Managing Interactions Aquaculture Project

River and Fisheries Trusts of Scotland

Sea Trout Post Smolt Monitoring Project Regional Report 2011

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Summary

The River and Fisheries Trusts of Scotland (RAFTS) Sweep Netting Monitoring Project, which forms part of the wider Managing Interactions Aquaculture project funded by Marine Scotland and coordinated and delivered by RAFTS and partner fishery trusts and district salmon fishery boards, was undertaken in 2011 to examine the sea trout post smolt populations and the potential interactions with sea lice for the West Coast of Scotland. This report presents details, analysis and findings from the twenty eight monitoring sites, which are summarised below.

The focus of this project was in two main areas;

1) Describe the current status of the post smolt sea trout populations surveyed; and

2) Present the number and stages of development of sea lice that were found on post smolt sea trout at each monitoring location.

In examining the current status of the post smolts the lengths of the sea trout were examined and found to be predominately under 260mm. In comparison, the weights of the post smolts exhibited variation across the monitoring sites. The majority of the monitoring sites had post smolts described as of “good condition” with the exception of the two monitoring sites in Wester Ross. Predation pressure was provisionally explored with only two sites indicating levels of predation that might require further exploration both these sites are located in Lochaber.

Two species of sea lice were examined, *L. salmonis* and *C. elongates.* The analysis focused on the sea lice loadings and examined the comparisons of these loadings across the monitoring sites. The *L. salmonis* loading pressure on the sea trout post smolts was further examined using two critical threshold levels which were the epizootic threshold (Costello, 2009) and the *L. salmonis* mobile threshold (Wells *et al* 2006).

The results indicated that five of the monitoring sites in 2011 experienced extensive heavy infestations (epizootic). To explore the impact of these heavy infestations further the Wells *et al*, 2006 threshold was explored to determine if the infection levels at the monitoring sites resulted in a detrimental impact. The implemented critical threshold level indicated that at one site >40% of the sampled post smolts were experiencing critically detrimental infestation level and five further sites experienced <10% of the sampled post smolts were experiencing critically detrimental infestation levels.

Further discussion is presented on the monitoring site and the comparisons to the fish farm activities within the study area this includes the distance to the nearest active fish farm, site biomass and year of production. Finally a comparison of wild sea lice counts to the published fish farm sea lice counts is also documented.

The report concludes on the lessons learnt from this first year of study and discusses the implications for the development and future direction of this project.

Managing Interactions Aquaculture Project
Sea Trout Post Smolt Monitoring Programme
Regional Report 2011

1. Project Background

In 2011, the Rivers and Fisheries Trusts of Scotland (RAFTS) and its member fishery trusts and partner district salmon fishery boards on the west coast of Scotland began a programme of work funded by the Scottish Government associated with the interactions between aquaculture and wild fish populations. The Managing Interactions Project is designed to support the better coordination and management of wild fisheries and stocks with the aquaculture industry. Underpinning this programme of work were 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 aquaculture sites both current and proposed. To achieve these strategic objectives three projects were identified 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.

The three Managing Interaction projects are overseen by a Steering Group, chaired by RAFTS, which includes representatives from a range of west coast fishery trusts and boards, Marine Scotland Science and Marine Scotland Policy.

The participating fishery trusts and boards are:

- Argyll Fisheries Trust
- Argyll District Salmon Fishery Board
- Lochaber Fisheries Trust
- 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

This paper will discuss further 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. Further details on the other two Managing Interactions projects will be made available on the RAFTS website (www.rafts.org.uk) and be reported separately.

In 1999 the Tripartite Working Group (TWG) had set up Area Management Agreements (AMA) which had been developed between local industry and wild fisheries interests throughout the west coast and the Western Isles. The AMAs were designed to encourage aquaculture and wild fisheries interests to work collaboratively on a number of objectives. These objectives included:

- single year class management and synchronised production / fallowing cycles within AMA zones;
- synchronised lice treatments zero ovigerous salmon lice particularly during the critical wild smolt migration period (Feb - June);
- the preparation of containment and contingency plans to minimise escapes impacts;
- ensure adherence to industry Codes of Practice;
- regular monitoring and information exchange between AMA partners;
- adherence to disease control mechanisms in wild fisheries; and
- finally a number of other local specific management aspects.

Under the TWG support to the AMAs a network of sweep netting sites were set up to monitor the wild fish populations and to support the local Area Management Groups (AMG). The results of these sweep netting activities were reported individually and locally to respective AMGs. The TWG project ended in March 2011 and the monitoring project was continued under the Managing Interactions project. Despite the cessation of the TWG, many of the AMAs remain active and are now run at the local level. Figure 1 indicates the distribution of currently signed AMAs on the West Coast of Scotland and the Western Isles.

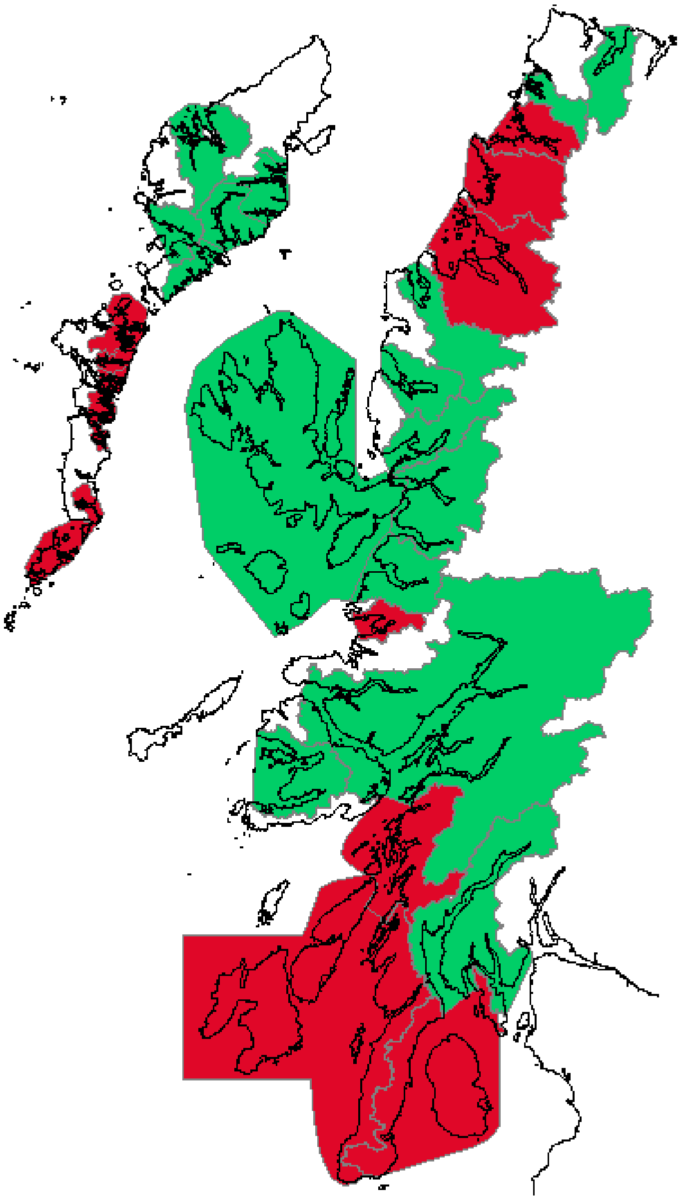

Figure 1: Map of Area Management Group Regions. Signed and active AMAs indicated by green shading with grey boundaries and Un-signed areas are shown as red with grey boundaries.

1.1 Strategic programme of post smolt sweep netting and analysis 2011

In early 2011 a complete and rigorous assessment of previous monitoring sites sampled under the TWG project along with a suite of potential monitoring sites were considered for inclusion in this project. The initial site assessments involved Trusts, Boards and Marine Scotland Science. The final network of sites identified includes twenty eight core sites throughout the West Coast of Scotland which aimed to give extended coverage of sites across a range of distances from fish farms. The project also aimed to focus 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).

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 2011

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 1837) and/or *Caligus elongatus* (Nordmann 1832). *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.

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.

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 “over-dispersion”, 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.

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).

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.

The sampling data from all the Trusts was compiled by the project coordinators in a structured Access Database (2010) in preparation for analysis. Analyses of the data involved descriptive statistics and graphs which were prepared in Excel (2010).

2.2 Site Information

The final network of sites identified includes twenty eight core sites throughout the West Coast of Scotland aimed at achieving good coverage of sites across a range of varying distances from active fish farms (Figure 2). The twenty eight sites were identified across six fisheries trusts on the west coast (Table 1). Each individual Trust was responsible for completion of the sweep netting surveys of the sites within their own area.

Table 1: Monitoring Site Details.

Map Site ID (Figure 2)	Sweep Netting Site	Fisheries Trust	Number of Site Visits	Number of Sea Trout Caught 260mm Threshold	Current Distance to Active Fish Farm (Km)
1	Carradale	Argyll	2	36	9
2	Southend	Argyll	1	0	44
3	Machrihanish	Argyll	1	0	31
4	Loch Fyne	Argyll	2	60	24
5	West Riddon	Argyll	2	33	3
6	Dunstaffnage	Argyll	2	41	4
7	West Tarbert	Argyll	1	0	22
8	Laggan Bay	Argyll	1	0	62
9	Kinlocheil	Lochaber	8	100	20
10	Camas na Gaul	Lochaber	6	83	6
11	Sunart	Lochaber	9	8	10
12	Tong	Outer Hebrides	4	71	40
13	Ardroil	Outer Hebrides	4	11	23
14	Borve	Outer Hebrides	4	181	10
15	Eishken	Outer Hebrides	3	41	3
16	Kyles	Outer Hebrides	3	55	23
17	Malacleit	Outer Hebrides	3	26	25
18	Slapin	Skye	3	27	4
19	Harport	Skye	3	29	2
20	Kyle of Durness	West Sutherland	2	59	22
21	Polla	West Sutherland	3	33	7
22	Laxford	West Sutherland	2	41	4
23	Kinloch	West Sutherland	1	0	35
24	Kannaird	Wester Ross	2	28	1.5
25	Boor Bay	Wester Ross	3	31	8
26	Flowerdale	Wester Ross	2	36	26
27	Carron	Wester Ross	3	0	10
28	Gruinard Bay	Wester Ross	1	0	14

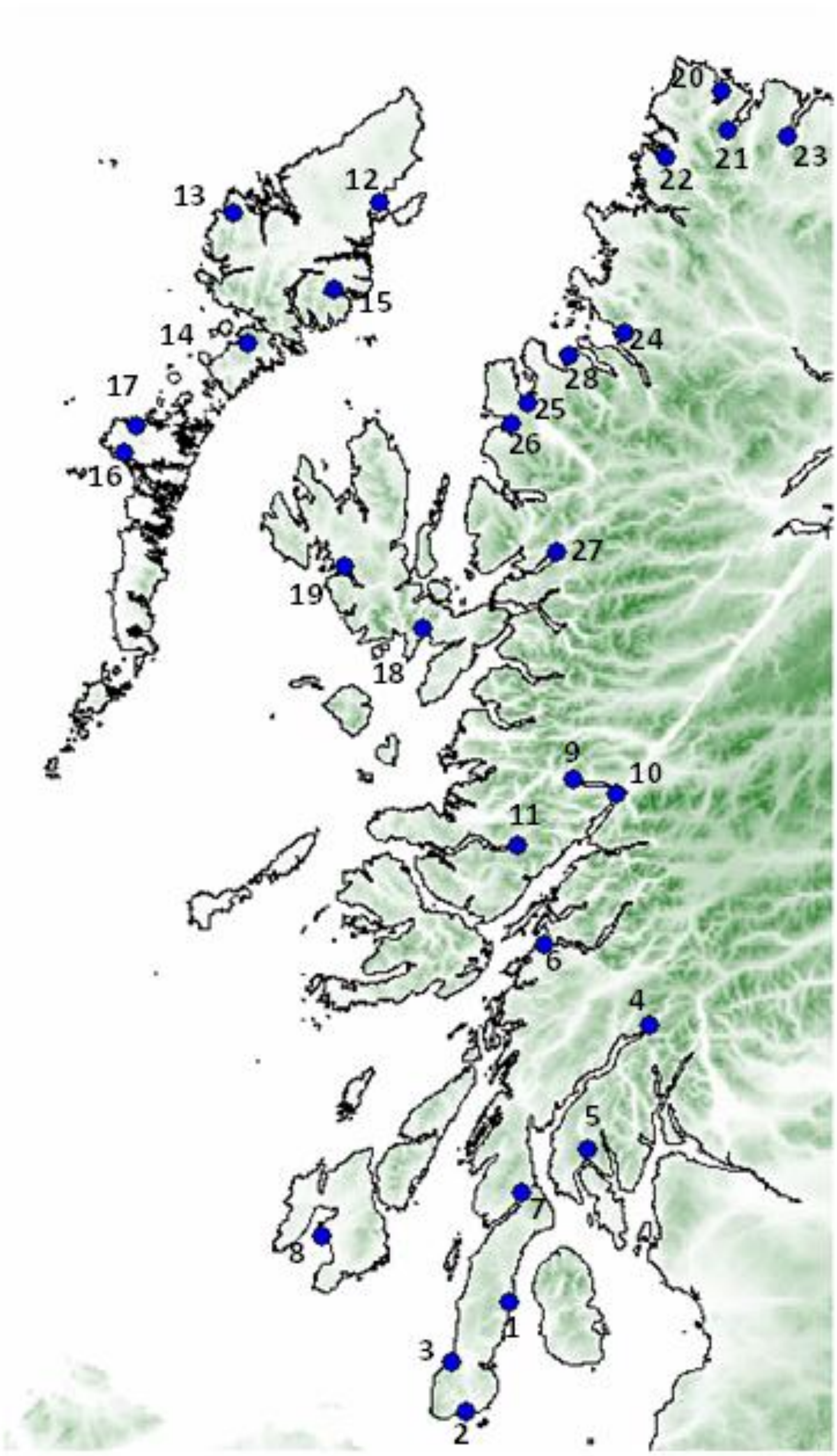

Figure 2: Geographical spread of monitoring sweeping sites sampled in 2011 (Blue dot indicates monitoring site please see Table 1 for full site details).

