Sea Lice Burdens of Sea Trout at Carradale, Argyll, 2023

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Background

Argyll Fisheries Trust undertook seine netting surveys at the estuary of the Carradale Water, Kintyre in early summer 2023 to assess burdens of a parasite (Sea lice; *Lepeophtheirus salmonis*) found on sea trout (*Salmo trutta*). The data collected aims to inform the Environment Monitoring Plan of the Eilean Grianain fish farm.

Main findings

- Sweep netting surveys were undertaken over four visits, the first in early June, the second in early July, the third in mid-July, and the fourth visit in late July. No trout were sampled in early June, with a total of 12 sea trout being sampled in July, including five small trout (< 150 g weight) and seven larger trout (> 150 grams).
- The percentage of trout sampled that were infected by sea lice (prevalence) averaged 60.0 % for small trout, 100.0 % for larger trout and 83.3 % for all trout sampled.
- For the smaller trout (<150g), the intensity of infection was 2.0 lice per infected trout in early July with no lice being found on smaller trout later in July. The average size of smaller trout and their condition increased between the early and the late July surveys. No smaller trout were sampled in the mid-July survey.
- The intensity of infection on larger trout was 10.7 lice per infected trout in early July, 8.0 lice in mid-July and 12.0 lice later in July.
- The total lice-related risk index (Taranger et al., 2015) estimates that the small trout had no sea lice-related risk and larger trout had a moderate (14.3 %) probability of increased mortality, reduced seawater growth and reproduction in 2023.
- When compared with the historical data collected at this site since 2007, a low total lice-related risk of increased marine mortality, reduced seawater growth and reproduction was found for small trout in 15 of the 16-year dataset. A moderate risk was found only in 2021.
- In the group of larger trout, the total lice-related risk of increased marine mortality, reduced seawater growth and reproduction was moderate in four years (2012, 2016, 2021 and 2023) and high in one other (2007) of the previous 11 years when larger trout were sampled.

Acknowledgements

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1. INTRODUCTION

Seine net surveys were conducted in the early summer of 2023 to fulfil the 'Carradale Wild Fish Monitoring' under contract by Mowi Scotland Ltd. This study continues a timeline of data collection at the site since 2007 which has formerly been funded by Tripartite Working Group and more recently by Marine Scotland Science. The aim of the surveys was to assess the sea lice burdens of post-smolt sea trout in Spring and early summer (May, June and July), shortly after the smolts have migrated from the freshwater to the marine habitat.

Assessing the potential impacts of sea lice on wild migratory salmonids at Carradale has been undertaken using a risk index developed within a wider risk assessment framework for aquaculture in Norway (Taranger et al., 2015). This tool attempts to quantify the total sea lice-related risk of increased marine mortality, reduced seawater growth and reproduction of sea 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 previous years (2007 to 2022) in this report to identify any trends in infection pressure and potential relation to production cycles of farm salmon in the Farm Management Area.

2. METHODS

The survey site is located on the east coast of Kintyre at the estuary of the Carradale Water (Figure 2.1 and Table 2.1). Surveys were conducted on four occasions between early-June and late-July 2023. The timing of surveys in 2023 were affected by high water temperatures during May and June.

Table 2.1 Sweep net survey site location & frequency

Site	Easting	Northing
River Carradale	180436	637177
Survey No.	Survey date	Stage of tide
Survey 1	02/06/2023	High tide
Survey 2	04/07/2023	High tide
Survey 3	18/07/2023	High tide
Survey 4	31/07/2023	High tide

The surveys of sea trout were undertaken by sweeps of a 50 m length beach seine net which was deployed by motorboat along a length of shoreline and retrieved by hand. Up to four sweeps of the net were undertaken at spots along the shore to locate the fish and capture sufficient fish to inform the study. The target number of samples was 30 trout over the study period.

The trout captured in each sweep were transferred to a container for inspection once the netting had been completed. 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 – attached (copepodids and chalimus), Mobile (sub-adults and adults excluding gravid females) and Gravid (adult females with eggs) lice stages.

Analysis was also carried out using the Norwegian risk assessment framework by Taranger et al. (2015) to categorise the increased mortality risk or compromised seawater growth or reproduction

to individual trout according to the number of lice present in relation to the body weight of the fish (no. lice/g^{-1}).

Fig. 2.1 Location of the Carradale Water netting site

The framework assumes that small sea trout post-smolts (<150 g body weight) will suffer 100% lice-related marine mortality, or compromised reproduction potential, 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} group, and 0% if the salmon lice infection is <0.01 lice g^{-1} fish weight.

Total increased mortality risk or compromised seawater growth or 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 increased mortality risk or compromised seawater growth or reproduction 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 four of the 15 previous years surveys (2007 to 2009 and 2011) 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 1.09 K for all years when trout were weighed, so assumes the trout that were not weighed were in good condition.

3. RESULTS

The results of the 2023 surveys are given below in terms of the characteristics of the sea trout sampled (3.1), their sea lice burdens (3.2), risk analysis of sea lice burdens (3.3) and comparison with historical data (3.4) collected at the site (2007-2022).

3.1 The sea trout sampled

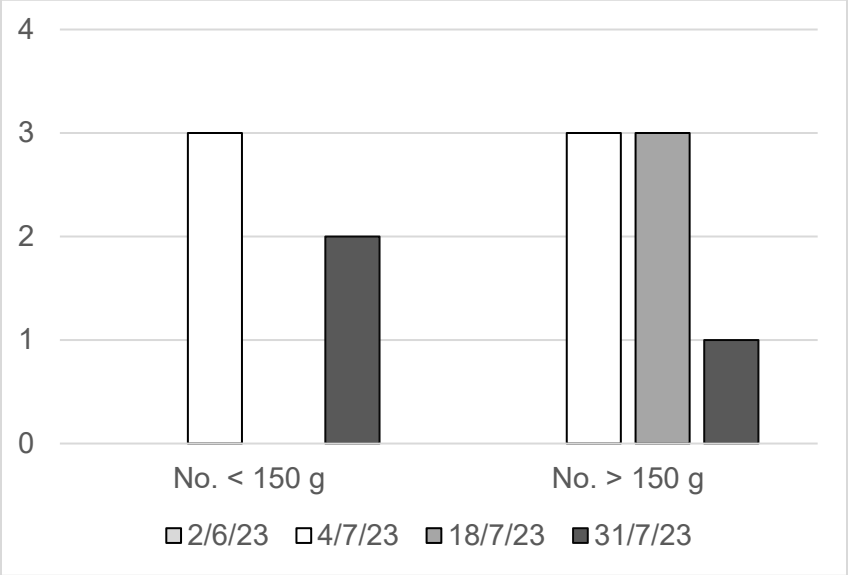
3.1.1 Number of trout analysed

A total of 12 sea trout were sampled in three of the four surveys conducted in 2023. The number of trout caught in sweep net surveys was none in early-June, six trout in early July, three trout in mid-July and three trout later in July (Table 3.1.1 and Figure 3.1.1). The total sample consisted of five trout of less than 150 grams wet weight (41.7 % of fish sampled) and seven trout of more than 150 grams (58.3 % of samples).

