Sea Lice Burdens of Sea Trout at Sound of Shuna, Argyll, 2023

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Background

Argyll Fisheries Trust undertook seine net and fyke net surveys in the Sound of Shuna Farm Management Area in summer 2023 to assess burdens of a parasite (Sea lice; *Lepeophtheirus salmonis*) found on sea trout (*Salmo trutta*).

Main findings

- A fixed fyke net sampled 39 seat trout over a period of five weeks, including four weeks in June and one week in August 2023.
- The survey assessed sea lice burdens on 29 trout under 150 grams (74.4 % of sample) and 10 trout over 150 grams (25.6 % of samples).
- The percentage of trout sampled that were infected by sea lice (prevalence) was 89.7 % for small trout (< 150 g) and 90.0 % for larger trout (> 150 g).
- The total lice-related risk index (Taranger et al., 2015) estimates a high sea lice-related risk of increased mortality or premature return to freshwater for smaller trout (58.8 %) and a high sea lice-related risk of increased marine mortality or compromised reproductive potential for larger trout (42.5 %) in 2023.
- Despite the lower number of sea trout collected by the fyke net in 2023 due to reduced sampling effort, the technique provided sufficient data to estimate the total lice-related risk to sea trout in the Sound of Shuna Management Area.

Acknowledgements

Argyll Fisheries Trust thanks Mowi Scotland Limited and Kames Fish Farming Limited for their assistance and funding of the 2023 study.

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1. INTRODUCTION

Argyll Fisheries Trust conducted surveys of the sea lice burdens of sea trout by fishing a stationary fyke net at Craobh Haven located between Loch Craignish and Loch Melfort over a period of five weeks in June and early July 2023. The aims of the surveys were to capture and assess the sea lice burdens of post-smolt sea trout in the Sound of Shuna Farm Management Area. This information is used to inform an Environment Management Plan (EMP) for fish farm operators in the area: Mowi Scotland Ltd. and Kames Fish Farming Ltd. The original intention of the study was to sample trout from June through August, but the high water temperature experienced during late June and early July meant that sampling was curtailed on the grounds of fish welfare. This study will also inform on-going development of the suitability of the fixed net sampling technique in the management area.

Assessing the potential impacts of sea lice on wild migratory salmonids in the Sound of Shuna has been undertaken using a risk index developed within a wider a risk assessment framework for aquaculture in Norway (Taranger et al., 2015). This tool attempts to quantify any increase in sea lice-related marine mortality or return prematurely to freshwater of smaller sea trout and marine mortality or compromised reproductive potential for larger trout. Due to the behaviour of salmon smolts, which migrate rapidly out of the study area, this study concentrates on the sea trout that mostly reside in coastal waters.

The 2023 results have been compared to the results of seine and Fyke net sampling undertaken in five other years (2008, 2009, 2010, 2021 and 2022) to compare sea lice infection pressure between years in relation to the production of farm salmon in the Sound of Shuna.

2. METHODS

Two sampling methods were employed to catch sea trout in the Sound of Shuna fish farm management area between June 5th and June 29th and August 1st to 5th, 2023.

2.1 Fyke net sampling

The fyke net deployment and sampling of fish was undertaken using a Standard Operating Procedure developed specifically for this type of net (Lochaber Fisheries Trust, 2020). The coastal fyke net consists of a lead and two wing nets which guide fish into a series of funnels via a central area (known as the heart) before entering a residence area which was raised and checked at regular intervals (usually two days fishing time) over a 17-day period. Fish were removed via a trap door and then sea trout were processed as described in section 2.3. All by-catch was released at the site. The Fyke net was set in one location in 2023, at Traigh nam Musgan (near Craobh Haven) (Table 2.1 and Figure 2.1).

Table 2.1 Net survey site locations 2023

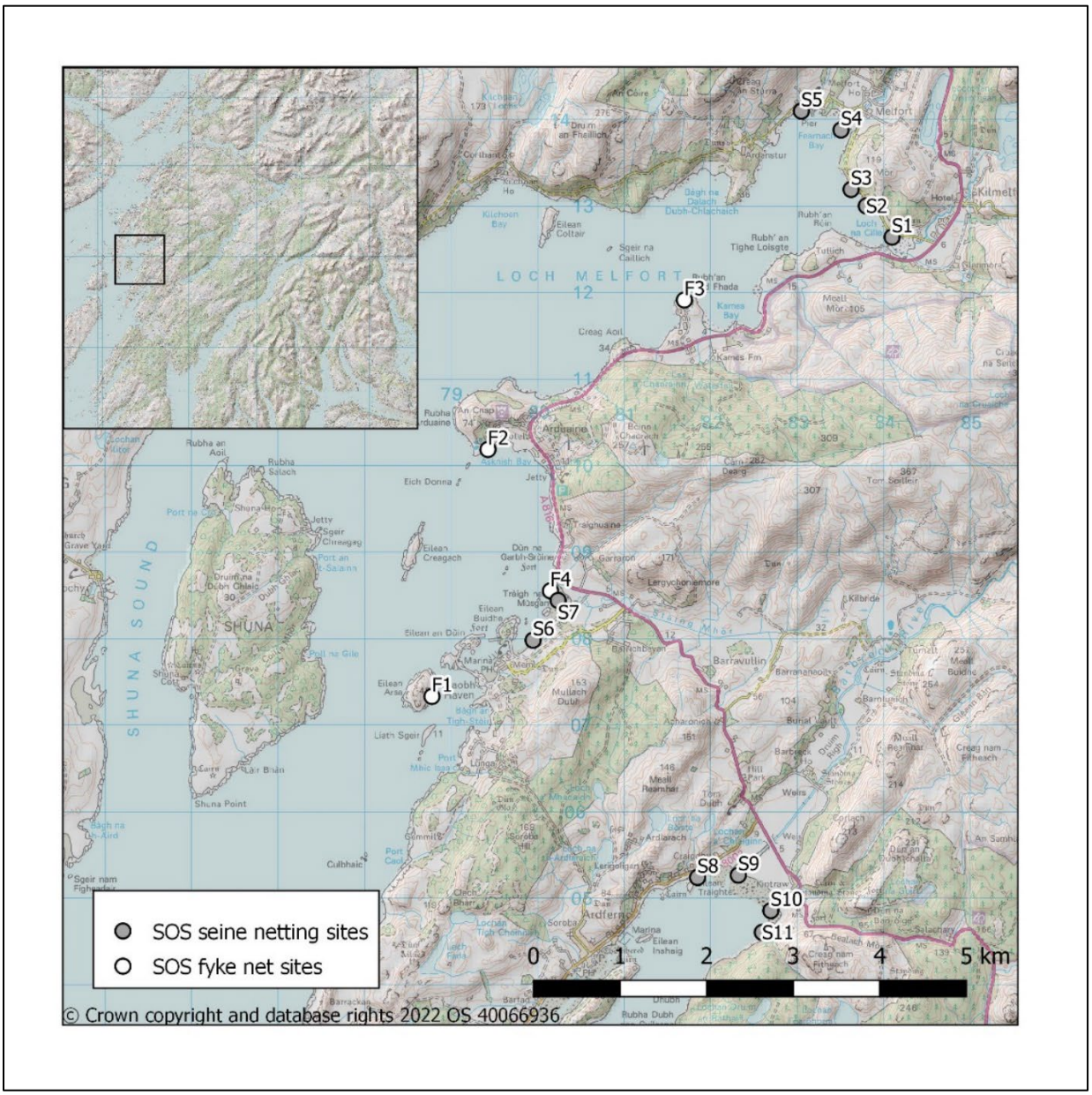
Site	Method	Location	Grid ref	Start	End	No. days
F4	Fyke	Traigh nam Musgan	NM 80145 08547	05/06/23	05/08/23	17

2.3 Data recording and analysis

Trout were anaesthetised prior to collection of length and weight information and counts of sea lice were undertaken according to the protocol prescribed by Scottish Fisheries Coordination Centre (SFCC, 2008). Data on the physical characteristics (length and weight) of the trout sampled and their sea lice burdens were recorded to calculate the following:

- Condition factor (K) – coefficient of the condition of the trout (Ricker, 1975).
- Prevalence of lice – number/percentage of trout sampled with a sea lice burden.
- Abundance of lice – the average (mean) number of sea lice per trout.
- Intensity of infection – the average (mean) number of lice per infected trout.
- The proportion of different life-stages of lice – Stage 1 attached (copepodids and chalimus), Stage 2 Mobile (sub-adults and adults excluding gravid females) and Stage 3 Gravid (adult females with eggs) lice stages.

Fig. 2.1 Location of the Sound of Shuna netting sites (2023 – F4)



Analysis was also carried out using the Norwegian risk assessment framework by Taranger et al. (2015) to categorise the increased lice-related risk of marine mortality or premature return to freshwater for individual trout according to the number of lice present in relation to the body weight of the fish (no. lice/g^{-1}).

The framework assumes that small sea trout post-smolts (<150 g body weight) will suffer 100% lice-related marine mortality or return prematurely to freshwater, if they are infected with >0.3 lice

g^{-1} fish weight. Furthermore, the lice-related marine mortality is estimated to be 50% if the infection is between 0.2 and 0.3 lice g^{-1} fish weight, 20% if the infection rate is between 0.1 and 0.2 lice g^{-1} fish weight, and finally 0% lice-related mortality if the salmon lice infection is <0.1 lice g^{-1} fish weight.

For larger sea trout (over 150 g) the risk analysis assumes that increased lice-related mortality or compromised reproduction will be 100% in the group if they have >0.15 lice g^{-1} fish weight, 75% for lice infections between 0.10 and 0.15 lice g^{-1} fish weight, 50% for lice infections between 0.05 and 0.10 lice g^{-1} fish weight, 20% for lice infections between 0.05 and 0.01 lice g^{-1} fish weight, and 0% if the salmon lice infection is <0.01 lice g^{-1} fish weight.

