Managing Interactions Aquaculture Project

2013

Regional Report;
2013 Sea Trout
Post Smolt Monitoring

November 2013

RAFTS
Rivers And Fisheries Trusts Of Scotland

Contents Page

Summary

The Rivers and Fisheries Trusts of Scotland, on behalf of the project partners, have managed the Sea Trout Post Smolt Monitoring Project over the last two years. This project is the only programme in Scotland that monitors the potential impacts of aquaculture on wild salmonid populations. The aims include developing an understanding of the current population status and identifying regional trends on the West Coast of Scotland for wild *Salmo trutta* (Sea Trout) and their interactions with two species of sea lice *Lepeophtheirus salmonis* and *Caligus elongates*.

During 2013, the Fisheries Trust on the West Coast gathered data from 22 monitoring sites. This involved collecting individual data from over 1000 captured sea trout. Data collected at each monitoring location included the length, weight, condition factor and predator damage of each sea trout at all monitoring locations.

All Sea Trout were examined for the presence of sea lice, which if found to be present were counted and staged as per the project methodology. Both species of sea lice were found to be present across the Scottish west coast region at varying levels. The information gathered highlights that the interactions between sea trout and sea lice are complex and potentially problematic at a number of the monitoring sites on the West Coast.

L. salmonis the most problematic species of sea lice to Sea Trout populations was identified as being present at all regional monitoring sites in 2013, 2012 and in 2011. Regionally there was a notable increase in 2013 of the Intensity and Median levels of *L. salmonis* compared to those recorded in 2012 and 2011, although the Abundance was very similar to 2012 levels. However, it is significant to note that the majority of aquaculture activities relevant to the corresponding monitoring site within the study area were in their second production year in 2013. To further explore the *L. salmonis* infestation pressure on wild Sea Trout populations data from each monitoring site was examined to determine if the levels of observed sea lice infection could be classed as an epizootic (Costello, 2009 and Beamish *et al*, 2009). Based on the results of calculating the threshold levels for an epizootic occurring in 2013 there are four monitoring sites that have experienced high sea lice presence levels that could potentially be categorised as epizootics.

To examine these high observed presence levels in more depth a detrimental tolerance threshold level was explored (Wells *et al*, 2006). In 2013, three monitoring sites are recorded as experiencing Sea Trout carrying potentially detrimental lice burdens.

In comparison *C. elongatus* is a sea lice species currently considered to be of lesser concern to Sea Trout populations; however it does have a potential cumulative burden with *L. salmonis*. From the samples collected in 2013 *C. elongatus* was identified as being present at 7 of the 22 monitoring sites.

The monitoring work undertaken in this project highlights the interaction issues that affect the Sea Trout populations on the West Coast of Scotland and the issues that need to be considered for management and conservation. With particular reference to the detrimental burden levels of sea lice on wild sea trout populations this project also explores how these findings can contribute to

identifying the significant challenging issues that need to be addressed through management and policy actions to protect the identified vulnerable sea trout populations.

1. Project Background

The 2013 project continues to develop an understanding of the current status and to establish regional trends on interactions between parasitic sea lice and wild fish across the West Coast of Scotland. This is a priority area of work for the Managing Interactions Aquaculture Project. The Managing Interactions Aquaculture Project is designed to support improved coordination and management of wild fisheries and stocks with the aquaculture industry. There are a number of significant priorities underpinning the work and include, the wild fish priorities of protecting sensitive and high value fresh water sites, improving practice and management at existing aquaculture sites and finally informing decisions on the location and biomass production at current and any proposed aquaculture site. To work towards achieving these strategic objectives three projects were initially identified in 2011 as key priorities and work streams within the overall Project.

These were:

- Strategic programme of post smolt sweep netting and analysis;
- Programme of genetic sampling and analysis; and
- Locational guidance and zones of sensitivity analysis.

In 2011 the programme of genetic sampling and analysis was completed and a report on this area of work is published on the RAFTS website. Into 2013 both the Strategic programme of post smolt sweep netting and analysis and the larger body of work in regards to the Locational guidance and zones of sensitivity analysis continues.

The Managing Interactions Aquaculture Project remains overseen by a Steering Group, chaired by RAFTS, which includes representatives from a range of west coast fishery trusts and District Salmon Fishery Boards, Marine Scotland Science and Marine Scotland Policy.

The participating fishery trusts and boards are:

- Argyll Fisheries Trust
- Argyll District Salmon Fishery Board
- Wester Ross Fisheries Trust
- Wester Ross District Salmon Fishery Board
- Skye Fisheries Trust
- Skye District Salmon Fisheries Board
- West Sutherland Fisheries Trust
- Outer Hebrides Fisheries Trust
- Western Isles Salmon Fisheries Board
- Lochaber Fisheries Trust (Post Smolt Survey only)

This paper will discuss further the continuance of the cooperative sea trout post smolt monitoring programme which was organised to monitor wild sea trout populations and sea lice levels on the west coast of Scotland.

2. Methods and Site Information

2.1 Sweeping Survey Techniques and Data Analysis

All chosen monitoring sites were surveyed in accordance with the Scottish Fisheries Co-Ordination Centre (SFCC) sampling protocol, "Sea Trout Netting and Sea Lice Sampling: A Standard Sweep Netting Protocol for Management, 2009". This ensured that the project complied with current recommended standards. The data gathering was conducted by participating fisheries trusts during the months of May, June and July 2013.

Sea Trout were captured during the hours of daylight using a sweep net which was deployed from the shoreline. Trust teams using the sweep nets would either employ hand hauling techniques or deploy the net from a boat. The sweep nets used were fifty metres in length and had a standard stretched mesh size of 20 mm. All sea trout caught within the sweep were removed and anaesthetised. Under anaesthesia the length (±1mm) and weight (±1g) were recorded and where possible, a scale sample was also taken. The Sea Trout were examined for the presence of sea lice, which if found to be present were counted and staged. Sea Lice counts were classified according to the two species under investigation *Lepeophtheirus salmonis* (Krøyer) and/or *Caligus elongatus* (Nordmann). *L. salmonis* was further staged by one of three gender and life-stages which were copepodid/chalimi, pre-adult/adult and ovigerous females as per the SFCC Protocol. Additional information was also collected on any other parasites present or any predator damage to the fish.

The focus of the subsequent analysis at the monitoring sites described is on the post smolt sea trout populations and included weights, lengths, condition indices and predator damage. Further to the population analysis there will be analysis on the sea lice loadings with comparisons between the monitoring sites.

As highlighted by Hazon *et al* 2006, parasite infestations of hosts generally do not show a normal distribution of variation among individual hosts. Typically, parasite populations show "*overdispersion*", or "*aggregation*" on certain individual hosts (i.e. many or most hosts are parasite-free, but a small number of hosts carry exceptionally heavy infestations). From a statistical viewpoint, it is inappropriate to calculate the arithmetic mean and error terms of infestation intensities if the data are not normally distributed. All lice data in the present study has therefore been log transformed prior to the calculation of the normal mean and error terms. A log transformation usually will stabilize the variance and render the error terms normal. However, calculated means and error terms were subsequently back transformed in order to allow the data to be displayed in a meaningful way. It should be noted however that the back-transformed mean will always be lower than the arithmetic mean. Ensuring that the distribution variation is normalised and appropriately accounted for is crucial to determine if the populations being monitored are experiencing lice loads that could be reported as having a detrimental impact. Analysing such lice loads appropriately can support the local management strategies and policies.

Four assessment methods were implemented to analyse and describe the sea lice distribution on the sea trout post smolt populations at the monitoring sites. These were:

- Prevalence: The percentage of fish in the sample infected by sea lice.
- Abundance: The mean number of sea lice per fish in the whole sample.
- Intensity: The mean number of sea lice per infected fish
- Abundance Median: The middle value when ranked numerically of sea lice within the population of fish.

Prevalence is an indication of the percentage of infected sea trout versus uninfected sea trout. To obtain a more comprehensive view of the distribution of sea lice amongst the sea trout sampled, abundance and intensity analysis was explored. Abundance gives an indication of the overall number of lice within the population whilst intensity provides a more accurate indication of the level of infestation on infected fish.

Finally a full range of site environmental factors was recorded at each site. On every visit to the monitoring site, water temperature, air temperature and salinity profiles were recorded. The collection of these environmental factors is important as it has been shown previously that temperature and salinity influence sea lice population dynamics (Butterworth *et al*, 2006).

The sampling data from all the Trusts was compiled by the project coordinator in a structured Excel (2013) spreadsheet. Analyses of the data involved descriptive statistics and graphs which were prepared in Excel (2013).

2.2 Site Information

From the experiences of the monitoring sites undertaken in 2011 the project undertook a further refinement and assessment of selected monitoring sites in 2012 and 2013. The refinement and assessment of the sites involved Trusts, Boards and Marine Scotland Science. The final network of sites for the 2013 sampling period includes twenty two sites (Figure 1). Twenty two of the sites are carried on from last year; one site was removed due to consistent low fish numbers caught. Two sites from Skye are included for assessment but due to unavailability of data for 2012 comparison studies are not possible, although they have been included for statistical analysis. Sites were selected to improve the coverage across the west coast with sites at distance from active fish farms. The project has a core focus of sampling efforts on the sea trout smolt run as previous studies have shown that post smolts are potentially the most vulnerable stage to sea lice infection (Finstad *et al*., 2000). This work is a continuation of previous post-smolt sweep netting which was a part of the Tripartite Working Group Area Management Groups, and is a continuation of a long time data series for some sites. An example of some longer time series data can be found in Appendix 8.

In accordance with the SFCC protocol, the project Steering Group agreed that for each site a target of >30 fish should be included in each sample and that this sample should be collected from a minimum of two survey dates at each site. Additional survey dates and greater number of fish would further improve and enhance the sample size available for analysis and the robustness of the analysis subsequently possible.

Table 1: Monitoring Site Details.

Site ID 2013	Site Name	Fishery Trust	No of Site Visits 2013	Total Number of Sea Trout Caught in 2013
1	Carradale	Argyll	2	58
2	Loch Fyne	Argyll	2	91
3	West Riddon	Argyll	2	58
4	Dunstaffnage	Argyll	2	31
5	Goil	Argyll	2	64
6	Kinlocheil	Lochaber	4	35
7	Camas na Gaul	Lochaber	4	70
9	Borrodale	Lochaber	4	42
10	Tong	Outer Hebrides	4	37
12	Borve	Outer Hebrides	3	62
13	Eishken	Outer Hebrides	3	63
14	Kyles	Outer Hebrides	3	20
15	Malacheit	Outer Hebrides	3	49
16	Kyle of Durness	West Sutherland	3	1
17	Polla	West Sutherland	2	102
18	Laxford	West Sutherland	3	33
19	Kinloch	West Sutherland	2	55
20	Kannaird	Wester Ross	2	52
21	Boor Bay	Wester Ross	3	34
22	Flowerdale	Wester Ross	2	43
23	Loch Slapin	Skye	3	27
24	Loch Harport	Skye	3	30

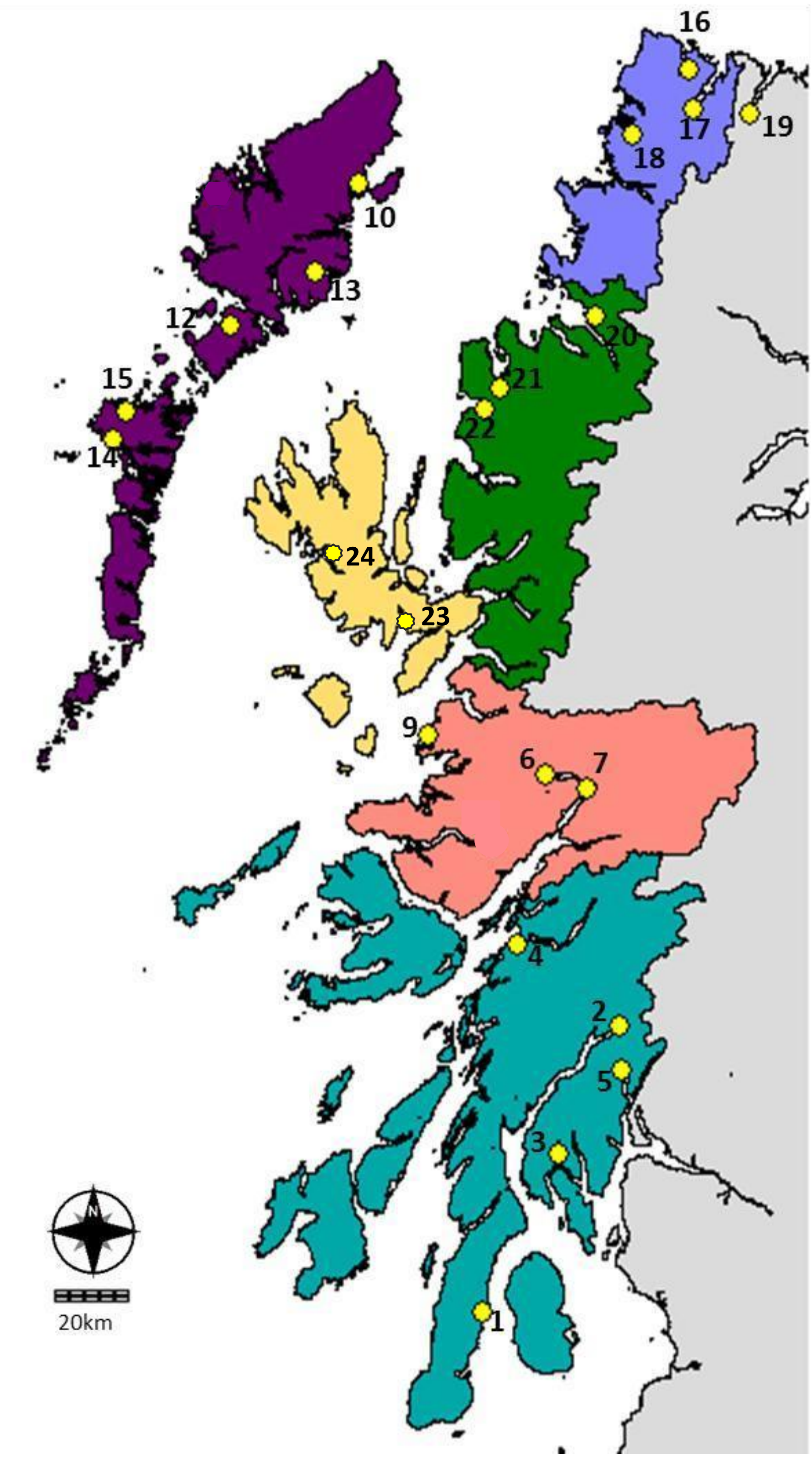

Figure 1: Geographical spread of monitoring sites sampled in 2013 (Yellow dot indicates monitoring site please see Table 1 for full site details). Trust Areas indicated as Blue = West Sutherland, Green = Wester Ross, Yellow = Skye, Pink = Lochaber, Cyan = Argyll and Purple = Outer Hebrides.