3. Sweep Netting Analysis Results

3.1. Sea Trout Analysis

The total number of post smolts caught at each site varied. The variation arose due to a number of factors such as weather conditions which led to unsafe sampling conditions and the simple absence of fish from both new sweep netting sites included to provide sample points at a range of distances from active fish farms and established sites where previous surveys had been successful in fish capture. Some sites did not produce the numbers of fish noted in previous years despite significant effort from the Trust teams. In addition five of the new monitoring sites were not successful although in some of these sites the minimum planned sampling effort was not delivered by the surveying trusts. An assessment and review of sites in the current study which were unsuccessful and did not provide the desired sample numbers will be required in advance of any future sweep netting activities.

Under the SFCC protocol the recommended minimum sample size for statistical analysis is currently advised as thirty fish. As can be seen from Table 1 fifteen of the initial twenty eight sites achieved this minimum sample size, four sites fell just below the minimum sample size and finally nine sites either produced very few fish or no fish at all well below the minimum sample size. However this report does present results for all sites that recorded data even if they fell below this minimum sample size and aims to report all observation of the samples taken over the study period.

3.1.1 Length, Weight and Condition Factor

Across the monitoring sites as anticipated the sea trout were predominately under 260mm (Figure 3). Unlike the sea trout post smolt length, the weight of the post smolts shows a much greater variation across the monitoring sites (Figure 4). It must be noted that weight data was not collected at all sites due to factors including severe weather conditions which created problems sampling weights under the environmental conditions being experienced. 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.

For monitoring sites that had available length and weight data the condition factor was calculated for all fish 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 fourteen sites with available data only two fall below the 1 factor level, Kinnaird and Flowerdale in Wester Ross (See Appendix 3 for further details).

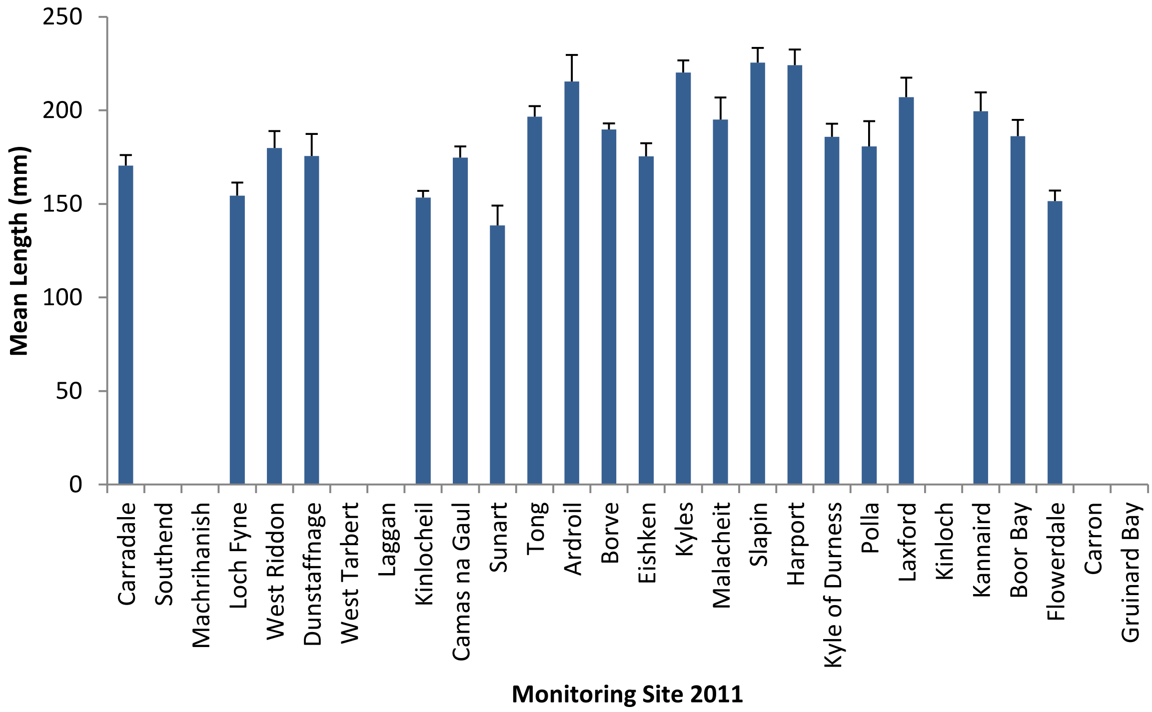

Figure 3: The mean sea trout lengths (mm) at each monitoring site.

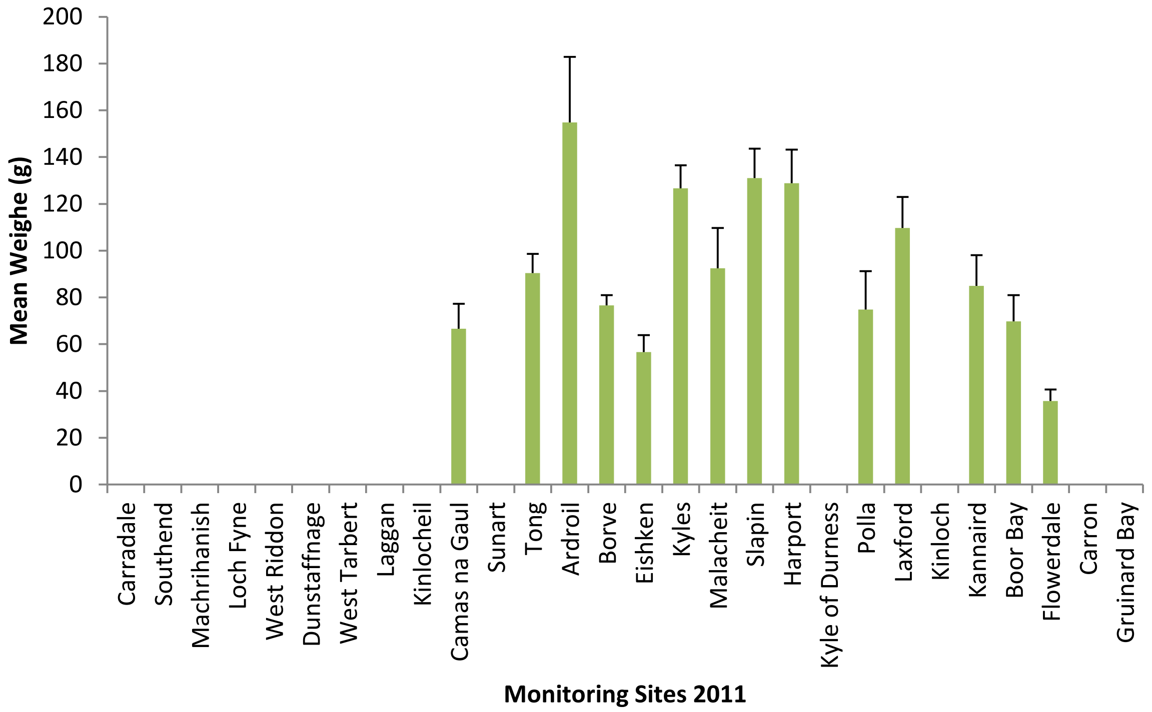

Figure 4: The mean sea trout weights (g) at each monitoring site. * Weight data was collected at only the sites indicated, please see Appendix three for full details.

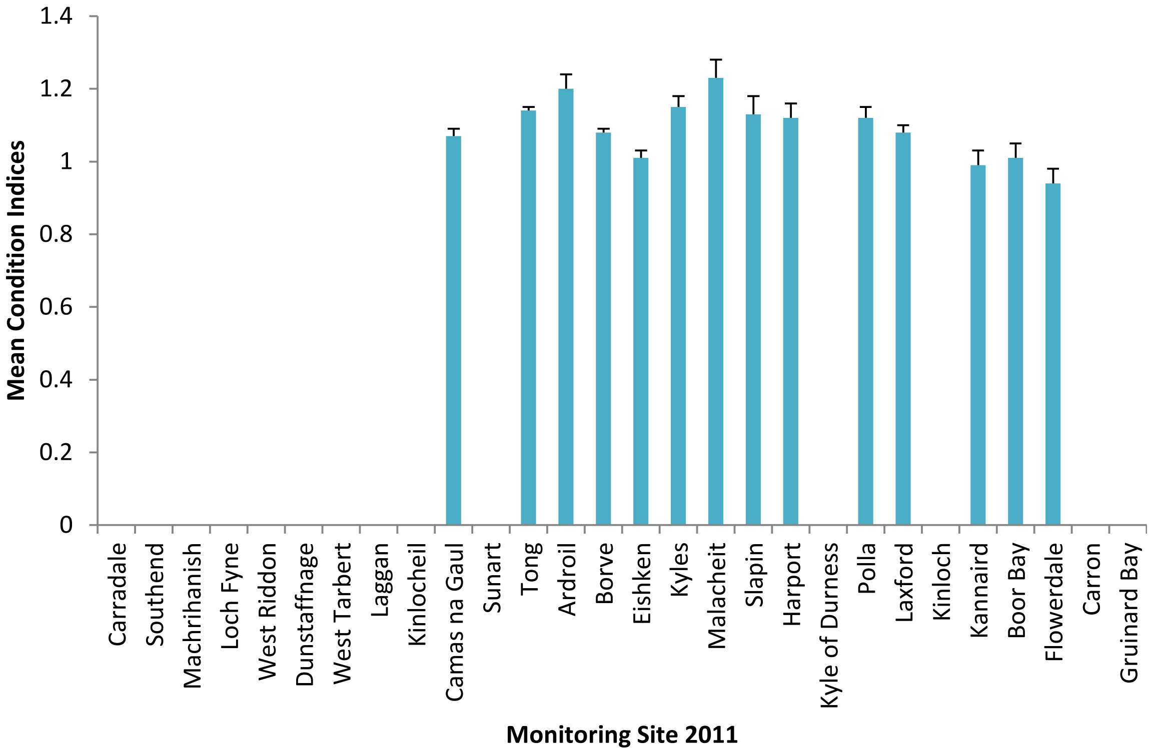

Figure 5: The mean sea trout Condition Indices at each monitoring site. * Weight data was collected at only the sites indicated, please see Appendix three for full details.

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 it was categorised to the likely predator species and the percentage level of damage/scale loss was also recorded by the Fisheries Biologist. Predation was observed at fifteen sites across the West Coast and the Western Isles (Figure 6).

From the predation recorded the majority were from seals and birds with a few recorded as due to otter damage. Two monitoring sites recorded indicative high levels of physical damage from predation which are Kinlocheil and Camas na Gaul both in Lochaber. It is recommended that further studies into predation pressure on the sea trout post smolts should be explored to further understand the pressure dynamics being experienced at these sites.

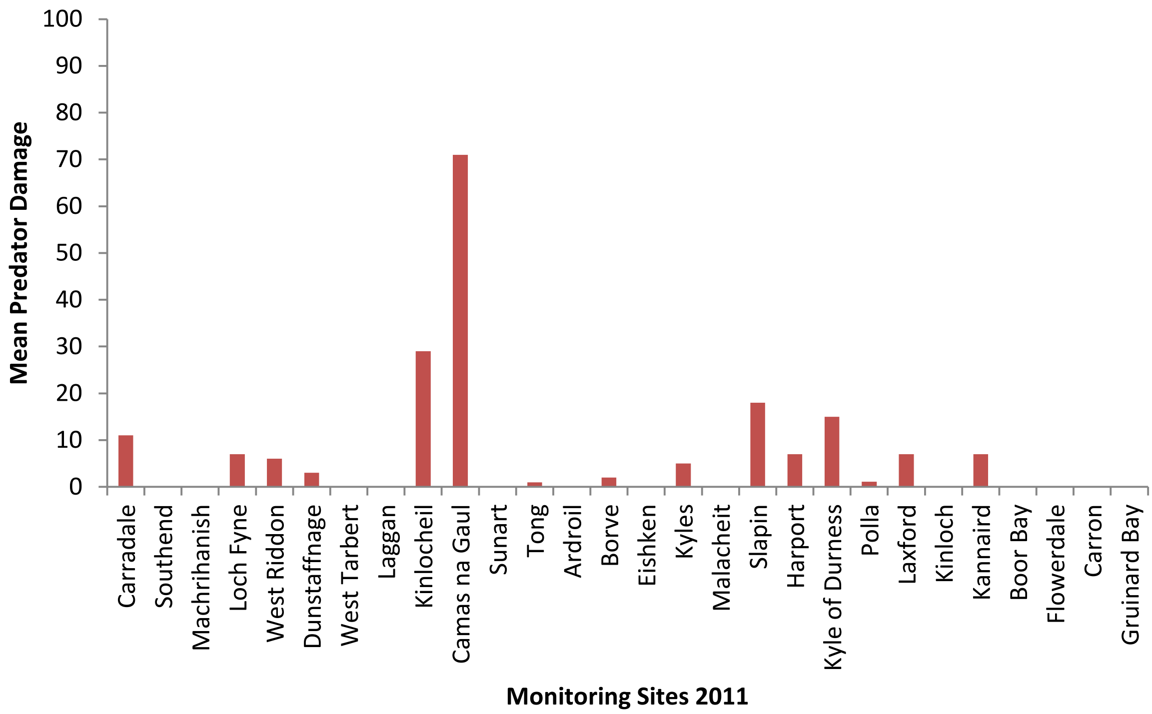

Figure 6: The percentage sea trout predator damage recorded at each monitoring site.

3.2 Sea Lice Analysis

3.2.1 *L. salmonis* Copepodid and Chalimi life Stages

The *L. salmonis* immature life stages under examination here are 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 significant levels for each of the sites with no information on background levels of sea lice data available. From the data collected in 2011 and considering the individual sites compared to the regional mean of 2.33 for abundance, a mean regional intensity of 8.36 and a regional mean prevalence of 31 it can been seen that the majority of sites reported and recorded levels of Copepodid/Chalimi presence below the regional mean for abundance, intensity and prevalence (Figure 7 and Figure 8). However there are three sites which could be classed as experiencing elevated levels of Copepodid/Chalimi presence when considering the regional means for abundance, intensity and prevalence these are Camas na Gaul (Lochaber), Kinnaird (Wester Ross) and Laxford (West Sutherland). To ensure that the regional means are not being representing by any particularly high outliners the median which is less influenced by outliers was explored. As can be seen from Figure 9 again Camas na Gaul (Lochaber), Kinnaird (Wester Ross) and Laxford (West Sutherland) are indicated as experiencing elevated levels.