Total increased risk of marine mortality or return prematurely to freshwater or compromised reproduction are calculated as the sum of the increased mortalities separately for each of the different “infection classes” in the sample, reflecting the distribution of the intensity of salmon lice infections of the different individuals sampled. The total risk to each infection class was further scored according to the system proposed by Taranger et al. (2012a); as low (up to 10% estimated increase in mortality), moderate (between 10 and 30% increase), and high (if the increase is calculated as 30% or more).

In two of the three previous years surveys (2008 and 2009) no fish weight data was recorded. To allow comparison with years when weight data was recorded, a weight was allocated to each trout based on the length of each trout and a condition factor of 1.20 K, which is higher than the average of 1.13 K for two previous years (2010 and 2021) when trout were weighed, so assumes the trout that were not weighed were in good condition.

3. RESULTS

The results of the fyke net surveys in 2023 are described below in terms of the characteristics of the sea trout sampled (3.1), the sea lice burdens of sea trout (3.2), risk analysis of sea lice burdens (3.3) and comparison with historical data (2008-2022) (3.4).

3.1 The sea trout sample

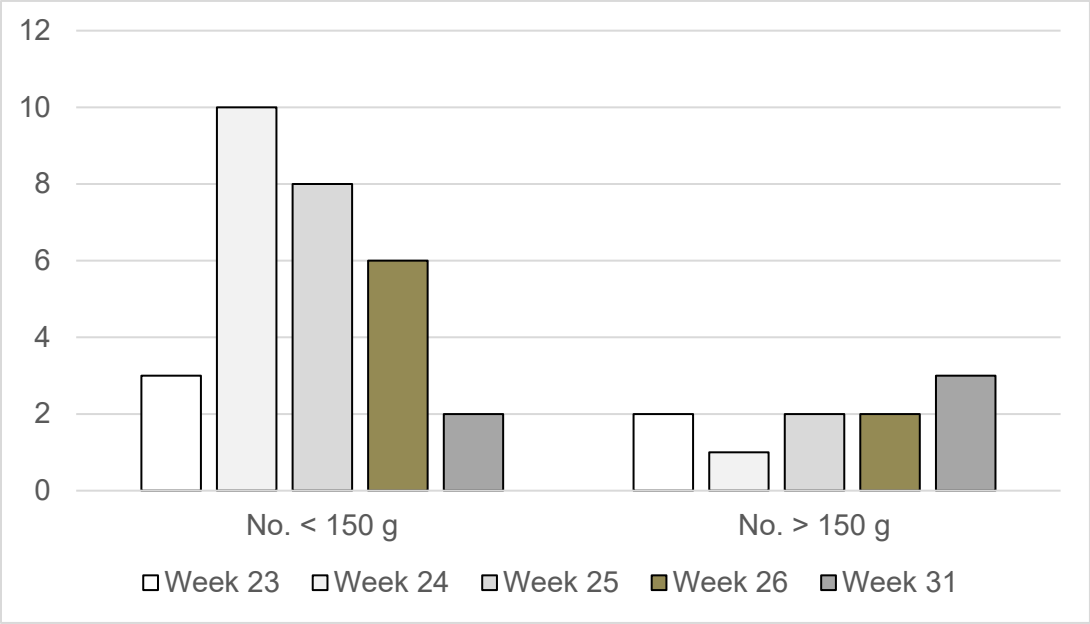
3.1.1 Number of trout

A total of 39 trout were sampled over five separate weeks. The catch consisted of 29 trout of less than 150 grams wet weight (74.4 % of fish sampled) and 10 trout of more than 150 grams (25.6 % of samples) (Table 3.1.1 and Figure 3.1.1). Total sample numbers ranged from five trout in weeks 23 and 31 and 11 trout in week 24.

Table 3.1.1 Number and size of trout sampled and analysed (2023)

Sample Date	No. Trout	No. < 150 g	No. > 150 g	< 150g (%)	> 150g (%)
Week 23	5	3	2	60.0	40.0
Week 24	11	10	1	90.9	9.1
Week 25	10	8	2	80.0	20.0
Week 26	8	6	2	75.0	25.0
Week 31	5	2	3	40.0	60.0
All Trout	39	29	10	74.4	25.6

Figure 3.1.1 Sample size (by week no.) in two size classes (<150 g and > 150 g)



3.1.2 Characteristics of sea trout

The average length (mm), weight (g) and condition factor (K) of the trout sampled in the surveys are described below in Table 3.1.2.

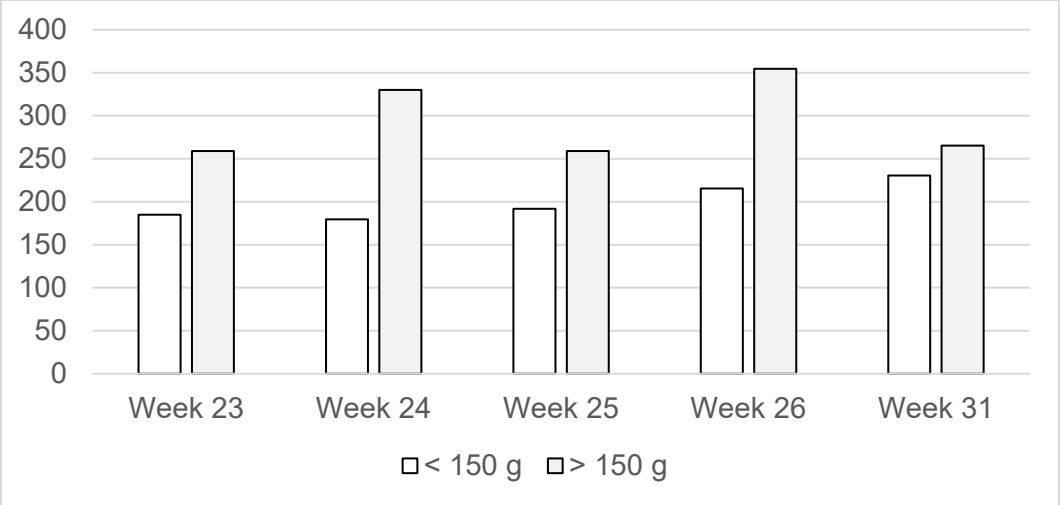
Table 3.1.2 Average length (mm), weight (g) and condition factor (CF) (K) of trout

Sample Period	< 150 g			> 150 g		
	Length (mm)	Weight (g)	CF (K)	Length (mm)	Weight (g)	CF (K)
Week 23	185.00	70.33	1.06	259.00	167.75	0.97
Week 24	179.50	63.60	1.08	330.00	423.50	1.18
Week 25	191.88	79.50	1.08	259.00	201.25	1.16
Week 26	215.33	106.92	1.06	354.50	652.25	1.11
Week 31	230.50	136.00	1.11	265.33	215.33	1.15

3.1.2.1 Length of sea trout

The average length of trout (Figure 3.1.2.1) of less than 150 g ranged from 179.5 mm in week 24 (mid-June) to 230.5 mm in in week 31 (early August) with a mean of 200.44 mm. The average length of trout of more than 150 g ranged from 259.0 mm in weeks 23 (early June) and 25 (mid-June) to 354.5 mm in week 26 (late June) with a mean of 293.57 mm.

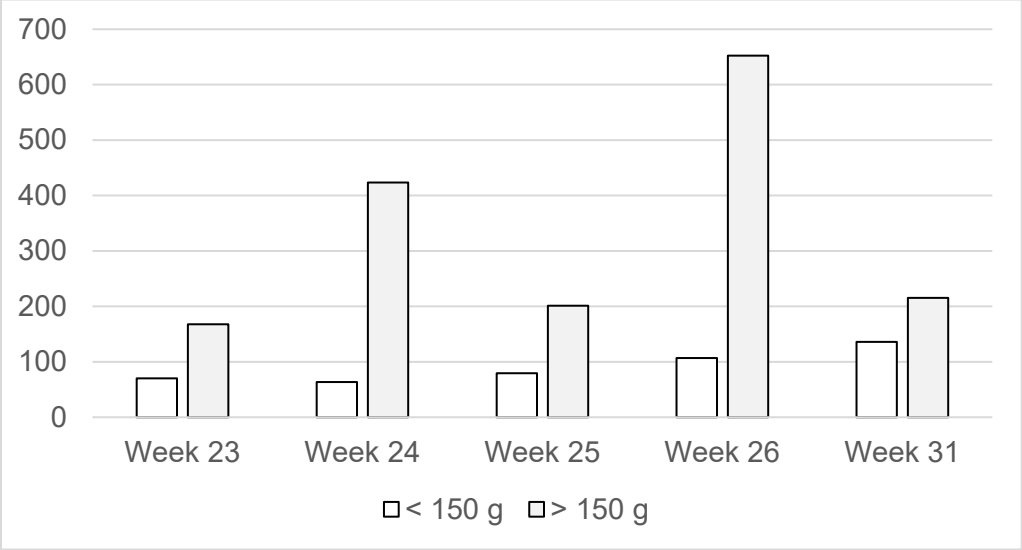
Figure 3.1.2.1 Average Length (mm) of trout sampled by week no.



3.1.2.2 Weight of sea trout

The average weight of trout (Figure 3.1.2.2) of less than 150 g weight ranged from 63.6 g in week 24 (mid-June) to 136.0 g in week 31 (early August). The average weight of trout of more than 150 g weight ranged from 167.8 g in week 23 (early June) to 652.3 g in week 26 (late June).