3. Sweep Netting Analysis Results

3.1. Sea Trout Analysis

In 2013 the total number of post smolts caught at each site showed some variation across the monitoring sites on the West coast of Scotland. The conditions of which the Trusts had to sample under this year have been particularly challenging with dry and low water levels recorded. Under the SFCC protocol the recommended minimum sample size for statistical analysis is currently advised as thirty fish. The majority of sites did sample above this threshold number. As can be seen from Figure 2, eighteen of the initial twenty two sites achieved this minimum sample size and four sites fell below the minimum sample size.

Figure 2: Total number of sea trout caught at each monitoring site including a break down to the number in sample of post smolts at 260mm threshold and 198mm threshold.

3.1.1 Length, Weight and Condition Factor

Across the monitoring sites in 2013 as observed in 2012 and 2011 the sea trout were predominately under 260mm (Figure 3) and showed variation in length across the monitoring sites. In comparison to the observed mean lengths of 2012 monitoring sites Boor Bay (Wester Ross), Flowerdale (Wester Ross), Loch Fyne (Argyll), West Riddon (Argyll), Loch Goil (Argyll), Borrowdale (Lochaber), Kyles (Outer Hebrides), Kinloch (West Sutherland) and Kanaird (Wester Ross) recorded a reduction in mean length in 2013. Whilst monitoring sites Camus na Gaul (Lochaber), Tong (Outer Hebrides), Eishgen (Outer Hebrides) and Malacleit (Outer Hebrides) have observed lengths which are marginally up on recorded mean lengths in 2012. Finally the remaining monitoring sites have observed lengths which are equivalent to those recorded for at the monitoring site in 2012.

Unlike the sea trout post smolt length, the weight of the post smolts shows greater variation across the monitoring sites (Figure 4) which was also the observation in 2011[1] and 2012. In 2013 the largest mean weights were recorded at Kyles (Outer Hebrides) and Tong (Outer Hebrides), whilst the smallest mean weights were recorded at Goil (Argyll), Kinloch (West Sutherland) Polla (West Sutherland) and Flowerdale (Wester Ross). In comparison to the observed mean weights of the 2012 monitoring sites Carradale (Argyll), Loch Fyne (Argyll), Dunstaffnage (Argyll), Goil (Argyll), Borrodale (Lochaber), Polla (West Sutherland), Kinloch (West Sutherland), Kinnaird (Wester Ross), Boor Bay (Wester Ross) and Flowerdale (Wester Ross) have recorded a notable reduction in mean weight in 2013.

Monitoring sites Riddon (Argyll), Kinlocheil (Lochaber), Camus na Gaul (Lochaber), Tong (Outer Hebrides) and Malacleit (Outer Hebrides) have observed weights which are greater than those recorded at these sites in 2012. Finally monitoring sites Kyles (Outer Hebrides) and Borrodale (Lochaber) and Eishgen (Outer Hebrides) have observed weights that are equivalent to those recorded in 2012. The observed notable reduction in mean weights at a number of monitoring sites will be discussed further in section 4.

To explore the sea trout post smolt condition factor, Fultons condition factor (Ricker, 1975) was employed. This factor assumes a relationship between the weight of a fish and its length, which calculates and allows for the description of the individual fish condition. The formula for Fultons Condition Factor is:

$$K = \frac{W}{L^3}$$

K = Fulton Condition Factor

W = Weight

L = Total Length

Finally a scaling factor is implemented to bring the factor close to 1.

All monitoring sites sampled in 2013 had available length and weight data and the condition factor was calculated for all post smolts at each monitoring site and is summarised in Figure 5. As a general rule if a fish has a condition factor of 1 or above it would be considered healthy and of the twenty one monitoring sites in 2013 the calculated Fulton Condition Factor indicates six sites fall below the factor 1 level. These six sites are Carradale (Argyll), Riddon (Argyll), Borrodale (Lochaber), Polla (West Sutherland), Kanaird (Wester Ross) and Boor Bay (Wester Ross). In 2011 only two sites fell below the Fulton Condition Factor, which were Kannaird (Wester Ross) and

[1]Please note weight data was not collected at all monitoring sites in 2011.

Flowerdale (Wester Ross). In 2012 and 2013 overall Condition Factor have remained poor at six sites. This observed reduction in condition factor across the monitoring sites will be discussed further in section 4.

In comparison to the observed mean condition indices of 2012 monitoring sites Loch Fyne (Argyll), Dunstaffnage (Argyll), Kinlocheill (Lochaber), Camus na Gaul (Lochaber), Tong (Outer Hebrides), Kyles (Outer Hebrides), Malacleit (Outer Hebrides), Kinloch (West Sutherland) and Flowerdale (Wester Ross) have observed Condition Indices which are greater than those recorded at these sites in 2013. Whilst monitoring sites Carradale (Argyll), West Riddon (Argyll), Borrodale (Lochaber), Polla (West Sutherland), Kannaird (Wester Ross) and Boor Bay (Wester Ross) have recorded a reduction in mean Condition Indices in 2013. Finally monitoring sites Goil (Argyll), Borrodale (Lochaber), Eishgen (Outer Hebrides) and Laxford (West Sutherland) have observed condition indices that are equivalent to those recorded at these monitoring sites in 2012.

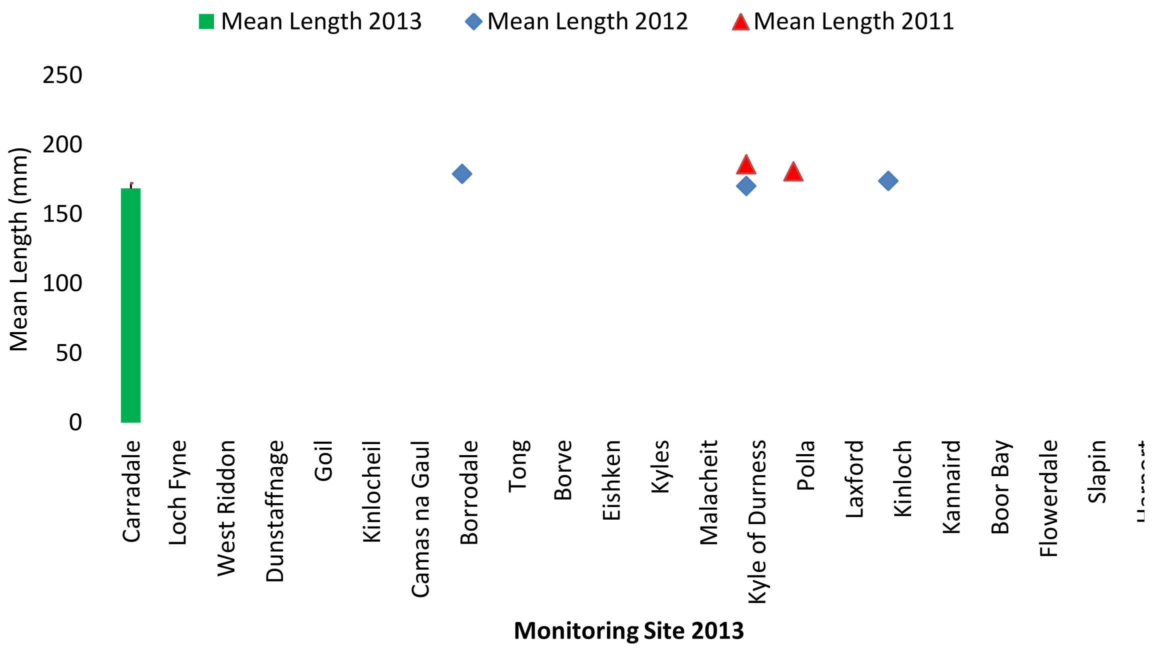

Figure 3: The mean sea trout lengths (mm) at each monitoring site with 95% Confidence Intervals.

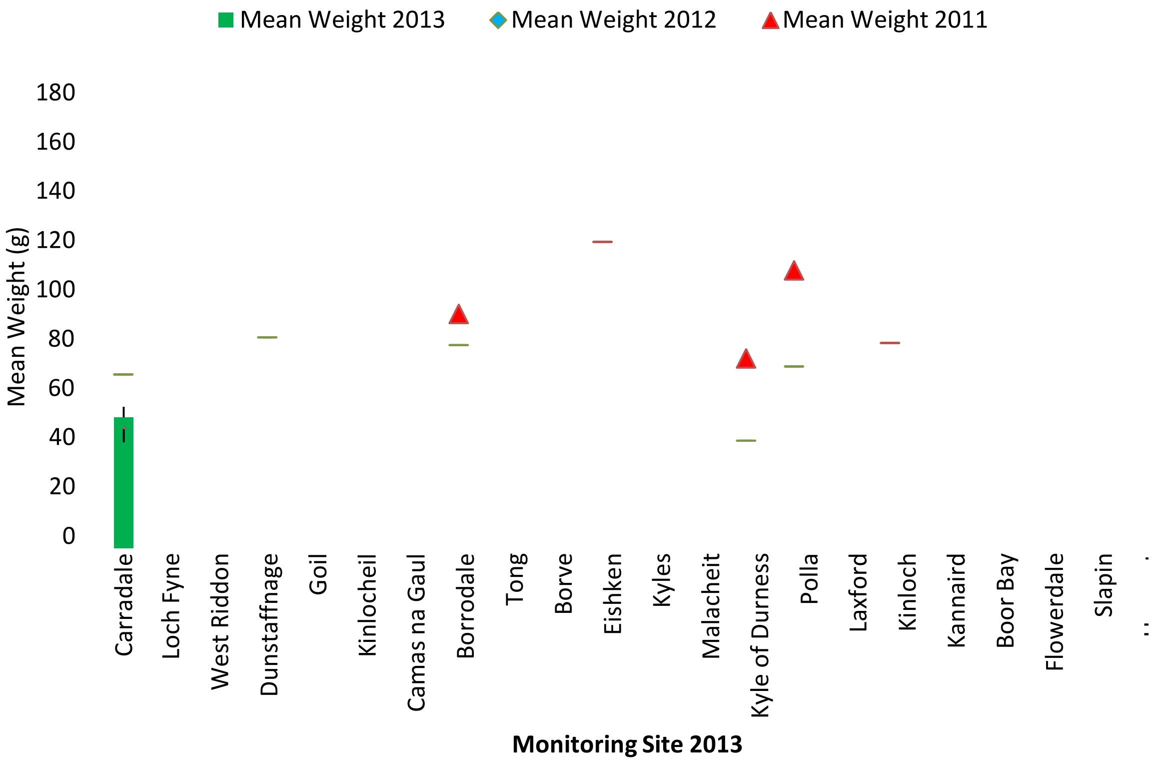

Figure 4: The mean sea trout weights (g) at each monitoring site with 95% Confidence Intervals.

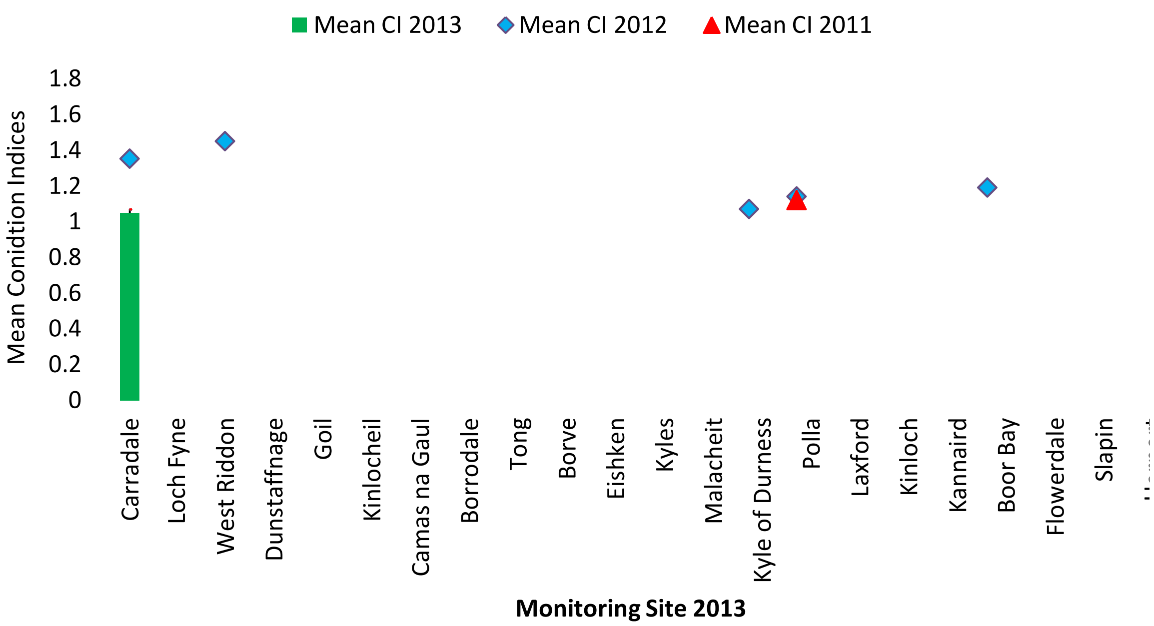

Figure 5: The mean sea trout Condition Indices at each monitoring site with 95% Confidence Intervals.

3.1.2 Predation Pressure

As with all ecosystem interactions the prey/predator relationships for sea trout is a natural process, however as identified the sea trout populations on the West coast are under pressure and declining (AST, 2011). It is important to understand the dynamics of the predation occurring. One of the dynamics relating to sea lice loadings and predation is particularly important to consider for example at sites were lice loads may be at elevated levels and weakening the fish, it may therefore be increasing a fish population's susceptibility to predation. Sea trout can encounter a range of predators throughout their life cycle. These include predators ranging from birds such as the Osprey or Heron, to mammals such as mink or otters and to marine mammals such as common and grey seals. Predation pressures are difficult to quantify and currently out with the scope of this study. It has been shown that predation by marine mammals may have a role in stock declines, but this impact is not well understood (Middlemas, *et al* 2003; Butler *et al*, 2006; Butler *et al*, 2011).

The scope of the study here is limited to examining whether predation could be identified as occurring or not occurring. There are no conclusions drawn on the detrimental level of impact on the sea trout populations under study may be experiencing due to predation. Whilst examining the sea trout for physical damage, if observed using the expert opinion of the biologists it was categorised by the pattern of damaged observed to the likely predator species and the percentage level of damage/scale loss was also recorded by the Fisheries Biologist. In 2013, predation was observed at nine sites across the West Coast (Figure 6).

