# AQUACULTURE-WILD FISH: WORKING TOWARDS IMPROVED MANAGEMENT

## 2014/15

# 2014 West Coast Fisheries Trusts' Sea Trout

# Post Smolt Monitoring Programme

**February 2015**

RAFTS

Rivers And Fisheries Trusts Of Scotland

**Contents Page**

**Summary**

The Rivers and Fisheries Trusts of Scotland, on behalf of the project partners, has managed the Sea Trout Post Smolt Monitoring Project since 2011. This project is the largest programme in Scotland that monitors the potential impacts of marine salmon aquaculture on wild salmonid populations. The aims of the programme 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*.

In 2014, the fisheries trusts of the West Coast gathered data from 21 monitoring sites. This involved collecting individual data from almost 1000 captured sea trout. Analysis of sea lice was only conducted at monitoring sites where more than 30 post-smolt sea trout were caught; of the 21 sites sampled, 14 sites caught the required number of sea trout.

*L. salmonis,* the most problematic species of sea lice to sea trout populations, was present at 19 of the 21 monitoring sites in 2014, compared with *L.salmonis* found at all regional monitoring sites in 2013, 2012 and in 2011. At four sites over 50% of sea trout were infected with sea lice, with the highest prevalence found at the Kyles site in the Outer Hebrides, where over 90% of trout were infected with sea lice. The data were analysed to investigate if any sea lice infestations were potentially harmful to sea trout populations using established criteria. Although the results at a number of sites indicated potentially harmful levels of sea lice, only one site in 2014 had a sufficient sample size and number of sea lice that might indicate an epizootic of sea lice within that population, which was at West Riddon, Argyll.

The variation in sea lice numbers between sites, and from year to year at the same site, demonstrate that there are many variables that can influence sea lice infestations on wild sea trout. These could include the timing when post smolt sea trout leave their rivers, sea temperatures and coastal salinities, wind directions and strength in the period prior to sampling, as well as the sea lice burdens on nearby aquaculture sites that can augment natural sea lice populations. To enable effective management of wild fish and farmed salmon, it is imperative that these variables are better understood.

**1. Project Background**

The 2014 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 Aquaculture-Wild Fish Interactions: Working Towards Improved Management Project. This 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 from a wild fish perspective underpinning the work which include: the protection of sensitive and high value fresh water sites; collecting information on wild fish stocks to contribute to help inform the improved practice and management at existing aquaculture sites; and 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 in the Managing Interactions Aquaculture Project 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 (http://www.rafts.org.uk/aquaculture/). In 2014 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 Aquaculture-Wild Fish Interactions: Working Towards Improved Management Project continues much of the work initiated under the Managing Interactions Aquaculture Project, and 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)

In 2012, Middlemas *et al* analysed the West Coast fisheries trusts' sea trout 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.

**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". [1]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 2014.

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 life-stages and gender, which were copepodid/chalimi, pre-adult/adult and ovigerous females as per the SFCC Protocol.

[1] SFCC "Sea Trout Netting and Sea Lice Sampling: A Standard Sweep Netting Protocol for Management, 2009".

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 have 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 used 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 were compiled by the project coordinator in a structured Excel (2010) spreadsheet. Analyses of the data involved descriptive statistics and graphs which were prepared in Excel (2010).

**2.2 Site Information**

The same 22 monitoring sites from 2013 were retained for sampling in 2014, however no sampling was carried out at Loch Harport in 2014 (Table 1 and Figure 1). Sites were selected to investigate the relationship between sea lice levels on post smolt sea trout sampled at monitoring sites and the distance to the nearest salmon fish farm, as discussed by Middlemas *et al*. (2012). The project has a core focus of sampling efforts on the sea trout post 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 (see appendix 6).

*Table 1. Sites sampled by fisheries trust area, with distance to nearest fish farm and year site was first sampled.*

| Site ID | Site | Fisheries Trust | Distance to nearest salmon fish farm (km) | Year Site First Sampled |
|---|---|---|---|---|
| 1 | Carradale | Argyll | 7 | 2007 |
| 2 | Loch Fyne | Argyll | 24 | 2005 |
| 3 | West Riddon | Argyll | 15 | 2005 |
| 4 | Dunstaffnage | Argyll | 3 | 2002 |
| 5 | Goil | Argyll | 42 | 2012 |
| 6 | Kinlocheil | Lochaber | 20 | 1999 |
| 7 | Camas na Gaul | Lochaber | 6 | 2002 |
| 9 | Borrodale | Lochaber | 12 | 2012 |
| 10 | Tong | Outer Hebrides | 38 | 2009 |
| 12 | Borve | Outer Hebrides | 10 | 2003 |
| 13 | Eishken | Outer Hebrides | 3 | 2009 |
| 14 | Kyles | Outer Hebrides | 29 | 2007 |
| 15 | Malacheit | Outer Hebrides | 20 | 2006 |
| 16 | Kyle of Durness | West Sutherland | 40 | 2009 |
| 17 | Polla | West Sutherland | 10 | 1997 |
| 18 | Laxford | West Sutherland | 5 | 1997 |
| 19 | Kinloch | West Sutherland | 32 | 2012 |
| 20 | Kannaird | Wester Ross | 3 | 2007 |
| 21 | Boor Bay | Wester Ross | 8 | 2008 |
| 22 | Flowerdale | Wester Ross | 26 | 2009 |
| 23 | Loch Slapin | Skye | 50 | 2009 |
| 24 | Loch Harport | Skye | 8 | 2009 |

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 2 shows the number of sea trout collected from each monitoring site. Insufficient sea trout were caught at eight sites to enable an analysis of sea lice. These sites were Goil, Borrodale, Malacheit, Kannaird, Boor Bay, Flowerdale, Loch Slapin and Loch Harport.