Table 3.1.1 Number of trout sampled and analysed (2023)

Sample Date	No. Trout	No. < 150 g	No. > 150 g	% > 150 g
2/6/23	0			
4/7/23	6	3	3	50.0
18/7/23	3	0	3	100.0
31/7/23	3	2	1	33.3
Total	12	5	7	58.3

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



3.1.2 Characteristics of sea trout sampled

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

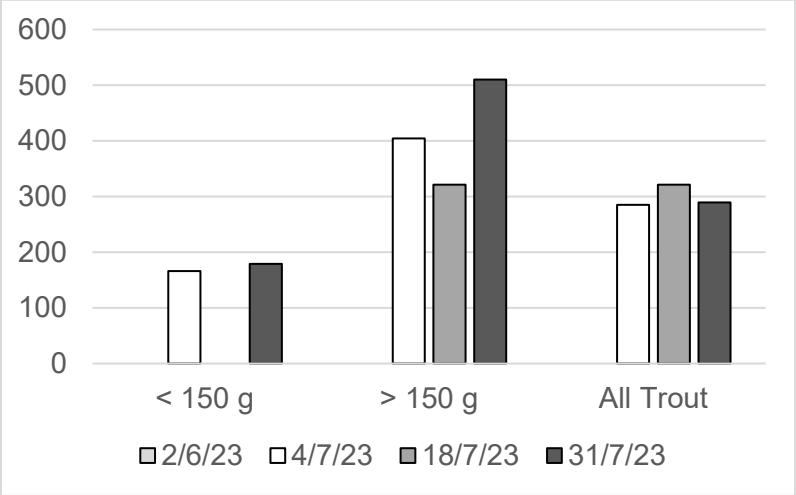
Table 3.1.2 Average length (mm), weight (g) and condition factor (CF) (K) of trout sampled

Sample Date	< 150 g			> 150 g			All Trout		
	Avg. Length (mm)	Avg. Weight (g)	Avg. CF (K)	Avg. Length (mm)	Avg. Weight (g)	Avg. CF (K)	Avg. Length (mm)	Avg. Weight (g)	Avg. CF (K)
2/6/23									
4/7/23	166.00	52.17	1.12	404.33	832.00	1.09	285.17	442.08	1.11
18/7/23				321.33	455.33	1.16	321.33	455.33	1.16
31/7/23	179.00	74.50	1.28	510.00	1441.00	1.09	289.33	530.00	1.21

3.1.2.1 Length of sea trout sampled.

The average length of sea trout less than 150 g weight rose from 166.0 mm in early July to 179.0 mm in late July (Figure 3.1.2.1). The average length of trout of more than 150 g weight was 404.3 mm in early July, 321.3 mm in mid-July and 510.0 mm in late July.

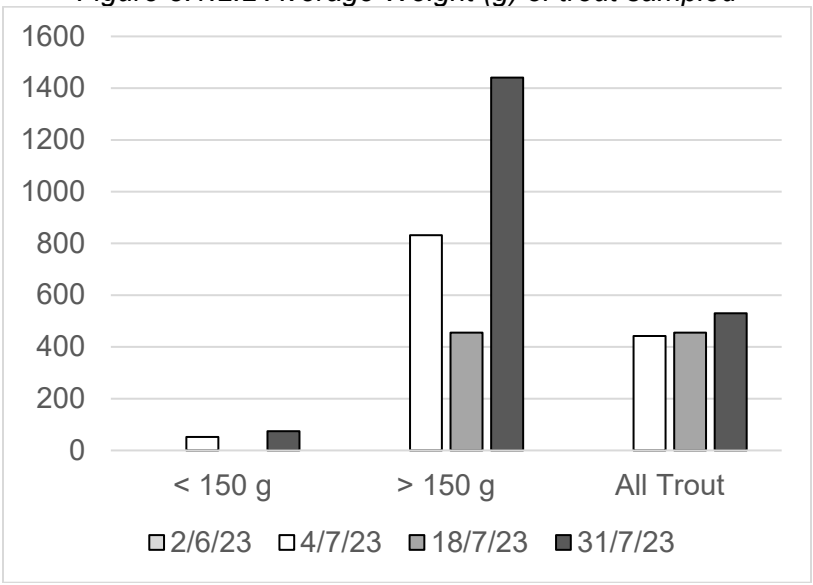
Figure 3.1.2.1 Average Length (mm) of trout sampled



3.1.2.2 Weight of sea trout sampled

The average weight of trout of less than 150 g weight rose from 52.2 g in early July to 74.5 g in late July (Figure 3.1.2.2). The average weight of trout of more than 150 g weight was 832.0 g in early July, 455.3 g in mid-July and 1,441.0 g in late July. The average weight of all trout sampled rose from 442.1 g in early July to 530.0 g late July.

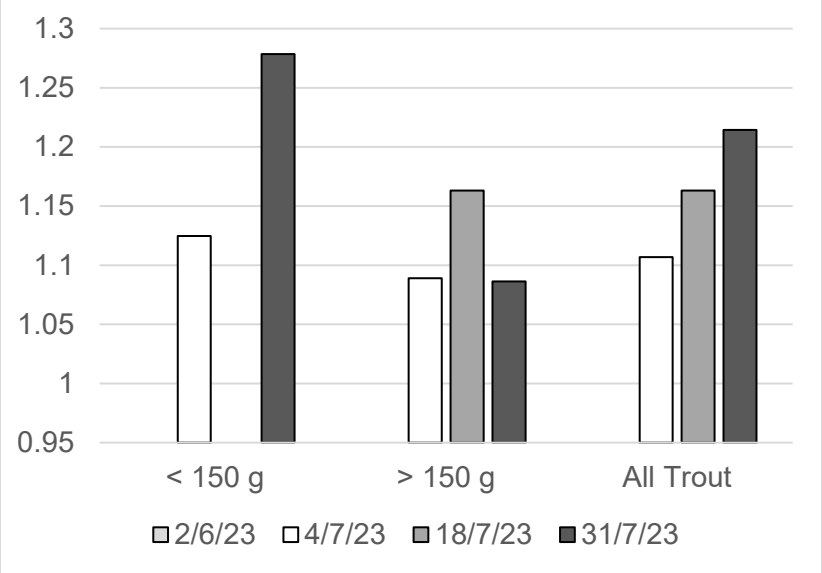
Figure 3.1.2.2 Average Weight (g) of trout sampled



3.1.2.3 Condition factor of sea trout sampled

The condition factor of trout of less than 150 g weight rose from 1.12 in early July to 1.28 in late July (Figure 3.1.2.3). The average condition factor of trout of more than 150 g weight was 1.11 in early July, 1.16 in mid-July and 1.21 in late July.

Figure 3.1.2.3 Average Condition Factor of trout sampled



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), intensity of infection (average number of lice per infected fish) and the different life stages of lice (Table 3.2.1).

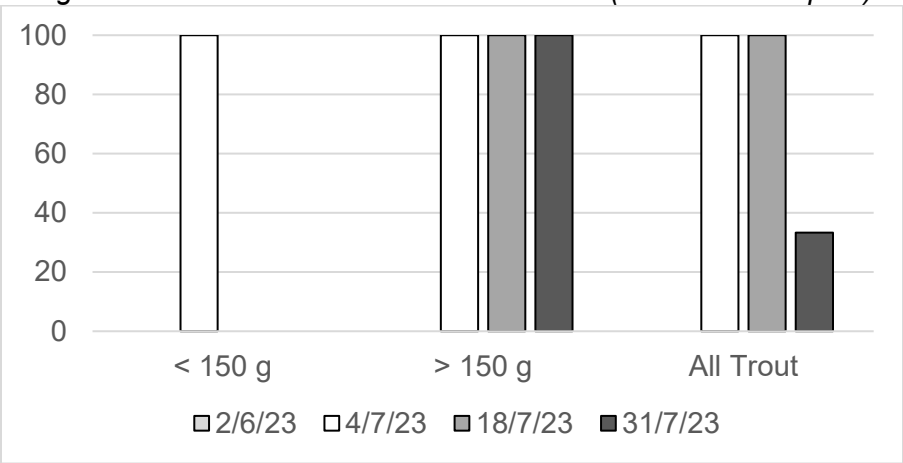
Table 3.2.1 Sea lice burdens of sea trout sampled

Sample Date	< 150 g			> 150 g			All Fish		
	Prevalence	Abundance	Intensity	Prevalence	Abundance	Intensity	Prevalence	Abundance	Intensity
2/6/23									
4/7/23	100.00	2.00	2.00	100.00	10.67	10.67	100.00	6.33	6.33
18/7/23				100.00	8.00	8.00	100.00	8.00	8.00
31/7/23	0.00	0.00	0.00	100.00	12.00	12.00	33.33	4.00	12.00

3.2.1 Prevalence of sea lice

The percentage of all trout sampled infected by sea lice was 100 % in early and mid-July and 33.3 % in late July (Figure 3.2.1). The percentage of trout less than 150 grams weight infected by lice was 100.0 % in early July and 0 % in late July with an mean of 60 %. The percentage of trout more than 150 grams weight infected by lice was 100.0 % over the survey period