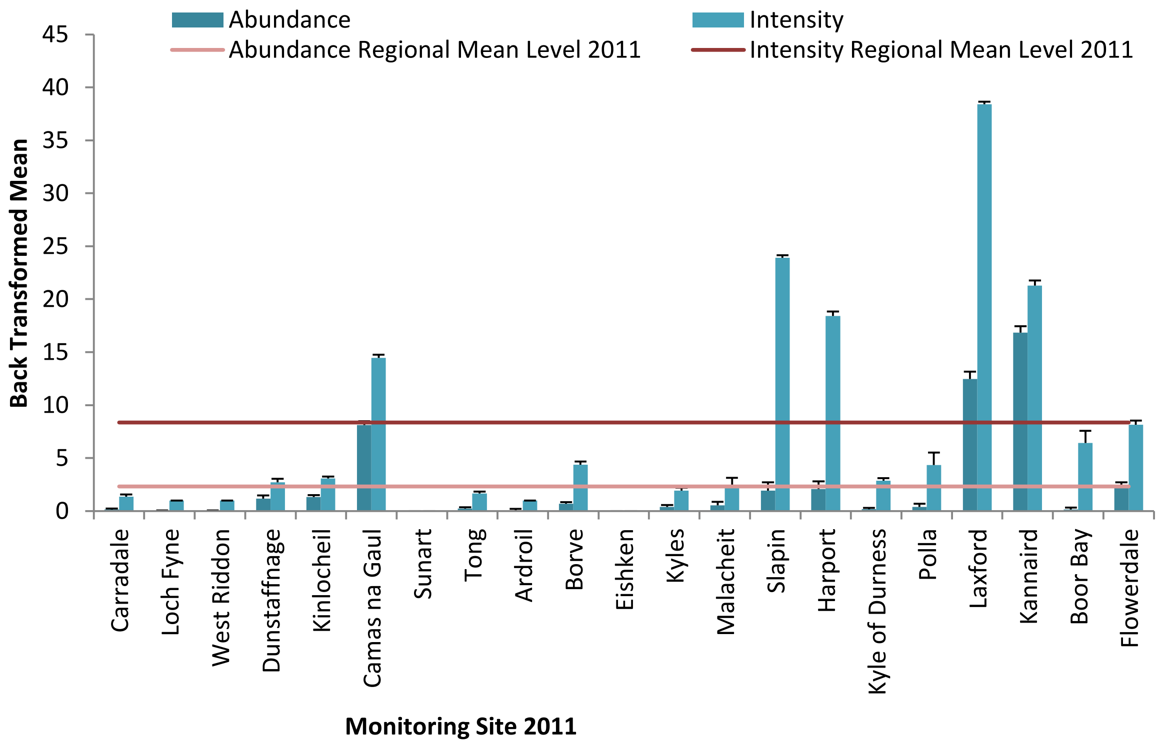

Figure 7: Back Transformed means in 2011 for Abundance and Intensity for Copepodid/ Chalimi at each monitoring site (including 95% confidence intervals).

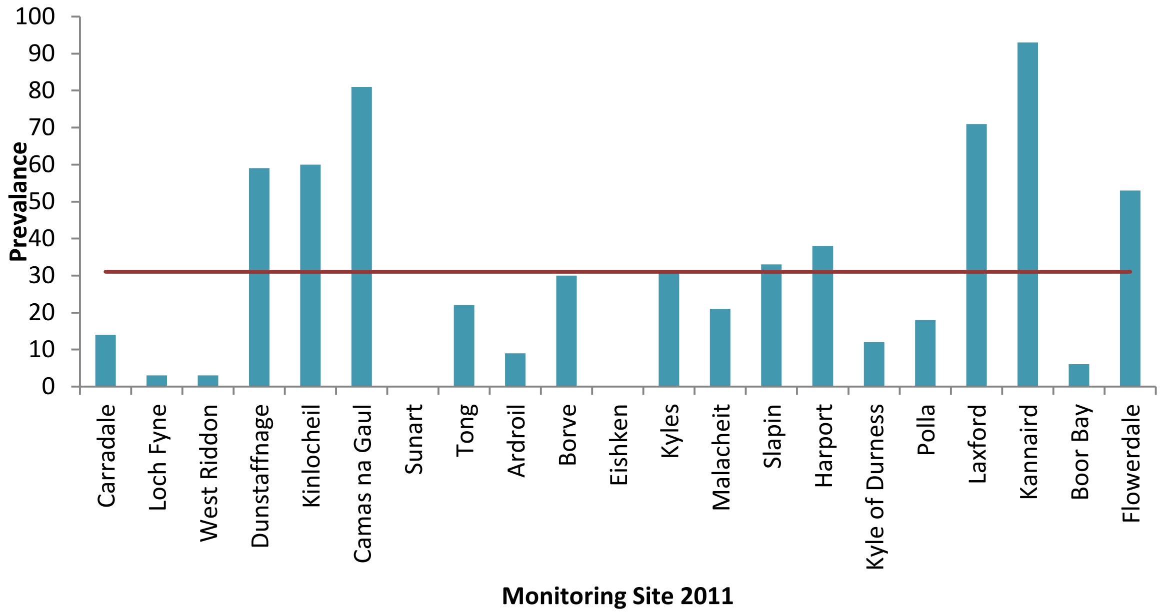

Figure 8: Prevalence results of Chalimi/Copepodid stages at each monitoring site. The prevalence regional mean level for 2011 is indicated on the graph as a red solid line.

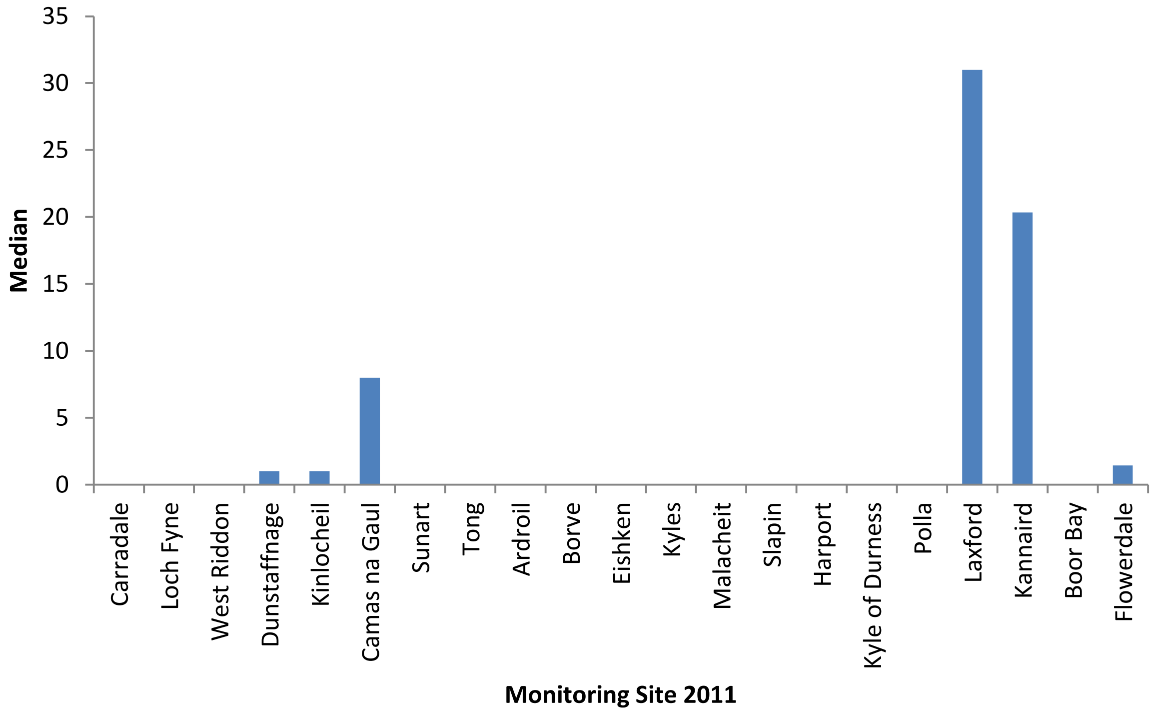

Figure 9: Median results of Chalimi/Copepodid stages at each monitoring site. The median regional level for 2011 is 0.

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 2011 and considering the individual sites compared to the regional mean of 1.17 for abundance, a mean regional intensity of 3.41 and a mean region prevalence of 37 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 10 and Figure 11). However there are five sites which could be classed as experiencing elevated levels of preadult and adult presence when considering the regional mean for abundance, intensity and prevalence. These are Dunstaffnage (Argyll), Kyles (Outer Hebrides), Malacleit (Outer Hebrides), Camas na Gaul (Lochaber) and Laxford (West Sutherland). 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 four of the five sites Dunstaffnage (Argyll), Kyles (Outer Hebrides), Malacleit (Outer Hebrides) and Camas na Gaul (Lochaber) are indicated as experiencing elevated levels. However the fifth site Laxford (West Sutherland) is below the regional median and therefore less likely to be experiencing elevated mobile life stages.

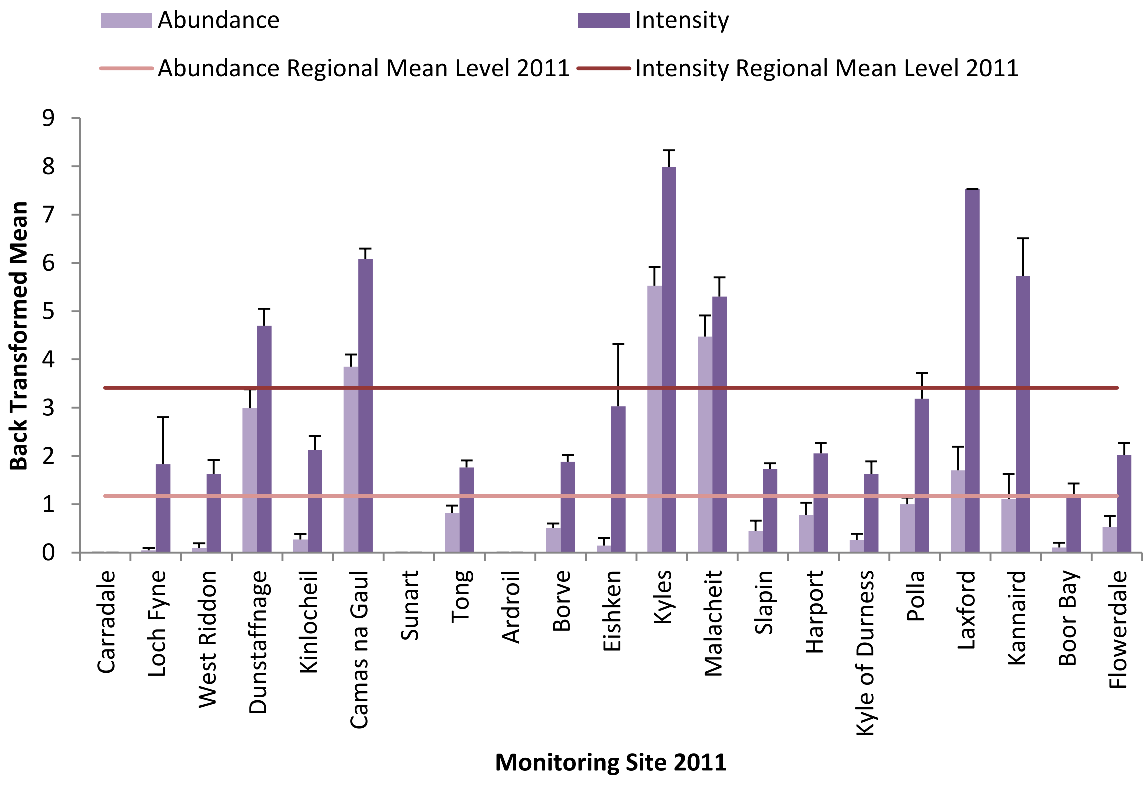

Figure 10: Back Transformed means in 2011 for Abundance and Intensity results for Preadult/Adult at each monitoring site (including 95% confidence intervals).

Figure 11: Prevalence results for Preadult/Adult *L. salmonis* stages at each monitoring site. The prevalence regional mean level for 2011 is indicated on the graph as a red solid line.

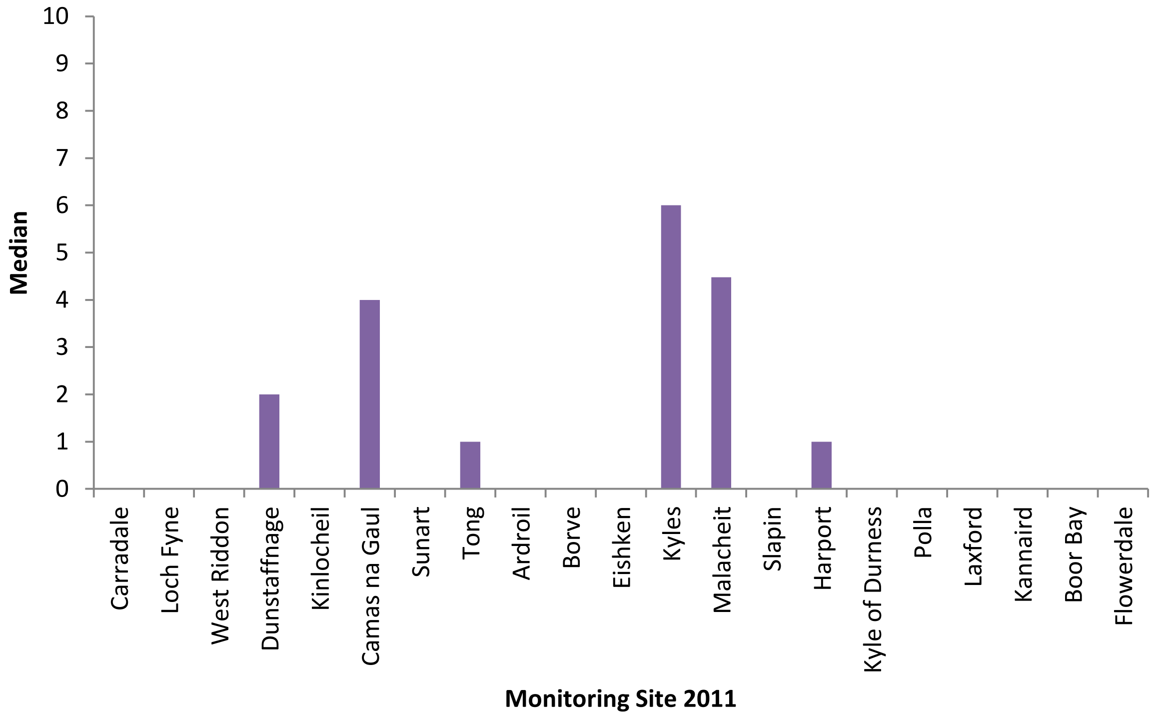

Figure 12: Median results for Preadult/Adult L. salmonis stages at each monitoring site. The median regional level for 2011 is 0.