*Table 2: Monitoring Site Details*

| Site ID | Site Name | Total Number of Sea Trout Caught in 2014 | Total Number of Post Smolts (260mm) within sample | Total Number of Wells Threshold Fish (198mm) within sample |
|---|---|---|---|---|
| 1 | Carradale | 45 | 43 | 39 |
| 2 | Loch Fyne | 76 | 71 | 60 |
| 3 | West Riddon | 66 | 62 | 60 |
| 4 | Dunstaffnage | 76 | 76 | 49 |
| 5 | Goil | 7 | 5 | 4 |
| 6 | Kinlocheil | 59 | 58 | 50 |
| 7 | Camas na Gaul | 62 | 59 | 49 |
| 9 | Borrodale | 16 | 12 | 12 |
| 10 | Tong | 46 | 46 | 34 |
| 12 | Borve | 64 | 62 | 38 |
| 13 | Eishken | 53 | 50 | 27 |
| 14 | Kyles | 40 | 40 | 20 |
| 15 | Malacheit | 31 | 27 | 14 |
| 16 | Kyle of Durness | 30 | 30 | 29 |
| 17 | Polla | 57 | 51 | 43 |
| 18 | Laxford | 98 | 94 | 81 |
| 19 | Kinloch | 30 | 30 | 28 |
| 20 | Kannaird | 29 | 29 | 17 |
| 21 | Boor Bay | 9 | 2 | 0 |
| 22 | Flowerdale | 21 | 20 | 20 |
| 23 | Loch Slapin | 44 | 13 | 4 |
| 24 | Loch Harport | 0 | 0 | 0 |