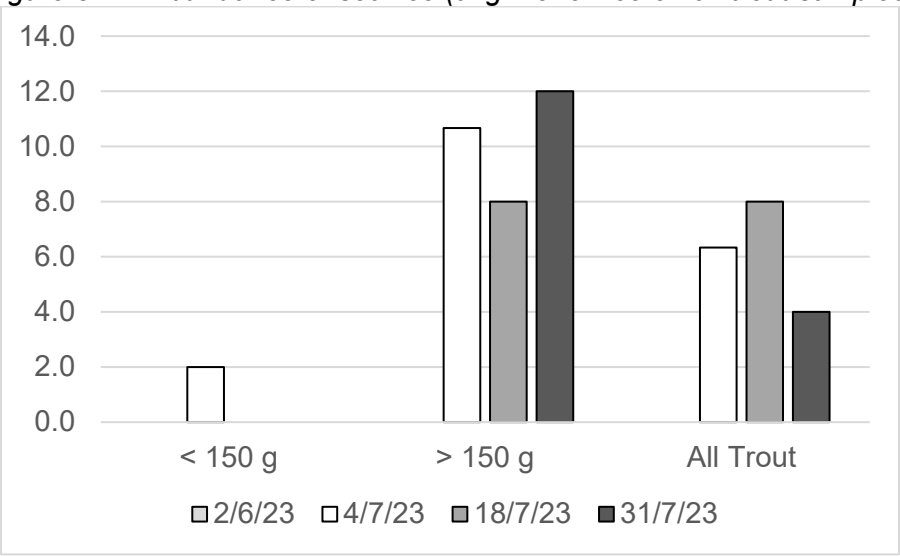
Figure 3.2.1 Prevalence of sea lice infection (% of trout sampled)



3.2.2 Abundance of sea lice

The average number of sea lice found across all the trout sampled was 6.33 in early July, 8.00 in mid-July and 4.0 lice per trout in late July (Figure 3.2.2). The abundance of lice found on all trout under 150 grams weight was 1.20 lice and the abundance of lice found on trout over 150 grams weight was 9.71 lice.

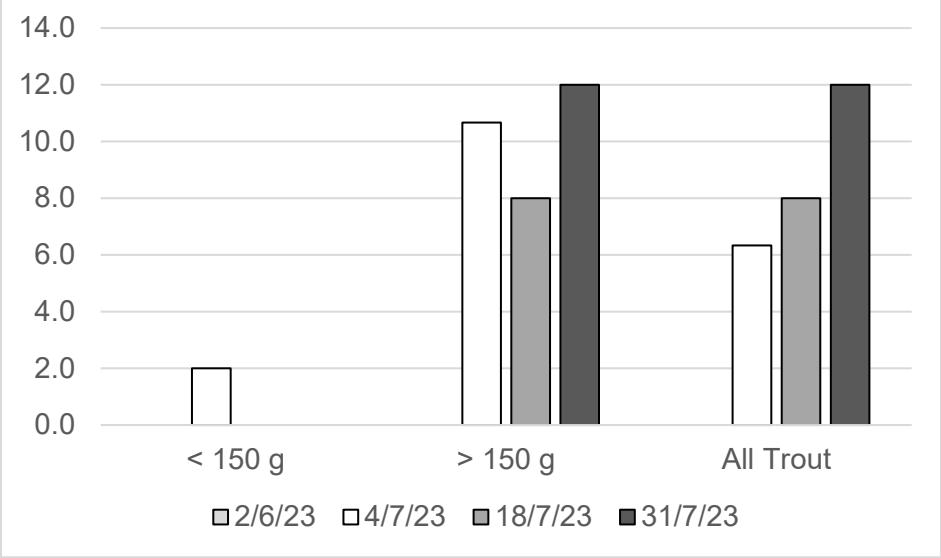
Figure 3.2.2 Abundance of sea lice (avg. no. of lice on all trout sampled)



3.2.3 Intensity of sea lice infection

The average number of sea lice found across all the infected trout was 6.33 in early July, 8.0 lice in mid-July and 12.0 lice per fish in late July (Figure 3.2.3). The intensity of infection found on all trout under 150 grams weight was 2.0 lice and the intensity of infection found on trout over 150 grams weight was 9.71 lice.

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



3.2.4 Life-stage of sea lice

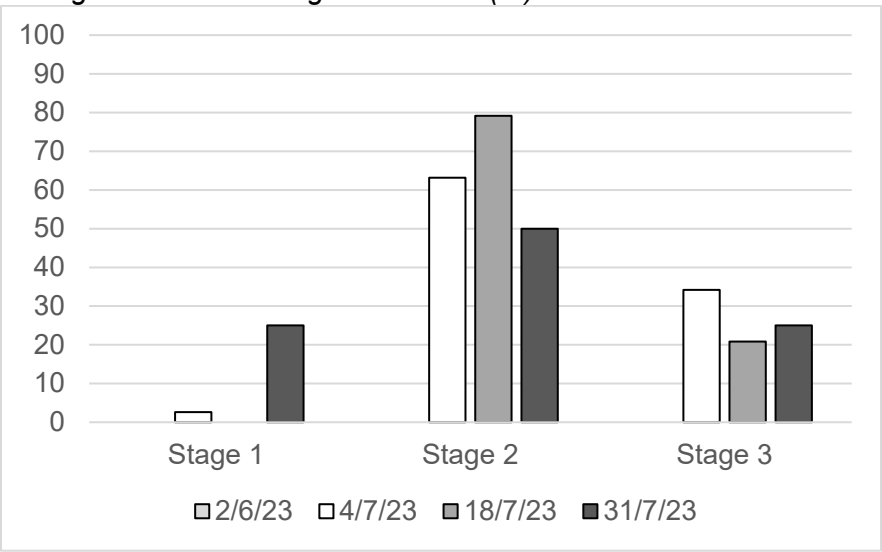
The proportion of the number of each life-stage of sea lice recorded are described below (Table 3.2.2 and Figure 3.2.4). The three stages of lice recorded were attached (stage 1), mobile (stage 2) and gravid female (stage 3).

Table 3.2.2 Life-stage of sea lice found on sea trout (% of all lice found)

Sample Date	Stage 1	Stage 2	Stage 3
2/6/23			
4/7/23	2.63	63.16	34.21
18/7/23	0.00	79.17	20.83
31/7/23	25.00	50.00	25.00

The proportion of attached sea lice (stage 1) found on trout ranged from 2.63 % in early July, none in mid-July and 25 % in late July. The proportion of mobile sea lice (stage 2) was 63.2 % in early July, 79.2 % in mid-July and 50.0 % in late July. The proportion of gravid female mobile sea lice (stage 3) was 34.2 % in early July, 20.8 % in mid-July and 25 % in late July.

Figure 3.2.4 Life-stage of sea lice (%) found on infected trout



3.3 Risk analysis of sea lice burdens

The Total increased mortality risk or compromised seawater growth or reproduction 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

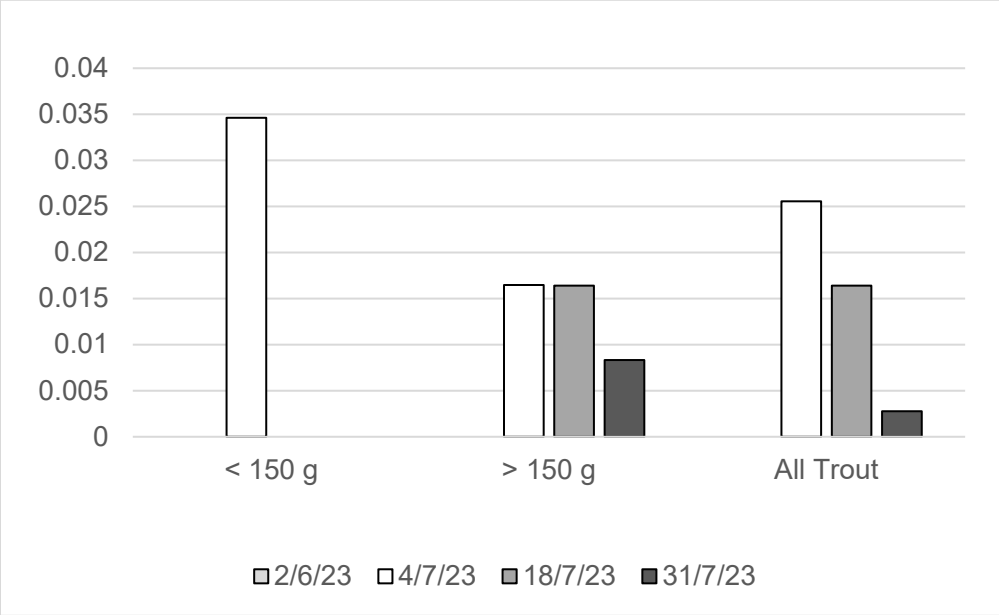
The average lice per gram of fish weight (lice / g^{-1}) is given for fish in both weight categories (above and below 150 grams weight) and across all fish in sampled in each survey below (Table 3.3.1 and Figure 3.3.1).