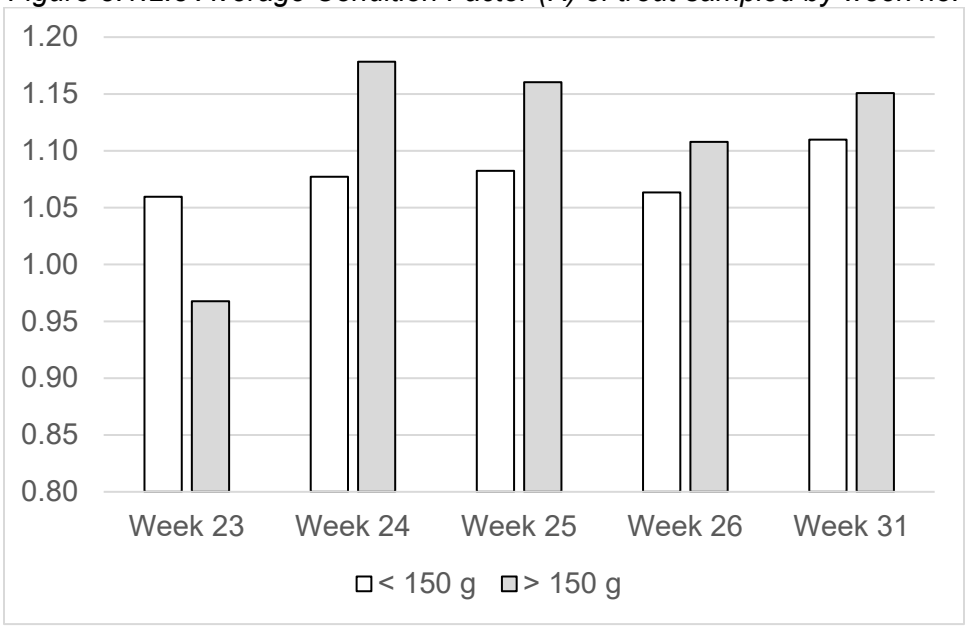
Figure 3.1.2.2 Average Weight (g) of trout sampled by week no.



3.1.2.3 Condition factor of sea trout

The condition factor (CF) of trout (Figure 3.1.2.3) of less than 150 g weight ranged from 1.06 in weeks 23 (early June) and 26 (late June) to 1.11 in week 31 (early August) with a mean of 1.08. The average condition factor of trout of more than 150 g weight ranged from 0.97 in week 23 (early June) to 1.18 in week 24 (mid-June) with a mean of 1.11.

Figure 3.1.2.3 Average Condition Factor (K) of trout sampled by week no.



3.2 Sea lice burdens of sea trout

The sea lice burdens of sea trout sampled in 2023 are summarised in terms of the prevalence of lice (% of fish infected), abundance of lice (average number of lice per fish) and intensity of infection (average number of lice per infected fish) below (Table 3.2.1). The analysis included first attached (stage 1), mobile (stage 2) and gravid female (stage 3) sea lice.

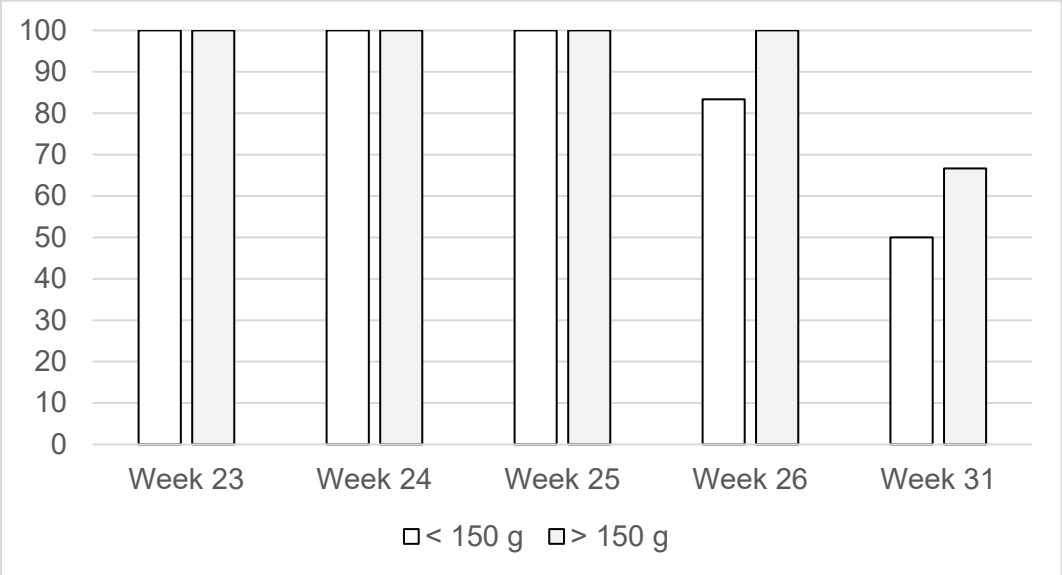
Table 3.2.1 Sea lice burdens of sea trout 2023

Sample Date	< 150 g			> 150 g		
	Prevalence	Abundance	Intensity	Prevalence	Abundance	Intensity
Week 23	100	17.33	17.33	100	16.00	16.00
Week 24	100	26.70	26.70	100	69.00	69.00
Week 25	100	40.13	40.13	100	25.00	25.00
Week 26	83.33	28.17	33.80	100	7.00	7.00
Week 31	50.00	1.00	2.00	66.67	3.67	5.50
All Trout	86.67	22.67	23.99	93.33	24.13	24.50

3.2.1 Prevalence of sea lice

The mean percentage of trout less than 150 grams weight infected by lice (Figure 3.2.1) was 86.67 (range 50.0 to 100 %) and the percentage of trout more than 150 grams weight infected by lice was 93.33 (range 66.67 to 100 %).

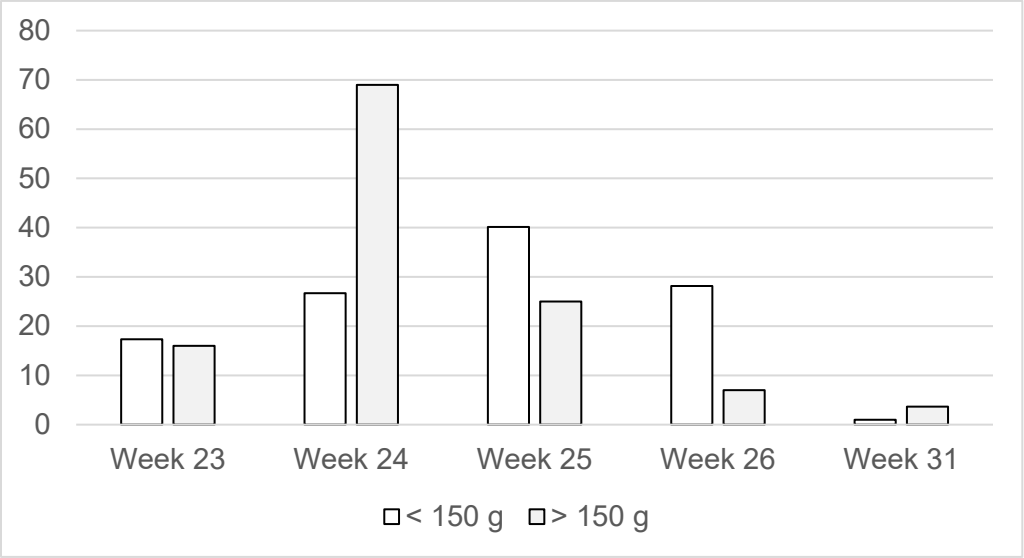
Figure 3.2.1 Prevalence of sea lice infection (% of all trout) by week no.



3.2.2 Abundance of sea lice

The mean abundance of lice found on trout under 150 grams weight (Figure 3.2.2) was 22.67 lice (range 1.0 to 40.1 lice) and the mean abundance of lice found on trout over 150 grams weight was 24.13 lice (range 3.67 to 69.0 lice).

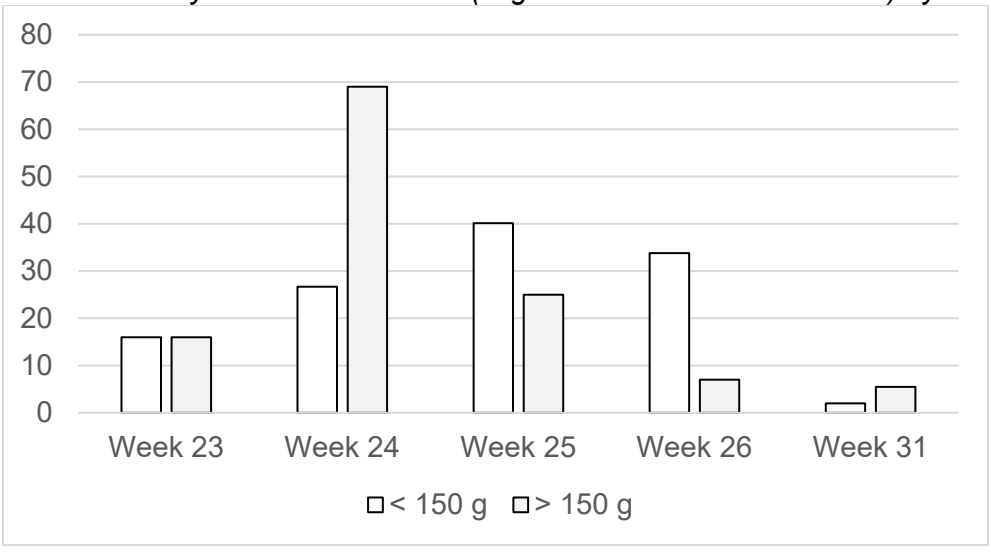
Figure 3.2.2 Abundance of sea lice (avg. no. of lice on all trout) by week no.



3.2.3 Intensity of sea lice infection

The mean intensity of infection found on trout under 150 grams weight (Figure 3.2.3) was 23.99 lice (range 2.0 to 40.1) and the mean intensity of infection found on trout over 150 grams weight was 24.50 lice (range 5.0 to 69.0 lice).

Figure 3.2.3 Intensity of sea lice infection (avg. no. of lice on infected trout) by week no.