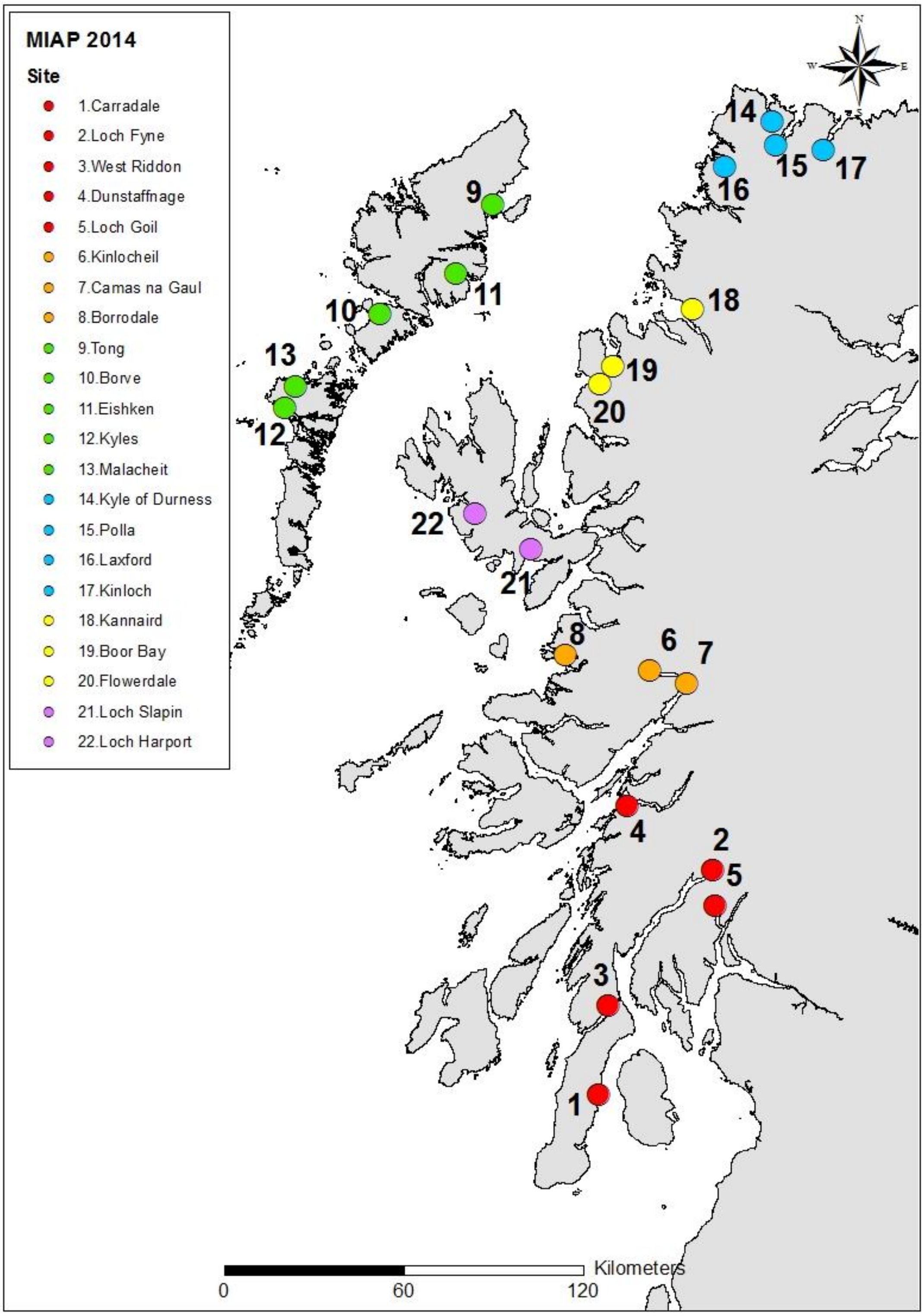


*Figure 1: Geographical spread of monitoring sites sampled in 2014 (Argyll sites in red; Lochaber sites in orange; Outer Hebrides sites in green; Wester Ross sites in yellow; West Sutherland sites in blue; Skye sites in purple).*

## 3. Sweep Netting Analysis Results

### 3.1. Sea Trout Analysis

In 2014, the total number of sea trout caught was 959, of which 880 were classed as post-smolts, with a fork length of less than 260mm. This compares with 946 post-smolt sea trout in 2013 and 971 in 2012. Under the SFCC protocol, the recommended sample size for statistical analysis is currently advised as 30 post-smolt sea trout. Sea lice numbers are only considered for those sites with thirty or more sea trout that are ≤260mm. Data for all sites sampled can be found in appendices.

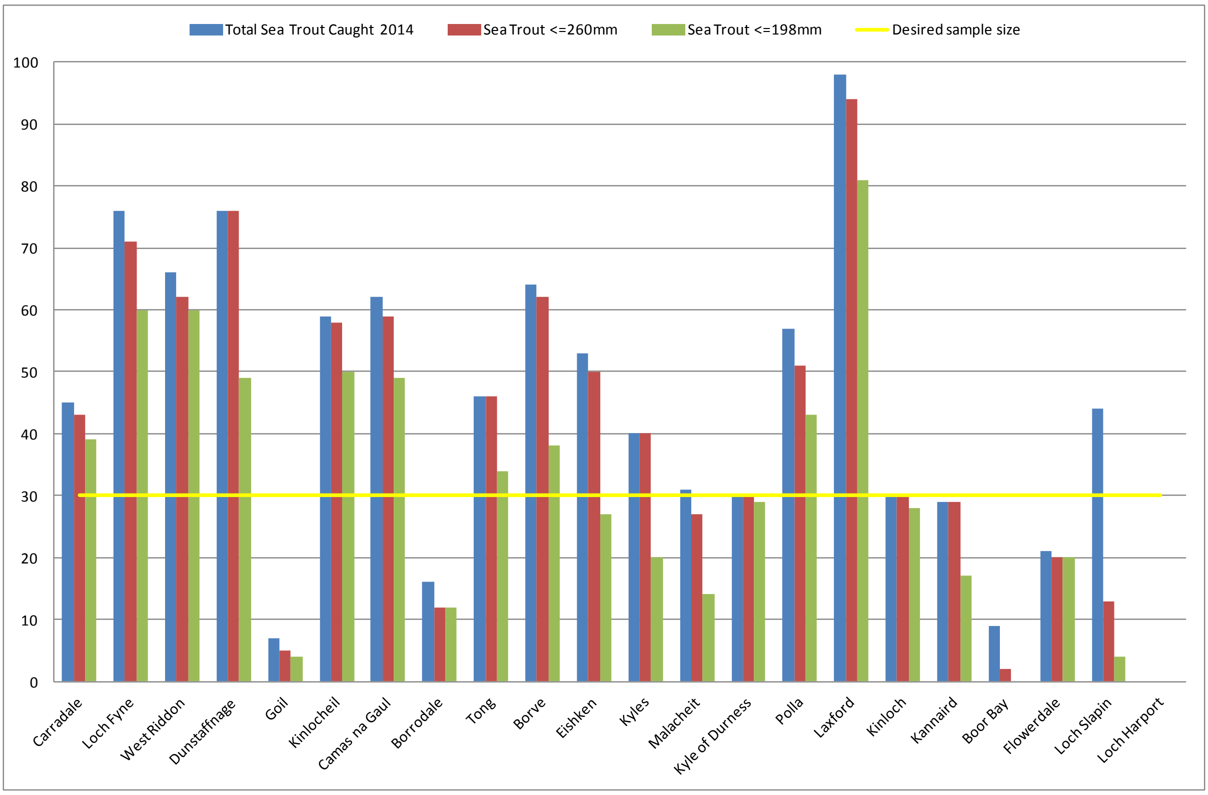


*Figure 2. Total number of sea trout caught at each monitoring site including a break down to the number in sample of post smolts at 260mm threshold and 198mm threshold.*

#### 3.1.1 Length, Weight and Condition Factor

The recorded lengths and weights of all post-smolt sea trout (<260mm) caught, are described in figures 3 and 4. Comparing 2014 with 2013, mean lengths increases greater than 10mm were recorded at Loch Fyne (Argyll), Eishken (Outer Hebrides), Polla, Kinloch (West Sutherland) and Kannaird (Wester Ross). Mean lengths decreases of more than 10mm were recorded at Tong, Kyles (Outer Hebrides) and Laxford (West Sutherland). Although large increases in mean length were recorded at Loch Goil and Boor Bay, the very small sample size means that these results cannot be treated with confidence.

