the TTL. The highest mean mobile sea lice level recorded for one-sea-winter salmon continues to fluctuate annually with 64.9 per fish observed in 2019, compared to 31.9 in 2018, 53.3 in 2017, and 37.6 in 2016. The highest numbers of *Caligus elongatus* recorded in 2019 were 14.19 per fish.

The regional data for mean ovigerous *L. salmonis* demonstrates the continued efforts to maintain levels below the TTL for the spring period in the West and Southwest regions. Regional data shows sea lice levels above the TTL for over half the sea lice inspections on one-sea-winter salmon in the Northwest during the spring period. These levels are attributed to elevated sea lice numbers reported in Donegal Bay and Mulroy Bay during the spring period. Two possible factors have been suggested to contribute to these raised levels. Firstly, average sea surface temperatures were slightly warmer than usual over winter which resulted in a faster rate of sea lice development (Hamre, *et al*., 2019). Secondly, thermal and mechanical delousing methods which were very successful at removing mobile sea lice, were

less successful at removing the early stage attached sea lice (Grøntvedt, *et al*., 2015; Overton, *et al*., 2018) which gave rise to elevated sea lice levels one month after de-lousing efforts.

Overall, mean sea lice levels across the country were marginally raised compared to 2018 but have followed the general trend of lower sea lice levels over the past several years. Infestation on smolts was low as is the common annual trend. Although raised in 2019, sea lice levels on grower fish continued to show a level of control in line with annual trends over the last number of years. Higher sea lice levels were observed in the run up to harvest on larger grower fish which is in keeping with recorded data from sea lice inspections of harvest fish. Control methods including veterinary medicines and non-medicinal delousing methods, as well as Single Bay Management practices, continue to have a positive impact on the control of sea lice in Irish salmon farming.

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 fewer were inspected in one or both pens sampled.
Ovigerous lice:	An egg bearing adult female sea lice.
Random (Ran.) Pen:	A pen 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.) Pen:	The selected pen 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 put under lights to hasten the onset of smoltification. 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.
TTL:	Treatment Trigger Levels

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APPENDIX 1.

Mean sea lice levels on salmonid farms in 2019.

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
BANTRY BAY					
MOWI IRL.					
Ahabeg					
Atlantic Salmon, 2019 S1/2	17/01/2019	0.00	0.00	0.00	0.00
	26/02/2019	0.00	0.00	0.25	0.59
	07/03/2019	0.00	0.00	0.81	1.09
	27/03/2019	0.00	0.00	2.99	4.85
	09/04/2019	0.00	0.02	3.00	5.49
	17/04/2019	0.00	0.00	1.99	4.69
	09/05/2019	0.00	0.00	1.93	6.14
	21/05/2019	0.00	0.00	0.32	1.17
	13/06/2019	0.00	0.00	0.10	0.16
	24/07/2019	0.02	0.07	0.06	0.06
	07/08/2019	0.00	0.00	0.03	0.03
	12/09/2019	0.05	0.14	1.40	4.43
	25/10/2019	0.05	0.12	0.15	0.29
	20/11/2019	0.06	0.06	0.06	0.14
Roancarraig					
Atlantic Salmon, 2019 S1/2	17/01/2019	0.00	0.00	0.02	0.02
	26/02/2019	0.00	0.00	1.11	2.68
	07/03/2019	0.00	0.00	0.73	1.41
	27/03/2019	0.00	0.00	2.54	4.41
	09/04/2019	0.00	0.00	1.37	2.35
	17/04/2019	0.00	0.00	2.86	5.40
	09/05/2019	0.00	0.00	1.34	3.18
	21/05/2019	0.00	0.00	0.00	0.00
	13/06/2019	0.00	0.00	0.80	1.80
	24/07/2019	0.00	0.00	0.12	0.31
	07/08/2019	0.00	0.07	0.12	0.32
	12/09/2019	0.03	0.13	0.76	1.75
	25/10/2019	0.04	0.10	0.09	0.19
	20/11/2019	0.10	0.28	0.14	0.21