3.2.4 Life-stage of sea lice

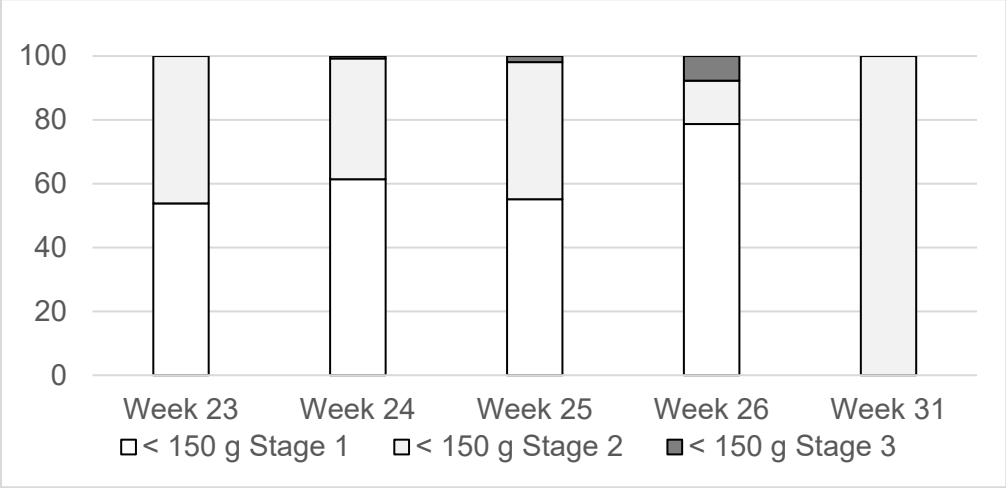
The proportion of the number of each life-stage of sea lice recorded are described below (Table 3.2.2) for trout under and over 150 grams weight. The three stages of lice recorded were attached (stage 1), mobile (stage 2) and gravid female (stage 3).

Table 3.2.2 Proportion of each life-stage of sea lice found on sea trout

Sample Date	< 150 g			> 150 g		
	Stage 1	Stage 2	Stage 3	Stage 1	Stage 2	Stage 3
Week 23	53.8	46.2	0.0	37.5	62.5	0
Week 24	61.4	37.8	0.7	39.1	53.6	7.2
Week 25	55.1	43.0	1.9	42.0	46.0	12.0
Week 26	78.7	13.6	7.7	42.9	21.4	35.7
Week 31	0.0	100.0	0.0	81.8	18.2	0.0
All Trout	61.90	35.51	2.59	42.61	48.30	9.09

Of the lice found on trout under 150 grams (Figure 3.2.4), the proportion of attached sea lice (stage 1) ranged from none in week 31 (early August) to 78.7 % in week 26 (late June) and averaged 61.9 % across all trout under 150 grams. The proportion of mobile sea lice (stage 2) ranged from 13.6 % in week 26 (late June) to 100 % in week 31 (early August) and averaged 35.5 % over the study period. When present, the proportion of gravid sea lice (stage 3) ranged from 0.7 % in week 24 (mid-June) to 7.7 % in week 26 (late June) and averaged 2.6 %.

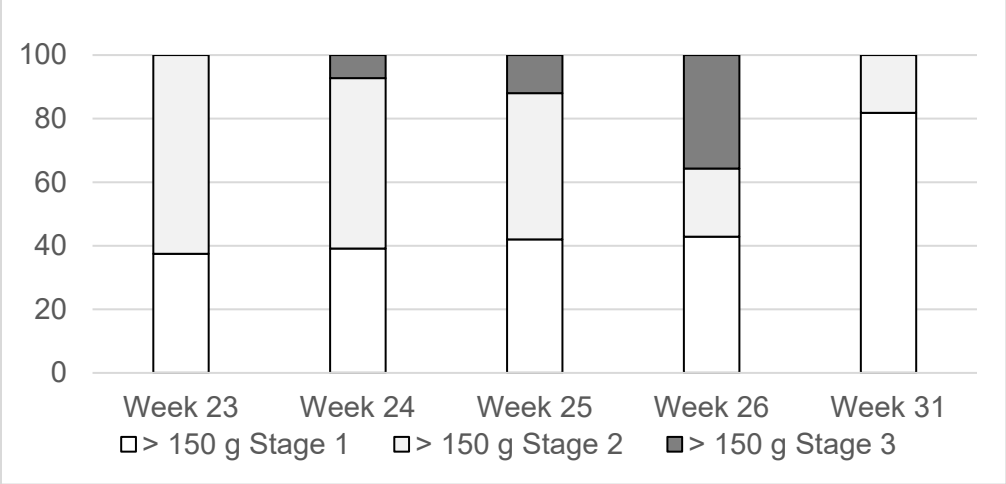
Figure 3.2.4 Proportion (%) of life-stage of sea lice found on infected trout < 150 g



On trout over 150 grams (Figure 3.2.5), the proportion of attached sea lice (stage 1) found ranged from 37.5 % in week 23 (early June) to 81.8 % in week 31 (early August) and averaged 42.6 %

across all larger trout. The proportion of mobile sea lice (stage 2) ranged from 18.2 % in week 31 (early August) to 62.5 % in week 23 (early June) and averaged 48.3 % across all larger trout. When present, the proportion of gravid female mobile sea lice (stage 3) ranged from 7.2 % in week 24 (mid-June) to 35.7 % in week 26 (late June) and averaged 9.1 % across all trout over 150 grams weight.

Figure 3.2.5 Proportion (%) of life-stage of sea lice found on infected trout > 150 g



3.3 Risk analysis of sea lice burdens

The lice-related risk of marine mortality or return prematurely to freshwater was calculated based on the number of lice per gram of fish weight and analysis was conducted separately for trout above and below 150 grams weight.

3.3.1 Average lice per gram fish weight

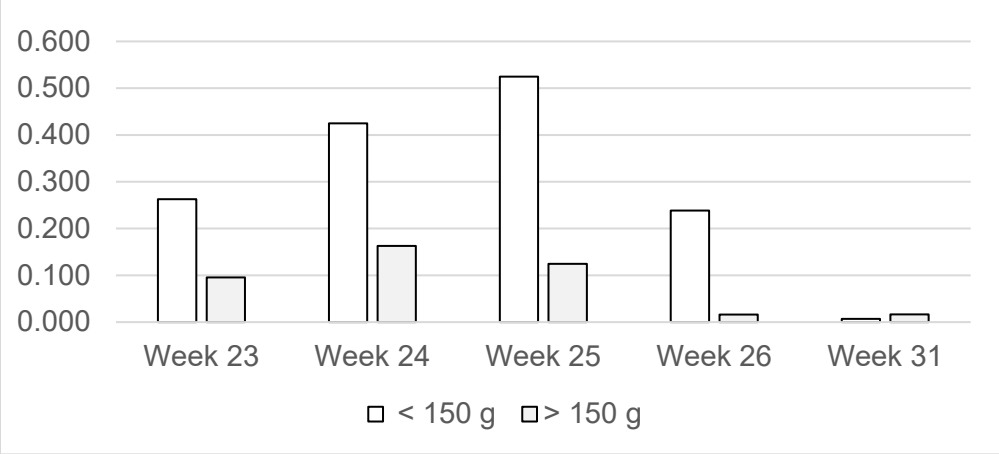
The average lice per gram of fish weight (lice / g^{-1}) is given for fish in both weight categories (above and below 150 grams weight) and across all fish sampled in each survey below (Table 3.3.1 and Figure 3.3.1).

Table 3.3.1 Sea lice burdens found on sea trout (Avg. no. lice/g^{-1})

Sample Period	< 150 g	> 150 g	All trout
Week 23	0.263	0.095	0.196
Week 24	0.425	0.163	0.380
Week 25	0.525	0.124	0.445
Week 26	0.239	0.016	0.183
Week 31	0.007	0.017	0.013
All Trout	0.368	0.068	0.291

The average number of sea lice per gram found on trout under 150 grams ranged from 0.007 in week 31 (early August) to 0.525 in week 25 (late June) and averaged 0.368 lice per gram. The average number of sea lice per gram on trout over 150 grams ranged from 0.016 in week 26 (late June) to 0.163 in week 24 (mid-June) and averaged 0.068. The number of sea lice per gram on all fish sampled averaged 0.291 lice per gram.

Figure 3.3.1 Sea lice burdens found on sea trout (Avg. no. lice/g^{-1}) by week



3.3.2 Risk analysis for trout under 150 grams weight

The average sea lice burden per gram of fish weight (for sea trout under 150 grams) is categorised below using the salmon lice risk index described by Taranger et. al. (2015). This is shown as a proportion of fish which fell into each category on each sample date (Table 3.3.2 and Figure 3.3.2).

Table 3.3.2 Lice-related risk index for trout < 150g (2023)

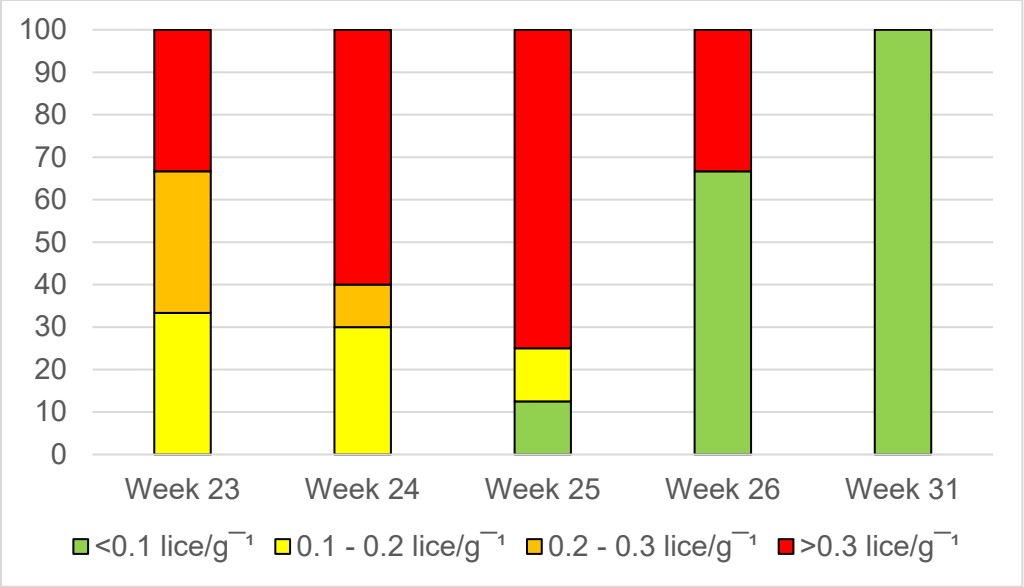
Sample period	Proportion (%) of sea trout (<150g) which fell into each risk assessment category				
	<0.1 lice/g^{-1}	0.1 - 0.2 lice/g^{-1}	0.2 - 0.3 lice/g^{-1}	>0.3 lice/g^{-1}	Total Risk (%)
Week 23	0.0	33.3	33.3	33.3	56.7
Week 24	0.0	30.0	10.0	60.0	71.0
Week 25	12.5	12.5	0.0	75.0	77.5
Week 26	66.7	0.0	0.0	33.3	33.3
Week 31	100	0.0	0.0	0.0	0.0
All < 150g	24.14	17.24	6.90	51.72	58.6