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 2014 had available length and weight data, except for Kyle of Durness (West Sutherland) and the condition factor was calculated for all post smolts at each monitoring site and is summarised in Figure 5. As a general rule a condition factor of 1 or above would be considered healthy. Of the 20 monitoring sites with data in 2014, the calculated Fulton Condition Factor was generally healthy for all sites, with three sites falling just below a condition factor of 1, however the fish from these sites were on average not considered 'unhealthy'.

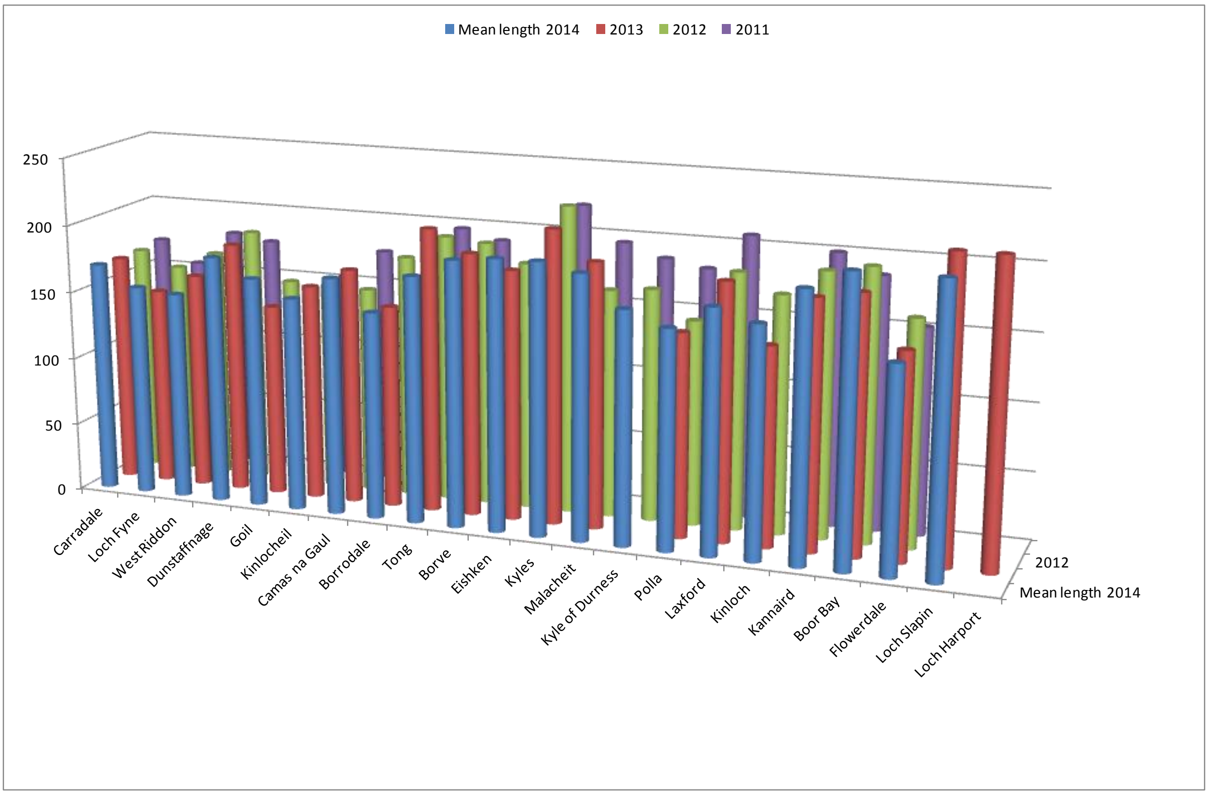


*Figure 3: The mean sea trout lengths (mm) at each monitoring site..*

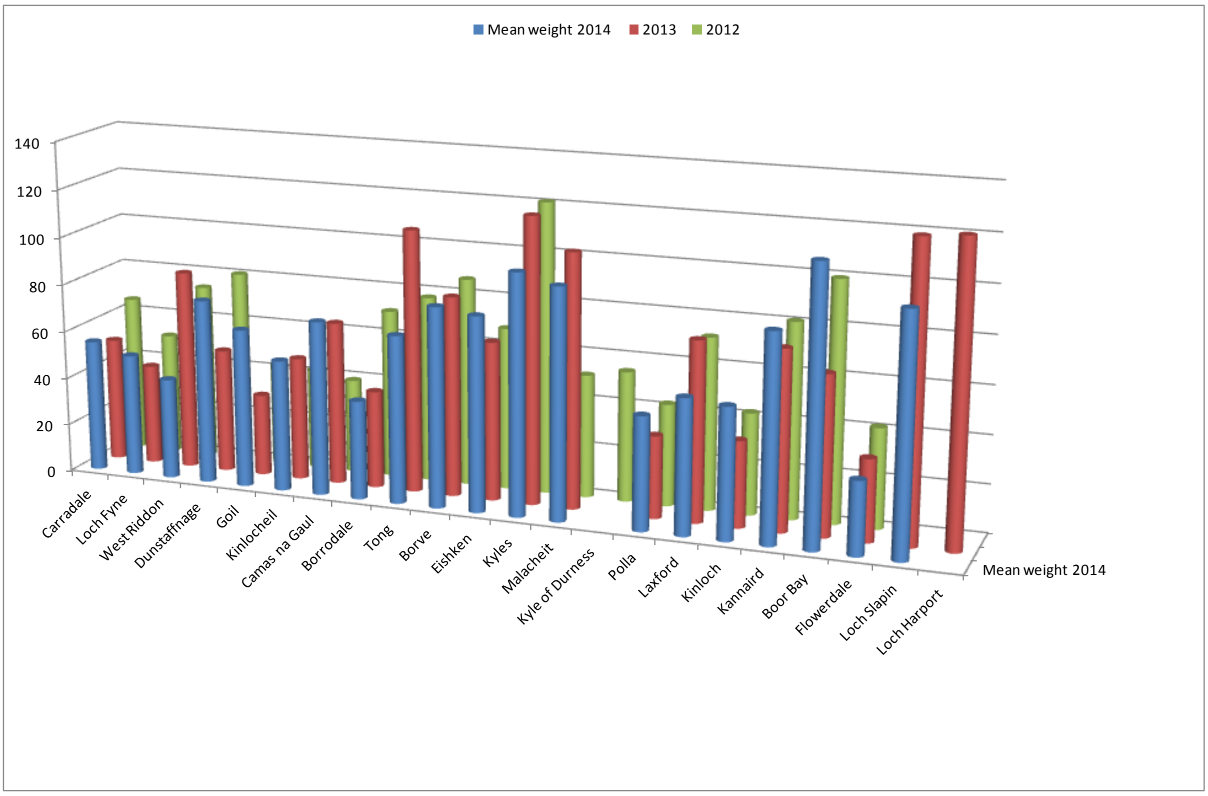