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

Sample Date	< 150 g	> 150 g	All Trout
2/6/23			
4/7/23	0.035	0.016	0.026
18/7/23		0.016	0.016
31/7/23	0.000	0.008	0.003

The average number of sea lice per gram on all fish sampled was 0.026 in early July, 0.016 in mid-July and 0.003 in late July. The average number of sea lice per gram on fish under 150 grams was 0.035 in early July and none in late July. The average number of sea lice per gram on fish over 150 grams was 0.016 in early and mid-July and 0.008 in late July.

Figure 3.3.1 Sea lice burdens found on sea trout (Avg. no. lice/g⁻¹)



3.3.2 Risk analysis for trout under 150 grams weight

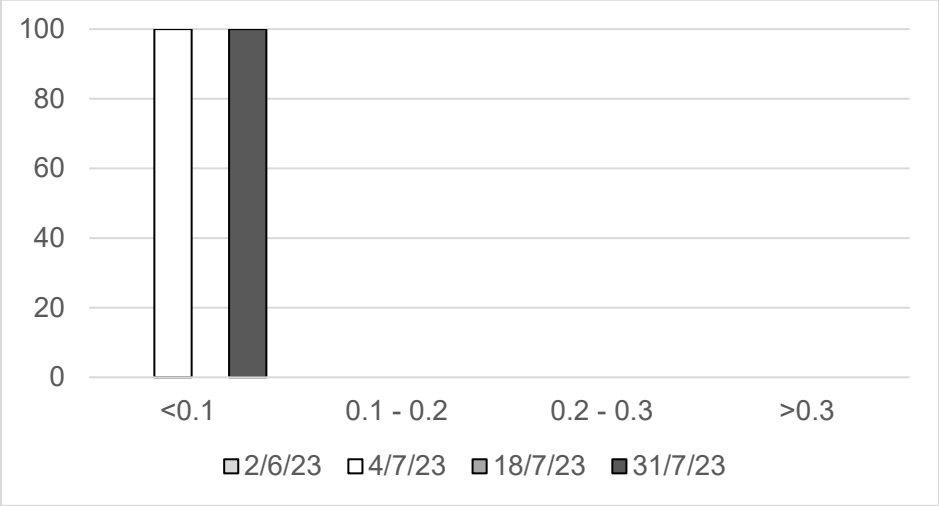
The average sea lice burden per gram of fish weight (for sea trout under 150 grams) is categorised below using the salmon lice risk index described by Taranger et. al. (2015). This is recorded as a proportion of fish which fell into each category on each sample date (Table 3.3.2 and Figure 3.3.2).

Table 3.3.2 Lice-related risk index for trout as the proportion (%) of trout < 150g

Sample Date	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	
2/6/23					
4/7/23	100.00	0.00	0.00	0.00	0.0
18/7/23					
31/7/23	100.00	0.00	0.00	0.00	0.0
All < 150 g	100.00	0.00	0.00	0.00	0.0

The percentage of smaller trout (<150 g) which had a burden of <0.1 lice/g⁻¹ was 100 % in the early July and the late July survey. The percentage of smaller trout which had between 0.1 – 0.2 lice/g⁻¹, between 0.2 – 0.3 lice/g⁻¹ and > 0.3 lice/g⁻¹ was none in all surveys. The Total lice-related risk is calculated as the sum of the increased mortalities in the sample (Table 3.3.2). The Total lice-related risk was 0 % in 2023 for the smaller group of trout sampled. The total risk to smaller trout was therefore categorised as being low (less than 10 % total lice-related risk).

Figure 3.3.2 Lice-related risk index for trout as the proportion (%) of trout < 150g



3.3.3 Risk analysis for trout over 150 grams weight

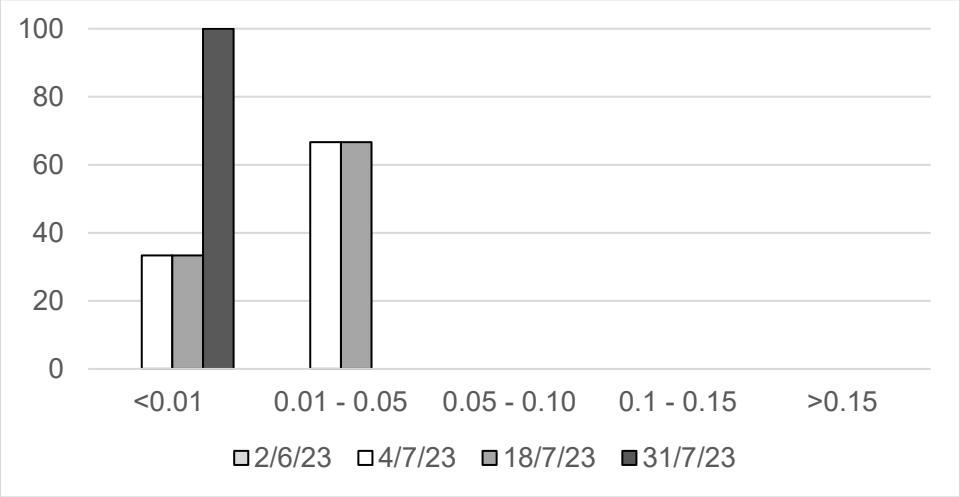
The average sea lice burden per gram of fish weight (for sea trout over 150 grams) is categorised below using the salmon lice risk index described by Taranger et. al. (2015). This is recorded as a proportion of fish which fell into each category on each sample date (Table 3.3.3 and Figure 3.3.3).

Table 3.3.3 Lice-related risk index for trout as the proportion (%) of trout > 150g

Sample Date	Proportion (%) of sea trout (>150g) which fell into each risk assessment category					Total Risk
	<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}	
2/6/23						
4/7/23	33.33	66.67	0.00	0.00	0.00	16.7
18/7/23	33.33	66.67	0.00	0.00	0.00	16.7
31/7/23	100.00	0.00	0.00	0.00	0.00	0.0
All > 150 g	42.86	57.14	0.00	0.00	0.00	14.3

The percentage of larger trout (>150g) sampled in early and mid-July that had <0.01 lice/g^{-1} was 33.3 %. The percentage of larger trout sampled which had between 0.01 – 0.05 lice/g^{-1} was 66.7 %. The percentage of larger trout (>150g) sampled in late July that had <0.01 lice/g^{-1} was 100.0 %. No larger trout had burdens of between 0.05 – 0.10 lice/g^{-1}, 0.10 – 0.15 lice/g^{-1} and > 0.15 lice/g^{-1}. The Total lice-related risk is calculated as the sum of the increased mortalities in the sample (Table 3.3.3). The Total lice-related risk was 14.3 % in 2023 for the larger group of trout sampled. The total risk to larger trout was therefore categorised as being moderate (between 10 and 30 % total lice-related risk).

Figure 3.3.3 Lice-related risk index for trout as the proportion (%) of trout > 150g



3.4 Comparison of historical data

A comparison of previous survey results can be made to provide additional context for the 2023 survey results. The number of trout and their sea lice burdens sampled since 2007 are described below. No sampling was undertaken in 2020 due to restrictions under Scottish Government guidance for the Coronavirus pandemic.