The percentage of smaller trout (<150 g) which had a burden of <0.1 lice/g^{-1} ranged from none in in weeks 23 and 24 (early to mid-June) to 100 % in week 31 (early August) and 24.1 % across all samples. The percentage of smaller trout which had between 0.1 – 0.2 lice/g^{-1} ranged from none

in weeks 26 (late June) and 31 (early August) samples to 33.3 % in week 23 (early June) and 17.2 % across all smaller trout. The percentage having between 0.2 – 0.3 lice/g^{-1} ranged from none in three samples to 33.3 % in week 23 (early June) and 6.9 % across all smaller trout. The percentage of smaller fish which had > 0.3 lice/g^{-1} ranged from none in week 31 (early August) to 75.0 % in week 25 (late June) and 51.7 % across all smaller trout.

The Total lice-related risk is calculated as the sum of the increased additional risk of marine mortality or early return to freshwater in the sample (Table 3.3.2 and Figure 3.3.4). The Total lice-related risk ranged from none in week 31 to 77.5 % in week 25 (late June) and 58.6 % across all smaller trout sampled. The total risk to smaller trout were therefore categorised as being high (> 30% total lice-related risk).

Figure 3.3.2 Lice-related risk index for trout as the proportion (%) of trout < 150g (by week no.)



3.3.3 Risk analysis for trout over 150 grams weight

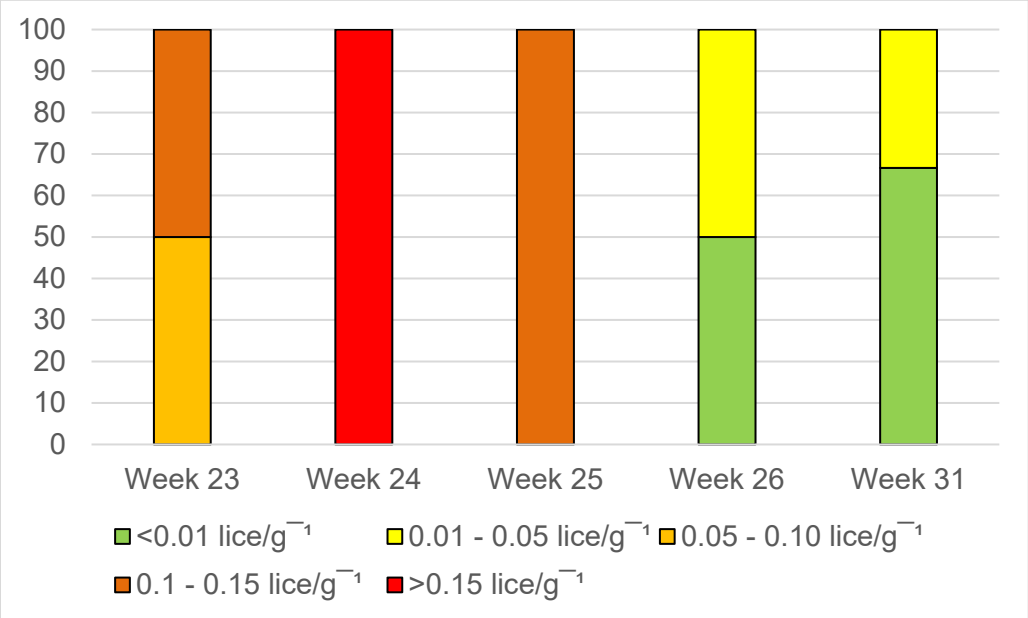
The average sea lice burden per gram of fish weight (for sea trout over 150 grams) is categorised below using the salmon lice risk index described by Taranger et. al. (2015). This is shown as a proportion of fish which fell into each category on each sample date (Table 3.3.3 and Figure 3.3.3). The percentage of larger trout sampled which had <0.01 lice/g^{-1} ranged from none in weeks 23 to 25 (early to mid-June) to 66.7 % in week 31 (early August) and 30.0 % across all larger trout. The percentage of trout which had between 0.01 – 0.05 lice/g^{-1} ranged from none in weeks 23 to 25 (early to mid-June) and 50.0 % in week 26 (late June) and 20.0 % across all larger trout. The percentage of trout which had between 0.05 – 0.10 lice/g^{-1} ranged from none from week 24 to 31

(mid-June to early August) to 50.0 % in week 23 (early June) and 10.0 % across all larger trout. The percentage of larger trout sampled that had between 0.10 – 0.15 lice/g^{-1} ranged from none in weeks 24 (mid-June) 26 (late June) and 31 (early August) to 100 % in week 25 (mid-June) and 30.0 % across all samples. The percentage of larger trout sampled that had over 0.15 lice/g^{-1} in 2023 was none in all but one sample (100 %) in week 24 (mid-June) and 10 % across all larger trout.

Table 3.3.3 Lice-related risk index for trout > 150g

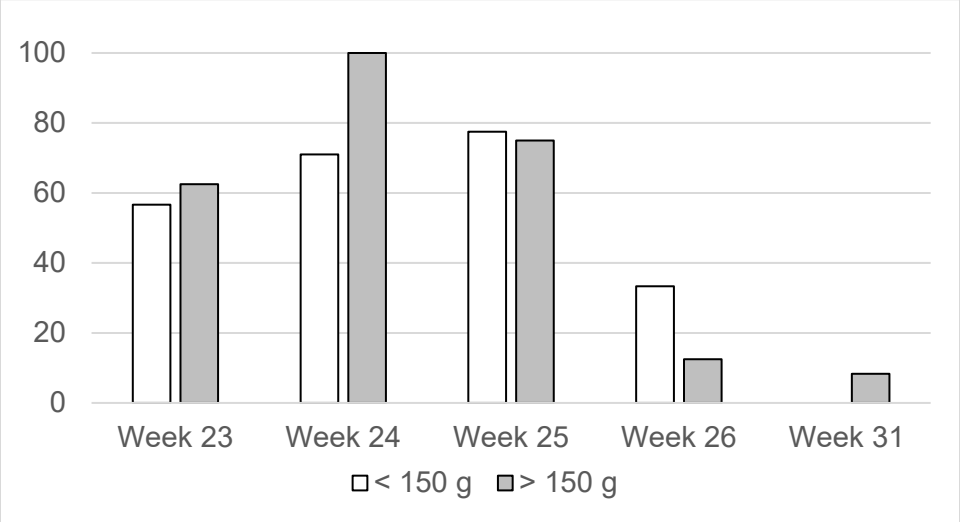
Sample period	Proportion (%) of sea trout (>150g) which fell into each risk assessment category					
	<0.01 lice/g^{-1}	0.01 - 0.05 lice/g^{-1}	0.05 - 0.10 lice/g^{-1}	0.1 - 0.15 lice/g^{-1}	>0.15 lice/g^{-1}	Total Risk (%)
Week 23	0.0	0.0	50.0	50.0	0.0	62.5
Week 24	0.0	0.0	0.0	0.0	100	100.0
Week 25	0.0	0.0	0.0	100	0.0	75.0
Week 26	50.0	50.0	0.0	0.0	0.0	12.5
Week 31	66.7	33.3	0.0	0.0	0.0	8.3
All > 150g	30.00	20.00	10.00	30.00	10.00	42.5

Figure 3.3.3 Lice-related risk index for trout as the proportion (%) of trout > 150g (by week no.)



The total lice-related risk is calculated as the sum of the increased mortalities in the sample (Table 3.3.3 and Figure 3.3.4). Total lice-related mortality for trout over 150 grams ranged from 8.3 % in week 31 (early August) to 100 % in week 24 (mid-June) and was 42.5 % across all larger trout sampled. The total lice-related risk for larger trout was therefore described as high (> 30 % mortality) in 2023.

Figure 3.3.4 Total lice-related risk for smaller and larger trout as the proportion (%) sampled over the study period (by week no.)



3.4 Comparison of historical data

A comparison of previous survey results can be made to provide additional context for the 2023 survey results. Trout over 150 grams were sampled only in 2021, 2022 and 2023 while trout under 150 grams were sampled in all six survey years between 2008 and 2023 (Table 3.4.1).

3.4.1 Number of trout

The number of trout sampled under 150 grams ranged from one in 2010 to 126 in 2022, with an average of 33 trout over the study period. The number of larger trout sampled, ranged from none (2008-10) to 16 in 2022 with an average of 5.3 larger trout (Table 3.4.1).