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
MURPHY'S IRISH SEAFOOD LTD.					
Cuan Baoi					
Atlantic Salmon, 2019	11/06/2019	0.00	0.00	0.15	0.37
	23/07/2019	0.02	0.04	1.04	1.29
	08/08/2019	0.00	0.02	0.87	1.13
	13/09/2019	0.04	0.10	0.25	0.40
	25/10/2019	0.00	0.00	0.02	0.02
	21/11/2019	0.00	0.08	0.06	0.08
KENMARE BAY					
MARINE HARVEST IRL.					
Inishfarnard					
Atlantic Salmon, 2018	17/01/2019	0.00	0.02	0.39	0.62
	26/02/2019	0.00	0.07	0.25	0.60
	07/03/2019	0.02	0.04	0.37	0.73
	27/03/2019	0.09	0.60	0.69	2.91
	09/04/2019	0.04	0.43	0.04	0.32
	17/04/2019	0.15	1.04	0.23	0.45
	09/05/2019	0.15	1.75	0.60	0.87
	21/05/2019	0.02	0.49	0.02	0.05
	13/06/2019	0.15	0.97	0.08	0.94
	18/09/2019	1.73	24.07	2.07	7.13
		Harvested Out			
MOWI IRL.					
Deenish					
Atlantic Salmon, 2019	10/05/2019	0.00	0.24	0.77	1.86
	22/05/2019	0.00	0.26	0.56	1.18
	12/06/2019	0.00	0.00	0.00	0.04
	24/07/2019	0.00	0.02	0.00	0.02
	08/08/2019	0.00	0.00	0.03	0.05
	13/09/2019	0.00	0.03	0.00	0.60
	24/10/2019	0.12	0.33	1.17	1.73
	19/11/2019	0.00	0.09	0.02	0.04

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
KILKIERAN BAY					
BRADAN BEO TEO.					
Ardmore					
Atlantic Salmon, 2018 S1/2	18/01/2019	0.63	25.36	0.64	1.53
	28/02/2019	1.29	25.07	0.66	1.40
	19/03/2019	0.30	1.99	0.02	0.06
	26/03/2019	0.08	2.15	0.04	0.06
		Harvested Out			
Atlantic Salmon, 2020 S1/2	27/11/2019	0.00	0.78	0.00	0.00
Daonish					
Atlantic Salmon, 2019 S1/2	10/01/2019	0.15	1.84	0.00	0.02
	07/02/2019	0.23	6.31	0.00	0.02
	08/03/2019	0.21	1.97	0.00	0.07
	22/03/2019	0.19	2.60	0.00	0.00
	10/04/2019	0.05	4.95	0.02	0.02
	29/04/2019	0.07	0.24	0.00	0.00
	08/05/2019	0.05	0.17	0.00	0.00
	29/05/2019	0.07	2.29	0.03	0.03
	27/06/2019	0.45	1.21	0.02	0.09
	12/07/2019	0.37	4.13	0.80	1.48
	01/08/2019	0.47	1.91	0.70	1.54
	11/09/2019	0.07	8.87	0.20	0.87
	02/10/2019	0.08	6.72	0.02	0.14
	27/11/2019	2.62	14.76	0.00	0.23

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	**Total**	**F + eggs**	**Total**
BERTRAGHBOY BAY					
BIFAND LTD. / MARINE HARVEST IRL.					
Outer Bertraghboy Bay					
Atlantic Salmon, 2018	26/02/2019	0.00	1.19	1.47	7.63
	05/03/2019	0.10	1.19	2.77	7.97
	27/03/2019	0.00	1.23	0.39	0.77
	12/04/2019	0.15	1.74	0.15	0.67
	17/04/2019	0.31	1.39	0.11	0.33
	03/05/2019	0.20	1.48	0.20	0.68
	27/05/2019	0.31	1.36	0.38	0.68
	24/06/2019	0.19	1.24	0.00	0.00
	03/07/2019	1.34	5.94	0.20	0.61
		Harvested Out			
Sealax					
Atlantic Salmon, 2018	05/12/2018	0.05	0.61	7.28	14.19
	26/02/2019	0.02	1.13	2.04	9.26
	05/03/2019	0.02	0.95	2.33	9.11
	27/03/2019	0.05	0.70	0.60	0.87
	02/04/2019	0.02	0.51	0.31	0.56
	17/04/2019	0.15	0.86	0.15	0.46
	03/05/2019	0.02	0.60	0.24	0.47
		Transferred to Outer Bertraghboy Bay			
MANNIN BAY					
MANNIN BAY SALMON COMPANY LTD.					
Corhounagh					
Atlantic Salmon, 2019 S1/2	25/06/2019	0.13	0.35	0.00	0.00
	03/07/2019	0.08	1.04	0.02	0.03
	28/08/2019	2.65	8.38	0.02	0.02
	25/09/2019	0.86	8.94	0.02	0.02
		Transferred to Fraochoilean			