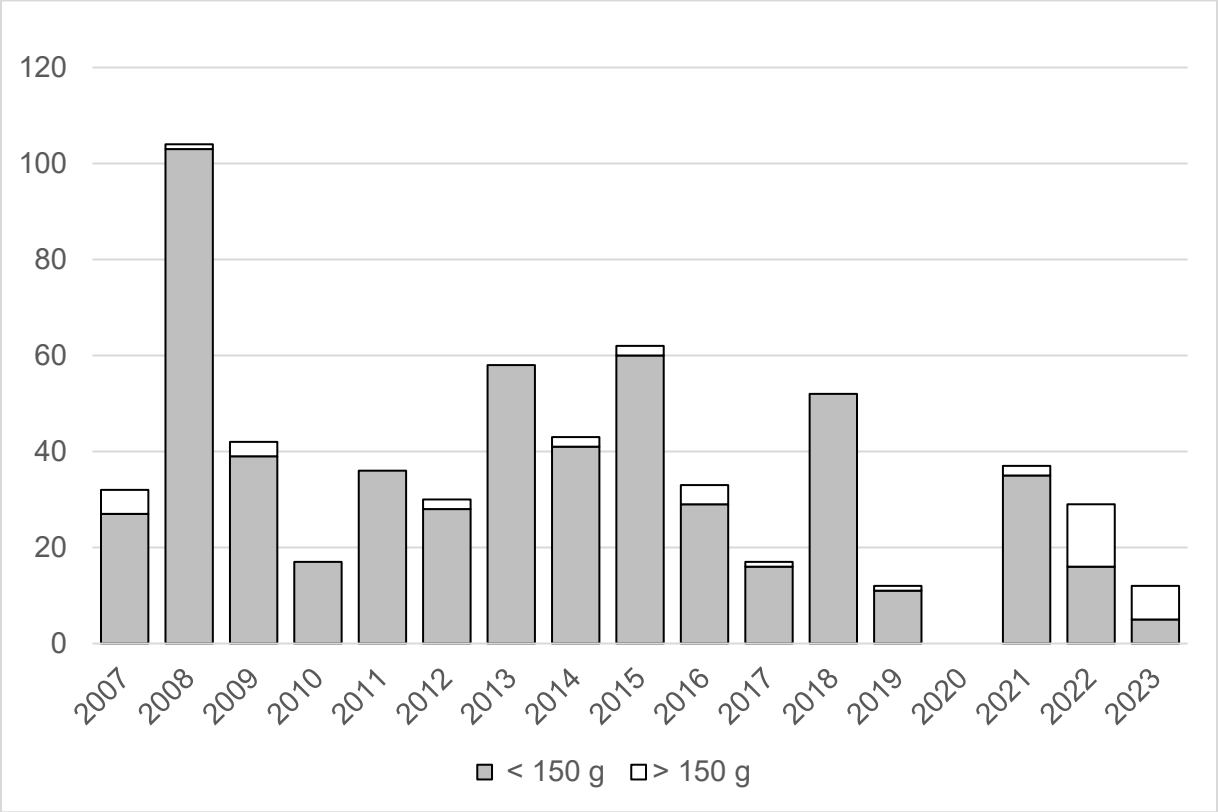
3.4.1 Number of trout analysed (2007-2023)

A total of 616 trout were sampled between 2007 and 2023 including 573 of less than 150 grams (93 % of all samples) and 43 trout of over 150 grams (7 % of all samples) (Table 3.4 and Figure 3.4.1). This ranges from 12 sea trout sampled in 2019 and 2023 to 104 in 2008, with an average of 38.5 sea trout sampled per year over the study period. The number of trout sampled under 150 grams ranged between 5 in 2023 and 103 in 2008 and averaged 35.8 trout per year over the study period. The total number of trout sampled over 150 grams ranged between none in 2011, 2012 and 2018 and 13 in 2022 and averaged 2.7 larger trout per year over the study period.

Table 3.4.1 Number of trout sampled and analysed (2007-2023)

Year	< 150 g	> 150 g	All trout	Year	< 150 g	> 150 g	All trout
2007	27	5	32	2016	29	4	33
2008	103	1	104	2017	16	1	17
2009	39	3	42	2018	52	0	52
2010	17	0	17	2019	11	1	12
2011	36	0	36	2020			
2012	28	2	30	2021	35	2	37
2013	58	0	58	2022	16	13	29
2014	41	2	43	2023	5	7	12
2015	60	2	62	%	94.9	7.1	

Figure 3.4.1 No. of trout sampled (2007-2023)



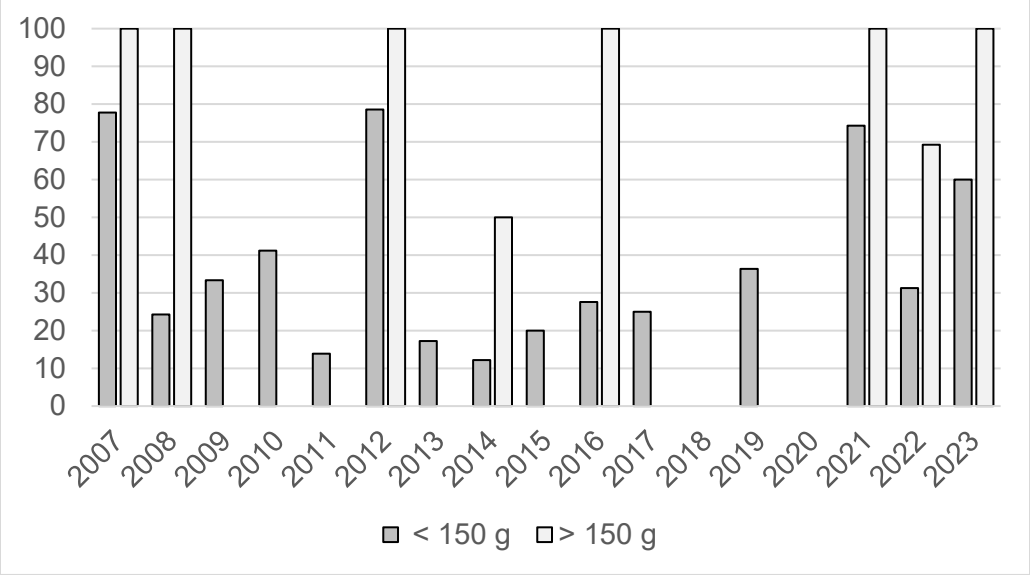
3.4.2 Prevalence of sea lice (2007-2023)

The percentage of trout under 150 grams infected by sea lice ranged between none in 2018 and 78.6 % in 2012, averaging 35.8 % across all smaller trout sampled over the study period (Table 3.4.2 and Figure 3.4.2). The percentage of trout over 150 grams infected by sea lice ranged between none in 2015, 2017 and 2011 and 100 % in 2007, 2012, 2016, 2021 and 2023, averaging 55.3 % for all larger trout over the study period.

Table 3.4.2 Prevalence (%) of lice found on sea trout (1999 - 2023)

Year	< 150 g	> 150 g	All trout	Year	< 150 g	> 150 g	All trout
2007	77.8	100.0	81.3	2016	27.6	100.0	36.4
2008	24.3	100.0	25.0	2017	25.0	0.0	23.5
2009	33.3	0.0	0.0	2018	0.0		0.0
2010	41.2		41.2	2019	36.4	0.0	33.3
2011	13.9		13.9	2020			
2012	78.6	100.0	78.8	2021	74.3	100	75.7
2013	17.2	0.0	17.2	2022	31.3	69.2	48.3
2014	12.2	50.0	14.0	2023	60.0	100.0	83.3
2015	20.0	0.0	20.0	Avg.	35.8	55.3	37.0

Figure 3.4.2 Prevalence (%) of trout infected by sea lice (2007-2023)



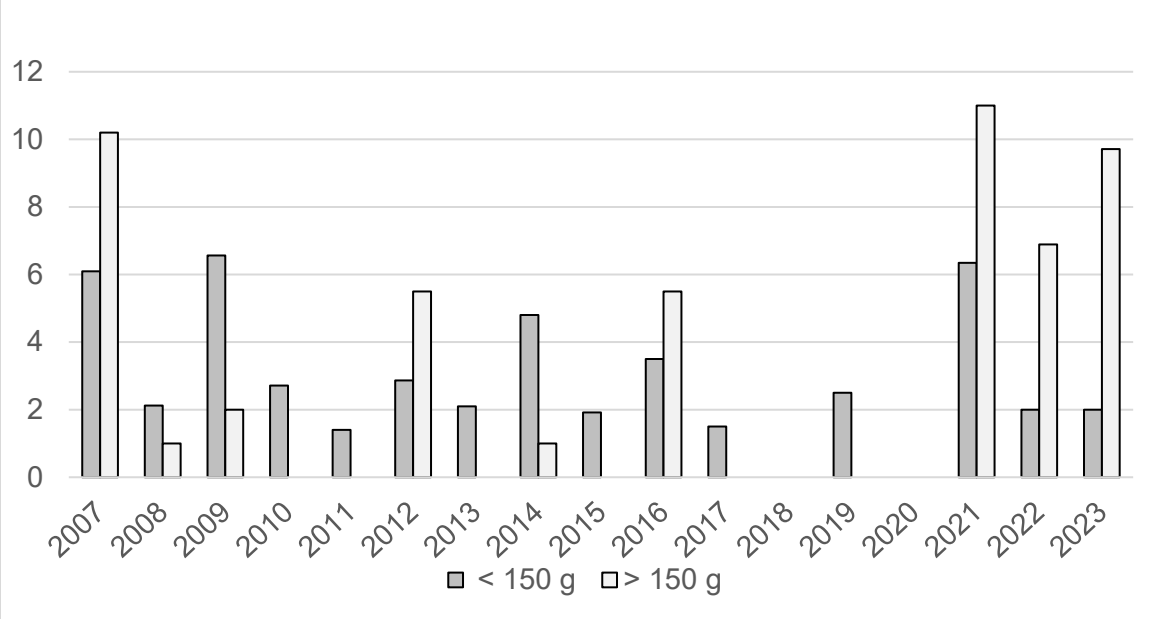
3.4.3 Intensity of sea lice infection (2007-2023)