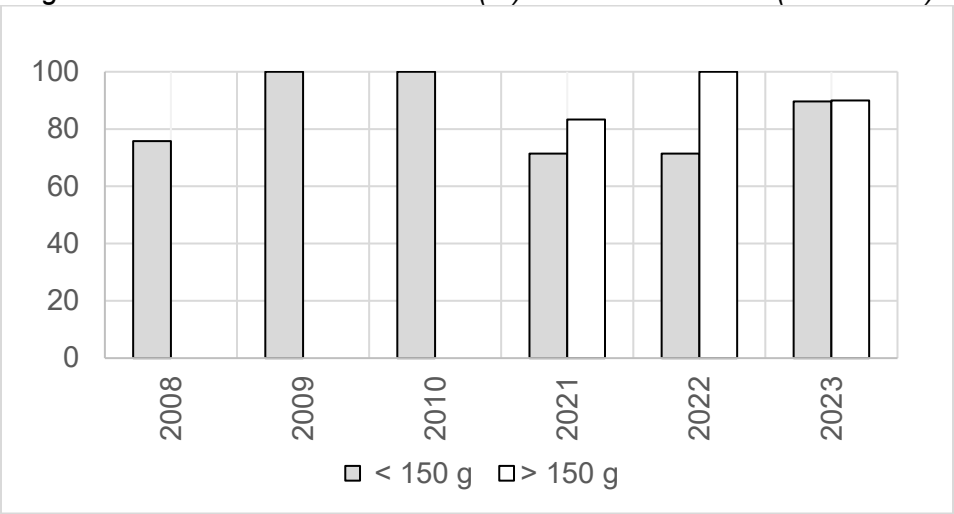
Table 3.4.1 Number of trout sampled and analysed (2008-2023)

Year	< 150 g				> 150 g			
	No. Trout	Prevalence (%)	Abundance	Intensity	No. Trout	Prevalence (%)	Abundance	Intensity
2008	33	75.8	7.6	10.0	0			
2009	2	100	2.5	2.5	0			
2010	1	100	7.0	7.0	0			
2021	7	71.4	20.7	29.0	6	83.3	15.0	18.0
2022	126	71.4	5.3	7.4	16	100	7.9	7.9
2023	29	89.7	28.0	31.2	10	90.0	17.6	19.6
Avg.	33.0	84.7	11.8	14.5	5.3	91.1	13.5	15.2

3.4.2 Prevalence of sea lice

The percentage of trout under 150 grams infected by sea lice (Table 3.4.1 and Figure 3.4.2) ranged between 71.4 % (in both 2021 and 2022) and 100 % in 2009 and 2010, averaging 84.7 % across all trout sampled. The percentage of trout over 150 grams infected by sea lice ranged between 83.3 % in 2021 and 100 % 2022 and averaged 91.1 %.

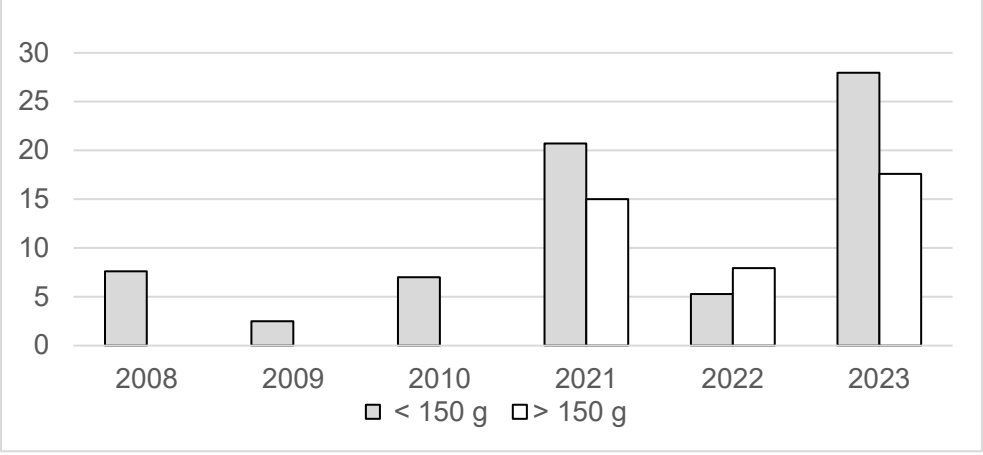
Figure 3.4.2 Prevalence of sea lice (%) found on sea trout (2008-2023)



3.4.3 Abundance of sea lice infection

The average number of sea lice (Table 3.4.1 and Figure 3.4.3) found on all trout under 150 grams ranged from 2.5 lice in 2009 to 28.0 lice in 2023, averaging 11.8 lice over the study period. The abundance of lice on trout over 150 grams ranged between 7.9 lice in 2022 and 17.6 lice in 2023 and averaged 13.5 lice between 2021 and 2023.

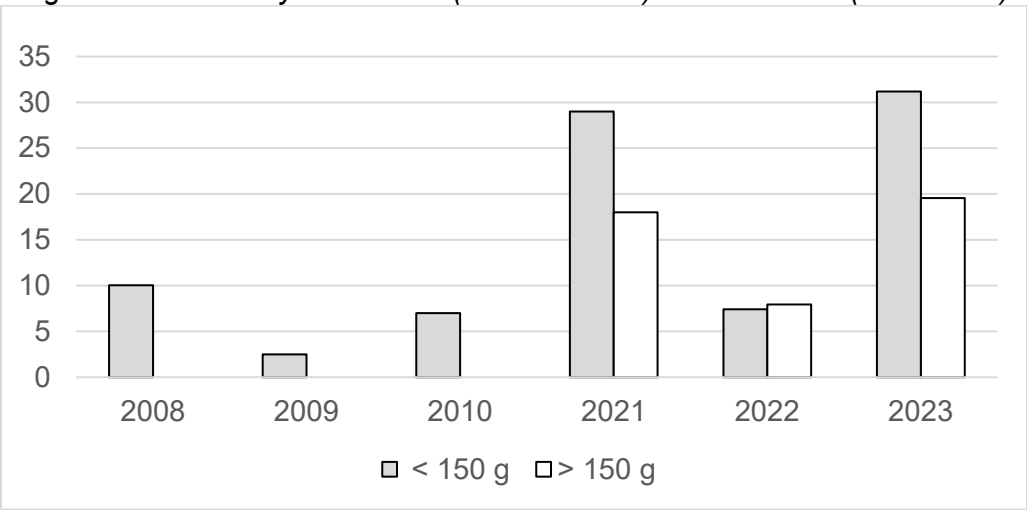
Figure 3.4.3 Abundance of sea lice (no. of sea lice) found on sea trout (2008-2023)



3.4.4 Intensity of sea lice infection

The average number of sea lice found on infected sea trout (Table 3.4.1 and Figure 3.4.4) under 150 grams ranged from 2.5 lice in 2009 to 31.2 lice in 2023, averaging 14.5 lice over the study period. The intensity of infection on trout over 150 grams ranged from 7.9 lice in 2022 to 19.6 lice in 2023.

Figure 3.4.4 Intensity of infection (no. of sea lice) found on trout (2008-2023)



3.4.5 Comparison of lice-related risk index for trout under 150 grams (2008-2023)

Of the smaller trout sampled over the study period 2008 – 2023, the proportion of trout that had a lice burden of less than 0.1 lice/g^{-1} ranged from none in 2010 to 100 % in 2009 and averaged 50.3 % across all surveys (Table 3.4.2 and Figure 3.4.5).

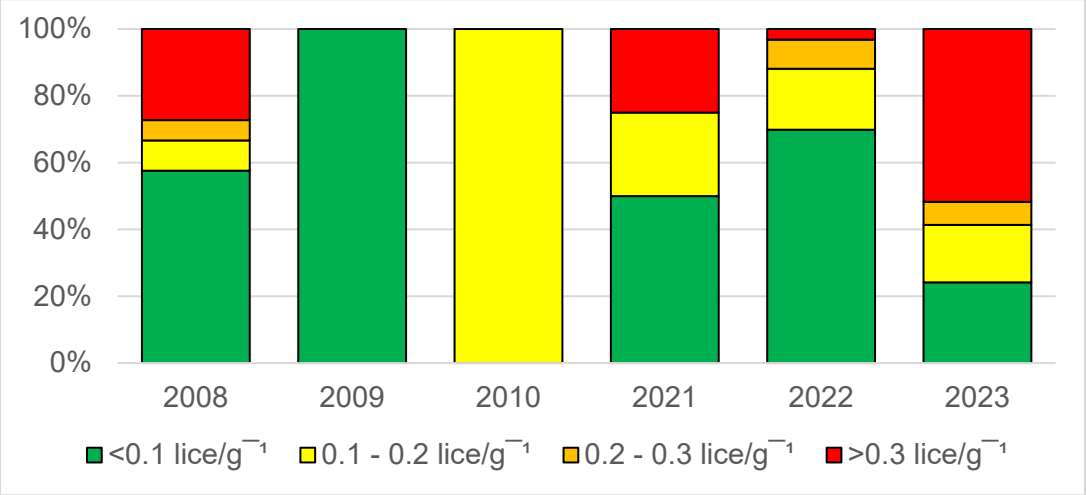
Table 3.4.2 Lice-related risk for trout < 150 grams (2008-2023)

Year	Proportion (%) of sea trout (<150g) which fell into each risk assessment category				Total Risk (%)
	<0.1 lice/g^{-1}	0.1 - 0.2 lice/g^{-1}	0.2 - 0.3 lice/g^{-1}	>0.3 lice/g^{-1}	
2008	57.6	9.1	6.1	27.3	32.1
2009	100	0.0	0.0	0.0	0.0
2010	0.0	100	0.0	0.0	20.0
2021	50.0	25.0	0.0	25.0	30.0
2022	69.8	18.3	8.7	3.2	11.2
2023	24.1	17.2	6.9	51.7	58.6
Avg.	50.26	28.26	3.61	17.86	25.32

The proportion of smaller trout that had a burden between 0.1 and 0.2 lice/g^{-1} ranged from none in 2009 to 100 % in 2010 and averaged 28.3 % across all years. The proportion of smaller trout

that had between 0.2 and 0.3 lice/g^{-1} ranged from none in three samples to 8.7 % in 2022 and averaged 3.6 %. The proportion of smaller trout that had more than 0.3 lice/g^{-1} ranged from none in two years and 51.7 % in 2023 and averaged 17.9 % over the study period.

Figure 3.4.5 Lice-related risk as % of samples under 150 grams (2008-2023)



3.4.5 Comparison of lice-related risk index for trout over 150 grams (2008-2023)

Of the larger trout sampled over the study period (2021 and 2023 only), the proportion of larger trout that had a lice burden of less than 0.01 lice/g^{-1} ranged between 16.7 in 2021 and 31.3 % in 2022 and averaged 25.97 % across all surveys (Table 3.4.3 and Figure 3.4.6).