*Figure 4: The mean sea trout weights (g) at each monitoring site. .*

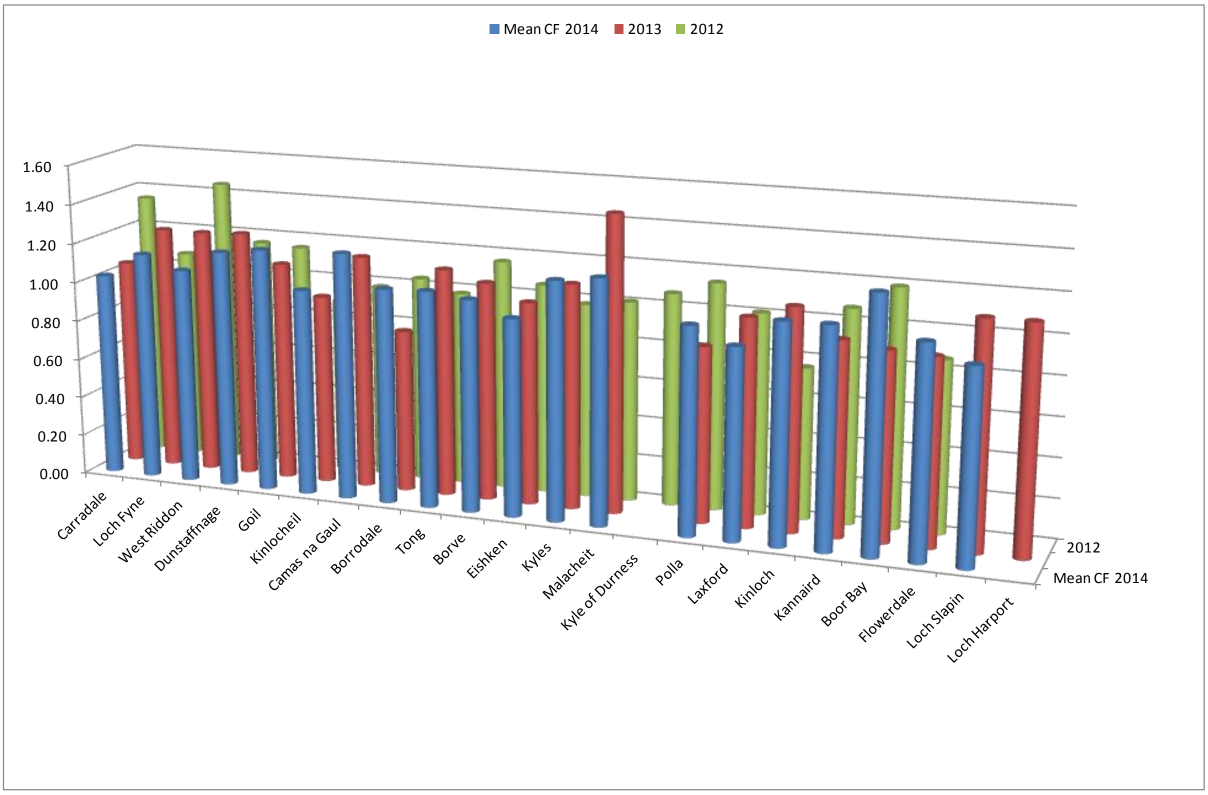


*Figure 5: The mean sea trout Condition Indices at each monitoring site.*

The mean lengths of fish sampled show good consistency across all sites since this project began in 2011, with means of 182mm in 2011, 176mm in 2012, and 177mm in 2013 and 2014. The weight variation, and thus condition factor variation, were similarly distributed, however it should be noted that collecting accurate and precise weight values in the field is difficult. Location of sampling and the wind direction can lead to errors with sensitive weighing scales, and therefore the weight and condition factor data should be treated with caution.