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 1000 eggs.

From the data collected in 2011 and considering the individual sites compared to the regional mean of 0.21 for abundance, a mean regional intensity of 1.65 and a regional mean prevalence of 15 it can been seen that the majority of sites reported and recorded levels of ovigerious female presence below the regional mean for abundance, intensity and prevalence (Figures 13 and 14). Only three sites could be classed as experiencing elevated levels of ovigerious female presence when considering the regional mean for abundance, intensity and prevalence these are Kyles (Outer Hebrides), Malacleit (Outer Hebrides) and Polla (West Sutherland). 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 15 two of the three sites Kyles (Outer Hebrides) and Malacleit (Outer Hebrides) are indicated as experiencing elevated levels. However the third site Polla (West Sutherland) is below the regional median and therfore unlikely to be experiencing elevated mobile life stages.

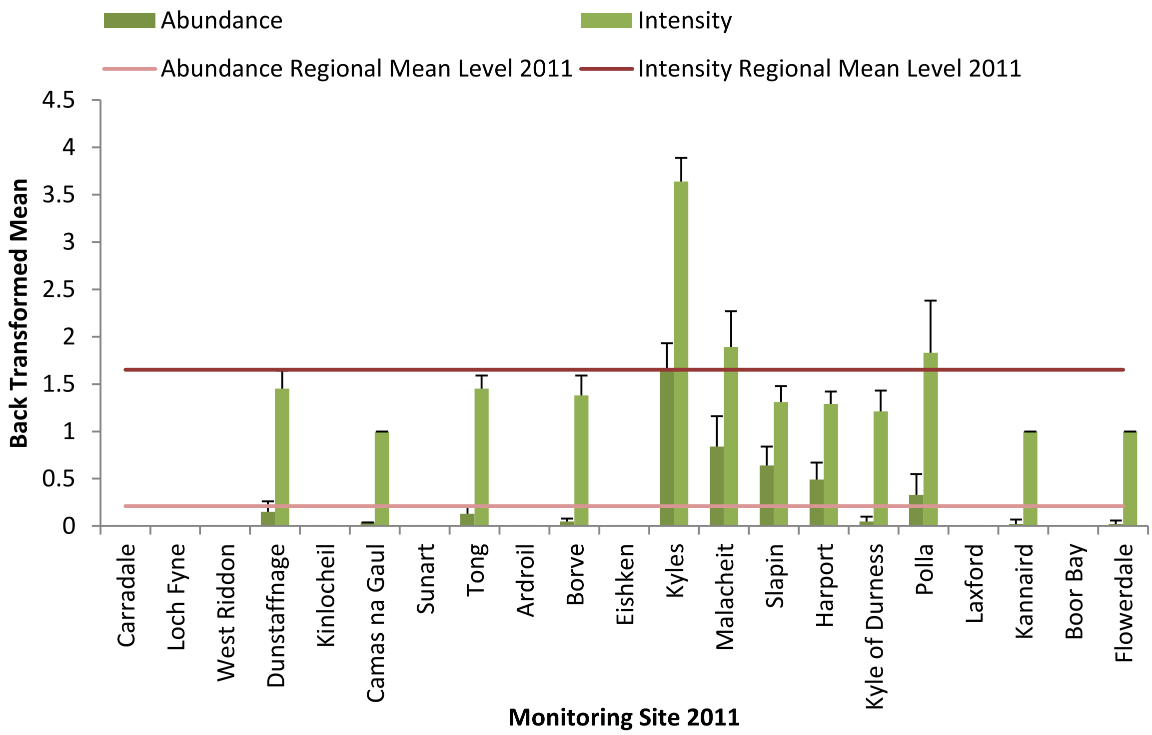

Figure 13: Back Transformed means in 2011 for Abundance and Intensity results *for L. salmonis* ovigerous females at each monitoring site (including 95% confidence intervals).

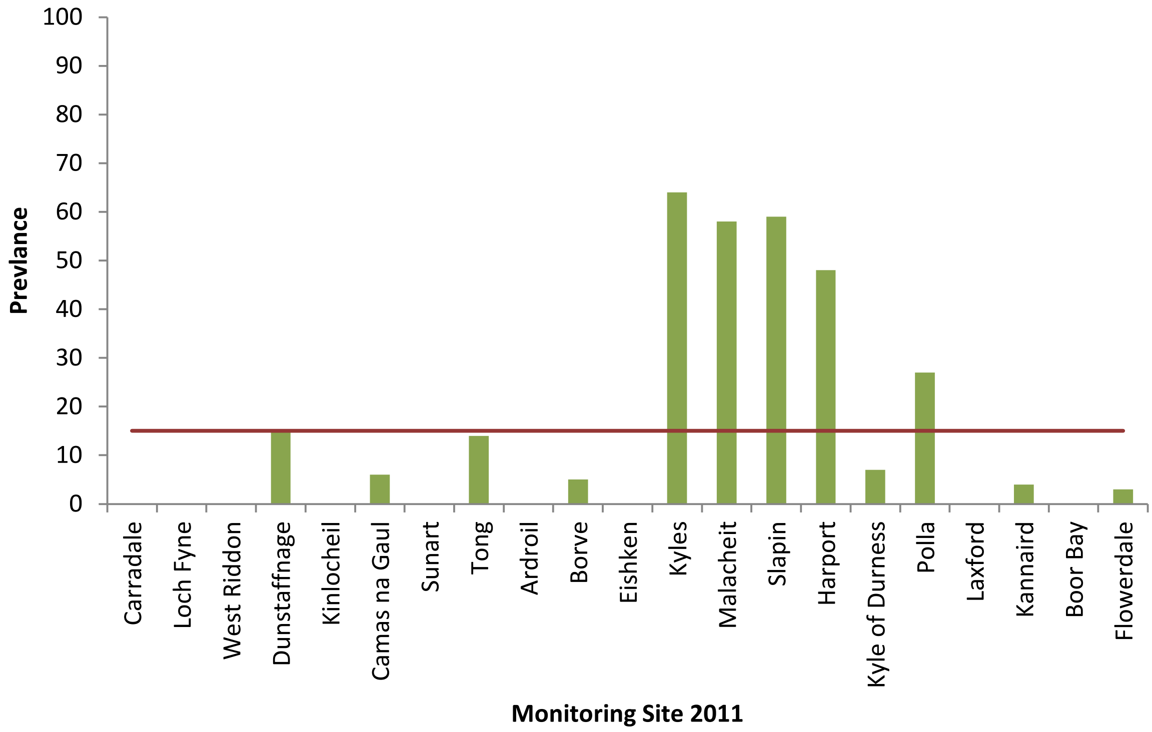

Figure 14: Prevalence results for *L. salmonis* ovigerous females stage at each monitoring site. The prevalence regional mean level for 2011 is indicated on the graph as a red solid line.

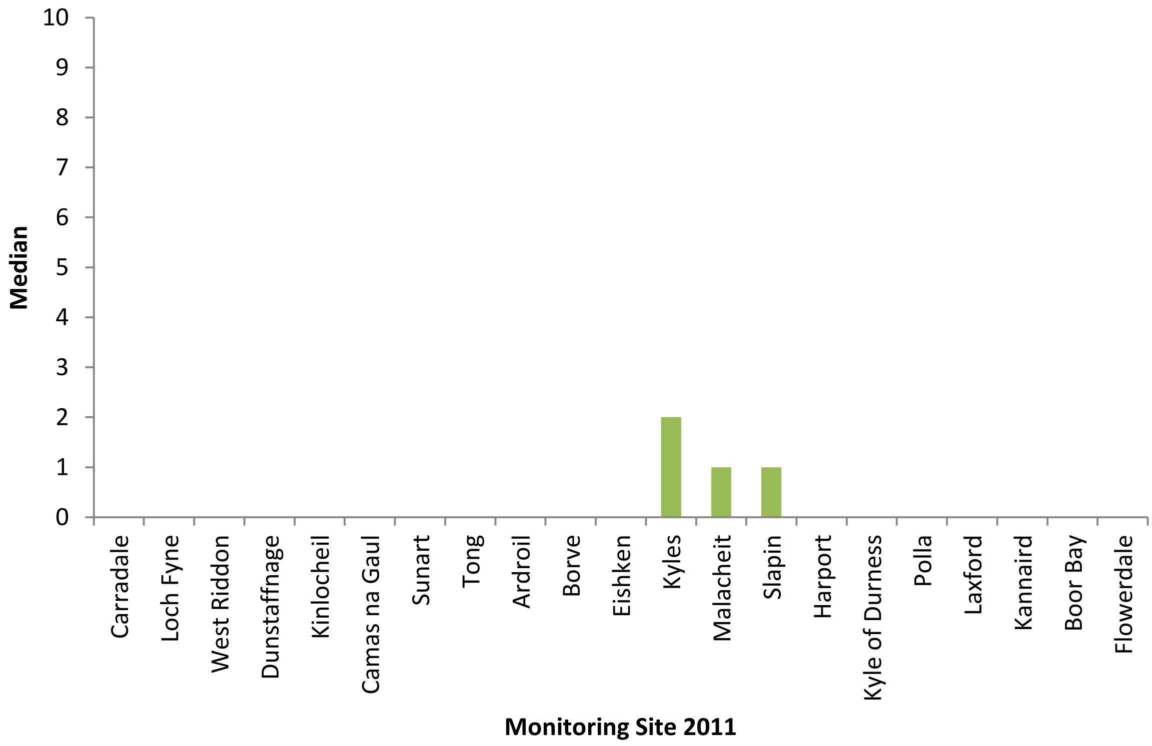

Figure 15: Median results for L. salmonis ovigerous females stage at each monitoring site. The median regional level for 2011 is 0.

3.2.4 *L. salmonis* all life Stages.

A final examination of the total counts of the 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 regional mean for abundance 3.81, regional mean for intensity of 7.75 and a regional mean prevalence of 50 in 2011 (Figures 16 and 17). However there are four sites which indicate elevated presence levels in comparison to the regional means. These are Kyles (Outer Hebrides), Camas na Gaul (Lochaber), Kinnaird (Wester Ross) and Laxford (West Sutherland). 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 18 all four sites Kyles (Outer Hebrides), Camas na Gaul (Lochaber), Kinnaird (Wester Ross) and Laxford (West Sutherland) are indicated as experiencing elevated levels. Further exploration of these results and their potential detrimental impacts can be found in section 4.

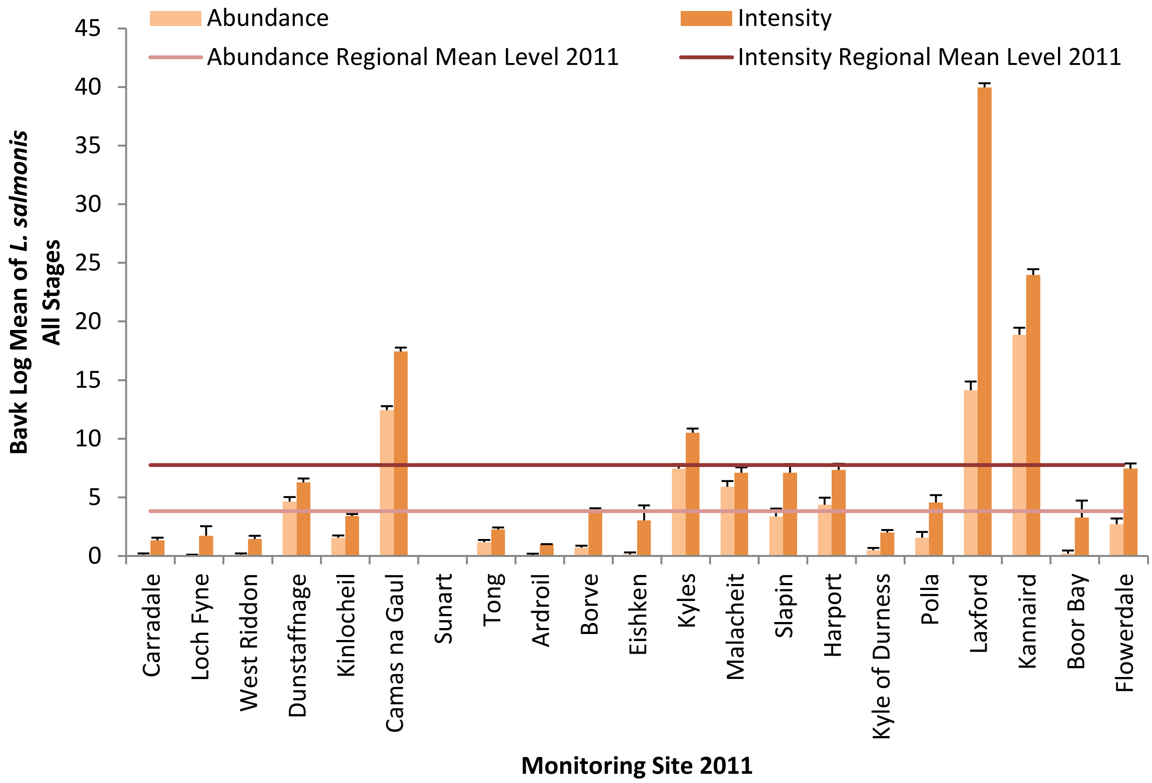

Figure 16: Back Transformed means in 2011 for Abundance and Intensity results for all *L. salmonis* stages at each monitoring site (including 95% confidence intervals).