The average number of sea lice found on infected sea trout under 150 grams ranged between none in 2018 and 6.6 lice in 2009, averaging 3.0 lice over the study period (Table 3.4.3 and Figure 3.4.3). The average number of lice on infected trout over 150 grams ranged between none in 2015, 2017 and 2019 and 11.0 lice in 2021, averaging 4.4 lice per infected trout sampled over the study period.

Table 3.4.3 Intensity of lice infection of sea trout (2007-2023)

Year	< 150 g	> 150 g	All trout	Year	< 150 g	> 150 g	All trout
2007	6.1	10.2	6.9	2016	3.5	5.5	4.2
2008	2.1	1.0	2.1	2017	1.5	0.0	1.5
2009	6.6	2.0	6.3	2018	0.0		0.0
2010	2.7		2.7	2019	2.5	0.0	2.5
2011	1.4		1.4	2020			
2012	2.9	5.5	3.4	2021	6.3	11	6.7
2013	2.1		2.1	2022	2.0	6.9	5.1
2014	4.8	1.0	4.2	2023	2.0	9.7	7.4
2015	1.9	0.0	1.9	Avg.	3.0	4.4	3.6

Figure 3.4.3 Intensity of sea lice infection found on trout (2007-2023)



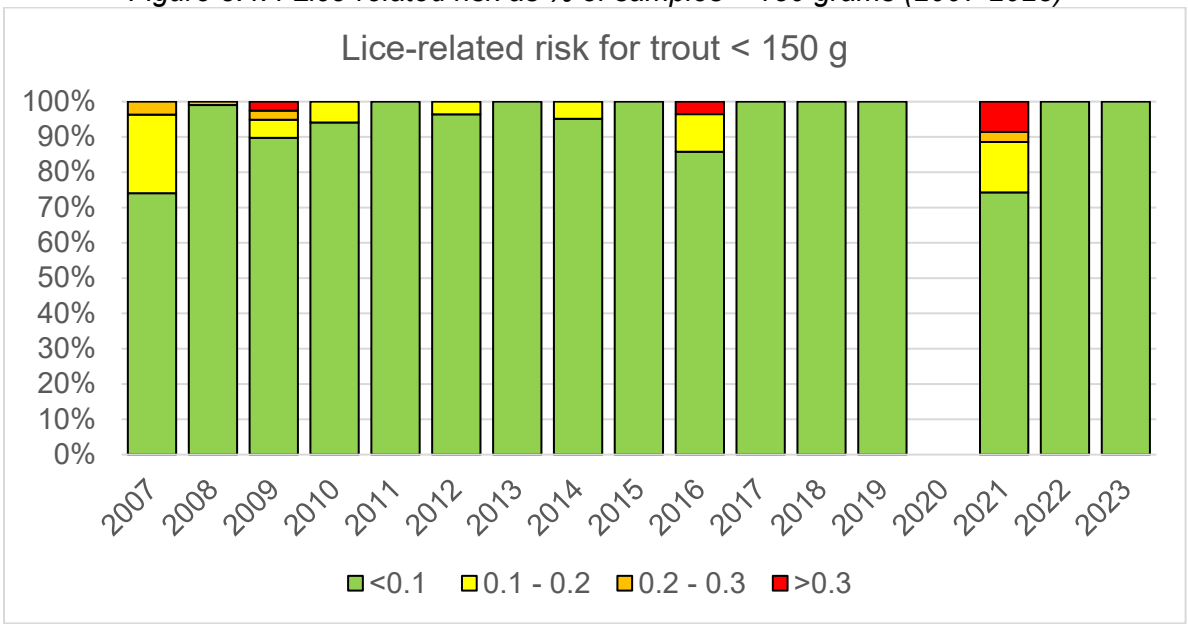
3.4.4 Lice-related risk index for trout under 150 grams (2007-2023)

The 2023 survey found that, according to the lice-related risk index proposed by Taranger et al. (2015) for trout under 150 grams, 100 % of trout had less than 0.1 lice/g^{-1}. Of the smaller trout sampled over the study period 2007 – 2023, an average of 94.2 % had less than 0.1 lice/g^{-1}, 4.5 % had between 0.1 and 0.2 lice/g^{-1}, 0.7 % had between 0.2 and 0.3 lice/g^{-1} and the remaining 1.0 % had more than 0.3 lice/g^{-1} (Table 3.4.4 and Figure 3.4.4).

Table 3.4.4 Lice-related risk as % of samples for trout < 150 grams (2007-2023)

Year	Proportion (%) of sea trout (<150g) which fell into each risk assessment category				Total Mortality (%)
	<0.1 lice/g^{-1}	0.1 - 0.2 lice/g^{-1}	0.2 - 0.3 lice/g^{-1}	>0.3 lice/g^{-1}	
2007	74.1	22.2	3.7	0.0	6.3
2008	99.0	0.0	1.0	0.0	0.5
2009	89.7	5.1	2.6	2.6	4.9
2010	94.1	5.9	0.0	0.0	1.2
2011	100.0	0.0	0.0	0.0	0.0
2012	96.4	3.6	0.0	0.0	0.7
2013	100.0	0.0	0.0	0.0	0.0
2014	95.1	4.9	0.0	0.0	1.0
2015	100.0	0.0	0.0	0.0	0.0
2016	89.7	11.1	0.0	3.7	5.9
2017	100.0	0.0	0.0	0.0	0.0
2018	100.0	0.0	0.0	0.0	0.0
2019	100.0	0.0	0.0	0.0	0.0
2020					
2021	74.3	14.3	2.9	8.6	12.9
2022	100.0	0.0	0.0	0.0	0.0
2023	100.0	0.0	0.0	0.0	0.0
Avg.	94.53	4.19	0.63	0.93	2.08

Figure 3.4.4 Lice-related risk as % of samples < 150 grams (2007-2023)



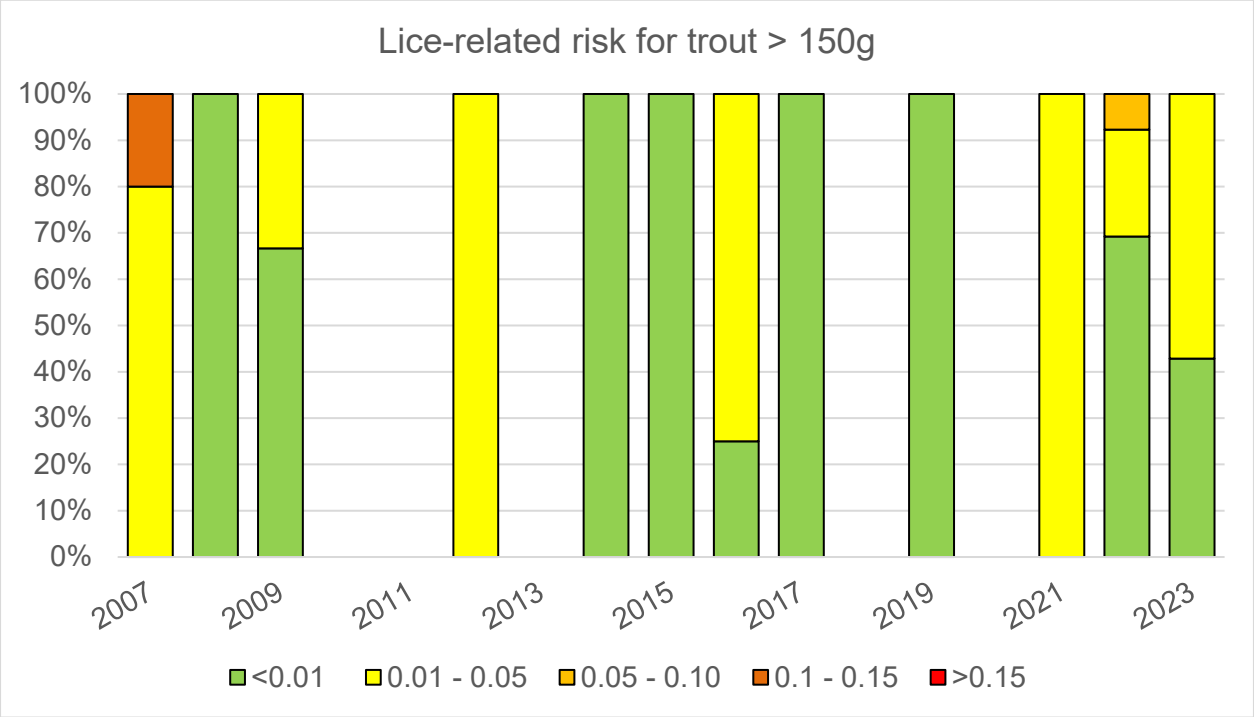
3.4.5 Lice-related risk index for trout over 150 grams (2007-2023)