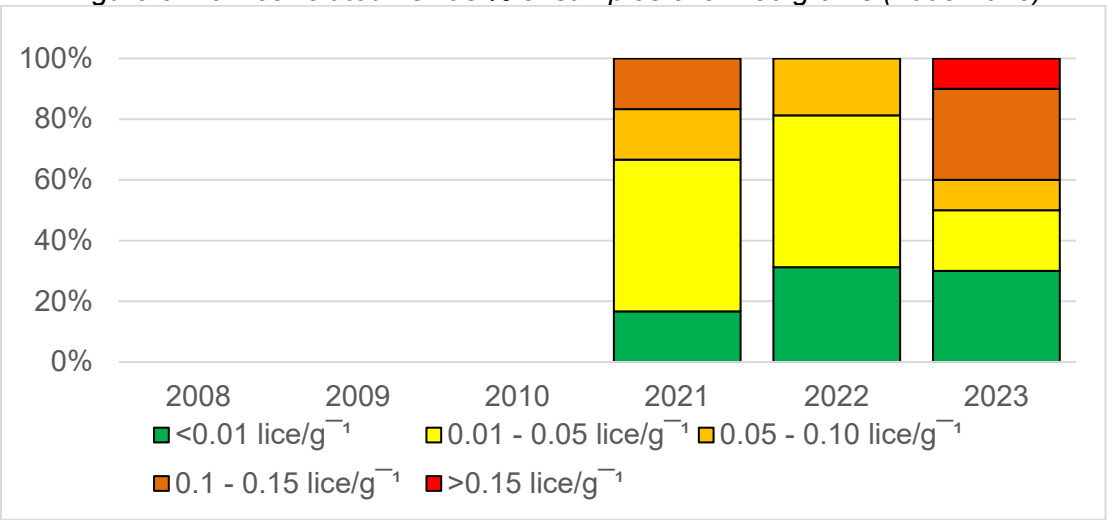
Table 3.4.3 Lice-related risk for trout < 150 grams (2008-2023)

Year	Proportion (%) of sea trout (>150g) which fell into each risk assessment category					
	<0.01 lice/g^{-1}	0.01 - 0.05 lice/g^{-1}	0.05 - 0.10 lice/g^{-1}	0.1 - 0.15 lice/g^{-1}	>0.15 lice/g^{-1}	Total Risk (%)
2008						
2009						
2010						
2021	16.7	50.0	16.7	16.7	0.0	33.3
2022	31.3	50.0	18.8	0.0	0.0	21.9
2023	30.0	20.0	10.0	30.0	10.0	42.5
Avg.	25.97	40.00	15.17	15.56	3.33	32.57

The proportion of larger trout that had a burden between 0.01 and 0.05 lice/g^{-1} was 50.0 % in both 2021 and 2022 and 20.0 % in 2023. The proportion of larger trout that had between 0.05 and 0.10 lice/g^{-1} ranged between 16.7 in 2021 and 18.8 % in 2022 and averaged 15.2 % across all years. The proportion of larger trout that had between 0.1 and 0.15 lice/g^{-1} was none in 2022, 16.7 % in

2021 and 30.0 % in 2023. No larger trout were found to have more than 0.15 lice/g^{-1} in 2021 and 2022 and 10 % of larger trout in 2023, averaging 3.33 % across all three years.

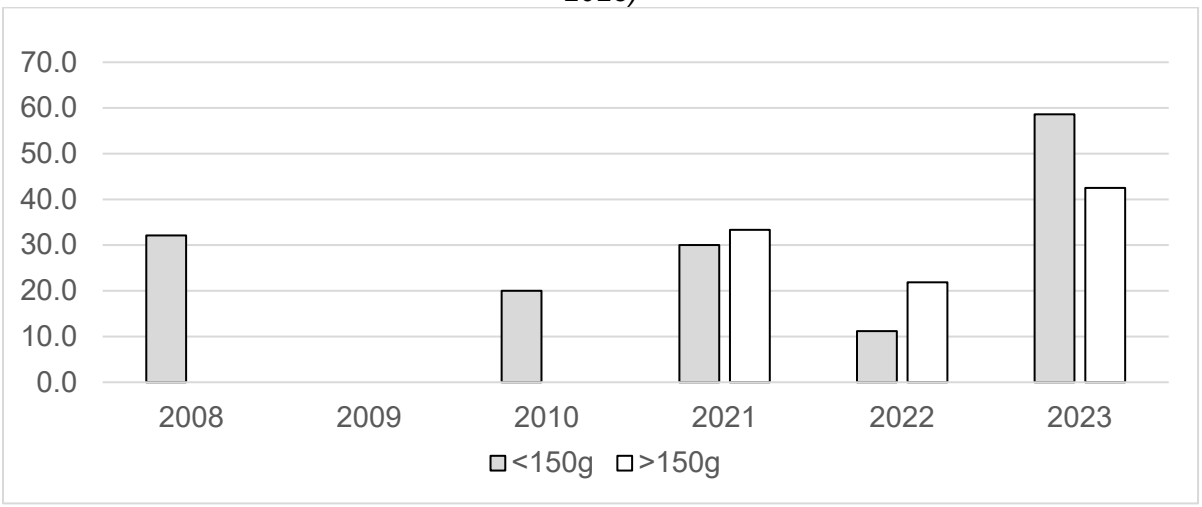
Figure 3.4.6 Lice-related risk as % of samples over 150 grams (2008-2023)



3.4.6 Comparison of total lice-related risk for trout under and over 150 grams (2008-2023)

The total lice-related risk is calculated as the sum of the increased mortalities in the sample. Total lice-related risk for trout under 150 grams (Table 3.4.2 and Figure 3.4.7) was estimated to be high (> 30% total risk) in 2008 (32.1 %), 2021 (30.0 %) and 2023 (58.6 %), moderate (between 10 and 30 %) in 2010 (20 %) and 2022 (11.2 %) and low risk (< 10 % total risk) in 2009 (0%). Total lice-related risk for larger trout (Table 3.4.3 and Figure 3.4.7) was estimated to be high (> 30 %) in 2021 (33.3 %) and 2023 (42.5 %) and moderate (between 10 and 30 %) in 2022 (21.9 %).

Figure 3.4.7 Total lice-related risk as % of samples for trout under and over 150 grams (2008-2023)



4 DISCUSSION

4.1 Factors affecting the number of trout

The number and size of trout sampled by the survey may be influenced by several factors, including survey location, method, and timing. The 2021 surveys sampled relatively few trout in both the mobile seine net and the fixed fyke net sampling. The 2022 seine net surveys also caught few trout, but the fyke net caught trout throughout its deployment over several weeks. In 2022, the fyke net was fished in three different locations before being fished for 45 days at Traigh nam Musgan catching 133 trout during this period (2.96 trout per day). The redeployment of the fyke net at Traigh nam Musgan in 2023 for a shorter period of 17 days caught 39 trout with a similar, but slightly lower catch per day (2.29 trout per day) (Table 4.1).

Table 4.1.1 Comparison of catches of sea trout by Fyke net (2023)

Period	No. days	No. Trout	CPUE (trout per day)
Week 23	2	5	2.50
Week 24	4	11	2.75
Week 25	4	10	2.50
Week 26	3	8	2.67
Week 31	4	5	1.25
Total 2023	17	39	2.29
Total 2022	45	133	2.96

While the CPUE of the Fyke net was lower in 2023 compared to 2022, the catch rate in June (weeks 23 to 26) was comparable to the average for 2022, suggesting a higher catch rate earlier in the sampling period compared to that found in the early August sampling (week 31). The fyke net was not fished during July because of the unusually high water temperatures. The net had been set and fished for periods of two nights (approximately 36 hours) through June before being serviced, but the trout in the net in the last week of June (week 26) were in poor condition and therefore, sampling was postponed until water temperatures reduced in early August. In addition, when servicing the fyke in 2023, there was a lack of bycatch and the knot on the cod end of the trap had been changed, suggesting the net had been opened between visits which may have contributed to the poor condition of some of the trout. Future sampling may require additional security and more frequent servicing (every 24 hours) to ensure trout are kept in good condition.

Data collected from numerous sites over several years in the region suggest sea trout post-smolts remain relatively close to river estuaries for the first few weeks after entering the sea before

dispersing more widely as the summer progresses. This dispersal has meant that sampling sea trout in significant numbers becomes more difficult later in the summer. Consequently, surveys are mostly conducted relatively close to river mouths in May and June when the density of trout may provide sufficient samples for analysis. Similarly in 2023, the catch per unit effort (CPUE) was higher in June (2.50 to 2.75 trout per day) compared to August (1.25 trout per day) although sampling effort was much lower in August (4 days) compared to June (13 days). In 2022, the numbers of sea trout sampled by the fyke net peaked in late June, but the amount of samples collected later in July was significant in that it extended the period of sample collection and overall number of samples that provide robustness to the analysis of the data collected by the study. The September sampling in 2022 was hampered by the amount of bycatch, particularly shoals of Mackerel, which caused the net to become less manageable, caused damage to sea trout in the net and attracted predators to the site. Therefore, fishing the net later in the summer and early autumn may not be sustainable in terms of conserving fish stocks in the area.

4.2 Sea lice burdens of sea trout

The sea lice found on the smaller trout (29 trout of less than 150 grams) sampled suggest that burdens of lice increased in the first three weeks of June before declining in the last week in June and were lower still in the first week of August. The lice present on smaller trout appeared to consist of a high proportion of the first-attached life-stage of sea lice (stage 1), which suggest that there was a persistent infection pressure from sea lice during this period. In contrast, in August, no first-attached stages of lice were present with only mobile stages present (stage 2 and stage 3) suggesting that that infection pressure had decreased later in the summer. The larger trout also differed in that they were found to have a higher proportion of first-attached (stage 1) lice in the August sampling, suggesting that the two groups of trout may have been utilising different habitats prior to sampling.