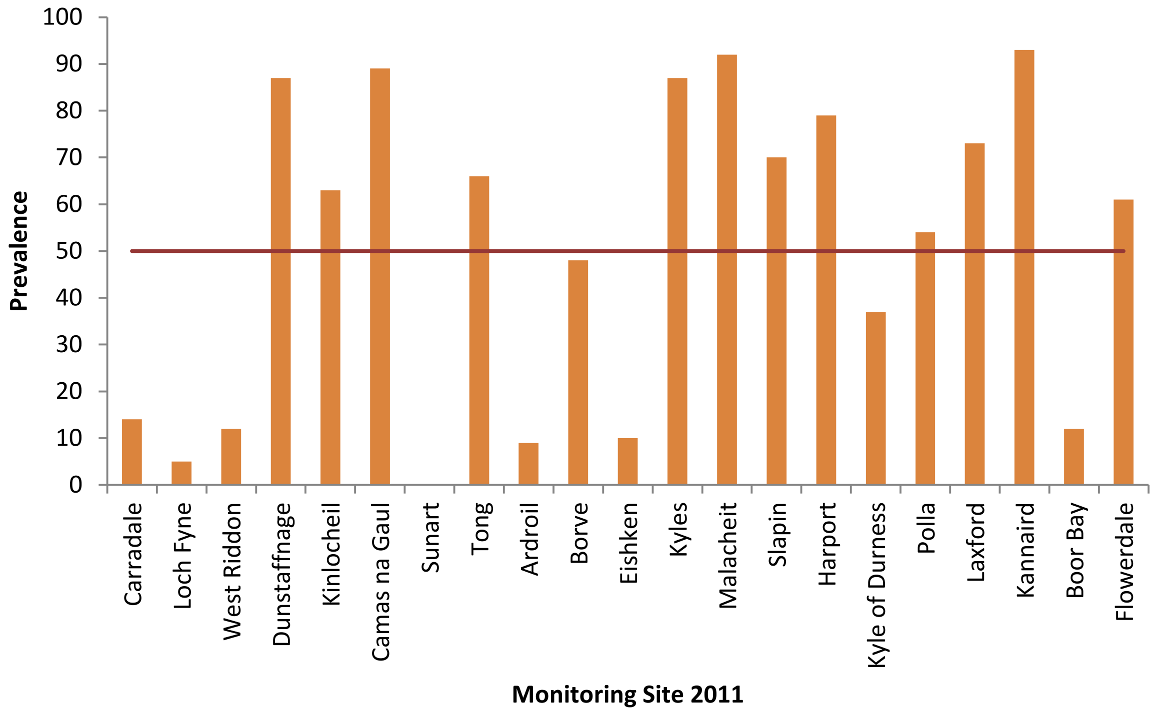

Figure 17: Prevalence results for all *L. salmonis* stages presence at each monitoring site. The prevalence regional mean level for 2011 is indicated on the graph as a red solid line.

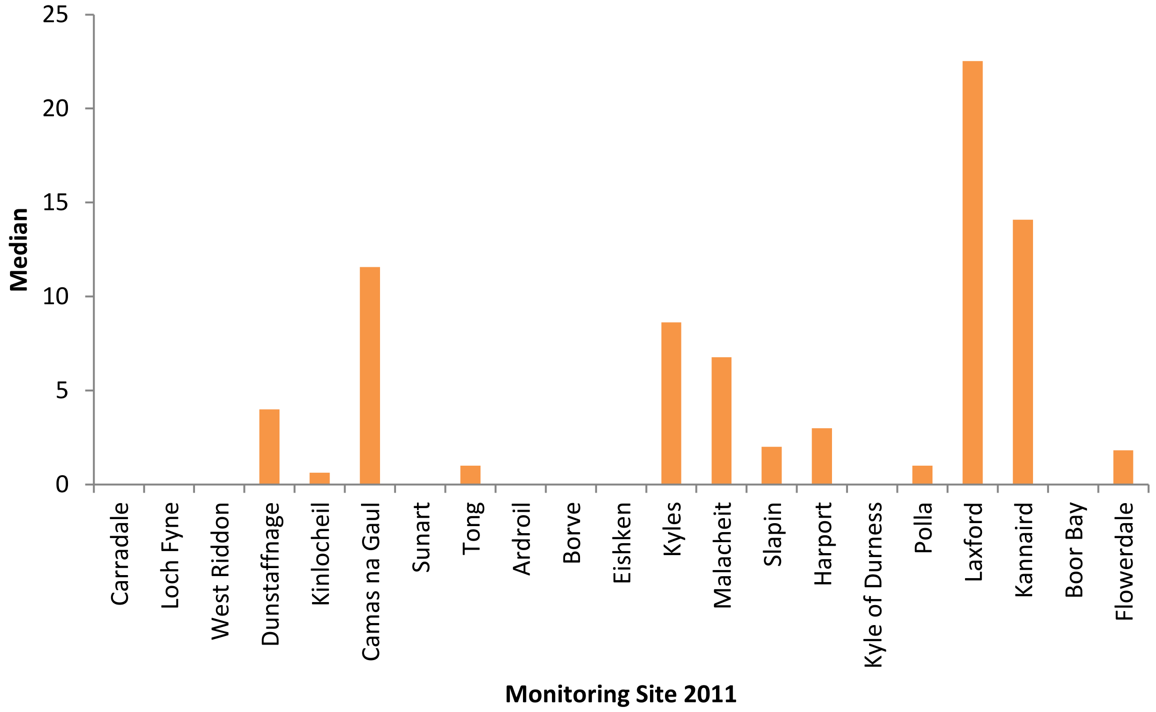

Figure 18: Median results for all *L. salmonis* stages presence at each monitoring site. The median regional level for 2011 is 1.

3.1.5 *C. Elongatus* all life Stages

Caligus elongatus is much smaller, 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 *C. elongatus* was only identified as being present in Skye, West Sutherland and the Outer Hebrides. 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 2011 and considering the individual sites compared to the regional mean of 0.48 for abundance, a mean regional intensity of 5.59 and a regional prevalence mean of 10. Where this species was identified as present, overall it was at extremely low presence levels. Only one site in West Sutherland Laxford demonstrates elevated presence levels in comparison to the regional means for abundance, intensity and prevalence (Figures 16 and 17). 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 18 Laxford (West Sutherland) is indicated as experiencing elevated levels.

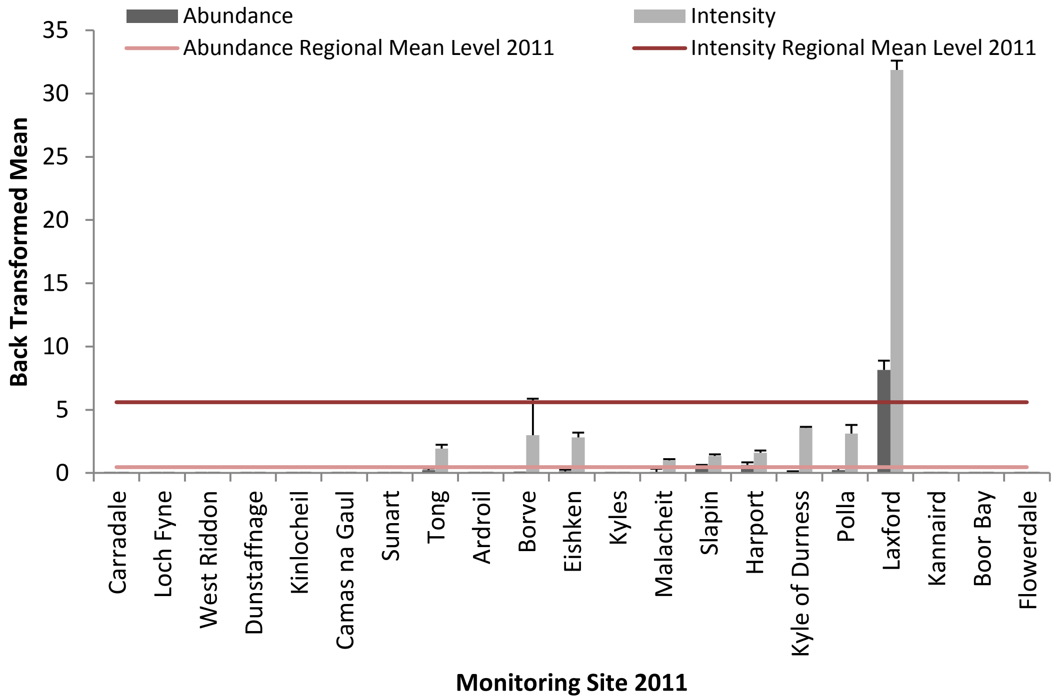

Figure 16: Back Transformed means in 2011 for Abundance and Intensity results for all *C. elongatus* stages at each monitoring site (including 95% confidence intervals).

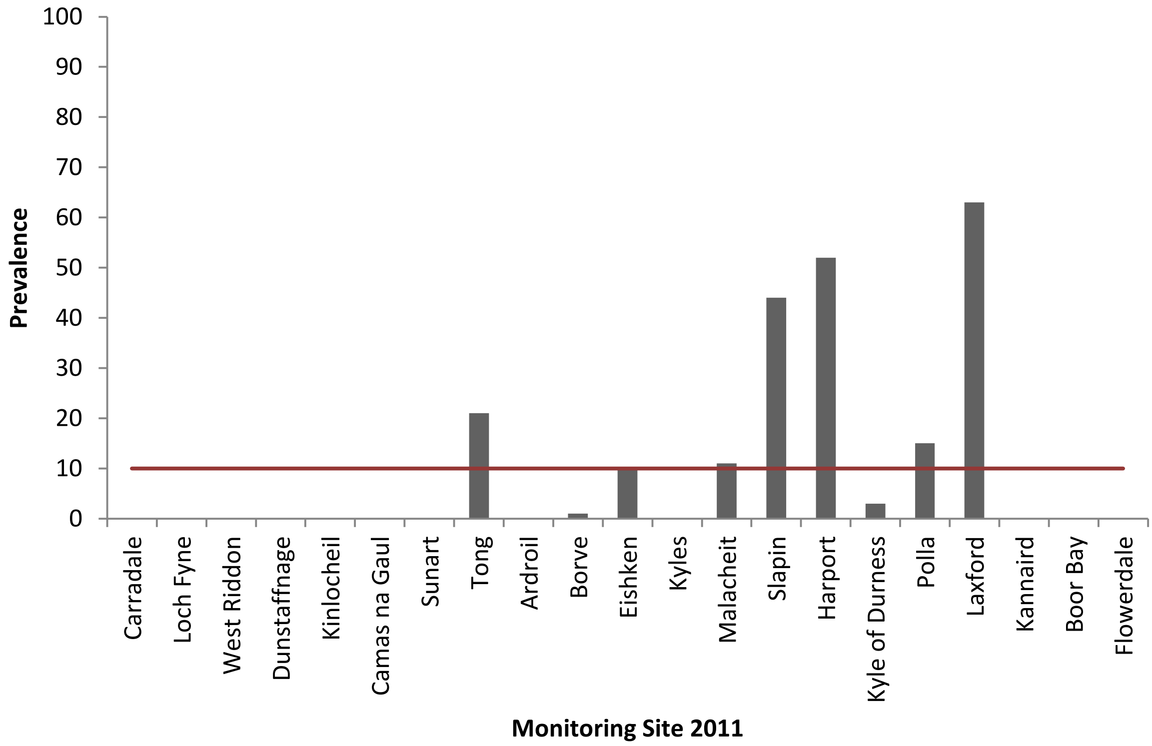

Figure 17: Prevalence results for Total *C. elongatus* presence at each monitoring site. The prevalence regional mean level for 2011 is indicated on the graph as a red solid line.

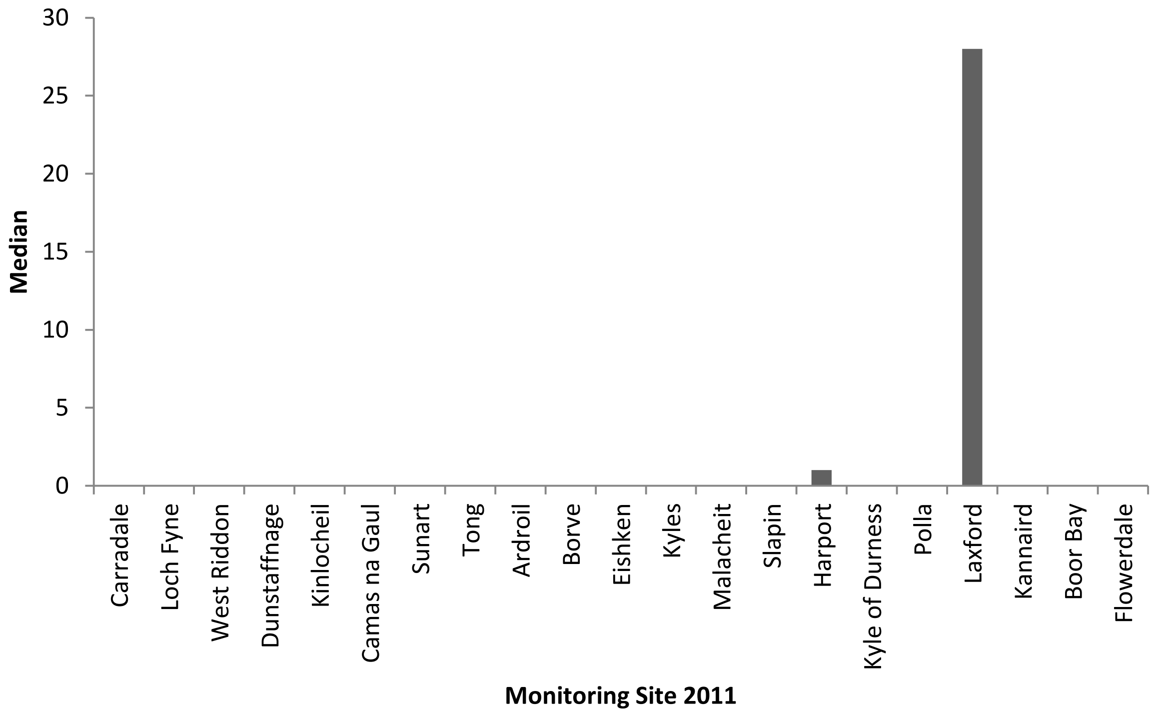

Figure 18: Median results for Total *C. elongatus* presence at each monitoring site. The median regional level for 2011 is 0.

4. Discussion

Overall when considering the results of the post smolt sea trout populations the lengths and weights are in line with the predicted results and from these, the mean condition factors across the populations are encouraging and indicative of fish in good condition. The majority of the sites showed low levels of damage from predation but some identified sites recorded levels of predator damage which may merit further work to attempt to quantify any detrimental impact caused by predators. Particularly as one of these sites Camas na Gaul (Lochaber) as discussed in section 4.1 are also indicating elevated lice loadings that may be having an impact on the dynamics of the prey/predator relationship in these areas.

To fully understand the implications of the sea lice presence 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 post smolt 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 was 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 there are five sites that have experienced sea lice levels that could potentially be categorised as epizootics (Figure 19). 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.