From the predation recorded in 2013 the majority were noted from birds. In comparison to predation damage recorded in 2012 it is interesting to note that seven sites where predation was recorded in 2013 are indicated at lower levels of predation than was recorded in 2012. The nine sites that recorded predation damage are Loch Fyne (Argyll), Loch Riddon (Argyll), Camus na Gaul (Lochaber), Borrodale (Lochaber), Kinloch (West Sutherland), Flowerdale (Wester Ross), Slappin and Harport (Skye).

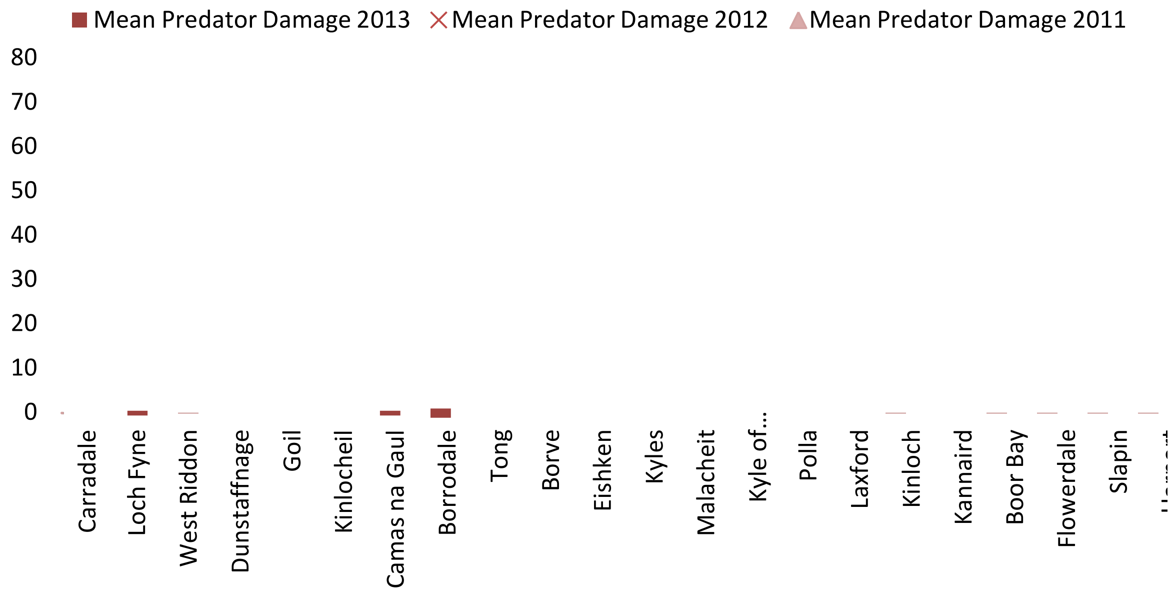

Figure 6: The percentage sea trout predator damage recorded at each monitoring site.

3.2 Sea Lice Analysis

3.2.1 *L. salmonis* Copepodid and Chalimi life Stages.

The life cycle of *L. salmonis* comprises of five distinct phases and ten life stages (Schram, 1993). The *L. salmonis* 3rd and 4th distinct phases which are the immature life stages under examination here are known as the Copepodid and Chalimi stages. These initial stages include the four stages of immature sea lice which attached to the sea trout by a frontal filament around which they feed on the fish mucus and skin. These immature stages are the smallest and are often extremely hard to discern on the fish host and as a result they are often under estimated in counts (Tully, 1989).

It can be extremely hard to determine sea lice levels that are significantly above background levels with no baseline sea lice data available. From the data collected in 2013 and considering the individual sites compared to the calculated regional mean prevalence of 31, the regional mean of 1.58 for abundance and a mean regional intensity of 6.0 it can been seen that the majority of sites reported and recorded levels of Copepodid/Chalimi presence below the regional mean for prevalence, abundance and intensity (Figure 7 and Figure 8). However there are six sites which could be classed as experiencing elevated levels of Copepodid/Chalimi presence in 2013 when considering the regional means for abundance, intensity and prevalence these are Dunstaffnage (Argyll), Kinlocheil (Lochaber), Camus na Gaul (Lochaber), Tong (Outer Hebrides), Laxford (West Sutherland) and Kanaird (Wester Ross). To ensure that the regional means are not being represented by any particularly high outliners the median which is less influenced by outliers was explored. As can be seen from Figure 8 all of the six sites are indicated as experiencing elevated median levels compared to the mean median levels in 2012.

In comparison to the observed results from the 2013 study period, the recorded mean regional prevalence for *L. salmonis* Copepodid and Chalimi stages has very slightly decreased from that recorded in the 2012 study period (Figure 7). Five monitoring sites, Eishken (Outer Hebrides), Kyles (Outer Hebrides), Polla (West Sutherland), Kanaird (Wester Ross) and Flowerdale (Wester Ross) has recorded mean prevalence levels that are equivalent to the 2012 study period. All other monitoring sites in 2013 have either significantly increased or decreased in comparison to those prevalence levels recorded in 2012.

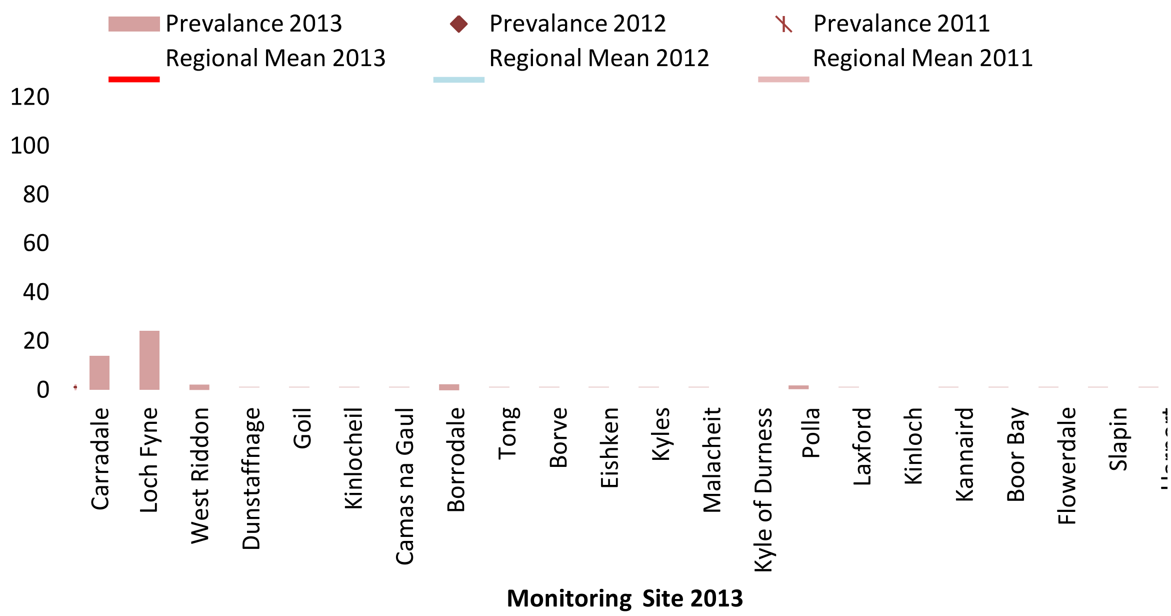

Figure 7: *L. salmonis* Copepodid/ Chalimi Prevalence and Regional mean results for 2011, 2012 and 2013.

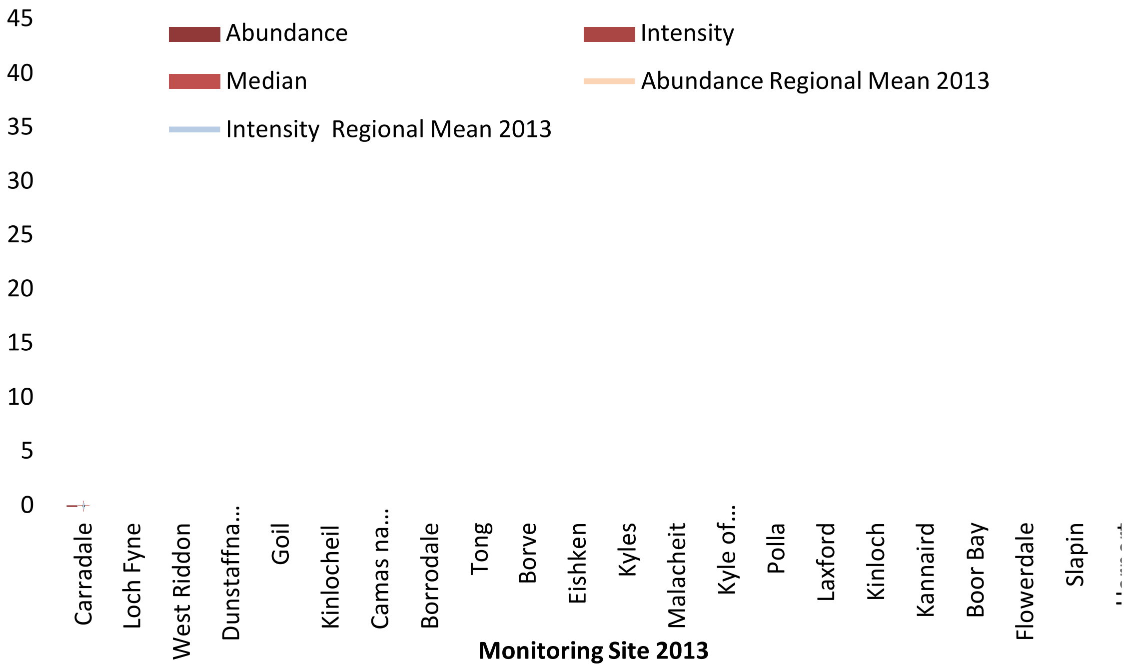

Figure 8: Back Transformed means in 2013 for Abundance, Intensity and Median for Copepodid/ Chalimi at each monitoring site (including 95% confidence intervals).

3.2.2 *L. salmonis* Mobile life Stages.

The *L. salmonis* stages under examination here are commonly referred to as the mobile life stages, which includes the two pre-adult stages of the male and female. The adult life stage here includes the adult male and female (without eggs strings). These life stages are easier to identify as they are larger and move freely to feed over the fish mucus and skin.

From the data collected in 2013 and considering the individual sites compared to the calculated regional mean of 35 for prevalence, a mean regional abundance of 1.00 and a mean regional intensity of 3.47. It can been seen that the majority of sites reported and recorded levels of preadult and adult presence below the regional mean for abundance, intensity and prevalence (Figure 9 and Figure 10). However there are six sites which could be classed as experiencing elevated levels of preadult and adult presence when considering the regional mean for prevalence, abundance and intensity. These are Dunstaffnage (Argyll), Camus na Gaul (Lochaber), Tong (Outer Hebrides), Kyles (Outer Hebrides), Malacleit (Outer Hebrides) and Kannaird (Wester Ross). There is a potential for the regional means to be representing particularly high outliners, therefore the median which is less influenced by outliers was explored to confirm the indicative elevated levels. As can be seen from Figure 10 when exploring the regional mean median all sites are indicated as experiencing elevated levels.

In comparison to the observed results from the 2013 study period, the recorded mean regional prevalence for *L. salmonis* mobile life stages has decreased from that recorded in the 2012 study period (Figure 9). Two monitoring site Kyles (Outer Hebrides) and Flowerdale (Wester Ross) have recorded mean prevalence levels that are equivalent to the 2012 study period. All other monitoring sites in 2013 have either significantly increased or decreased in comparison to those prevalence levels recorded in 2012 (Figure 9).

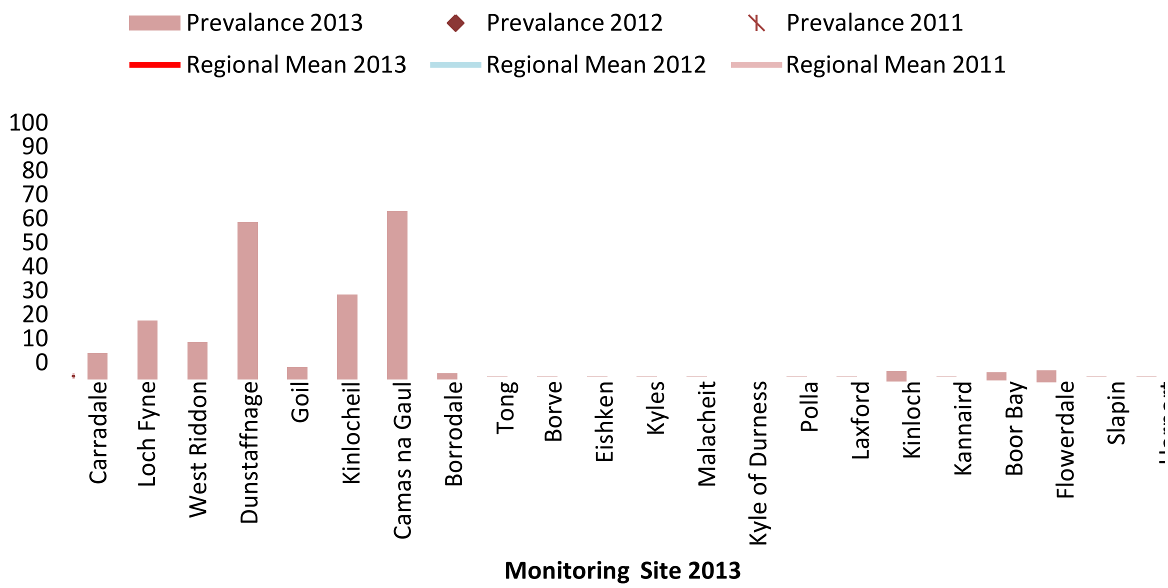

Figure 9: *L. salmonis* Mobile life Stages Prevalence and Regional mean results for 2011, 2012 and 2013.