When analysing the sea lice data, it is important to have confidence that the observed differences in sea lice levels are not due to the size of sea trout sampled, as larger sea trout can carry more sea lice (Middlemas *et al.* 2012). The consistency of size of fish across sites and across years suggests that there are no major differences in the size of sea trout between years, which indicate that changes in sea lice levels are not due to fish size.

### 3.2 Sea Lice Analysis

#### 3.2.1 *L. salmonis* all life Stages.

Of the fourteen sites available for analysis of sea lice data, the sites with the highest prevalence of sea lice were West Riddon (81%), Eishken (82%) and Kyles (92%) (figure 6). A comparison of the 2014 and 2013 data (figure 7) shows that nine of the fourteen sites recorded a lower prevalence in 2014, with three sites showing a higher prevalence. No comparison was made for the Kyles site, as insufficient numbers of sea trout were caught in 2012 or 2013 for analysis, and insufficient numbers of sea trout were caught at Kyle of Durness in 2013 to enable analysis. The largest decreases in prevalence were recorded at Camas na Gaul, which saw a 93% decrease in prevalence from 2013 to 2014, Kinlocheil, which saw a 60% decrease, and Laxford, which saw a 55% decrease in prevalence. The West Riddon site recorded a 64% increase in prevalence compared with 2013, however the 2014 prevalence was 17% lower than the 2012 figure. The Eishken site recorded a 61% increase from 2013 data, and 28% increase from the 2012 data.

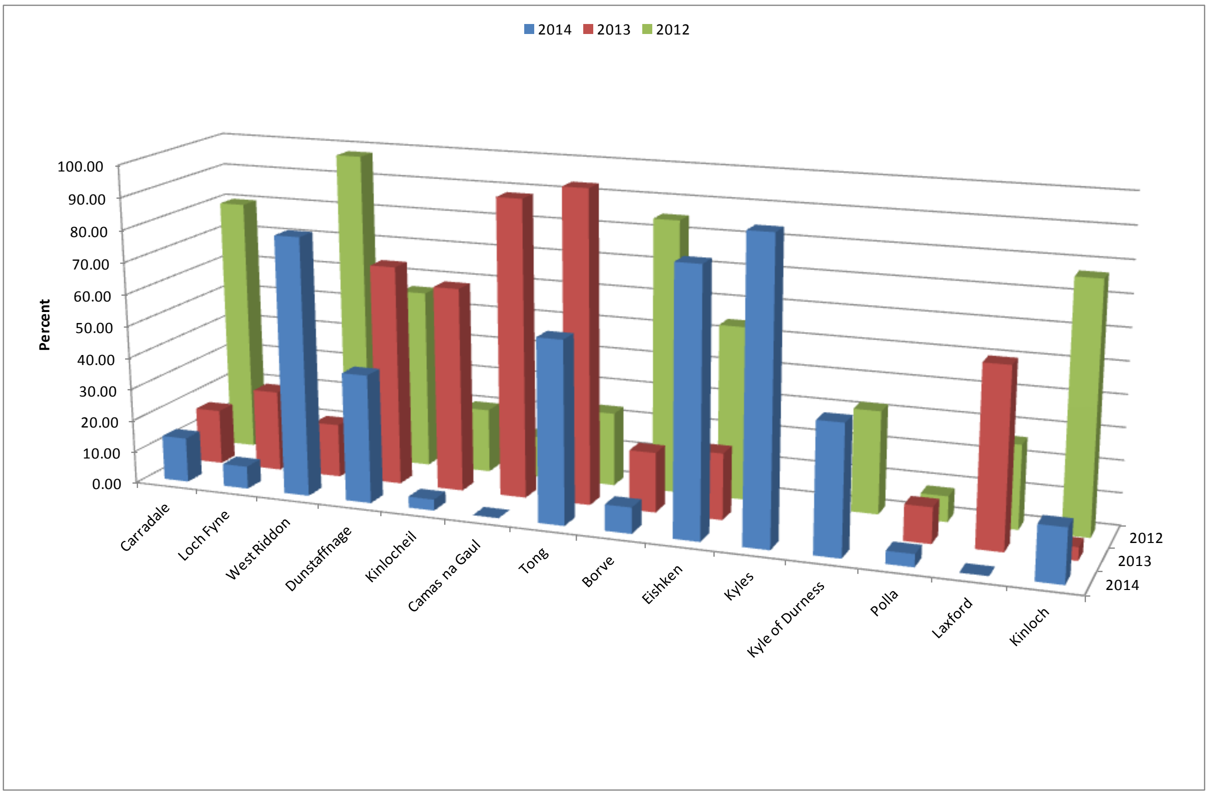


*Figure 6: L. salmonis all life Stages Prevalence results for 2012, 2013 and 2014 for sites with >30 post smolt sea trout ≤260mm.*