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
CLIFDEN BAY					
Hawks Nest					
Atlantic Salmon, 2019 S1/2	11/01/2019	0.00	0.00	0.10	0.12
	06/02/2019	0.00	0.00	0.13	0.22
	14/03/2019	0.00	0.10	0.20	0.34
	21/03/2019	0.02	0.18	0.39	0.46
	04/04/2019	0.06	0.19	0.07	0.09
	25/04/2019	0.06	0.16	0.00	0.00
	09/05/2019	0.04	0.25	0.00	0.02
	28/05/2019	0.11	1.02	0.00	0.00
		Transferred to Corhounagh & Fraochoilean			
BALLINAKILL HARBOUR					
BIFAND LTD.					
Fraochoilean					
Atlantic Salmon, 2019 S1/2	25/06/2019	0.02	0.16	0.00	0.04
	04/07/2019	0.10	0.47	0.05	0.14
	27/08/2019	0.67	3.53	0.04	0.05
	10/09/2019	4.77	17.24	0.20	0.37
	22/10/2019	1.12	12.64	0.14	0.27
	28/11/2019	7.67	30.85	0.02	0.05
ROSROE SALMON LTD.					
Atlantic Salmon, 2018 S1/2	28/01/2019	0.67	9.44	0.03	0.39
	18/02/2019	2.15	50.08	0.18	0.85
	07/03/2019	0.77	24.36	0.11	0.86
		Harvested Out			

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	**Total**	**F + eggs**	**Total**
KILLARY HARBOUR					
Rosroe					
Atlantic Salmon, 2018 S1/2		Transferred to Fraochoilean			
	24/01/2019	0.71	4.87	0.05	0.23
	08/02/2019	0.63	15.99	0.18	0.30
	15/03/2019	0.04	1.43	0.03	0.06
	28/03/2019	0.10	3.43	0.03	0.09
	09/04/2019	0.04	5.18	0.00	0.00
	16/04/2019	0.06	4.87	0.00	0.00
		Harvested Out			
CLEW BAY					
CLARE ISLAND SEAFARMS LTD.					
Clare Island Smolt Site					
Atlantic Salmon, 2017		Harvested Out			
Atlantic Salmon, 2019	10/05/2019	0.00	0.14	0.40	0.86
	30/05/2019	0.00	0.09	0.00	0.00
	26/06/2019	0.00	0.11	0.22	0.85
	24/07/2019	0.00	0.05	0.00	0.05
	13/08/2019	0.00	0.10	0.02	0.39
	13/09/2019	0.00	0.06	0.02	0.02
	14/10/2019	0.03	0.29	0.19	0.41
		Transferred to Seastream			

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
Portlea					
Atlantic Salmon, 2018	04/12/2018	0.00	0.00	0.03	0.07
	11/02/2019	0.02	0.22	2.12	4.52
	01/03/2019	0.01	0.15	1.32	3.65
	25/03/2019	0.00	0.24	0.92	2.03
	01/04/2019	0.00	0.82	0.49	1.55
	23/04/2019	0.08	1.19	0.08	0.19
	10/05/2019	0.32	1.22	0.00	0.00
	30/05/2019	0.05	0.22	0.04	0.10
	26/06/2019	0.03	1.24	0.08	0.13
	24/07/2019	0.14	2.25	1.32	2.77
	13/08/2019	0.68	4.63	1.73	3.27
	13/09/2019	0.07	3.42	1.13	2.07
		Harvested out			
Seastream					
Atlantic Salmon, 2019	19/11/2019	0.05	0.08	0.15	0.41
BEALACRAGHER BAY					
CURRAUN BLUE LTD.					
Curraun					
Atlantic Salmon, 2019 S1/2	17/01/2019	0.00	0.00	0.02	0.03
	11/02/2019	0.00	0.05	0.02	0.02
	01/03/2019	0.00	0.00	0.00	0.00
	25/03/2019	0.00	0.00	0.02	0.02
	09/04/2019	0.00	0.00	0.02	0.03
	23/04/2019	0.02	0.10	0.02	0.04
	10/05/2019	0.00	0.08	0.05	0.09
	30/05/2019	0.02	0.53	0.86	1.43
	26/06/2019	0.61	4.45	0.91	1.73
	24/07/2019	0.43	2.78	0.00	0.00
	13/08/2019	0.00	1.46	0.00	0.00
	13/09/2019	0.00	0.00	0.00	0.00
	14/10/2019	0.00	0.33	0.00	0.00
	19/11/2019	0.02	0.69	0.00	0.00