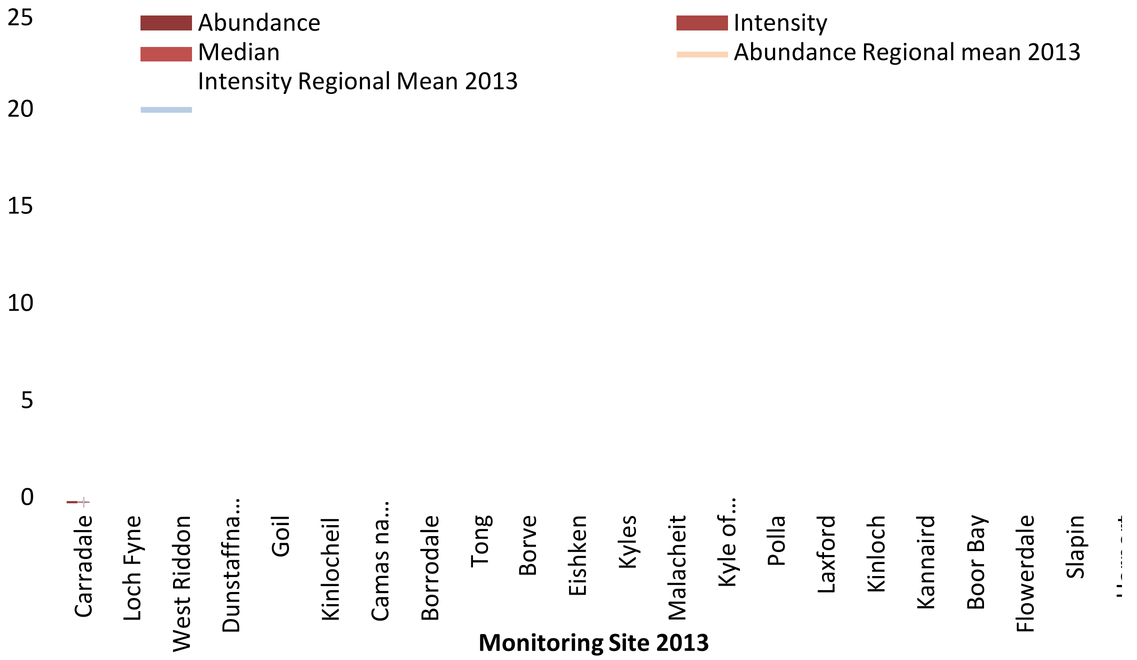

Figure 10: Back Transformed means in 2013 for Abundance, Intensity and Median results for Preadult/Adult at each monitoring site (including 95% confidence intervals).

3.2.3 *L. salmonis* Ovigerous Female life Stage.

The final *L. salmonis* life stage examined on the post smolt sea trout was the Ovigerous female. Ovigerous females are easily identified by two visible egg strings which can average carry a total of a thousand eggs.

From the data collected in 2013 and considering the individual sites compared to the calculated regional mean of 10.1 for prevalence, a mean regional abundance of 0.12 and a regional mean intensity of 0.87 it can been seen that the majority of sites reported and recorded levels of ovigerious female presence below the regional mean for prevalence, abundance and intensity (Figures 11 and 12). Only four sites could be classed as experiencing elevated levels of ovigerious female presence when considering the regional mean for prevalence, abundance and intensity these are Dunstaffnage (Argyll), Tong (Outer Hebrides), Kyles (Outer Hebrides) and Malacleit (Outer Hebrides). There is a potential for the regional means to be representing particularly high outliners, therefore the median which is less influenced by outliers was explored to confirm the indicative elevated levels. As can be seen from Figure 12 none of the four sites have recorded a median which is elevated and therefore these sites are unlikely to be experiencing elevated ovigerous life stages.

In comparison to the observed results from the 2013 study period, the recorded mean regional prevalence for *L. salmonis* Ovigerous female stage has increased from that recorded in the 2012 study period. Three monitoring sites have significantly decreased Carradale (Argyll), Goil (Argyll) and Borve (Outer Hebrides) and five monitoring sites have marginally increased, Loch Fyne (Argyll), Dunstaffnage (Argyll), Tong (Outer Hebrides), Kyles (Outer Hebrides) and Malacleit (Outer Hebrides) mean prevalence’s in comparison to those prevalence levels recorded in 2012 (Figure 11). The remaining monitoring sites have recorded mean prevalence levels in 2013 that are equivalent to the recorded means in the 2012 study period.

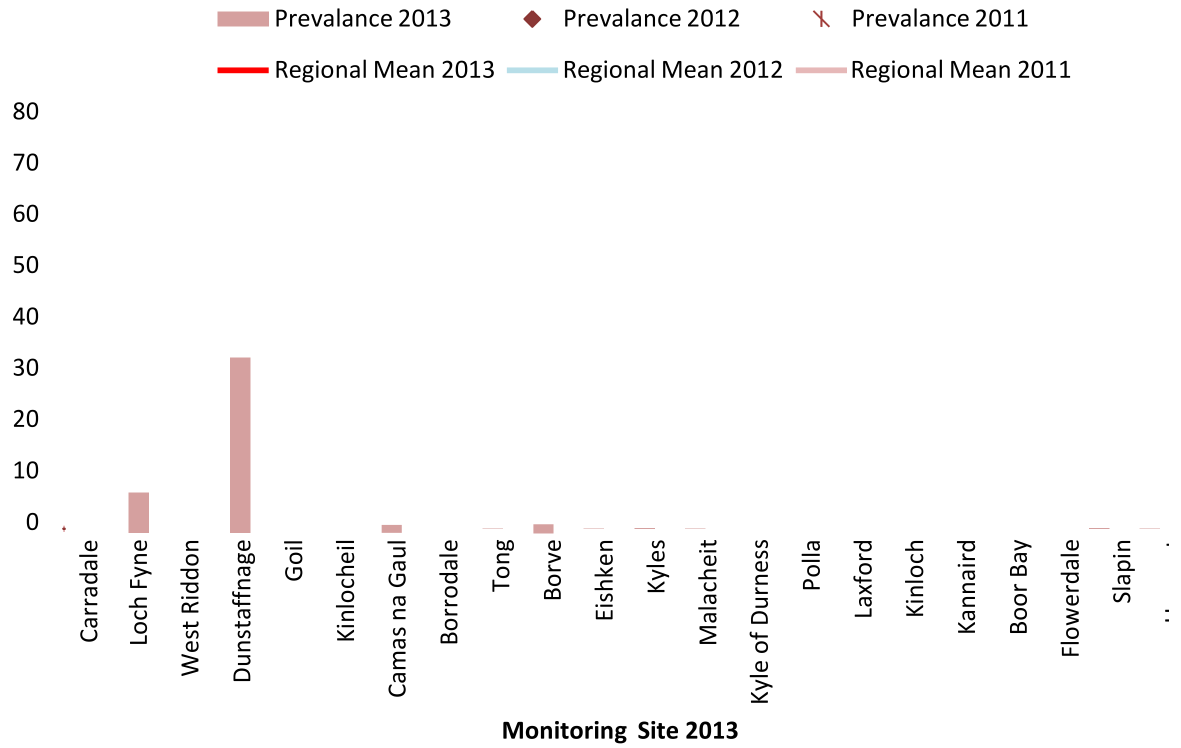

Figure 11: *L. salmonis* Ovigerous Female life Stage Prevalence and Regional mean results for 2011, 2012 and 2013.

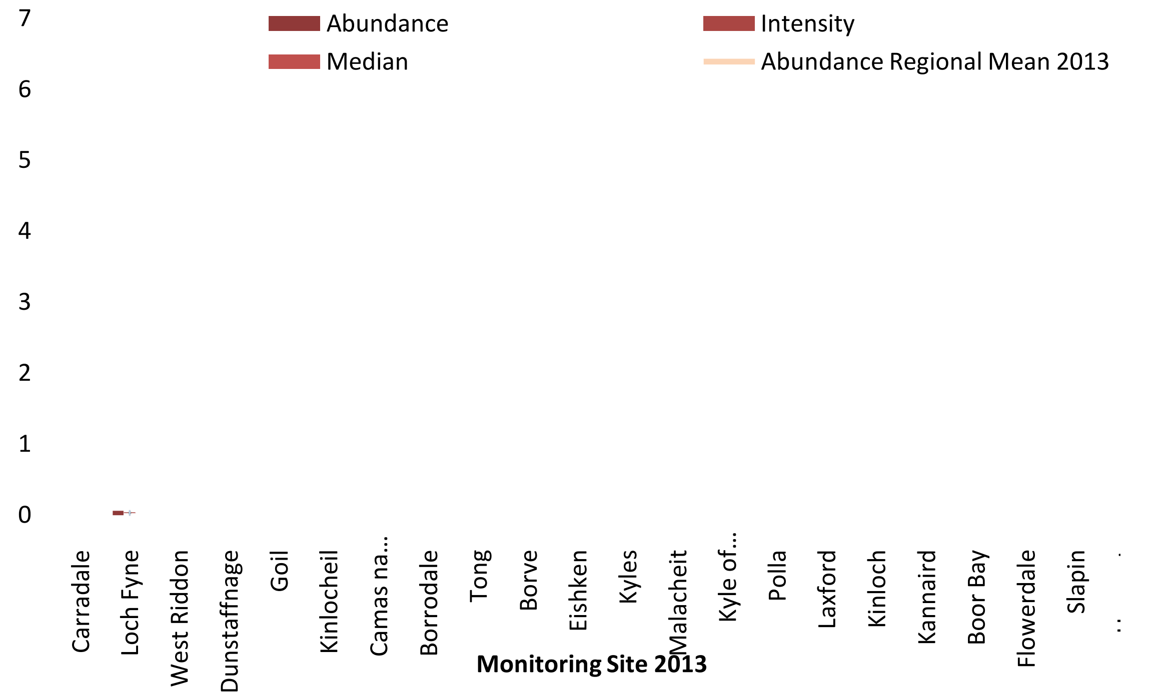

Figure 12: Back transformed means in 2013 for Abundance, Intensity and Median results for *L. salmonis* ovigerous females at each monitoring site (including 95% confidence intervals).

3.2.4 *L. salmonis* all life Stages.

A final examination of the total counts of all the *L. salmonis* life Stages was under taken. Overall the majority of the monitoring sites sampled experienced low levels of *L. salmonis* presence when considering the calculated regional mean for prevalence of 43, a regional mean for abundance of 2.29 and a regional mean intensity of 6.68 in 2013 (Figures 13 and 14). There are eight sites which indicate elevated presence levels in comparison to these regional means which are Dunstaffnage (Argyll), Kinlocheill (Lochaber), Camus na Gaul (Lochaber), Tong (Outer Hebrides), Kyles (Outer Hebrides), Malacleit (Outer Hebrides), Laxford (West Sutherland) and Kinnaird (Wester Ross). There is a potential for the regional means to be representing particularly high outliners, therefore the median which is less influenced by outliers was explored to confirm the indicative elevated levels. As can be seen from Figure 14 six of the sites Dunstaffnage (Argyll), Camus na Gaul (Lochaber), Tong (Outer Hebrides), Kyles (Outer Hebrides), Malacleit (Outer Hebrides), Kinnaird (Wester Ross) are indicated as experiencing elevated levels. However, the remaining two site Kinlocheil (Lochaber) and Laxford (West Sutherland) are recorded as below the regional median and therefore less likely to be experiencing elevated total *L. salmonis* presence. Further exploration of these results and their potential detrimental impacts can be found in section 4.

In comparison to the observed results from the 2013 study period, the recorded mean regional prevalence for total *L. salmonis* stages in 2013 (43%) is slightly less than that recorded mean regional prevalence from 2012 (52%). Nonetheless, it is important to note that only two monitoring sites recorded mean prevalence levels in 2013 which could be described as equivalent to those recorded in the 2012 study period. As such, although the yearly recorded prevalence is only slightly less the site by site sea lice levels are showing much more variability between the two years of study. Nine monitoring sites have significantly increased and eight monitoring sites have significantly deceased mean prevalence’s in 2013 in comparison to those prevalence levels recorded at the same monitoring sites in 2012 (Figure 13).

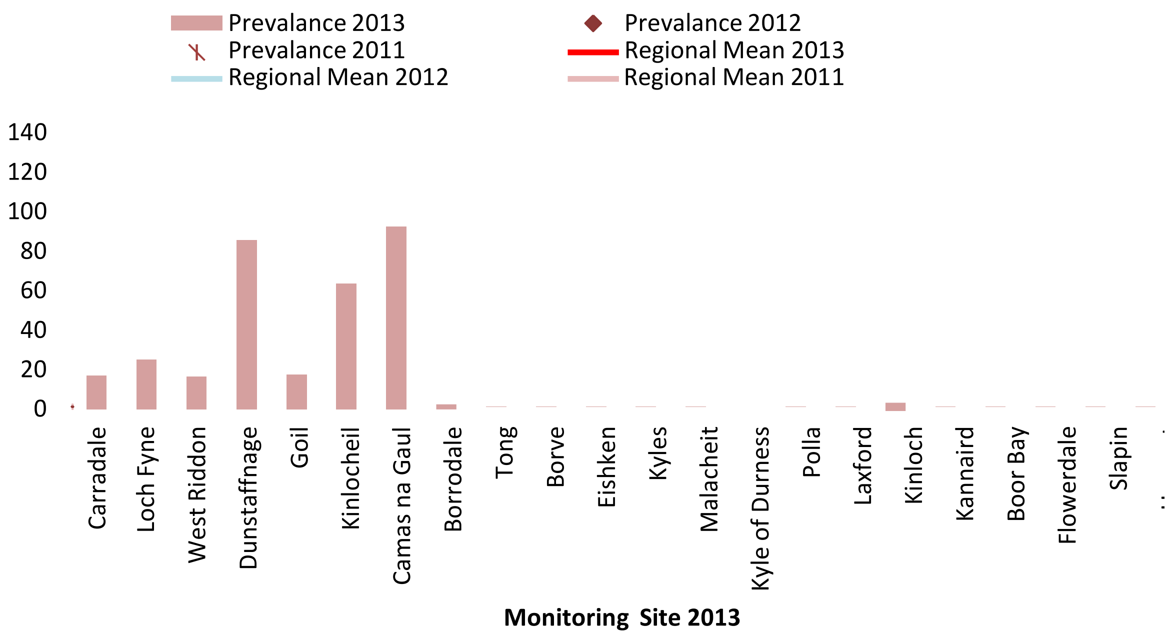

Figure 13: *L. salmonis* all life Stages Prevalence and Regional mean results for 2011, 2012 and 2013.

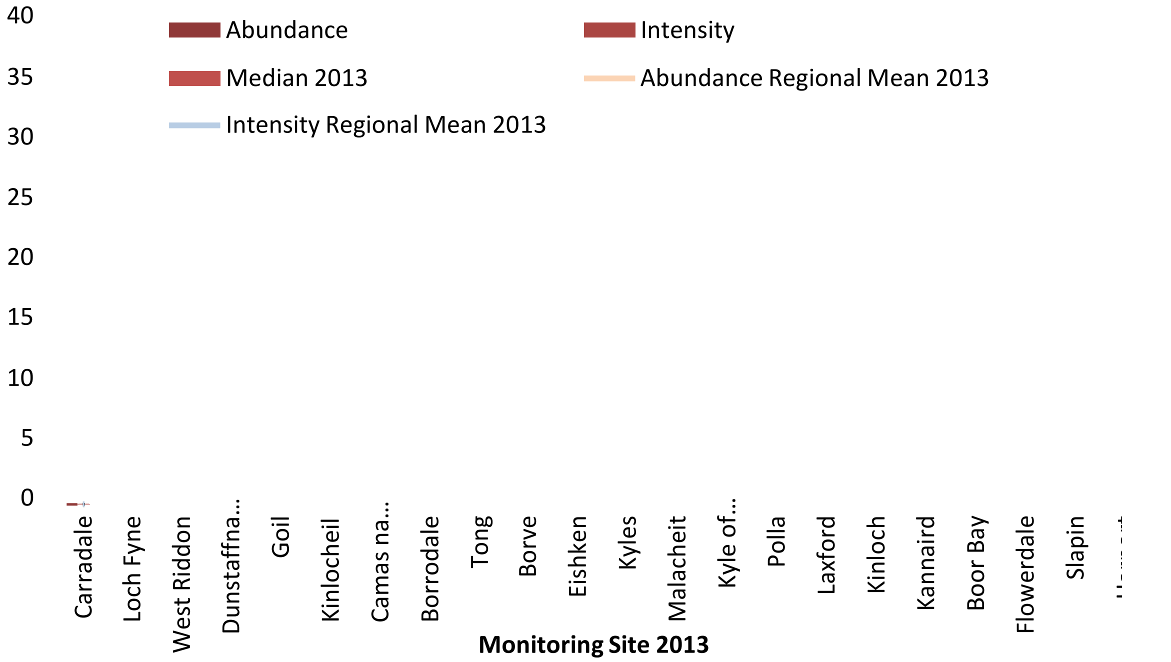

Figure 14: Back Transformed means in 2013 for Abundance, Intensity and Median results for all *L. salmonis* stages at each monitoring site (including 95% confidence intervals).