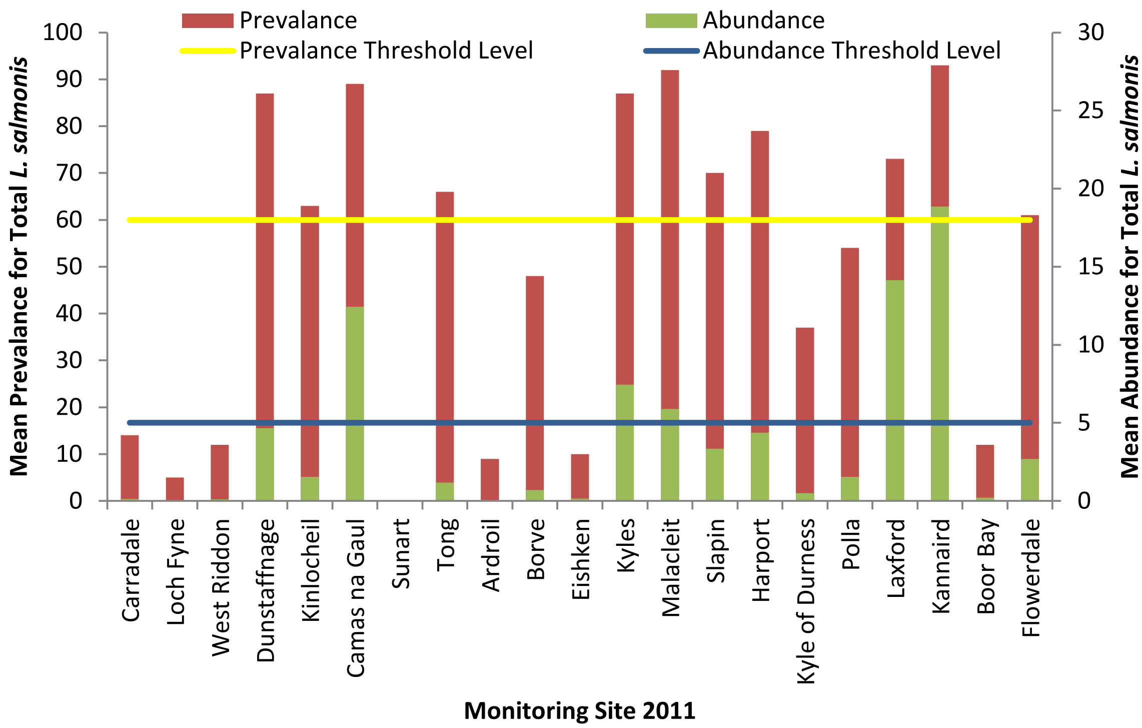

Figure 19: Prevalence and Abundance results for all *L. salmonis* stages at each monitoring site in 2011. The Costello 2009 threshold levels for identifying epizootics are highlighted on the graph by a solid yellow line for the prevalence threshold and a solid blue line for the abundance threshold.

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 was implemented. As not all weight data was available for all sites as was employed under the previous study by Middlemas *et al* 2010, 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.

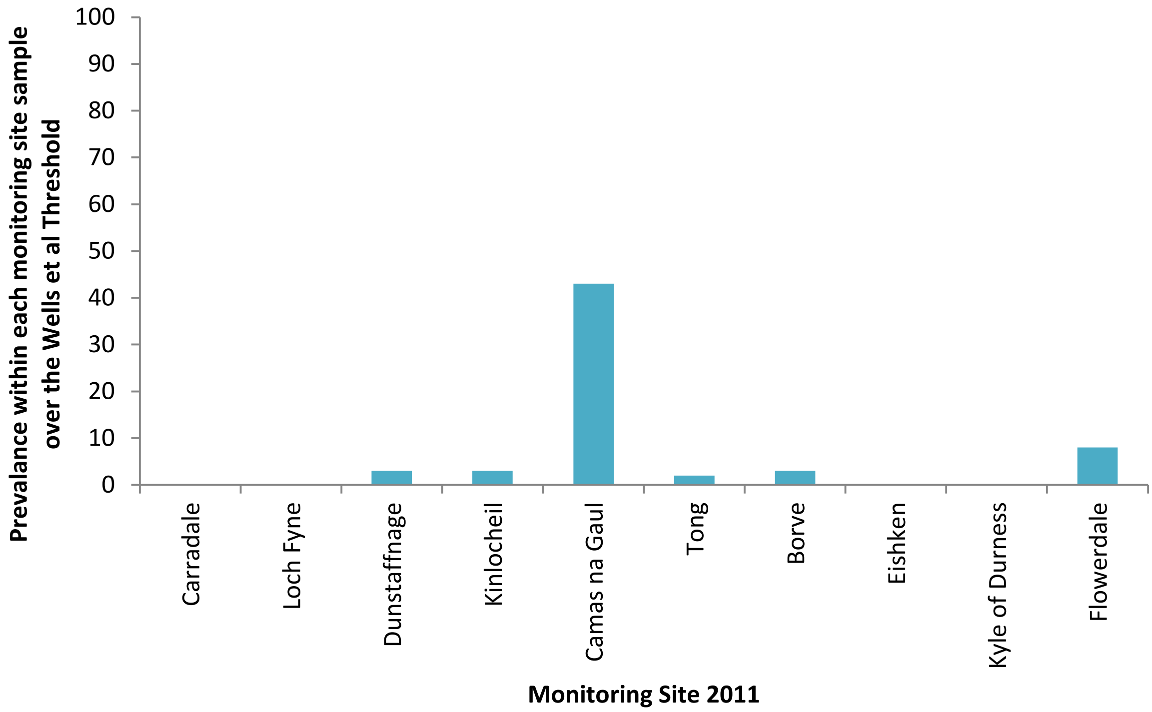

Figure 20: Percentage of fish within each monitoring site sample which has been identified over the Wells et al, 2006 threshold.

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 were identified for each monitoring site (Figure 20). One monitoring site Camas na Gaul which has 43% of the sample carrying detrimental lice loads. In comparison all other sites with a valid sample size have experienced less than 10% of the sample recorded as carrying detrimental loads.

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

> "*that a level of 10% or fewer of wild sea trout in any given population in Ireland bearing total infestations of ≥13 lice • fish-1 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-1) >10% should perhaps be considered a cause for concern*."

Being able to adopt such an acceptable or unacceptable proportion of lice loadings in Scotland would aid the local management strategies and policies greatly. To achieve this would require the collation and evaluation of sea trout captured at 50km and greater from active fish farms in Scotland and this is one of the aims of the managing interactions monitoring work as it goes forward into 2012.

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 a number of the monitoring sites in 2011 *C. elongates* was identified as also 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

4.2.1 Monitoring Site comparisons to nearest active Fish Farm.

Previous monitoring data collected under the TWG project was analysed by Marine Scotland Science (Middlemas *et al*, in peer review) which explored the levels of sea lice in relation to distance to fish farm covering the period of 2003 to 2009. Whilst only a preliminary analysis of the 2011 data could be carried out as part of this study, further exploration of this factor remains a priority going forward into 2012.

Data was obtained from Scottish Environment Protection Agency on the nearest farms to the monitoring site. Data acquired included year of production and mean biomass at fish farm site for the period of May to July 2011. As can be seen from Figure 21 the majority of the active fish farm sites were in the second year of production. It was anticipated that the data collected in 2011 would allow for further analyses of the distance aspect of sea lice interactions between wild fish and farmed fish. This year monitoring sites between 10km to 20km and 25km to 40km have not been as successful as in previous years. As mentioned previously this was is due to factors including severe weather conditions which created unsafe sampling conditions and the simple absence of fish at survey times. In respect of some the new sites the minimum planned sampling effort was not implemented by trusts and, therefore, it is not clear whether these sites are unsuitable for further sampling effort or should be retained. Whilst a decreasing infestation pattern can be observed as distance is increased from the active fish farm it is not statistically robust to draw any conclusions at this time (Figure 22).

In comparison when considering the fish farm site biomass levels it has previously been reported that with increasing biomass levels it can create a situation were greater infestation levels on wild fish are experienced. Again this pattern of increasing infestation levels with greater biomass on site can be observed for 2011, however it is not statistically robust to draw any conclusions at this time (Figure 23).

Finally when considering the interactions of the farmed with the wild fish it is not only the nearest farm but the accumulation of active fish farms that needs to be considered when trying to objectively address management and policy practices to help manage the interactions. A distance band analysis was carried out in Idrisi from the monitoring site to indicate how many active fish farms were present (Appendix 7). A further complicating factor when considering the accumulation of fish farms in an area is the presence of non-active licenses and a number of these do fall within the distance bands from the monitoring sites. There is currently no clear framework on notification of when any of these inactive sites may become active again and this is a highly complicating factor for wild fisheries when trying to manage the interactions. This is a factor that is currently under consideration in the Scottish Government Consultation Bill and hopefully from this clarification will be achieved that will aid the appropriate management and policy guidance on this factor in the future. The data gathered in the 2011 surveys reported here is available to Marine Scotland Science for use in further and on going analysis of sweep netting results that may be undertaken.

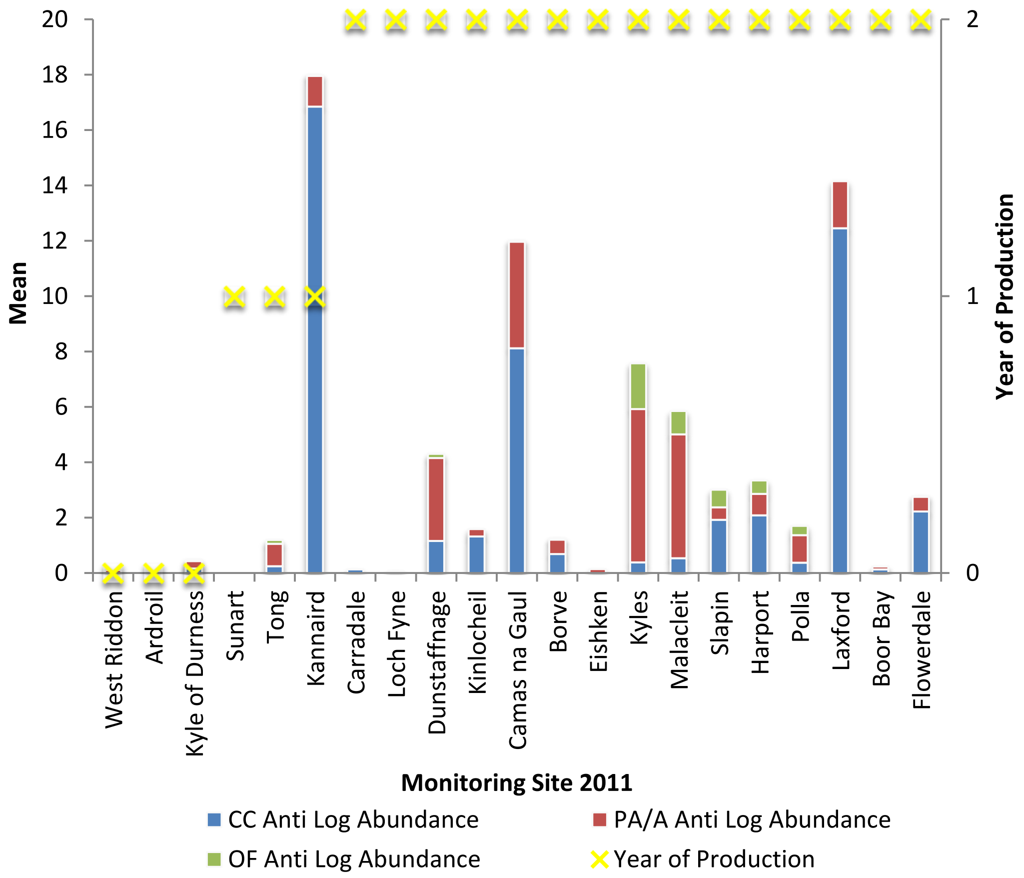

Figure 21. Year of production in 2011 of the nearest active fish farm to the monitoring site (yellow cross) and the mean abundance of *L. salmonis* staged per SFCC protocol.

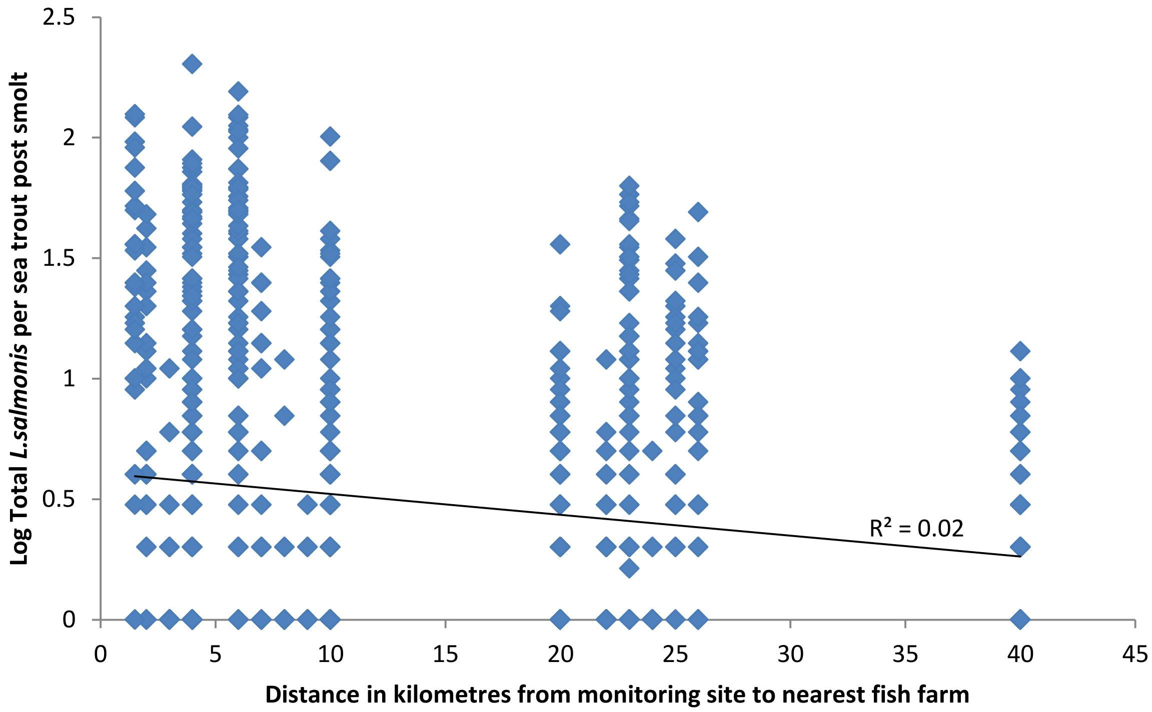

Figure 22 *L. salmonis* Log total per individual fish host for each monitoring site compared to the distance in km to the nearest active fish farm 2011.