The 2023 survey found that 42.9 % of trout over 150 grams had burdens less than 0.01 lice/g^{-1}, 57.1 % had between 0.01 and 0.05 lice/g^{-1}. Of the larger fish sampled over the study period 2007 - 2023, an average of 58.6 % had less than 0.01 lice/g^{-1}, 39.1 % had between 0.01 and 0.05 lice/g^{-1}, 0.6 % had between 0.05 and 0.10 lice/g^{-1}, 1.7 % had between 0.10 and 0.15 lice/g^{-1} and none had more than 0.15 lice/g^{-1} (Table 3.4.5 and Figure 3.4.5).

Table 3.4.5 Lice-related risk as % of samples for trout > 150 grams (2007-2023)

Year	Proportion (%) of sea trout (>150g) which fell into each risk assessment category					Total Mortality (%)
	<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}	
2007	0.0	80.0	0.0	20.0	0.0	35.0
2008	100.0	0.0	0.0	0.0	0.0	0.0
2009	66.7	33.3	0.0	0.0	0.0	8.3
2010						
2011						
2012	0.0	100.0	0.0	0.0	0.0	25.0
2013						
2014	100.0	0.0	0.0	0.0	0.0	0.0
2015	100.0	0.0	0.0	0.0	0.0	0.0
2016	25.0	75.0	0.0	0.0	0.0	18.8
2017	100.0	0.0	0.0	0.0	0.0	0.0
2018						
2019	100.0	0.0	0.0	0.0	0.0	0.0
2020						
2021	0.0	100.0	0.0	0.0	0.0	25.0
2022	69.2	23.1	7.7	0.0	0.0	9.6
2023	42.9	57.1	0.0	0.0	0.0	14.3
Avg.	58.65	39.05	0.64	1.67	0.00	11.33

Figure 3.4.5 Lice-related risk as % of samples for trout > 150 grams (2007-2023)



3.4.6 Estimated total increased lice-related risk (2007-2023)

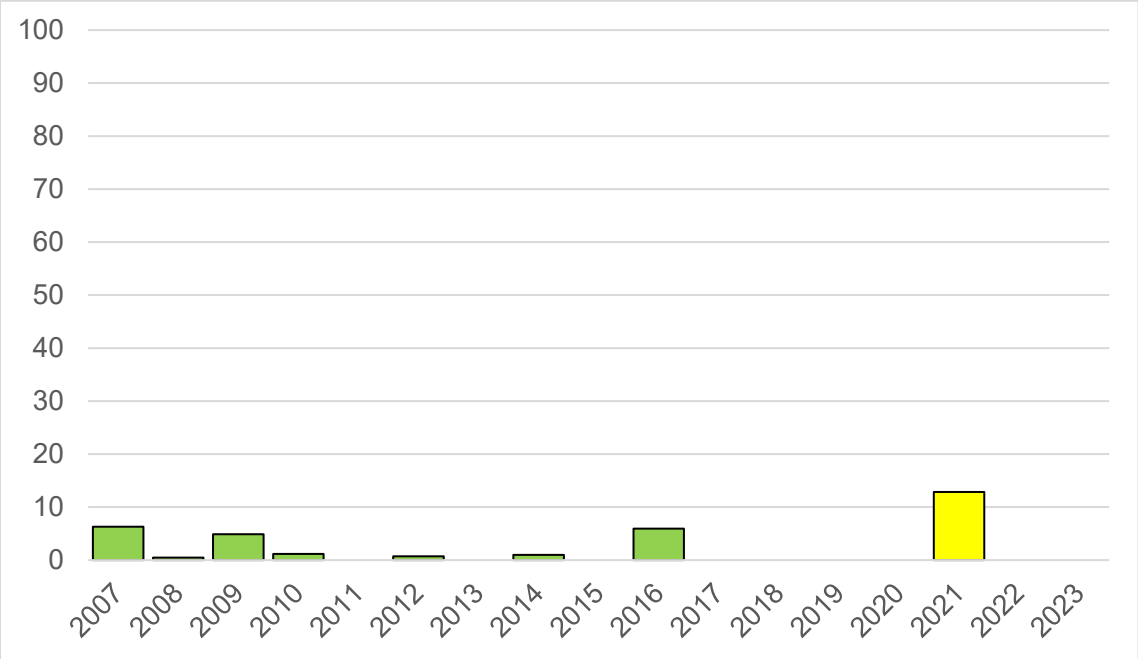
The total increased mortality risk or compromised seawater growth or reproduction is calculated as the sum of the increased mortalities separately for each of the two different size groups in the sample (Table 3.4.6, Figure 3.4.6, and Figure 3.4.7). Total lice-related mortality in 2023 was estimated to be none for trout under 150g and 14.3 % for trout over 150g, which was categorised as being of moderate risk (between 10 and 30 % total lice-related mortality).

Table 3.4.6 Total lice-related risk to the sea trout of less and more than 150g (% of sample), categorised as low (green), moderate (yellow) and high (red), 2007-2023

Year	< 150 g	> 150 g	Year	Fish < 150 g	Fish > 150 g
2007	6.3	35.0	2016	5.9	18.8
2008	0.5	0.0	2017	0.0	0.0
2009	4.9	8.3	2018	0.0	
2010	1.2		2019	0.0	0.0
2011	0.0		2020		
2012	0.7	25.0	2021	12.9	25.0
2013	0.0		2022	0.0	9.6
2014	1.0	0.0	2023	0.0	14.3
2015	0.0	0.0	Avg.	4.30	11.06

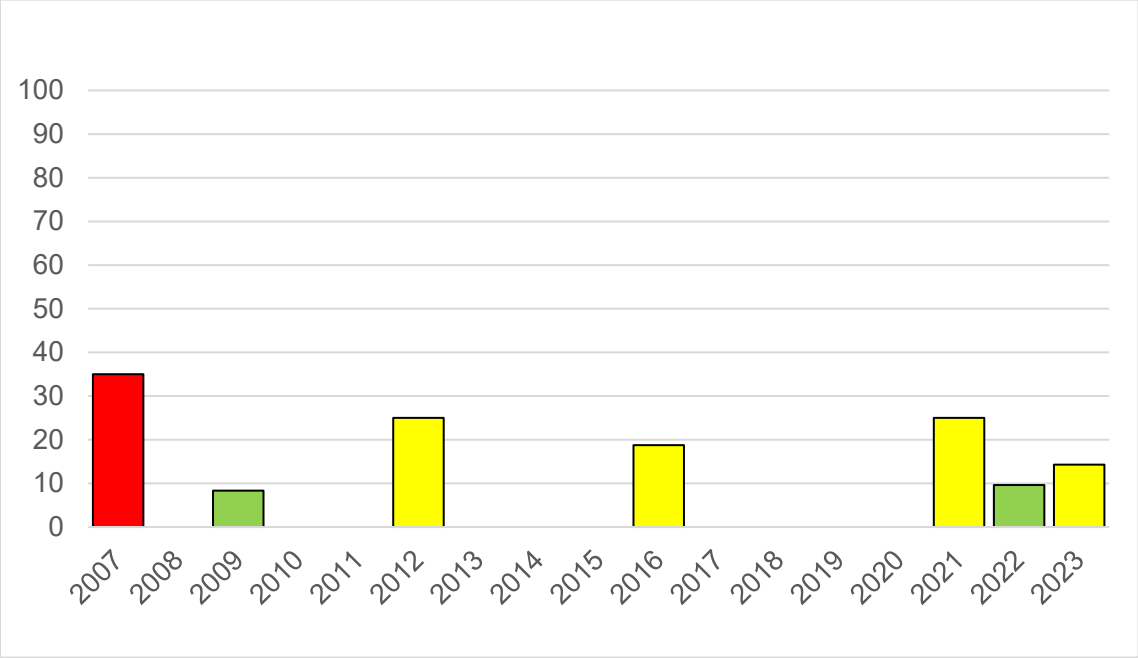
The total increased mortality risk or compromised seawater growth or reproduction for the smaller trout (< 150g) was categorised as low in 15 of the 16 previous annual surveys (2007-2023). The total increased mortality risk or compromised seawater growth or reproduction for the smaller trout was categorised as moderate (between 10 and 30%) only in 2021 and no high (more than 30%) risk was found over the study period.