3.2.5 *C. elongatus* all life Stages.

Caligus elongatus is much smaller sea lice species, lighter in colouration and a host generalist (Wootten *et al*., 1982) that has been recorded on over eighty host species (Kabata, 1979). The *C. elongatus* life cycle has less stages then *L. salmonis* as it moults directly from chalimus IV to the adult stages (Piasecki, 1996). Whilst currently of lesser concern in Scotland than the sea louse *L. salmonis, C. elongatus* is present and does have the potential to become a problem which should not be underestimated. Bergh *et al*., 2001 reported high intensity *C. elongatus* infestations, and consequentially severe head lesions, were reported for juvenile farmed halibut *Hippoglossus hippoglossu*. As a host generalist there are possibilities in Scotland that if presence levels become elevated, farmed and wild fish could experience detrimental problems from *C. elongatus*.

From the data collected throughout the monitoring sites in 2013 *C. elongatus* was identified as being present in three Trust areas, Argyll, Outer Hebrides and West Sutherland. It can be extremely hard to determine significant levels for each of the sites with no information on background levels of sea lice data available. From the data collected in 2013 and considering the individual sites compared to the calculated regional mean of 5.4 for prevalence, a mean regional abundance of 0.15 and a regional intensity mean of 1.06. Where this sea lice species was identified as present, its levels varied across the monitoring sites. Four monitoring sites Loch Fyne (Argyll), Tong (Outer Hebrides), Polla (West Sutherland) and Laxford (West Sutherland) have elevated presence levels in comparison to the regional means for prevalence, abundance and intensity (Figures 15 and 16). There is a potential for the regional means to be representing particularly high outliners, therefore the median which is less influenced by outliers was explored to confirm the indicative elevated levels. As can be seen from Figure 16 all the monitoring have recorded below the regional median and therefore less likely to be experiencing elevated total *C. elongatus* presence levels.

In comparison to the observed results from the 2012 study period, the recorded mean regional prevalence for total *C. elongatus* stages in 2013 (5.4%) is less than that recorded mean regional prevalence from 2012 (9%). Six monitoring sites recorded mean prevalence levels in 2013 which could be described as equivalent to those recorded in the 2012 study period. Eight monitoring sites have significantly decreased and five monitoring sites have increased recorded mean prevalence's in comparison to those prevalence levels recorded at the same monitoring sites in 2012 (Figure 15).

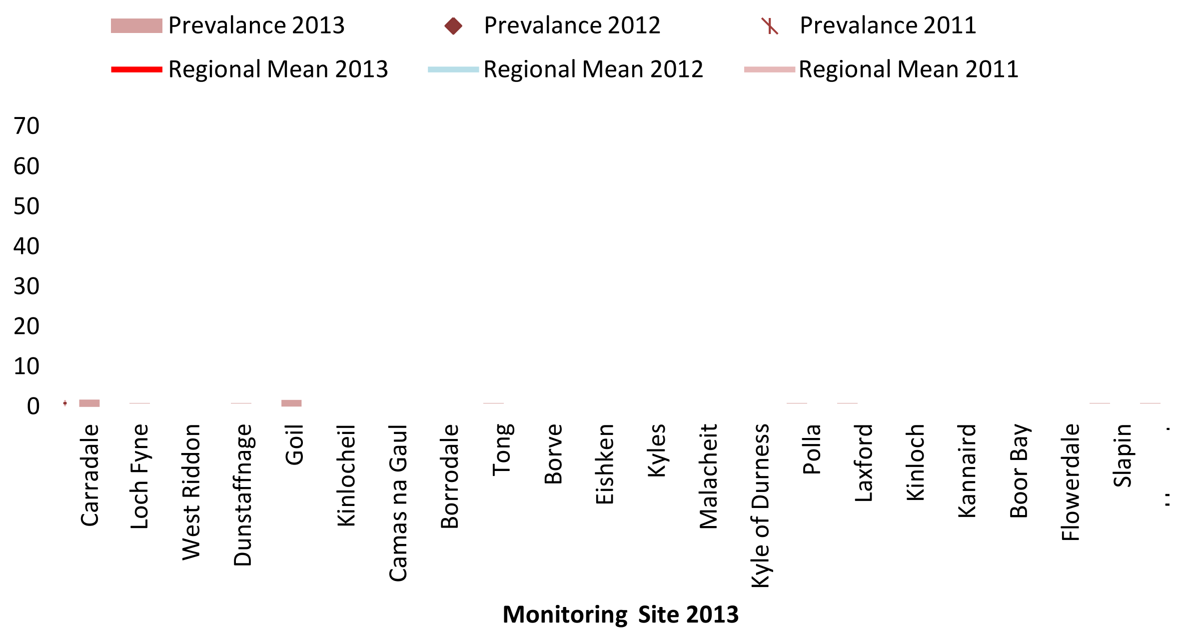

Figure 15: *Caligus elongatus* prevalence and regional mean results for 2011, 2012 and 2013.

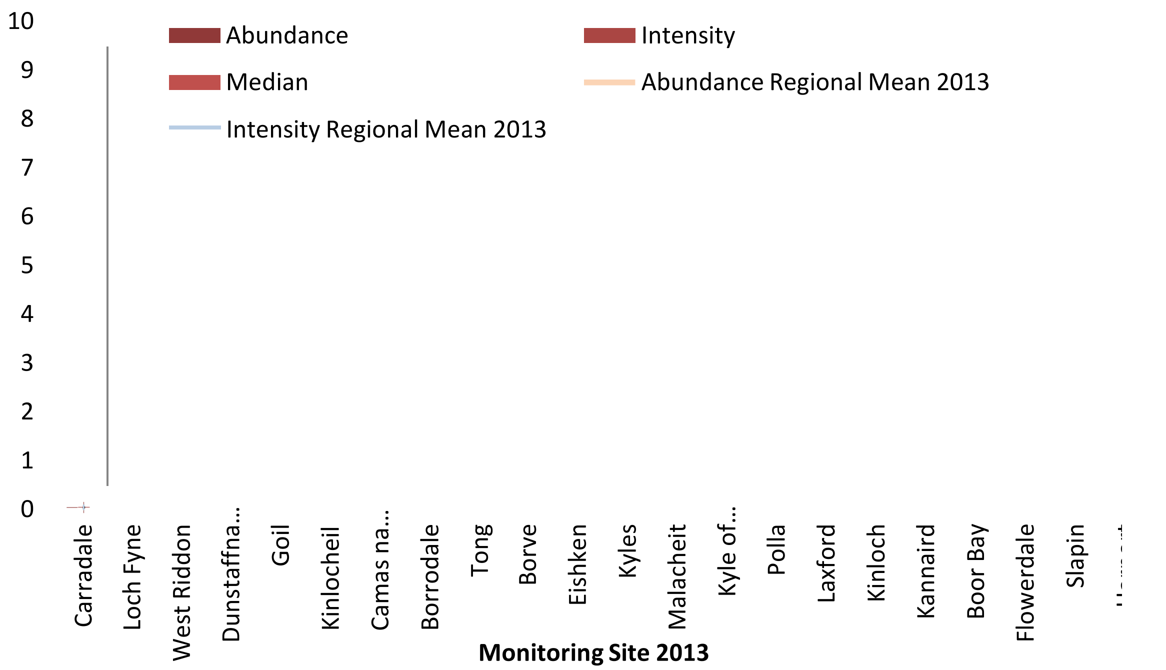

Figure 16: Back Transformed means for in 2013 for Abundance, Intensity and Median results for all *C. elongatus* stages at each monitoring site (including 95% confidence intervals).

4. Discussion

The results of the post smolt sea trout populations indicate that the mean lengths have decreased slightly at ten of the sites when compared to those recorded in 2012. The greater variation in the results of the post smolt sea trout populations indicate that the mean lengths have decreased slightly at ten of the sites when compared to those recorded in 2012. The greater variation in recorded mean weights across the monitoring sites during the 2-year period is noted and warrants ongoing monitoring and further investigation.

This weight variation is demonstrated by the recorded decrease in weights of the post smolts at ten of monitoring sites in 2013 compared to those recorded in 2012. This is also coupled with the comparable observed improvement in condition indices and an increase in lice loadings at these monitoring sites (Carradale (Argyll), Borrodale (Lochaber), Riddon (Argyll), Boor Bay (Wester Ross)). Sites that have shown a reduction in condition indice but an increase in lice loadings are Polla (West Sutherland) and Kannaird (Wester Ross).

It should be noted that previous studies have indicated there may be a relationship to sea lice loadings and juvenile host weight (Jones and Nemec 2004). Previous work has proposed that observed reductions in sea trout post smolt weights and associated lower lice loadings could be attributed to the potential residence time within the marine environment (Brooks, 2005). Sea Trout post smolts will gain weight at a higher rate with increased residency within the marine environment, which also consequentially is the area of exposure to infection from sea lice.

It is recognised that there may be a number of other localised environmental factors also playing a part in the observed reduction in infection levels and weight results in this study (Amundrud and Murray 2009; Penston *et al*, 2011). The sampling period and the stages of the lice observed in 2013 were comparable to those observed in 2012. This work is in the early stages and it is not yet possible to draw definitive conclusions on the data from 2013 which demonstrated the reduction of weight, reduction in condition indices and lower lice levels compared to the 2012 results.

Of the twenty two monitoring sites, nine recorded low levels of damage from predation with one site showing significantly increased levels of predation. Overall the observed predation damage in 2013 was very similar to that recorded in the 2012 study period.

To fully understand the implications of the sea lice presence recorded at the monitoring sites and whether or not detrimental impacts were being experienced further analyses were performed based on the results of previous studies.

4.1 Exploring the pressures from Sea Lice on wild sea trout populations.

A number of factors need to be considered when analysing the results collected at the monitoring sites. Sweep netting studies may over- or under-estimate the levels of lice on wild fish. It is sometimes impossible to sample those fish which have succumbed to heavy infestation loads and therefore such fish will not be sampled potentially leading to an underestimate of the true lice levels. Equally, it is possible that those fish with no lice, or small levels of lice are better able to evade the net than fish with higher lice levels, potentially leading to overestimates. Therefore presenting a true reflection of infestation levels on the sea trout population as a whole is problematic and leads to an inherent difficulty in drawing meaningful conclusions on threshold levels and their impact on sea trout populations (Middlemas *et al*., 2010). As long as these inherent difficulties are presented and considered it is possible to draw conclusions that can be attributed to the population and inform local management strategies and policies.

To further explore the sea lice infestation pressure on wild sea trout populations, data from each monitoring site were examined to determine if the levels of observed sea lice infection could be classed as an epizootic. Sea lice epizootics are characterised by unusually high infestations that are maybe fatal, and although currently rare in Scotland they have previously been reported (Butler, 2002). Epizootics recorded on sea trout in Europe and Pacific salmon in British Columbia tend to have over 60% prevalence and more than 5 lice per fish (Costello, 2009 and Beamish *et al*, 2009).

Based on the results of calculating threshold levels for an epizootic occurring in 2013 there are five sites; Dunstaffnage (Argyll), Camus na Gaul (Lochaber), Kyles (Outer Hebrides), Tong (Outer Hebrides) and Kannaird (Wester Ross) that have experienced sea lice levels that could potentially be categorised as epizootics (Figure 17). This however, is not the final picture as this is only indicates that these sea trout populations are experiencing heavy, large infestations and further analysis is required to determine if these high observed levels are having a detrimental impact. To examine these high levels in more depth a tolerance threshold level was explored.

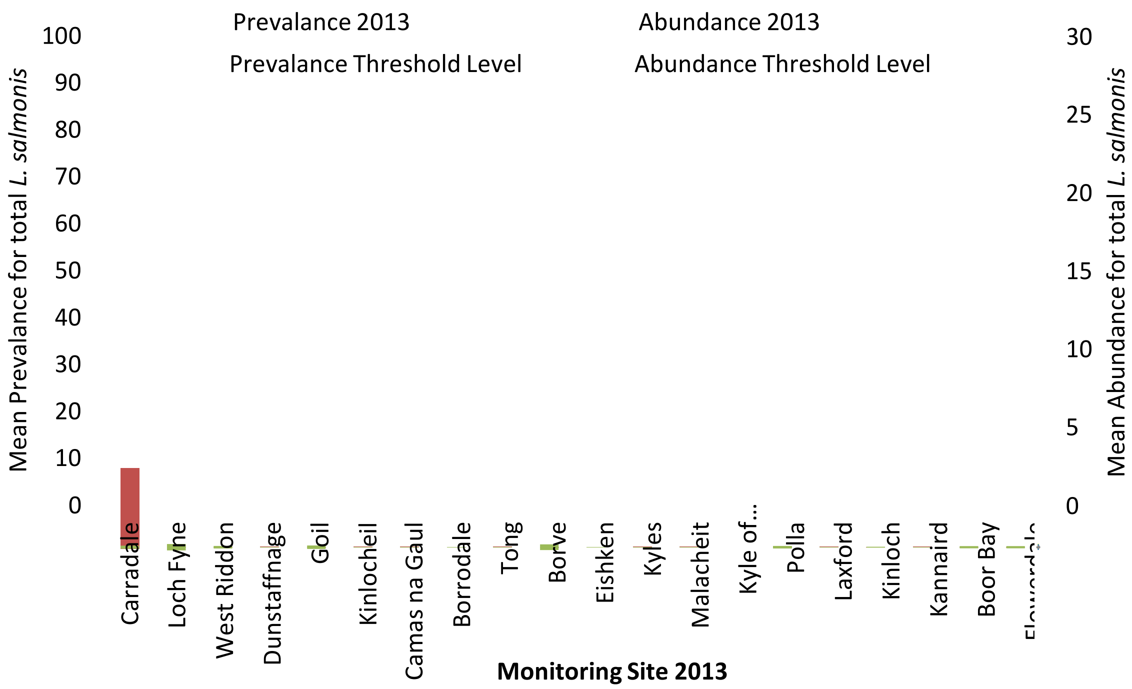

Figure 17: Prevalence and Abundance results for all life stages at each monitoring site in 2013. The Costello 2009 threshold levels for identifying epizootics are highlighted on the graph by a solid yellow line for the prevalence threshold and a solid blue line for the abundance threshold.