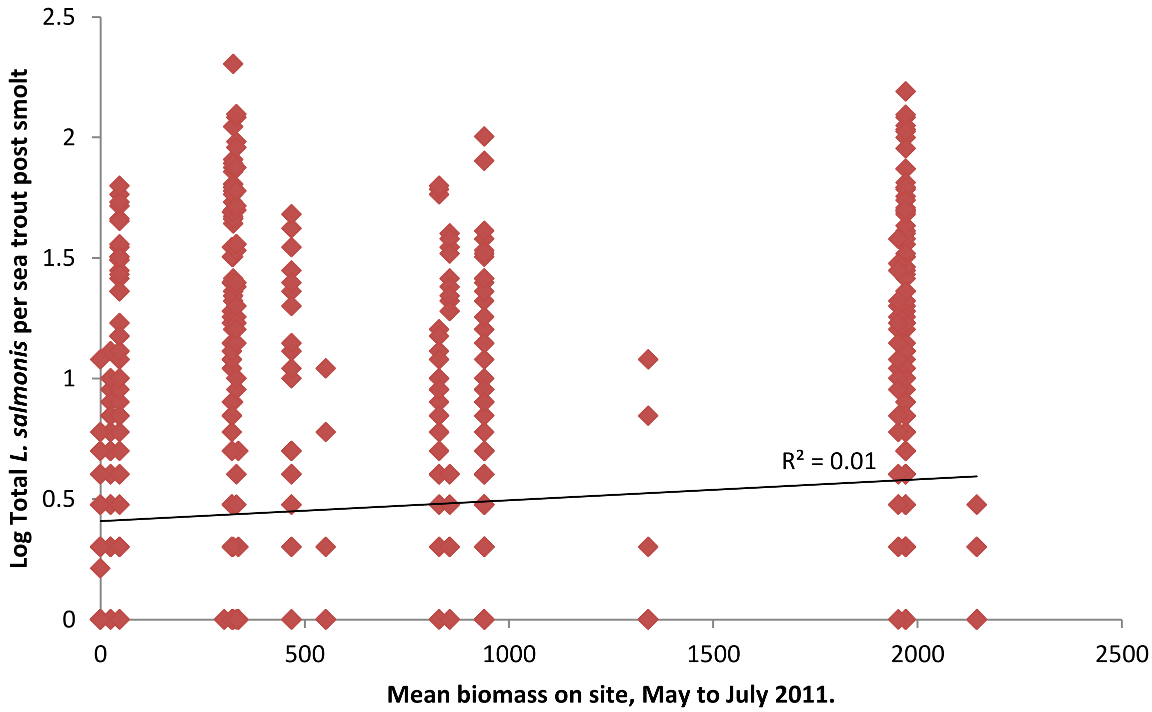

Figure 23. *L. salmonis* total per individual fish host for each monitoring site compared to the mean biomass on the nearest active fish farm for the period of May to July 2011.

4.2.2 Monitoring Site Sea Lice Counts in comparison to Farmed Fish sea lice counts.

In 2010 the Scottish Salmon Producers Organisation (SSPO) developed a dedicated health management system which is specifically designed to assist its members to improve lice management across Scotland. The information gathered and analysed in this system is published in reports on their website for six management regions across Scotland[1].

The six management regions are Orkney, West Shetland, East Shetland, North Mainland, South Mainland and the Western Isles. The monitoring sites within the Managing Interactions project fall into the North Mainland (encompassing the coastline (and associated islands) from Loch Eriboll in the north to Rubh' Arisaig, near Loch nan Ceall on the west coast), South Mainland (encompassing the coastline (and associated islands) from Rubh' Arisaig, near Loch nan Ceall on the west coast, to Irvine, towards south west Scotland.) and the Western Isles (encompasses all islands in the Western Isles including Harris, Lewis, North and South Uist, Benbecula, Barra and the associated smaller islands).

The interactions between farmed and wild fish in relation to sea lice is a contentious issue in Scotland and elsewhere which are not yet fully researched or understood (Harvey, 2009). Nonetheless the most realistic approach within the current understanding of the wild and farmed fish interactions should be a precautionary approach as highlighted by Revie *et al* 2009. It had been anticipated that the published wild fish lice counts could be examined alongside the published farm lice counts. However, the highly aggregated form, covering large geographical areas, in which the SSPO published their results did not allow this comparative evaluation to be undertaken. Nevertheless it is possible to report on the regional lice count information published by SSPO.

The SSPO reports indicate that in the period of May 2011 the Western Isles and the South Mainland lice numbers across these two regions, on average, remained below the suggested lice treatment threshold set out in the National Treatment Strategy for the Control of Sea Lice on Scottish Salmon Farms (NTS) and the Code of Good Practice (CoGP). However, the North Mainland, lice numbers across this region were, on average, 32% above the suggested treatment threshold set out in the NTS and CoGP (Figure 24A). In June 2011 the SSPO reports indicate that again the Western Isles and the South Mainland, lice numbers across these two regions, on average, remained below the suggested lice treatment threshold set out in the NTS and CoGP and the North Mainland had lice numbers across this region, on average, which were 138% above the suggested lice treatment threshold set out in the NTS and CoGP (Figure 24B). Finally in July 2011 the SSPO reports indicated that the Western Isles and the South Mainland, lice numbers across these two regions, on

[1] (http://www.scottishsalmon.co.uk/science/sea_lice/regional_reports(1).aspx)

average, remained below the suggested lice treatment threshold set out in the NTS and CoGP and for the North Mainland during July, lice numbers were, on average, 149% above the suggested lice treatment threshold set out in the NTS and CoGP (Figure 24C).

The principle objective of comparing the results of sea lice counts on wild fish with the counts on the farmed fish was to assess their interrelationships. This will enable appropriate management strategies and policies to be utilised to protect vulnerable wild fish stocks. Unfortunately due to the published data on farmed sea lice counts being produced in an aggregated regional form, it has not yet been possible to make these comparisons. Potentially this is probably the most challenging issue between wild and farmed sectors regarding the publication of fish farm sea lice data and is currently under discussion in the Aquaculture and Fisheries consultation bill. It is recommended that further work, at a local level, on this potential interrelationship is needed to understand the relationships. In order to fully explore the potential interrelationships, and the sea lice pressure dynamics being experienced on farmed and wild fish, extended local data sharing protocols are required.

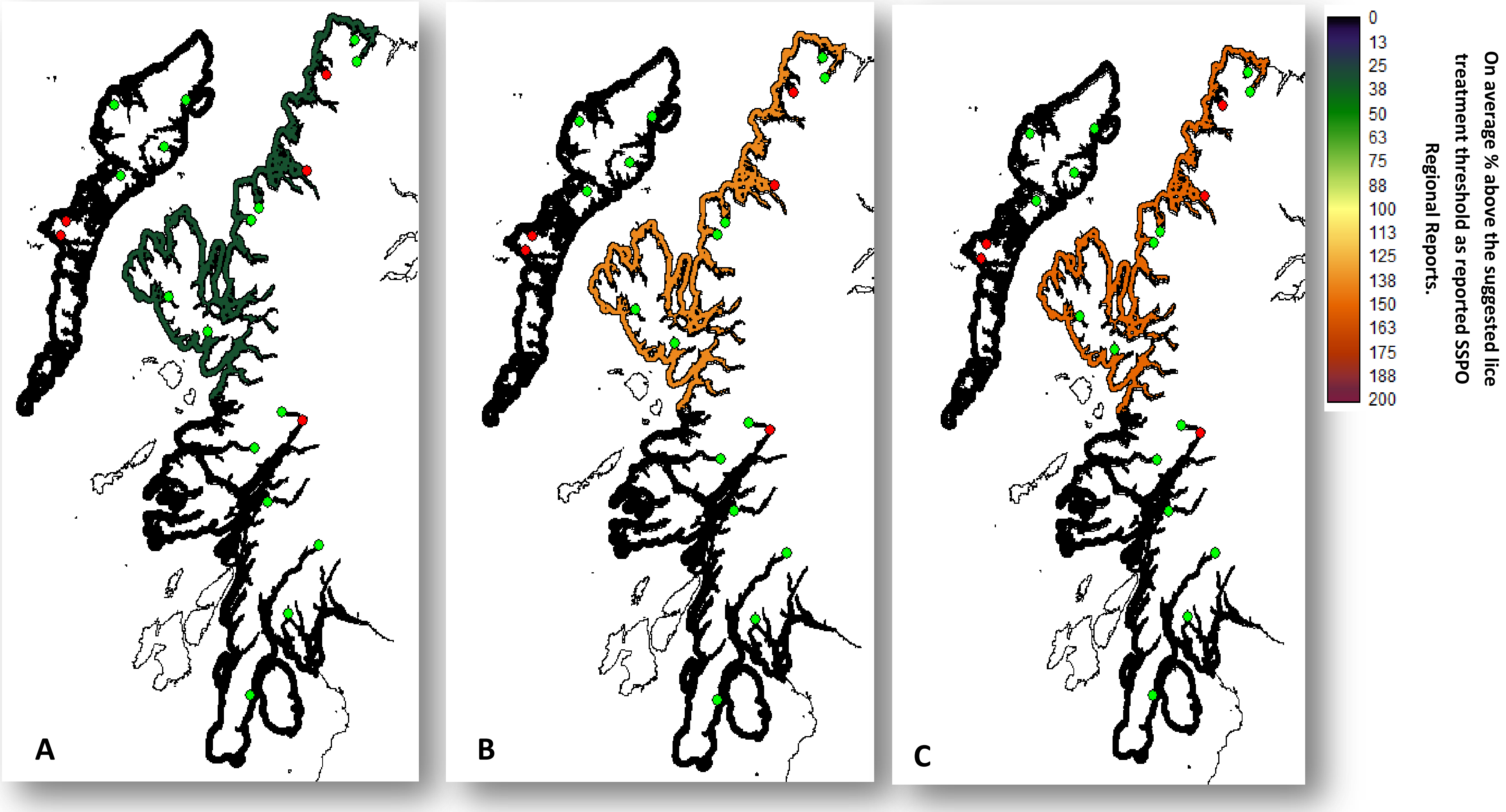

Figure 24: Map layers representing the reported farm sea lice levels in relation to the CoGP and NTS threshold levels. 0 indicates for that period on average the region is below the threshold level. The green dots indicate wild monitoring sites which did not exceed one of predetermined explored determinant threshold levels. In comparison the red dots indicate wild monitoring sites that did exceed one or more of the predetermined explored determinant threshold levels.

5. Conclusions

This first year of the sweep netting monitoring programme coordinated by RAFTS as part of the Managing Interactions Aquaculture Project has seen a number of refinements being made to the protocol, data collection and analyses at a regional level. There has also been a number of important lessons learnt that have indicated where further refinements are needed. This was in relation to the identified monitoring sites, the sea lice counting protocol and development of the current RAFTS structured Access database for collation and analysis of data to be developed in the future to create an online management support tool.

Future sampling should be undertaken at a further refined network of sweep netting sites to ensure the inclusion of sample locations across a full range of distances from active fish farms. To deliver such a sample network, and in particular one which includes sites of greater distance from aquaculture production sites, locations may need to be sought from outside the current study area; potentially from the lower Clyde, Ayrshire or Solway areas.

Some of the current monitoring sites were not successful in yielding desired fish numbers and a reassessment of sites to be retained or discarded will be made in early 2012 which will support the refinement and extension of the sampling network across the West Coast. Although it should be noted there will always be an inherent unpredictability of sampling fish in these environments and it may be that in any given sample year some sites do not provide the desired sample sizes and fish numbers aimed for.

In a number of sites a full set of environmental information was not recorded at survey. This, alongside a review of the method of lice counts to be used (underwater or above water) should be improved and concluded in future sampling protocols.

The provision of sample records from trusts to RAFTS for coordination may be enhanced and made more administratively efficient were an online data base available for use by trusts. RAFTS is currently exploring the viability of such a system for its current staff and whether the operating system being considered could host such a database.

For 2011 the results indicated that five 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. The implemented critical threshold level indicates that potentially one of the monitoring sites had elevated levels of sea lice presence within the fish population above the critical detrimental impact threshold level.

This study was able to explore the comparisons of the monitoring data to nearest active fish farm year of production and biomass. However it was unable to explore the reported high levels of sea lice counts at the monitoring sites in 2011 and their potential link to the high sea lice levels reported as being above the trigger threshold treatment levels of farms. This was due to the current regional nature of the data released by the SSPO. Being able to properly draw conclusions on 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.

It is recognised that there are concerns around confidentiality aspects within the Scottish aquaculture industry regarding the reporting of sea lice counts from farms and the way this data is handled. Previously data sharing has taken place where it was possible to resolve conflicts to accommodate the perceived concerns. One solution included having Regional Development Officers working on the Tripartite Working Group Project. It should be recognised that there are potential benefits for all parties and it is hoped that new arrangements can be put in place and be implemented to aid the principal objective of evaluating the interrelationships between farmed fish, wild fish and the problematic parasitic sea lice species on the West Coast of Scotland.

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7. Appendix

Appendix 1

Scottish Government Managing Interactions:
North West Coast Aquaculture Project.

Sweep Netting Project

Counts carried out by............................ No of personnel.................................... Method of Counting Sea Lice.........................

Weather Conditions............................... Water Temperature (deg C)............................. Air Temperature (deg C).............................

Salinity (PSU)..