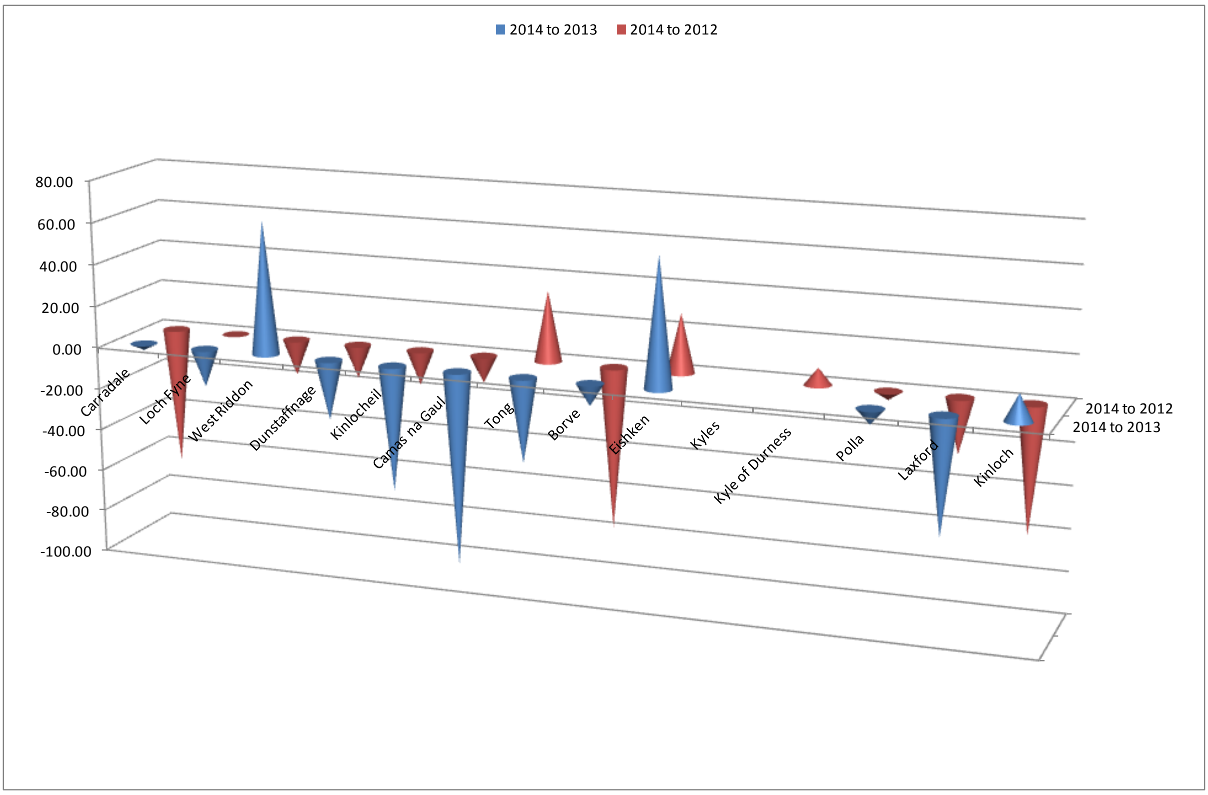


*Figure 7: Variation in prevalence between 2014 and 2013, and 2014 and 2012 for all* L. salmonis *data.*

In 2014, the highest abundance was recorded at Kyles (figure 8), with an average of 8.5 sea lice per post-smolt sea trout. The abundance at West Riddon was 4.5 sea lice, 2.9 at Tong and 3.4 at Eishken. Overall, abundance was low, with a median figure of 0.26 across all sites. The largest increase in abundance was recorded at Kyles (figure 9), which saw an increase of over 6 sea lice per sea trout compared with 2013 data. Eight of the fourteen sites recorded a decrease in abundance compared with 2013 data, with the largest decreases seen at Dunstaffnage and Camas na Gaul (both 6.8) and Laxford (3.4). Three sites recorded an increase compared with 2013 data, with the largest increase seen at West Riddon (4.3).