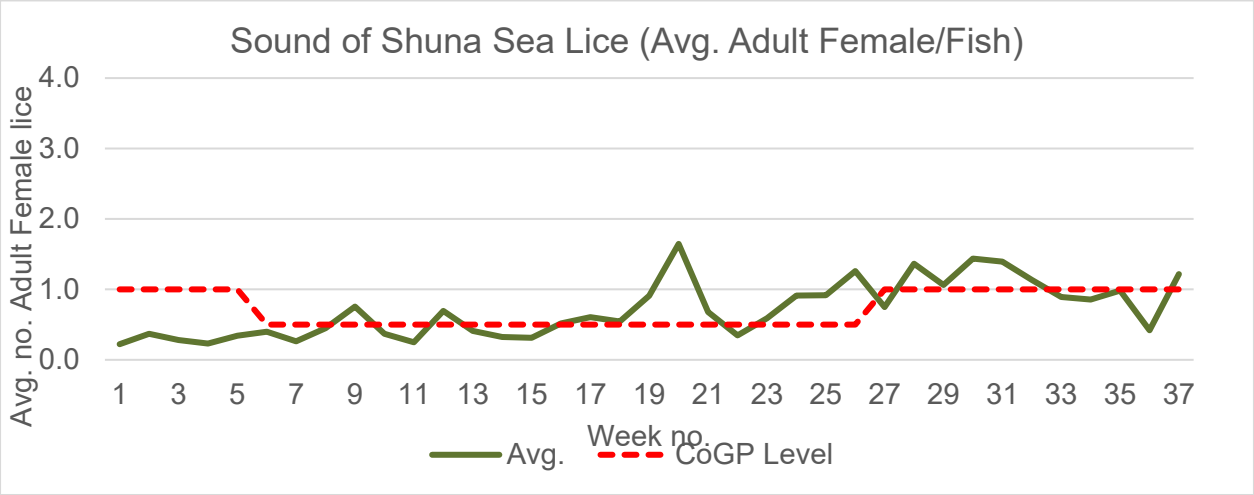
4.3 Factors affecting the lice-related risk for sea trout

Environmental factors impacting the reproduction of sea lice and the distribution of larvae can influence sea lice numbers found on sea trout at the survey site. The influence of these many factors may vary significantly from year-to-year making it difficult to attribute the influence of any specific environmental factor on sea lice burdens found on sea trout. Anthropogenic influences on sea lice larvae in the environment such as fish farms are more easily identified and can be managed through a variety of on-farm lice control methods. The number of potential hosts for sea lice at fish farm sites and the average number of adult female sea lice (i.e., the reproductive stage)

per fish on the farm can be calculated and therefore their potential influence on the results of surveys can be estimated. The number of lice on farm fish generally tend to increase over time during a farm's production cycle and therefore, the number of lice larvae present in the environment is expected to be higher in the second year of the production cycle.

At the time of survey in summer 2023 (weeks 23 to 26 and week 31), published sea lice data for salmon farms (through Scottish Government's Aquaculture website) show that average adult female lice numbers (abundance) on farmed fish in the Sound of Shuna farm management area were higher than the Industry's Code of Good Practice (CoGP) 0.5 adult female lice per fish level (Figure 4.3.1). Average on-farm sea lice levels were also higher than the CoGP level of 1.0 adult female lice in the four weeks prior to sampling in week 31 (weeks 28, 29, 30 and 31). It is important to note that the thresholds set under the Industry's CoGP are predicated on farmed fish health and are not designed to protect wild fish.

Figure 4.3.1 Average adult female sea lice (no. lice per fish by week no.) on farms and estimated for wild sea trout, weeks 1 to 37, 2023



The estimated average adult female sea lice abundance for sea trout in Sound of Shuna in 2023 were higher than that counted on farmed salmon in weeks 23 to 26 but were lower in week 31. While this comparison may be useful in comparing the relative burdens of the two groups of fish, larger sample sizes of sea trout over a longer period would be required to better understand relationships in sea lice burdens over time.

The lice burdens found in 2023 appear to be detrimental to the health of sea trout when analysed by the methods described by Taranger. The analysis suggested that the lice-related risk was high

(> 30 % risk) overall for both smaller and larger trout. When analysed week-to-week, risk was high (>30 %) for smaller trout in the first four weeks of sampling but fell to a low risk (< 10 %) in week 31. Sea lice-related risk to larger trout was also high from week 23 to week 25 and moderate risk (between 10 % and 30 %) in week 26 and low in week 31. However, the lower number of both small and large trout sampled in each week make this data less robust than the total number of samples collected over the whole study period. Increasing the sample size in each week will be required to provide more robust information on the dynamics of the infestation of lice on wild sea trout in future years to better inform future management.

4.4 Sampling site and method considerations for future monitoring

The risk analysis assumes that individuals caught in the study are representative for the sea trout populations in the area, which may originate from several different rivers in the Sound of Shuna Farm Management Area. The location of the fyke net survey site that sampled most of the trout, is close to the estuary of Staing Mhor, a coastal stream which sea trout are likely to use for spawning and juvenile recruitment. Therefore, the fyke net may have sampled a higher proportion of trout originating from this river and therefore could be less representative for those populations of trout originating from rivers located further away from the survey site. Despite this potential bias, the site provided a much higher number of samples than other sites trialled in the management area which can be used to provide an assessment of potential effects of aquaculture on wild sea trout. It may be productive to sample other sites with similar physical characteristics, although the current location is close to the shore base at Craobh Haven which allow easier access to the sampling site at Traigh nam Musgan.

The risk analysis is also not able to identify the proportion of the population that are resident or have returned to the site to shed lice or visit the site for short periods. The datasets from other sampling sites do suggest that relatively high numbers of trout with no or relatively low lice burdens are sampled at sites close to estuaries, suggesting that smaller trout do normally inhabit these estuarine sites in the late spring and early summer period. The surveys sample fish that have not ventured very far from the estuary and therefore may have a reduced risk of infection. The fyke net locations used in 2021 were further away from estuaries but did not catch sufficient numbers of trout to make a reliable analysis of sea lice on local sea trout populations. The 2022 and 2023 surveys did however sample a higher proportion of larger trout, providing some indication that the technique can be useful in monitoring the lice burdens on the larger trout that are thought to be more transient and more likely to accumulate a lice burden over time. The location of the fyke net

may be crucial in sampling enough trout to make the findings more conclusive and therefore gathering information on the movement of trout in the Sound of Shuna may be key to ensuring that monitoring efforts provide sufficient samples from which to draw firm conclusions. Acoustic tags and receivers could be used to track the movements of individual sea trout to better identify potential sampling sites and understand any differences in the risk of infection to different age groups of trout over a wider area.

The results of the 2022 and 2023 surveys suggest that sampling using the fyke net over a period in the summer months has potential to provide sufficient samples to assess the sea lice burdens of trout in the Sound of Shuna Management Area.

5 REFERENCES

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Appendix I – Sampling data

Sampling				Sea trout			Sea Lice				
Week	Date	count	Fish No.	Length (mm)	Weight (g)	Condition factor	1	2	3	Total	Lice / gram^{-1}
23	07/06/23	1	1	207	107	1.206	12	11	0	23	0.215
	07/06/23	2	2	264	168	0.913	4	7	0	11	0.065
	07/06/23	3	3	172	49.5	0.973	12	10	0	22	0.444
	07/06/23	4	4	254	167.5	1.022	8	13	0	21	0.125
	07/06/23	5	5	176	54.5	1.000	4	3	0	7	0.128
24	14/06/23	6	1	195	83.5	1.126	30	12	2	44	0.527
	14/06/23	7	2	180	55	0.943	27	6	0	33	0.600
	14/06/23	8	3	173	56	1.082	34	22	0	56	1.000
	14/06/23	9	4	196	75	0.996	9	1	0	10	0.133
	14/06/23	10	5	196	84.5	1.122	7	6	0	13	0.154
	14/06/23	11	6	163	48.5	1.120	3	10	0	13	0.268
	14/06/23	12	7	162	45	1.058	16	3	0	19	0.422
	14/06/23	13	8	153	39.5	1.103	5	1	0	6	0.152
	16/06/23	14	1	192	79.5	1.123	16	16	0	32	0.403
	16/06/23	15	2	185	69.5	1.098	17	24	0	41	0.590
	16/06/23	16	3	330	423.5	1.178	27	37	5	69	0.163
25	20/06/23	17	1	183	64	1.044	19	42	0	61	0.953
	20/06/23	18	2	212	91	0.955	85	22	0	107	1.176
	22/06/23	19	1	190	71.5	1.042	18	11	0	29	0.406
	22/06/23	20	2	206	92.5	1.058	26	30	0	56	0.605
	22/06/23	21	3	265	205.5	1.104	10	12	1	23	0.112
	22/06/23	22	4	253	197	1.216	11	11	5	27	0.137
	22/06/23	23	5	237	148.5	1.116	3	6	0	9	0.061
	22/06/23	24	6	157	41.5	1.072	3	5	0	8	0.193
	22/06/23	25	7	173	63.5	1.226	10	11	1	22	0.346
	22/06/23	26	8	177	63.5	1.145	13	11	5	29	0.457
26	28/06/23	27	1	445	1133.5	1.286	6	1	3	10	0.009
	28/06/23	28	2	222	110.5	1.010	52	2	3	57	0.516
	29/06/23	29	1	264	171	0.929	0	2	2	4	0.023
	29/06/23	30	2	234	125	0.976	70	18	10	98	0.784
	29/06/23	31	3	187	80	1.223	0	0	0	0	0.000
	29/06/23	32	4	193	79	1.099	1	2	0	3	0.038
	29/06/23	33	5	223	108	0.974	6	1	0	7	0.065
	29/06/23	34	6	233	139	1.099	4	0	0	4	0.029
31	03/08/23	35	1	258	231	1.345	9	1	0	10	0.043
	03/08/23	36	2	232	142	1.137	0	2	0	2	0.014
	03/08/23	37	3	236	151	1.149	0	1	0	1	0.007
	05/08/23	38	1	302	264	0.958	0	0	0	0	0.000
	05/08/23	39	2	229	130	1.083	0	0	0	0	0.000