Site Code			Date		Time		Catchment			
Fish	**Length (mm)**	**Weight (g)**	**Copepodid/Chalimus**	**Preadult/Adult**	**Ovigerous Females**	**Caligus**	**Dorsal Fin Damage**	**Predator Damage**	**Black Spots**	**Any Additional Notes/Scale REadings**

Appendix 2

Table A1: Site Environmental Conditions over sample period

Sweep Netting Site	Mean Water Temperature	Mean Air Temperature	Mean Salinity
Carradale	*	*	*
Southend	*	*	*
Machrihanish	*	*	*
Loch Fyne	*	*	*
West Riddon	*	*	*
Dunstaffnage	*	*	*
West Tarbert	*	*	*
Laggan Bay	*	*	*
Loch Eil	11.60	10.80	28.80
Camas na Gaul	13.20	11.80	35.20
Sunart	14.50	11.80	33.20
Tong	10.95	13.23	35.00
Ardroil	12.85	14.03	19.50
Borve	13.78	14.63	17.75
Eishken	13.67	13.80	35.00
Kyles	15.13	14.13	23.30
Malacheit	16.03	15.63	35.00
Loch Slapin	11.86	12.50	31.10
Loch Harport	10.50	11.57	26.62
Kyle of Durness	13.35	14.35	11.50
Polla	11.88	14.50	2.50
Laxford	9.50	13.70	5.50
Kinloch	*	*	*
Kannaird	13.00	10.00	27.00
Boor Bay	12.25	13.50	24.50
Flowerdale	11.50	14.00	16.00
Carron	*	14.50	*
Gruinard Bay	*	*	*

* No Data

Appendix 3

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

Sweep Netting Site	Mean length (± s.d.) (mm)	Mean Weight (± s.d.) (g)	Mean Condition Factor (± s.d.)
Carradale	170.39 (±17.39)	*	*
Southend	*	*	*
Machrihanish	*	*	*
Loch Fyne	99.35 (±75.97)	*	*
West Riddon	32.20 (± 46.15)	*	*
Dunstaffnage	71.19 (± 83.15)	*	*
West Tarbert	*	*	*
Laggan Bay	*	*	*
Loch Eil	153.40 (± 18.29)	*	*
Camas na Gaul	174.69 (±27.95)	66.63 (± 30.90)	1.07 (± 0.06)
Sunart	138.50 (± 15.30)	*	*
Tong	196.52 (±24.65)	90.35 (±35.17)	1.14 (±0.06)
Ardroil	215.45 (±24.06)	154.80 (± 32.06)	1.20 (± 0.70)
Borve	189.78 (± 22.83)	76.56 (± 29.96)	1.08 (±0.09)
Eishken	175.37 (± 23.03)	56.66 (± 23.50)	1.01 (± 0.08)
Kyles	220.22 (±24.38)	126.62 (±37.35)	1.15 (± 0.11)
Malacheit	195.08 (± 30.35)	92.43 (±45.12)	1.23 (± 0.13)
Loch Slapin	225.41 (± 20.96)	130.96 (±33.45)	1.13 (± 0.13)
Loch Harport	220.03 (± 23.30)	128.83 (±39.66)	1.12 (± 0.11)
Kyle of Durness	185.76 (± 27.71)	*	*
Polla	180.72 (± 39.31)	74.88 (±47.90)	1.12 (± 0.11)
Laxford	207.07 (± 34.09)	109.72 (±40.52)	1.08 (± 0.07)
Kinloch	*	*	*
Kannaird	199.43 (± 27.64)	84.96 (±35.46)	0.99 (± 0.12)
Boor Bay	185.61 (± 25.49)	69.55 (±34.22)	1.02 (± 0.13)
Flowerdale	151.39 (± 17.77)	35.67 (±15.11)	0.97 (± 0.11)
Carron	*	*	*
Gruinard Bay	*	*	*

* No Data

Appendix 4

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

Monitoring Site	Prevalence	Abundance (± s.d.)	Intensity (± s.d.)	Median
Carradale	14	0.13 (± 0.36)	1.35(± 0.25)	0
Southend	*	*	*	*
Machrihanish	*	*	*	*
Loch Fyne	3	0.02 (± 0.14)	1(± 0)	0
West Riddon	3	0.02(± 0.13)	1(± 0)	0
Dunstaffnage	59	1.16(± 1.33)	2.70(±1.04)	1
West Tarbert	*	*	*	*
Laggan Bay	*	*	*	*
Kinlocheil	60	1.32(± 1.31)	3.08(± 0.84)	1
Camas na Gaul	81	8.12(± 3.05)	14.45(± 2.14)	8
Sunart	0	0(± 0)	0(± 0)	0
Tong	22	0.24(± 0.55)	1.65(± 0.42)	0
Ardroil	9	0.06(± 0.23)	1(± 0)	0
Borve	30	0.69(± 1.64)	4.38(± 0.31)	0
Eishken	0	0(± 0)	0(± 0)	0
Kyles	29	0.39(± 0.78)	1.91(± 0.28)	0
Malacheit	31	0.54(± 1.14)	2.47(± 1.07)	0
Loch Slapin	33	1.92(± 3.74)	23.92(± 0.24)	0
Loch Harport	38	2.08(± 3.51)	18.41(± 0.80)	0
Kyle of Durness	12	0.17(± 0.57)	2.87(± 0.32)	0
Polla	18	0.37(± 1.19)	4.33(± 1.68)	0
Laxford	71	12.45(± 4.81)	38.41(± 0.78)	31
Kinloch	*	*	*	*
Kannaird	93	16.85(± 2.54)	21.28(± 1.73)	20.35
Boor Bay	6	0.13(± 0.65)	6.42(± 0.75)	0
Flowerdale	53	2.22(± 2.46)	8.15(± 1.10)	1.45
Carron	*	*	*	*
Gruinard Bay	*	*	*	*

* No Data

Appendix 5

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

Monitoring Site	Prevalence	Abundance (± s.d.)	Intensity (± s.d.)	Median
Carradale	0	0(± 0)	0(± 0)	0
Southend	*	*	*	*
Machrihanish	*	*	*	*
Loch Fyne	3	0.04(± 0.23)	1.83(± 0.63)	0
West Riddon	5	0.09(± 0.33)	1.62(± 0.26)	0
Dunstaffnage	79	2.99(± 1.84)	4.70(± 1.37)	2
West Tarbert	*	*	*	*
Laggan Bay	*	*	*	*
Kinlocheil	21	0.27(± 0.71)	2.12(± 0.80)	0
Camas na Gaul	80	3.85(± 1.78)	6.08(± 1.31)	4
Sunart	0	0(± 0)	0(± 0)	0
Tong	59	0.82(± 0.85)	1.76(± 0.59)	1
Ardroil	0	0(± 0)	0(± 0)	0
Borve	39	0.51(± 0.87)	1.88(± 0.76)	0
Eishken	10	0.14(±0.61)	3.03(± 1.33)	0
Kyles	85	5.53(± 2.41)	7.99(± 1.78)	6
Malacheit	92	4.47(± 1.60)	5.30(± 1.34)	4.48
Loch Slapin	37	0.45(± 0.67)	1.73(± 0.26)	0
Loch Harport	52	0.78(± 0.88)	2.05(± 0.47)	1
Kyle of Durness	24	0.26(± 0.59)	1.63(± 0.55)	0
Polla	48	1(± 1.56)	3.19(± 1.40)	0
Laxford	46	1.70(± 2.69)	7.53(± 0.63)	0
Kinloch	*	*	*	*
Kannaird	39	1.11(± 2.06)	5.73(± 1.66)	0
Boor Bay	12	0.10(± 0.31)	1.21(± 0.22)	0
Flowerdale	39	0.53(± 0.83)	2.02(± 0.53)	0
Carron	*	*	*	*
Gruinard Bay	*	*	*	*

*No Data

Appendix 6

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

Monitoring Site	Prevalence	Abundance (± s.d.)	Intensity (± s.d.)	Median
Carradale	0	0(± 0)	0(± 0)	0
Southend	*	*	*	*
Machrihanish	*	*	*	*
Loch Fyne	0	0(± 0)	0(± 0)	0
West Riddon	0	0(± 0)	0(± 0)	0
Dunstaffnage	15	0.15(± 0.40)	1.45(± 0.25)	0
West Tarbert	*	*	*	*
Laggan Bay	*	*	*	*
Kinlocheil	0	0(± 0)	0(± 0)	0
Camas na Gaul	6	0.04(± 0)	1(± 0)	0
Sunart	0	0(± 0)	0(± 0)	0
Tong	14	0.13(± 0.38)	1.45(± 0.24)	0
Ardroil	0	0(± 0)	0(±0)	0
Borve	5	0.05(± 0.23)	1.38(± 0.36)	0
Eishken	0	0(± 0)	0(± 0)	0
Kyles	64	1.66(± 1.50)	3.64(± 0.95)	2
Malacheit	58	0.84(± 1.05)	1.89(± 0.89)	1
Loch Slapin	59	0.64(± 0.62)	1.31(± 0.37)	1
Loch Harport	48	0.49(± 0.57)	1.29(± 0.26)	0
Kyle of Durness	7	0.05(± 0.23)	1.21(± 0.22)	0
Polla	27	0.33(± 0.78)	1.83(± 0.96)	0
Laxford	0	0(± 0)	0(± 0)	0
Kinloch	*	*	*	*
Kannaird	4	0.02(± 0.14)	1(± 0)	0
Boor Bay	0	0(± 0)	0(± 0)	0
Flowerdale	3	0.02(± 0.12)	1(± 0)	0
Carron	*	*	*	*
Gruinard Bay	*	*	*	*

* No Data

Appendix 7

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

Monitoring Site	Prevalence	Abundance (± s.d.)	Intensity (± s.d.)	Median
Carradale	14	0.12(±0.36)	1.35(±0.25)	0
Southend	*	*	*	*
Machrihanish	*	*	*	*
Loch Fyne	5	0.05(±0.28)	1.71(±0.70)	0
West Riddon	2	0.11(±0.36)	1.45(±0.26)	0
Dunstaffnage	87	4.65(±1.80)	6.29(±1.31)	5
West Tarbert	*	*	*	*
Laggan Bay	*	*	*	*
Kinlocheil	63	1.55(±1.46)	3.41(±0.97)	1
Camas na Gaul	89	12.44(±2.77)	17.44(±2.33)	16
Sunart	0	0(±0)	0(±0)	0
Tong	66	1.18(±1.06)	2.26(±0.75)	1
Ardroil	9	0.06(±0.23)	1(±0)	0
Borve	48	0.71(±1.88)	3.83(±1.73)	0
Eishken	10	0.14(±0.61)	3.03(±1.33)	0
Kyles	87	7.44(±2.59)	10.52(±1.86)	9
Malacheit	92	5.89(±1.89)	7.10(±1.54)	7
Loch Slapin	70	3.35(±3.12)	7.09(±2.44)	2
Loch Harport	79	4.38(±2.52)	7.35(±1.77)	3
Kyle of Durness	37	0.50(±0.83)	1.99(±0.61)	0
Polla	54	1.55(±2.22)	4.56(±1.93)	1
Laxford	73	14.13(±5.14)	39.96(±1.33)	34
Kinloch	*	*	*	*
Kannaird	93	18.85(±2.69)	23.98(±1.82)	23
Boor Bay	12	0.20(±0.76)	3.28(±1.47)	0
Flowerdale	61	2.69(±2.50)	7.46(±1.39)	2
Carron	*	*	*	*
Gruinard Bay	*	*	*	*

* No Data

Appendix 8

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

Monitoring Site	Prevalence	Abundance (± s.d.)	Intensity (± s.d.)	Median
Carradale	0	0(± 0)	0(± 0)	0
Southend	*	*	*	*
Machrihanish	*	*	*	*
Loch Fyne	0	0(± 0)	0(± 0)	0
West Riddon	0	0(± 0)	0(± 0)	0
Dunstaffnage	0	0(± 0)	0(± 0)	0
West Tarbert	*	*	*	*
Laggan Bay	*	*	*	*
Kinlocheil	0	0(± 0)	0(± 0)	0
Camas na Gaul	0	0(± 0)	0(± 0)	0
Sunart	0	0(± 0)	0(± 0)	0
Tong	21	0.25(±0.65)	1.93(±0.68)	0
Ardroil	0	0(±0)	0(±0)	0
Borve	1	0.01(±0.18)	3(±1.66)	0
Eishken	10	0.14(±0.51)	2.83(±0.39)	0
Kyles	0	0(± 0)	0(± 0)	0
Malacheit	11	0.08(±0.25)	1(± 0)	0
Loch Slapin	44	0.46(±0.58)	1.34(±0.28)	0
Loch Harport	52	0.64(±0.70)	1.60(±0.36)	1
Kyle of Durness	1.69	0.05(±0.33)	3.58(±0.82)	0
Polla	15	0.24(±0.75)	3.12(±0.82)	0
Laxford	63	8.16(±4.99)	31.87(±1.01)	28
Kinloch	*	*	*	*
Kannaird	0	0(± 0)	0(± 0)	0
Boor Bay	0	0(± 0)	0(± 0)	0
Flowerdale	0	0(± 0)	0(± 0)	0
Carron	*	*	*	*
Gruinard Bay	*	*	*	*

* No Data

Appendix 9

Table A8: Percentage of individual sea trout (198mm) within each sample at the individual monitoring sites over the threshold levels.

Site Name	% of Sea trout over the Wells et al Threshold	Sample Size
Carradale	0	34
Southend	*	*
Machrihanish	*	*
Loch Fyne	0	52
West Riddon	0	24
Dunstaffnage	3	31
West Tarbert	*	*
Laggan	*	*
Kinlocheil	3	99
Camas na Gaul	43	69
Sunart	0	8
Tong	2	41
Ardroil	0	3
Borve	3	131
Eishken	0	35
Kyles	0	9
Malacheit	29	14
Loch Slapin	67	3
Loch Harport	20	5
Kyle of Durness	0	43
Polla	9	22
Laxford	18	11
Kinloch	*	*
Kannaird	33	12
Boor Bay	0	24
Flowerdale	8	36
Carron	*	*
Gruinard Bay	*	*

*= No Data

Appendix 10

Table A9: Information on active fish farms in km distance bands to the monitoring site.

Monitoring Site	Number of Fish farm Sites up to 5km from monitoring Site Active in 2010/11	Number of Fish farm Sites up to 10km from monitoring Site Active 2010/11	Number of Fish farm Sites up to 20km from monitoring Site Active 2010/11
Carradale	0	1	1
Southend	0	0	0
Machrihanish	0	0	0
Loch Fyne	0	0	0
West Riddon	1	1	3
Dunstaffnage	1	6	9
West Tarbert	0	0	0
Laggan Bay	0	0	0
Kinlocheil	0	0	1
Camas na Gaul	0	1	2
Sunart	0	1	3
Tong	0	0	0
Ardroil	0	0	0
Borve	0	1	2
Eishken	2	3	5
Kyles	0	0	0
Malacleit	0	0	0
Slapin	1	1	1
Harport	1	1	1
Kyle of Durness	0	0	0
Polla	0	2	2
Laxford	3	3	4
Kinloch	0	0	0
Kannaird	1	1	4
Boor Bay	0	1	1
Flowerdale	0	0	0
Carron	0	1	4
Gruinard Bay	0	0	4