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
DONEGAL BAY					
MARINE HARVEST IRL.					
Creevin					
Atlantic Salmon, 2018 S1/2	05/12/2018	1.79	10.95	0.52	1.04
	19/02/2019	4.37	28.26	0.00	0.02
	23/03/2019	0.22	2.62	0.00	0.00
	29/03/2019	0.68	10.50	0.02	0.12
	10/04/2019	0.14	8.07	0.00	0.05
	24/04/2019	1.87	64.93	0.15	0.30
		Harvested Out			
OCEAN FARM LTD.					
McSwynes					
Atlantic Salmon, 2019 S1/2	05/12/2018	0.02	0.51	0.20	0.62
	19/02/2019	0.57	4.50	0.67	1.33
	20/03/2019	0.00	0.07	0.00	0.03
	29/03/2019	0.00	3.09	0.00	1.00
	10/04/2019	0.29	9.64	0.28	0.72
	30/04/2019	0.16	3.74	0.00	0.02
	20/05/2019	0.08	4.72	0.09	0.13
	29/05/2019	0.07	1.53	0.00	0.07
	11/06/2019	0.05	5.82	0.20	0.40
	16/07/2019	0.02	0.88	0.14	0.22
	14/08/2019	0.42	1.04	0.00	0.05
	25/09/2019	0.87	3.63	0.02	0.02
	16/10/2019	1.42	6.54	0.16	0.59
	08/11/2019	2.50	7.50	0.00	0.04

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
Ocean Inver					
Atlantic Salmon, 2018 S1/2	05/12/2018	1.74	13.78	1.04	1.35
	19/02/2019	0.03	1.16	0.00	0.00
	20/03/2019	1.67	11.42	0.20	0.27
	29/03/2019	0.05	1.55	0.00	0.02
	10/04/2019	0.54	27.47	0.17	0.37
	30/04/2019	10.65	52.29	1.32	2.06
	20/05/2019	0.97	3.44	0.09	0.44
	29/05/2019	0.39	1.05	0.02	0.02
	11/06/2019	0.15	10.34	0.32	0.74
		Harvested Out			
MULROY BAY					
MARINE HARVEST IRL.					
Cranford B					
Atlantic Salmon, 2018 S1/2	06/12/2018	0.13	3.40	0.23	0.37
	06/02/2019	0.23	2.73	0.24	0.41
	19/03/2019	1.19	12.44	0.48	0.73
	28/03/2019	4.49	24.94	0.60	0.77
	17/04/2019	1.83	6.00	0.04	0.06
	25/04/2019	0.31	2.09	0.00	0.00
	15/05/2019	0.53	14.41	0.08	0.30
		Harvested Out			
MOWI IRL.					
Glinsk					
Atlantic Salmon, 2018	06/12/2018	0.00	0.35	0.02	0.02
	06/02/2019	0.25	1.90	0.17	0.38
		Harvested Out			
Atlantic Salmon, 2019	12/06/2019	0.00	0.03	0.00	0.00
	15/07/2019	0.00	0.04	0.00	0.00
	09/08/2019	0.00	0.00	0.00	0.00
	19/09/2019	0.00	0.00	0.00	0.00
	15/10/2019	0.00	2.21	0.02	0.05
	22/11/2019	0.16	6.99	0.04	0.04

	Date	*Lepeophtheirus salmonis*		*Caligus elongatus*	
		F + eggs	Total	F + eggs	Total
Millstone					
Atlantic Salmon, 2018 S1/2		Transferred to Cranford B			
	06/12/2018	0.57	4.75	0.24	0.33
		Harvested Out			
Atlantic Salmon, 2019	12/06/2019	0.00	0.10	0.00	0.00
	15/07/2019	0.00	0.00	0.02	0.02
	09/08/2019	0.00	0.04	0.00	0.00
	19/09/2019	0.00	0.05	0.00	0.00
	15/10/2019	0.00	2.54	0.03	0.07
	22/11/2019	0.42	11.54	0.00	0.02
LOUGH SWILLY					
Lough Swilly					
Atlantic Salmon, 2018	06/12/2018	0.03	0.31	1.39	10.48
	06/02/2019	0.07	0.37	4.70	8.33
	19/03/2019	0.00	1.37	0.07	0.16
	28/03/2019	0.30	3.55	0.22	0.34
	11/04/2019	0.26	2.56	0.07	0.22
	25/04/2019	0.56	1.66	0.02	0.03
	15/05/2019	0.03	4.13	0.30	0.91
	31/05/2019	0.20	7.33	0.00	0.02
	27/06/2019	1.20	4.09	0.00	0.02
	15/07/2019	1.79	4.93	0.09	0.14
	09/08/2019	0.97	2.29	0.00	0.00
		Harvested Out			

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