Figure 3.4.6 Total lice-related risk (% of sample) for sea trout < 150g categorised as low (green), moderate (yellow) and high (red), (2007-2023)



The total increased mortality risk or compromised seawater growth or reproduction for the larger trout (> 150g) was categorised as none in 2008, 2014, 2015, 2017 and 2019. A low risk (< 10 % of samples) was assessed in 2009 and 2022. A moderate risk (between 10 and 30%) was found in four annual assessments (2012, 2016 2021 and 2023). The total increased mortality risk or compromised seawater growth or reproduction for the larger trout was categorised as high (more than 30%) only in 2007.

Figure 3.4.7 Total lice-related risk (% of sample) for sea trout > 150g categorised as low (green), moderate (yellow) and high (red), (2007-2023)



4. DISCUSSION

4.1 Factors affecting the number and size of trout sampled

The number and size of trout sampled in each year may have been influenced by many factors related to recruitment of trout in freshwater, movements of trout in the marine environment, the behaviour and abundance of prey and predators, and sea lice burdens. The number of smaller and larger trout appear to have changed in recent years: The 2017, 2019, 2022 and 2023 surveys sampled a lower-than-average number of small trout (16, 11, 16 and 5 respectively) compared to an average for the study period (38 larger trout). Conversely, the 2022 and 2023 surveys sampled an above average number of larger trout (13 and 7 respectively) compared to the other annual surveys (2.7 larger trout) over this period.

The timing of surveys in 2023 was affected by warm environmental conditions with little rain, higher water temperature and bright clear water conditions during surveys. After not catching any fish in early June 2023, sampling was delayed until July. Therefore, sampling in 2023 was mainly conducted in the later part of the survey period (May to July). Physical changes to the survey sites in the form of movement of sandbanks has meant that the water within the reach of the beach seine net has become much shallower. This may decrease the cover for fish and reduce the time spent in this area. Catches in the netting surveys in recent years have been higher when the river flow has been higher (and the water discoloured). Lack of physical cover for trout at the survey site may therefore be a factor influencing the number of trout present at the site. Due to the lack of trout present at the site and the site conditions in early June, the timing of the following surveys was delayed coinciding with higher water level in the river after rainfall. This change timing and delay in sampling effort may have some influence on the characteristics of the fish caught. This may be particularly important for the larger group of trout as they are rarely encountered by seine net surveys at this site.

The average length and weight (and therefore their condition factor) of all trout sampled was found to increase between the early July (1.11), the mid-July (1.16) and the late July survey (1.21), suggesting that trout present at the site were able to find sufficient prey during the survey period.

4.2 Factors affecting the lice-related risk for sea trout

Environmental factors impacting the reproduction of sea lice and the distribution of larvae may 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 compared against the results of these surveys. 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 2023, fish farms were in the second year of the two-year farming cycle and numbers of farm fish were likely being reduced through harvest. Published sea lice data for salmon farms (through Scottish Government's Aquaculture website http://aquaculture.scotland.gov.uk/data/data.aspx) show that average adult female lice numbers on farmed fish at the Eilean Grianain site, located 5 km north of the survey site, were higher than the industry's Code of Good Practice level of 0.5 adult female lice per fish for 6 weeks during the 20-week lower threshold period (mid-February to late June). The on-farm data suggests that there may potentially be a significant influence from sea lice on farm fish on the results of this survey on wild trout in 2023, but this may be less significant if numbers of fish on the farm was being reduced through harvest.

There was a relatively low proportion of newly attached lice (stage 1) found on the trout (2.6 to 25 % of all lice) during July compared to mobile (stage 2) (50.0 to 79.2 %) and gravid females (stage 3) (20.8 to 25 %). This data suggests that infection pressure from new lice (early life-stages of lice) were low during July, which may reflect the reducing potential for infection pressure as the number of farm fish was reduced on the fish farm. The higher percentage of mobile and gravid female lice may also be related to the higher number of larger trout sampled which have spent more time in the marine environment where lice are likely to be accumulated over time. Four of the seven larger trout sampled had lice burdens over 0.01 lice/ g^{-1} suggesting that there was some increased mortality risk or compromised seawater growth or reproduction because of their infection. The 14.3 % total increased mortality risk or compromised seawater growth or reproduction, calculated for the larger group of trout was within the moderate category value of between 10 and 30 %. This suggest that there was some effect on larger trout in 2023 which may have caused them to return to the estuary of the Carradale Water and utilise the lower water salinity to reduce their lice burden. Further research is required to draw any conclusions in this respect.

The longer-term data collected suggest that potential increased mortality risk or compromised seawater growth to the smaller group of trout was categorised as low (< 10 %) in all years except for 2021 when a moderate risk was found. The increased mortality risk or compromised seawater growth to the smaller group of trout in 2021 was 12.9 %, which was just within the moderate category (10 to 30 %) compared to an average of 4.3 % over the study period. Except for 2021, the longer-term data also found no significant trend in risk to smaller trout was found between the first and second year of farm production, indicating that the fish farm production cycle may not have been a significant influence on the sea lice burdens found on the smaller trout sampled. The larger trout were found to have moderate of high increased mortality risk or compromised seawater growth or reproduction in four previous years to 2023, but analysis of on-farm lice data in relation to production cycles will be required to inform any trends in the lice burdens of older trout.

4.3 Sampling site and method considerations for future monitoring

The Taranger 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 area. The location of the sampling site, which is close to the estuary of the Carradale Water, may sample 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.

The Taranger risk analysis is also not able to identify the proportion of the population that return to the site to shed lice, are resident or visit the site for short periods. The dataset shows that relatively high numbers of trout with no or relatively low lice burdens have been sampled at the site in numerous years between 2007 and 2021, suggesting that smaller trout do normally inhabit the site in the late spring and early summer period. The surveys may also sample fish that have not ventured very far from the estuary and therefore may have a reduced risk of infection. The lack of information on the movement of sea trout in Kilbrannan Sound makes the influence of these factors on the survey results difficult to determine. To reduce the potential for bias in the survey sampling and further inform analysis of the results, alternate sampling methods and sites should be considered.

The beach seine net sampling technique has proven reliable at this site where the gradient is shallow and relatively weed-free, which allows the net to be fished effectively. However, this method is limited to a relatively small portion of the shoreline which is largely of steeper gradient

and has more aquatic vegetation where other sampling techniques would be required. The beach seine sampling is also undertaken over a relatively short period close to estuaries where post-smolt sea trout appear to remain for some time. Occasional sampling later in the summer has produced fewer samples of smaller trout, suggested trout either return to freshwater or migrate further afield, limiting our knowledge of sea lice burdens on sea trout during the remainder of the year. Therefore, it may be beneficial to consider other sites and sampling techniques.

Fixed net sampling in full strength seawater over a longer period may reduce the potential for the influence of freshwater on the survey results and deliver a larger number of samples over a longer period. Ideally, this study would operate both a fixed net further away and the estuarine net simultaneously to compare results. Additionally, acoustic tags and receivers may 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.

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