The threshold level for impact to be explored is from Wells *et al*. (2006) where this study found that abrupt changes in a range of physiological parameters occurred at thirteen mobile lice per fish (weight range 19-70g). This level could be detrimental to the fish host. It was suggested within this study that a management strategy should be applied if the populations are experiencing more than 13 mobile lice per fish. The lice figures used in this analysis were all mobile stages and the proportion of chalimi converted into the expected number of mobile lice. To calculate the likely survival rate of chalimi to adult stages Bjørn and Finstad (1997) recommended survival rate of 0.63 which was implemented. Only those fish below 198mm (the equivalent of 70g) were considered in this analysis. It was also deemed appropriate only to consider monitoring sites that have sample sizes of thirty fish or greater.

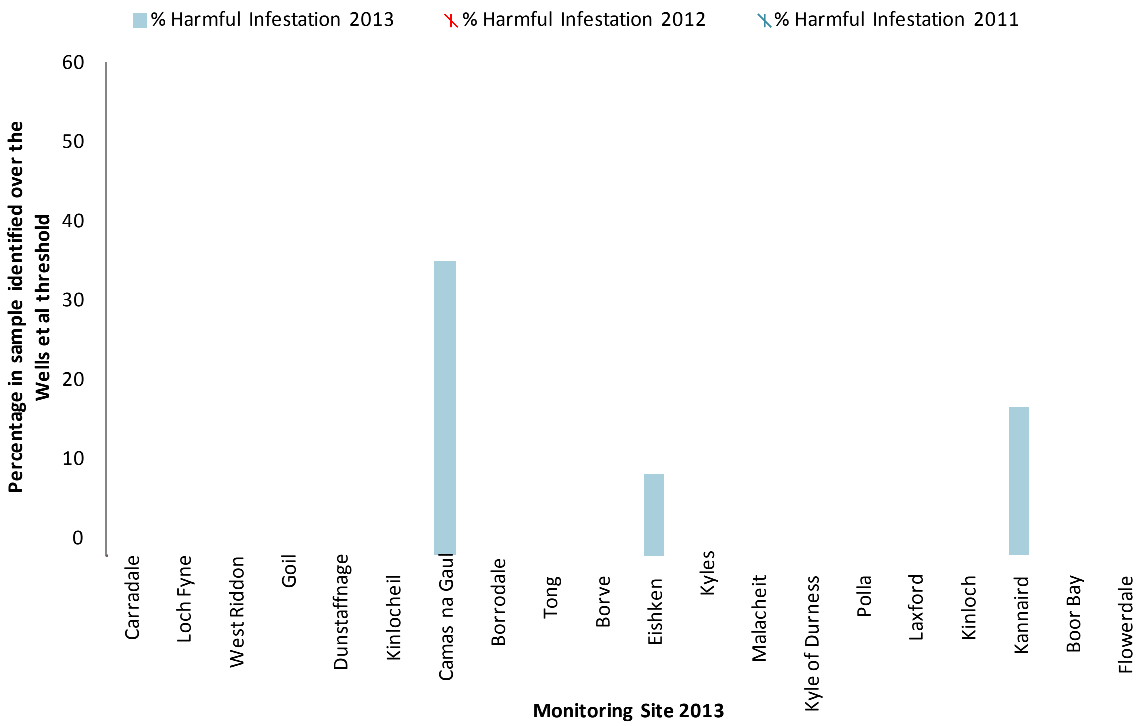

Figure 18: Percentage of fish within each monitoring site sample which has been identified over the Wells et al, 2006 threshold.

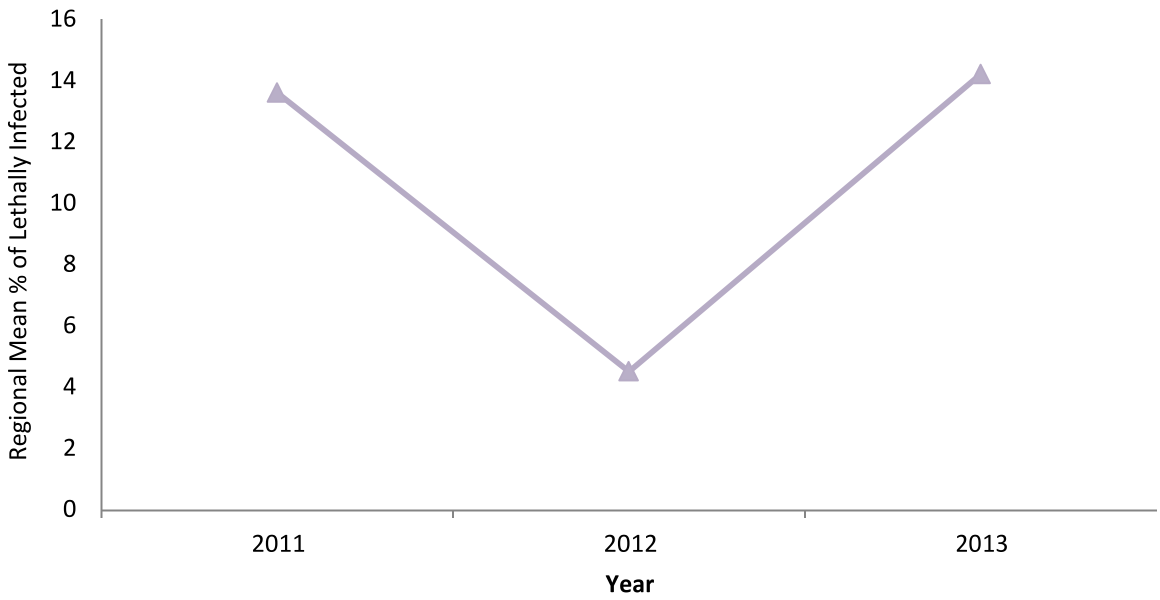

Figure 19: Total regional mean percentage of sea tout post smolts lethally infected over the period 2011 to 2013.

Within each of the monitoring samples the percentage of individual fish in each sample that appeared over the threshold and therefore more likely to be carrying a detrimental sea lice burden was identified for each monitoring site (Figure 18). In 2013, three sites are recorded as experiencing fish carrying detrimental lice loadings. One monitoring site in the Outer Hebrides (Eishken) which has 10% of the sample carrying detrimental lice loads. The second site in Lochaber (Camus na Gaul) has experienced 36% of the sample recorded as carrying detrimental loads and the third site in Wester Ross (Kannaird) which has 18% of the sample recorded as carrying detrimental loads. In comparison, to these three sites all other sites with a valid statistical sample size recorded no fish carrying detrimental lice loadings. In comparison to the observed results from the 2012 and 2011 study period from Figure 19 it can be seen that there is an increase in the total regional mean percentage of sea tout post smolts lethally infected.

There is currently no guidance on the acceptable proportion of fish exceeding the Wells *et al* (2006) threshold. Although the EU project "Sustainable Management of Interactions between Aquaculture and Wild Salmonid" Hazon *et al* (2006) propose :

"*that a level of 10% or fewer of wild sea trout in any given population in Ireland bearing total infestations of ≥13 lice/fish should be adopted as indicative of a satisfactory or acceptable lice loading. Within any given sea trout stock, frequencies of heavily-infested juvenile sea trout (i.e. those ≥13 lice/ fish) >10% should perhaps be considered a cause for concern*."

For the Scottish context, identification and adoption of a universally accepted level for the acceptable proportion of lice loadings would support policy development and more effective local management strategies. However this would require further work to develop a sound understanding of the sea trout population dynamics on the West Coast of Scotland. Work has begun to achieve this aim with sites at greater distance added to the suite of monitoring sites in 2012 and further refinements were made in 2013.

In conclusion when considering the epizootic threshold (Costello, 2009) and the *L. salmonis* mobile threshold (Wells *et al,* 2006), it is possible to identify the post sea trout populations in the study areas that are under pressure from detrimental sea lice loadings and where management strategies are required to support the reduction of sea lice burdens on the post smolts. However, it should be noted that the detrimental impact from sea lice has concentrated solely on one species *L. salmonis* in this study. At seven of the monitoring sites in 2011, twelve monitoring sites in 2012 and seven monitoring sites in 2013 *C. elongates* was identified as present and although not seen as such a serious problem species as *L. salmonis* the relationship and the likely additive effect of the two species occurring together merits further exploration in the future.

4.2 Managing Interactions

The complex interactions between sea lice levels on wild sea trout populations and those observed at active fish farm sites remains a highly contentious issue. The data and information gathered in preliminary work to the current project has helped to inform the wider scientific debate. Middlemas *et al*, 2012 collated and analysed the West Coast Fisheries Trust sweep netting data from 2003 to 2009 and concluded that;

"*the proportion of wild sea trout with potentially damaging levels of sea lice infestations on the West Coast of Scotland was related to their fork length, distance to the nearest farm and the weight of salmon on that farm*".

The study was able to predict that the maximum range of effect of sea lice from farms is approximately 31km. There remains an inherent uncertainty with this estimation of distance due to the previous study being focused solely on localised investigations. Following on from this work, in 2011, the subsequent project undertaken by RAFTS and its project partners introduced significant refinements. These included the coordinated strategic West Coast Region focus of this project, which also now includes sampling of monitoring sites at greater distances and on the North Coast. The data collected in this project is available to Marine Scotland Science and it is envisaged that the development of the new data set will enable some of the questions and uncertainties identified in the previous work to be further explored and definitive conclusions drawn.

4.2.1 Monitoring Site comparisons to nearest active Fish Farm.

Data was obtained from the Scottish Environment Protection Agency on the nearest active fish farms to the monitoring sites. Seventeen monitoring sites that were surveyed in both 2012 and 2013 are assimilated into this analysis. The year of production of the nearest active farm sites in 2012 were, zero fish farm site were fallow, ten were in first year of production and seven were in second year of production. In comparison for 2013 these active fish farm sites, four were in a fallow period, one site was in first year of production and twelve sites were in second year of production.

In Scotland fish farm production cycles are typically carried out over a two year period. Throughout the production cycles the cage pen depth is static, as such over the two year period fish weight and surface area rises. The significances of this are that the surface area of fish per cubic metre of water will also increase over time (Heunch *et al*, 2003). It is also well documented that into the second year of production on fish farms there will be a greater level of sea lice present (Revie *et al*. 2002; Lees *et al*. 2008). Further to this Middlemas *et al* (2010) has identified a relationship pattern that indicates connectivity between local fish farm production cycles and the infestations levels of wild sea trout smolts.

As documented earlier (Figure 19) there has been a recorded increase in the total regional mean percentage of sea tout post smolts lethally infected between 2012 and 2013. This observed increase is in line with an increase in the number of fish farms in second year of production nearest to the monitoring sites. In 2012 there were 47% of the nearest fish farms to the seventeen monitoring sites in second year of production whilst in 2013 there were 65% of the nearest fish farms to the seventeen monitoring sites in second year of production. An increasing infestation pattern can be observed over the production cycles from the data collected in 2012 and 2013 (Figure 20) where 41% of the monitoring sites record an increased total *L. salmonis* prevalence in year two of production compared to the prevalence levels recorded in a 1st year or fallow period of production.

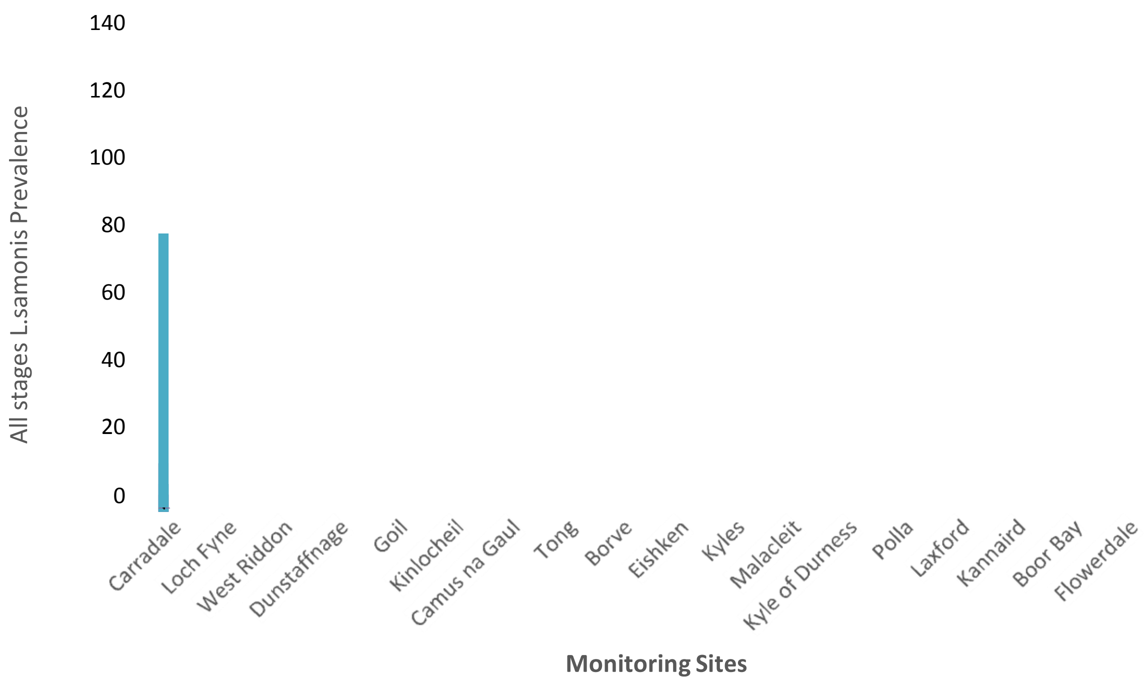

Figure 20: Year of production for 2011, 2012 and 2013 of the nearest active fish farms to each monitoring site. Orange = Fallow, Blue = 1st Year of Production and Purple = 2nd Year of Production.

Clearly the interrelationship between wild sea lice levels and year of production is a pattern that is supported by the evidence that is being gathered within this study, however it should be noted this is not the only driving factor in this interrelationship. Similarly in 2012 one or more monitoring sites are documented as breaking one or more detrimental thresholds and in 2013 one monitoring site is documented as breaking one or more detrimental threshold whilst the nearest active fish farm was in year one of production (Table 3 and 4).

There are significant natural and fish farming activity variations between the monitoring sites that will in all probability also have an impact on the infestations levels of L. salmonis at each monitoring site. Such differences between the monitoring sites includes the loch system flushing rates, loch system orientation, the distance to nearest farms, the number of farms in proximity in differing year of production and the size of the sea trout populations present within the study area. Additionally, environmental factors may impact on temporal and spatial occurrences of post smolts or sea lice. For instance, dispersal of sea lice will be affected by wind direction (Amundrud and Murray 2009).

Further contributing factors may also demonstrate good sea lice management can successfully lower the release rates of sea lice nauplii stages, however there are no data available on the management of sea lice at a local farm site level in Scotland to be able to consider the impact of this factor at this time. Further contributing factors may also be attributed to sea lice management on the fish farm sites. As Robbins *et al* 2010 demonstrated good sea lice management can successfully lower the release rates of sea lice nauplii stages however there is no data available on the management of sea lice at a local farm site level in Scotland to be able to consider the impact of this factor at this time.

Table 2: Monitoring sites in 2011 which broke one or both of the detrimental sea lice loading thresholds and the year of production to the nearest active fish farm.

Monitoring Site 2011	**Area**	**Over the Epizootic Threshold**	**Over the 10≥ Detrimental Threshold**	**Year of Production of Nearest Farm**
Camas Na Gaul	Lochaber	Yes	Yes	2
Kyles	Outer Hebrides	Yes	No	2
Malacliet	Outer Hebrides	Yes	No	2
Laxford	West Sutherland	Yes	No	2
Kannaird	Wester Ross	Yes	Yes	1

Table 3: Monitoring sites in 2012 which broke one or both of the detrimental sea lice loading thresholds and the year of production to the nearest active fish farm.

Monitoring Site 2012	**Area**	**Over the Epizootic Threshold**	**Over the 10≥ Detrimental Threshold**	**Year of Production of Nearest Farm**
West Riddon	Argyll	Yes	No	1
Goil	Argyll	Yes	No	2
Borrodale	Lochaber	Yes	No	2
Borve	Outer Hebrides	Yes	No	2
Kannaird	Wester Ross	Yes	Yes	2

Table 4: Monitoring sites in 2013 which broke one or both of the detrimental sea lice loading thresholds and the year of production to the nearest active fish farm.

Monitoring Site 2013	**Area**	**Over the Epizootic Threshold**	**Over the 10≥ Detrimental Threshold**	**Year of Production of Nearest Farm**
Tong	Outer Hebrides	Yes	No	Fallow
Kyles	Outer Hebrides	Yes	No	2
Camus na Gaul	Lochaber	Yes	Yes	1
Kannaird	Wester Ross	Yes	Yes	2
Dunstaffnage	Argyll	Yes	No	2

5. Conclusions

In 2013 at 22 monitoring sites across the west coast and islands of Scotland over one thousand sea trout were evaluated and essential data recorded. The lessons learnt and refinements identified by the 2011 and 2012 study were successfully incorporated into the 2013 project.

At each monitoring site in 2013, the Sea Trout populations under examination showed status and trends that were diverse across the west coast region. It was also recorded that there was a reduction in the mean weights and improvement in condition indices in 2013 when compared to the 2012 recorded results. Whilst the mean recorded lengths remained static between the years.

For 2013 the results indicated that four monitoring sites experienced extensive heavy infestations (epizootic). The management threshold level for infestation levels (Wells *et al*, 2006) was used to determine if the infection levels resulted in detrimental impact effects. This implemented critical threshold level indicates that potentially three of the monitoring sites had elevated levels of sea lice presence within the fish population that potentially could be having a critical detrimental impact.

Data comparisons between wild fish sea lice counts and farm site sea lice counts remains problematic but we hope to see better relationships between the two industries in the future enabling improved comparisons. Being able to properly draw conclusions on links across what is occurring between farmed fish, wild fish and sea lice within a local area is of paramount importance in ensuring that the appropriate management strategies and policies are employed for the health and wellbeing of the wild fish and for the sustainable development of farmed fish within a defined area.

The monitoring work undertaken in this project highlights the interaction issues that are of relevance for all stakeholders involved with the management and conservation of Sea Trout populations on the West Coast of Scotland. The data and information gathered within this project has also informed and contributed to the wider scientific debate. The strengths of this project are clear from the early results and will continue to be further expanded in the third year. It is an important contributor in helping to support the development and understanding of the interactions between wild fish populations and sea lice on the West Coast Scotland.

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7. Appendix

Appendix 1

Table A1: Monitoring Site Mean Environmental Conditions over sample period in 2013.

Monitoring Site	Mean Water Temperature (°C)	Mean Air Temperature (°C)	Mean Salinity (PSU)
Carradale	14.6	15.3	19
Loch Fyne	9.3	10.5	13
West Riddon	10.8	11.1	24.5
Dunstaffnage	11.2	13.3	18.5
Goil	13.1	14.3	13.5
Kinlocheil	13	17.4	24.7
Camas na Gaul	12.8	17.0	18.2
Borrodale	12.3	17.0	23.8
Tong	16.8	15.9	35
Borve	13.9	19.1	35
Eishken	13.8	17.4	35
Kyles	12.5	13.6	35
Malacheit	13.2	14.4	35
Kyle of Durness	14.5	15.6	12.3
Polla	14.1	16.4	11.5
Laxford	13.6	21.5	10
Kinloch	10.4	13.5	3
Kannaird	14.0	15.0	22
Boor Bay	13.3	14.0	29
Flowerdale	15.0	18.0	23
Harport	10.0	12.3	33.7
Slapin	11.3	14.3	32

Appendix 2

Table A2: Sea Trout Post Smolt (Threshold 260mm) Analysis for 2013

Monitoring Site	Mean length (± s.d.) (mm)	Mean Weight (± s.d.) (g)	Mean Condition Factor (± s.d.)
Carradale	168.3 (± 16.03)	51.6 (±16.1)	1.05(±0.08)
Loch Fyne	145.7 (± 27.34)	41.8 (± 27.7)	1.24 (± 0.22)
West Riddon	185.3 (± 33.1)	83.6 (± 41.6)	1.24 (± 0.32)
Dunstaffnage	159.6 (± 18.8)	51.6 (± 16.5)	1.25 (± 0.22)
Goil	141.4 (± 21.2)	34.01 (± 24.7)	1.11 (± 0.24)
Kinlocheil	159.1 (± 37.4)	31.4 (± 43.6)	0.96 (± 0.33)
Camas na Gaul	173.9 (± 29.6)	68.0 (± 36.4)	1.18 (± 0.15)
Borrodale	149.0 (± 22.1)	40.6 (± 31.3)	0.82 (± 0.47)
Tong	208.4 (± 22.1)	109.4 (± 42.8)	1.15 (± 0.27)
Borve	192.8 (± 30.03)	83.32 (± 38.3)	1.10 (± 0.12)
Eishken	183.1 (± 20.3)	66.1 (± 30.18)	1.02 (± 0.13)
Kyles	214.9 (± 28.5)	119.0 (± 57.18)	1.13 (± 0.45)
Malacheit	193.9 (± 36.0)	105.7 (± 46.9)	1.49 (± 0.73)
Kyle of Durness	*	*	*
Polla	149.1 (± 31.4)	34.18 (± 34.3)	0.88 (± 0.26)
Laxford	187.6 (± 33.04)	74.8 (± 38.9)	1.04 (± 0.12)
Kinloch	145.2 (± 19.8)	35.8 (± 16.5)	1.11 (± 0.123)
Kannaird	181.5 (± 50.5)	74.6 (± 86.1)	0.97 (± 0.16)
Boor Bay	187.2 (± 28.4)	66.1 (± 35.3)	0.94 (± 0.14)
Flowerdale	150.2 (± 22.9)	34.0 (± 24.5)	0.93 (± 0.20)
Harport	220.1 (±25.1)	123.9 (±41.0)	1.13 (±0.11)
Slapin	220.0 (±23.3)	122.4 (±34.1)	1.28 (±0.13)

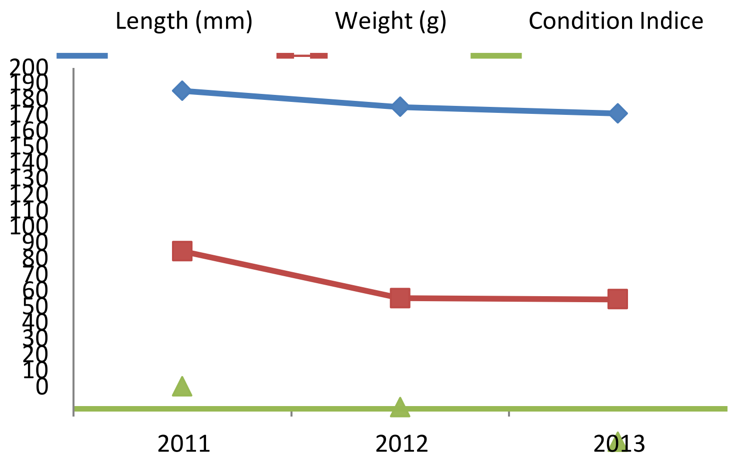

Figure A1: Regional mean results for length, weight and condition Indices for post smolt sea trout in 2011, 2012 and 2013.

Appendix 3

Table A3: Prevalence, Abundance, Intensity and Median analysis for Copepodid/Chalimi at each monitoring site 2013.

Monitoring Site	Prevalence	Abundance (± s.d.)	Intensity (± s.d.)	Median
Carradale	13.79	0.12(± 0.35)	1.33(± 0.23)	0
Loch Fyne	24.2	0.30(± 0.67)	1.99(± 0.51)	0
West Riddon	2.08	0.01(± 0.11)	1.00(± 0)	0
Dunstaffnage	85.7	5.86(± 2.47)	8.45(± 1.79)	5
Goil	17.74	0.25(± 0.65)	0.54(± 0.17)	0
Kinlocheil	54.5	1.12(± 1.16)	2.98(± 0.57)	1
Camas na Gaul	91.2	7.46(± 2.02)	9.4(± 1.52)	7.5
Borrodale	2.38	0.03(± 0.18)	2(± 0)	0
Tong	80	3.28(± 1.52)	3.22(± 0.80)	3
Borve	5.08	0.13(± 0.86)	10.5(± 4.02)	0
Eishken	20.63	1.13(± 3.49)	38.4(± 0.29)	0
Kyles	12.5	0.22(± 0.77)	4.0(± 0)	0
Malacheit	20.6	0.31(± 0.74)	2.77(± 0.26)	0
Kyle of Durness				
Polla	1.4	0.02(± 0.14)	2.0(± 0)	0
Laxford	51.7	3.32(± 3.88)	15.96(± 1.55)	2
Kinloch	0	0.00(± 0)	0(± 0)	0
Kannaird	78.9	6.3(± 3.18)	11.4(± 2.07)	5.5
Boor Bay	9.7	0.14(± 0.55)	0.14(± 0.55)	0
Flowerdale	6.98	0.11(± 0.60)	3.2(± 2.56)	0
Harport	51.7	4.87 (±5.9)	9.73 (±4.63)	2
Slapin	81.5	9.93 (±7.57)	12.2 (±10.5)	9

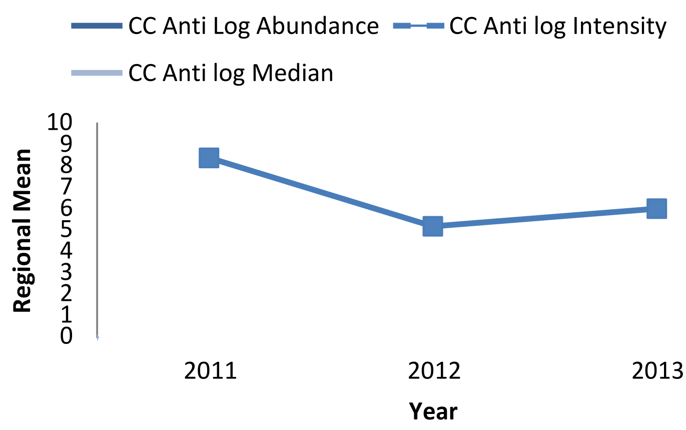

Figure A2: Regional mean results for Copepodid/Chalimi Abundance, Intensity and Median in 2011, 2012 and 2013.

Appendix 4

Table A4: Prevalence, Abundance, Intensity and Median analysis for Preadult/Adult at each monitoring site 2013.

Monitoring Site	Prevalence	Abundance (± s.d.)	Intensity (± s.d.)	Median
Carradale	10.34	0.1 (±0.35)	1.57 (±0.34)	0
Loch Fyne	23.08	0.19(±0.39)	1.04 (±0.09)	0
West Riddon	14.6	0.13(±0.35)	1.25 (±0.22)	0
Dunstaffnage	61.9	3.69(±2.99)	11.15 (±1.2)	5
Goil	4.84	0.03(±0.16)	1.0(±0)	0
Kinlocheil	33.3	0.39(±0.66)	1.76 (±0.38)	0
Camas na Gaul	66.18	1.69(±1.41)	3.4 (±0.22)	2
Borrodale	2.38	0.05(±0.4)	8.0 (±0)	0
Tong	88.6	2.09(±1.09)	3.1 (±0.69)	2
Borve	16.95	0.25(±0.79)	2.7 (±1.17)	0
Eishken	20.63	0.52(±1.27)	6.55 (±1.09)	0
Kyles	75	1.59(±1.09)	2.55 (±0.71)	1.45
Malacheit	91.2	4.72(±1.76)	5.77(±1.40)	6
Kyle of Durness				0
Polla	11.11	0.12(±0.42)	1.85 (±0.41)	0
Laxford	37.9	1.26(±2.33)	7.56(±1.58)	0
Kinloch	4.08	0.03(±0.14)	1.0 (±0)	0
Kannaird	94.7	2.15(±2.16)	4.71 (±1.79)	0
Boor Bay	3.23	0.04(±0.22)	0.04 (±0.22)	0
Flowerdale	4.65	0.03(±0.16)	1.0(±0.18)	0
Harport	69.0	1.50 (±1.38)	2.25 (±1.07)	1.5
Slapin	88.9	2.85 (±1.66)	12.2 (±1.26)	3

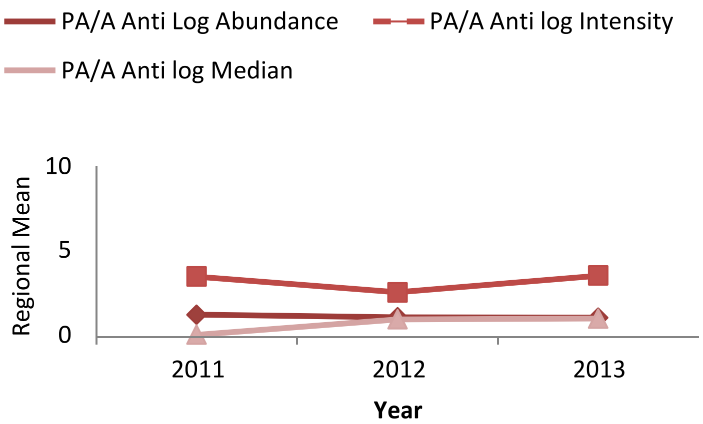

Figure A3: Regional mean results for Preadult/Adult Abundance, Intensity and Median in 2011, 2012 and 2013.

Appendix 5

Table A5: Prevalence, Abundance, Intensity and Median analysis for Ovigerous Females at each monitoring site 2013.

Monitoring Site	Prevalence	Abundance (± s.d.)	Intensity (± s.d.)	Median
Carradale	0	0.0(±0.0)	0.0(±0.0)	0
Loch Fyne	7.69	0.06(±0.25)	1.21(±0.3)	0
West Riddon	0	0.0(±0.0)	0.0(±0.0)	0
Dunstaffnage	33.3	0.48(±0.94)	2.25(±0.86)	0
Goil	0	0.0(±0.0)	0.0(±0.0)	0
Kinlocheil	0	0.0(±0.0)	0.0(±0.0)	0
Camas na Gaul	1.47	0.01(±0.09)	1.0(±0)	0
Borrodale	0	0.0(±0.0)	0.0(±0.0)	0
Tong	48.6	0.59(±0.84)	1.96(±0.53)	0
Borve	1.69	0.03(±0.29)	6.0(±0.0)	0
Eishken	9.52	0.08(±0.26)	1.14(±0.18)	0
Kyles	75	0.6(±0.65)	1.45(±0.26)	0
Malacheit	14.71	0.39(±0.70)	1.45(±0.36)	0
Kyle of Durness	0	0	0	0
Polla	0	0.0(±0.0)	0.0(±0.0)	0
Laxford	0	0.0(±0.0)	0.0(±0.0)	0
Kinloch	0	0.0(±0.0)	0.0(±0.0)	0
Kannaird	0	0.0(±0.0)	0.0(±0.0)	0
Boor Bay	0	0.0(±0.0)	0.0(±0.0)	0
Flowerdale	0	0.0(±0.0)	0.0(±0.0)	0
Harport	31.0	0.37(±0.61)	1.22(±0.44)	0
Slapin	74.1	1.11(±0.85)	1.5 (±0.61)	0

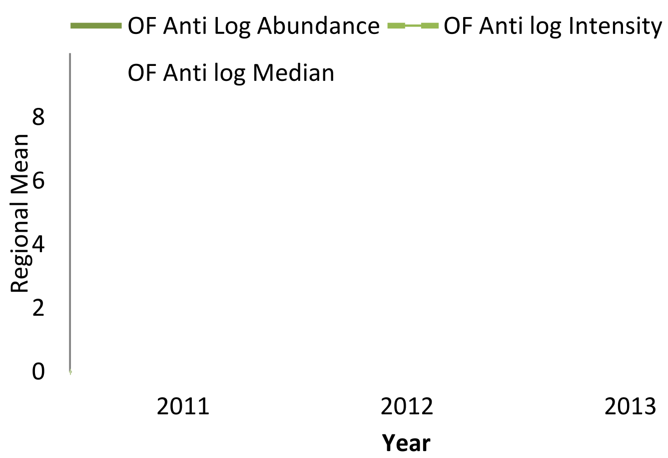

Figure A4: Regional mean results for Ovigerous Females Abundance, Intensity and Median in 2011 and 2012.

Appendix 6

Table A6: Prevalence, Abundance, Intensity and Median analysis for Total *L. salmonis* at each monitoring site 2013.

Monitoring Site	Prevalence	Abundance (± s.d.)	Intensity (± s.d.)	Median
Carradale	17.2	0.18(±0.47)	1.59(±0.43)	0
Loch Fyne	25.3	0.38(±0.79)	2.56(±0.45)	0
West Riddon	16.7	0.14(±0.35)	1.16(±0.24)	0
Dunstaffnage	85.7	7.4(±3.31)	11.0(±2.5)	16.15
Goil	17.7	0.198(±0.53)	1.77(±0.49)	0
Kinlocheil	63.6	1.17(±1.04)	2.39(±0.64)	1.26
Camas na Gaul	92.6	6.8(±1.8)	8.3(±1.42)	7.54
Borrodale	2.4	0.06(±0.43)	9.26(±0)	0
Tong	97.1	5.31(±1.2)	6.5 (±0.76)	6.52
Borve	18.6	0.35(±1.2)	3.25(±1.61)	0
Eishken	20.6	1.07(±3.24)	33.3(±0.21)	0
Kyles	87.5	2.5(±1.09)	6.65(±0.78)	5
Malacheit	55.9	7.73(±1.15)	7.37(±1.21)	6
Kyle of Durness	*	*	*	*
Polla	11.11	0.13(±0.44)	1.95(±0.48)	0
Laxford	55.2	3.44(±3.78)	13.9(±1.82)	1.89
Kinloch	4.08	0.03(±0.14)	1.0(±0)	0
Kannaird	123.7	6.48(±3.32)	7.24(±3.55)	5.7
Boor Bay	9.67	0.12(±0.49)	0.12(±0.49)	0
Flowerdale	9.3	0.11(±0.52)	1.87(±0.16)	0
Harport	69.0	6.37(±6.54)	9.55(±2.55)	4.5
Slapin	88.9	12.8 (±8.6)	14.4 (±7.76)	13

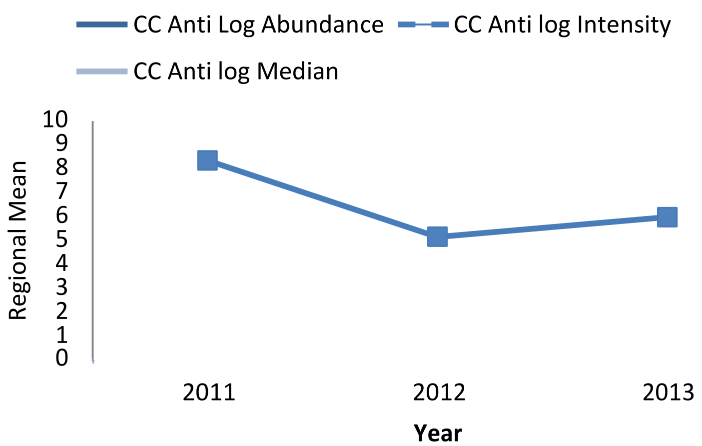

Figure A5: Regional mean results for Total *L. salmonis* Abundance, Intensity and Median in 2011, 2012 and 2013.

Appendix 7

Table A7: Prevalence, Abundance, Intensity and Median analysis for *C. elongatus* at each monitoring site 2013.

Monitoring Site	Prevalence	Abundance (± s.d.)	Intensity (± s.d.)	Median
Carradale	1.72	0.01 (±0.1)	1.0 (±0.0)	0
Loch Fyne	9.89	0.09 (±0.33)	1.71 (±0.21)	0
West Riddon	0	0.0 (±0.0)	0.0 (±0.0)	0
Dunstaffnage	4.76	0.07 (±0.35)	3.0 (±0)	0
Goil	1.61	0.01(±0.09)	1.0 (±0)	0
Kinlocheil	0	0.0 (±0.0)	0.0 (±0.0)	0
Camas na Gaul	0	0.0 (±0.0)	0.0 (±0.0)	0
Borrodale	0	0.0 (±0.0)	0.0 (±0.0)	0
Tong	22.9	0.28 (±0.67)	1.91 (±0.69)	0
Borve	0	0.0 (±0.0)	0.0 (±0.0)	0
Eishken	0	0.0 (±0.0)	0.0 (±0.0)	0
Kyles	0	0.0 (±0.0)	0.0 (±0.0)	0
Malacheit	0	0.0 (±0.0)	0.0 (±0.0)	0
Kyle of Durness				
Polla	16.67	0.09 (±0.47)	3.64 (±1.18)	0
Laxford	44.8	2.35 (±3.3)	7.93 (±2.66)	0
Kinloch	0	0.0 (±0.0)	0.0 (±0.0)	0
Kannaird	0	0.0 (±0.0)	0.0 (±0.0)	0
Boor Bay	0	0.0 (±0.0)	0.0 (±0.0)	0
Flowerdale	0	0.0 (±0.0)	0.0 (±0.0)	0
Harport	27.6	0.3 (±0.53)	1.13 (±0.35)	0
Slapin	37.0	0.41 (±0.57)	1.10 (±0.32)	0

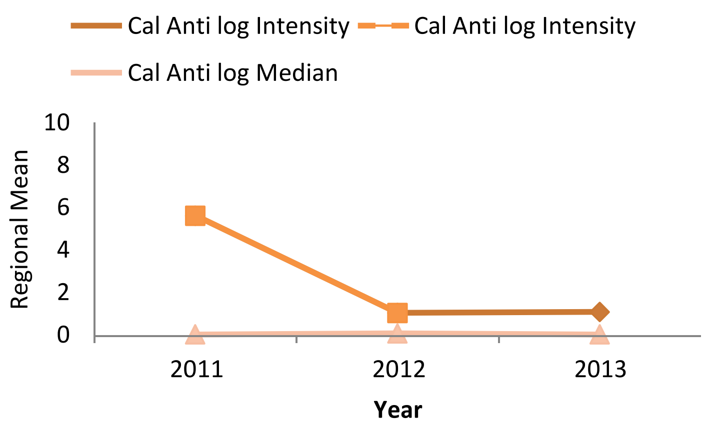

Figure A6: Regional mean results for *C. elongatus* Abundance, Intensity and Median in 2011, 2012 and 2013.

Appendix 8

Long term sweep net data series for three sites.

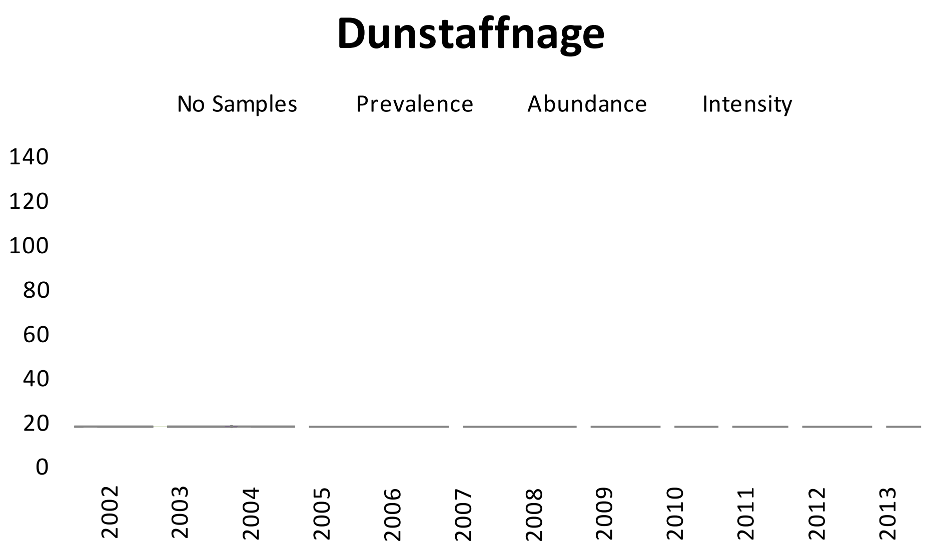

Figure A7. Post smolt sweep netting data for Dunstaffnage from 2002 to 2013.

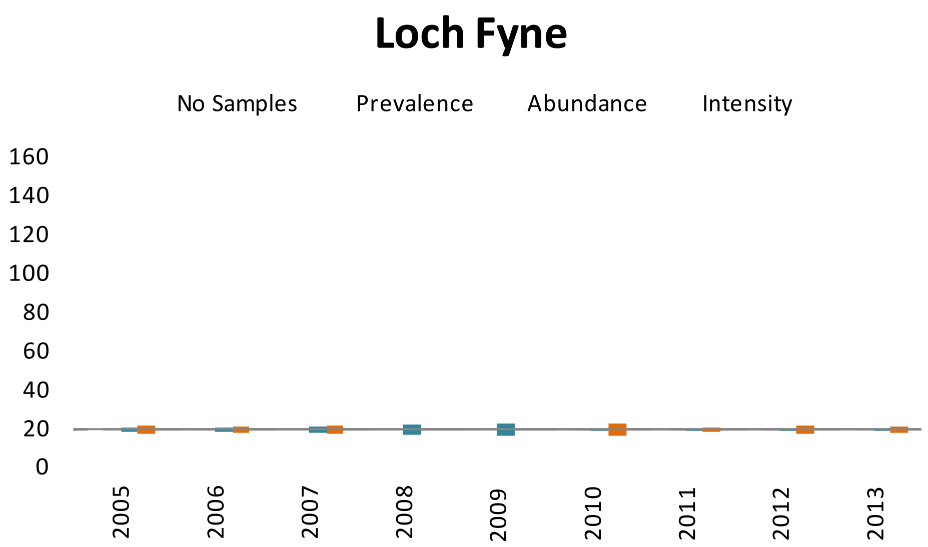

Figure A8. Post smolt sweep netting data for Loch Fyne from 2005 to 2013.

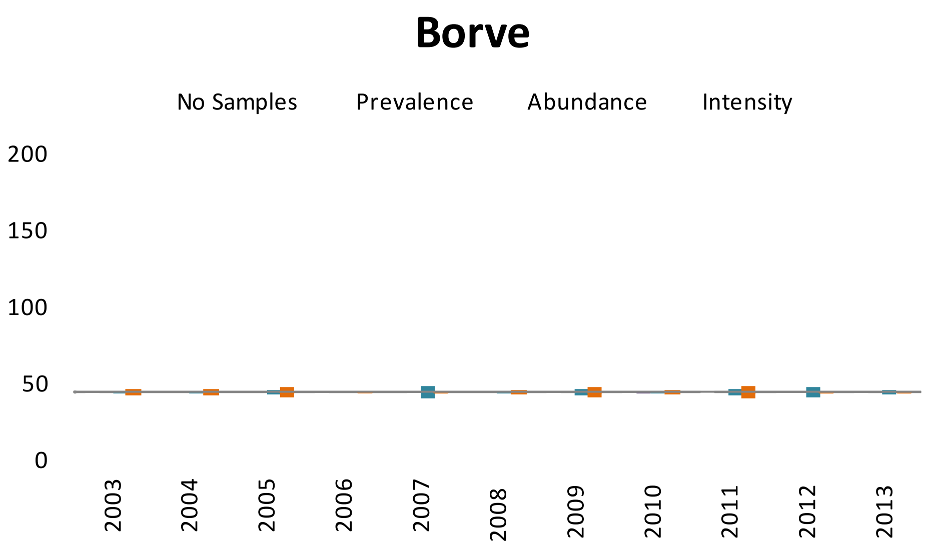

Figure A9. Post smolt sweep netting data for Borve from 2003 to 2013.