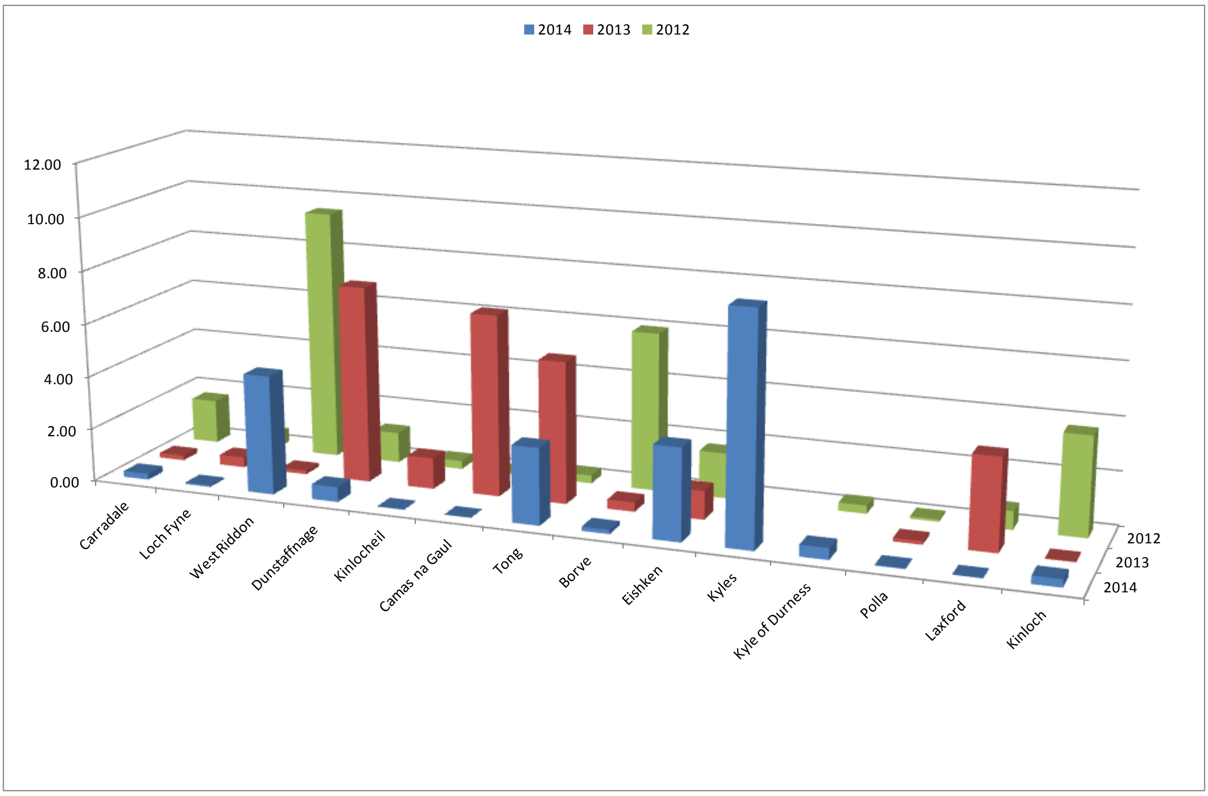


*Figure 8: Back Transformed Abundance for all L. salmonis stages at each monitoring site for 2012, 2013 and 2014.*

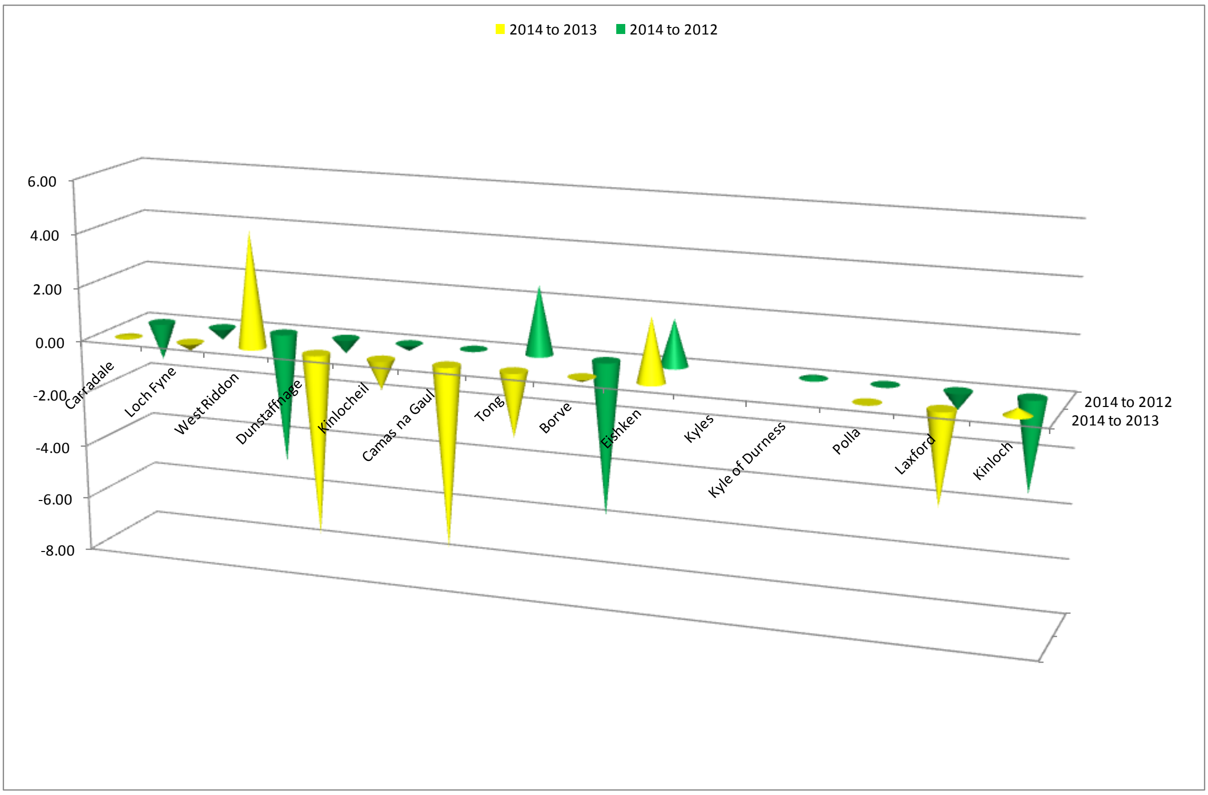


*Figure 9: Variation in abundance between 2014 and 2013, and 2014 and 2012 data.*

The highest numbers of sea lice per infected sea trout, or intensity, in 2014 were recorded at Kyles (0.5) and Tong (9.9), both in the Outer Hebrides. West Riddon also recorded a high intensity of 7.24 lice per infected fish. Six of the fourteen sites recorded a decrease in intensity from 2013 figures, with the largest decrease recorded at Eishken, although the intensity at Eishken in 2013 was unusually high at 33 lice per infected fish, and the 2014 figure was only 0.14 lice less than the 2012 figure. Six sites recorded an increase in intensity, with the largest increase seen at West Riddon (6 lice).

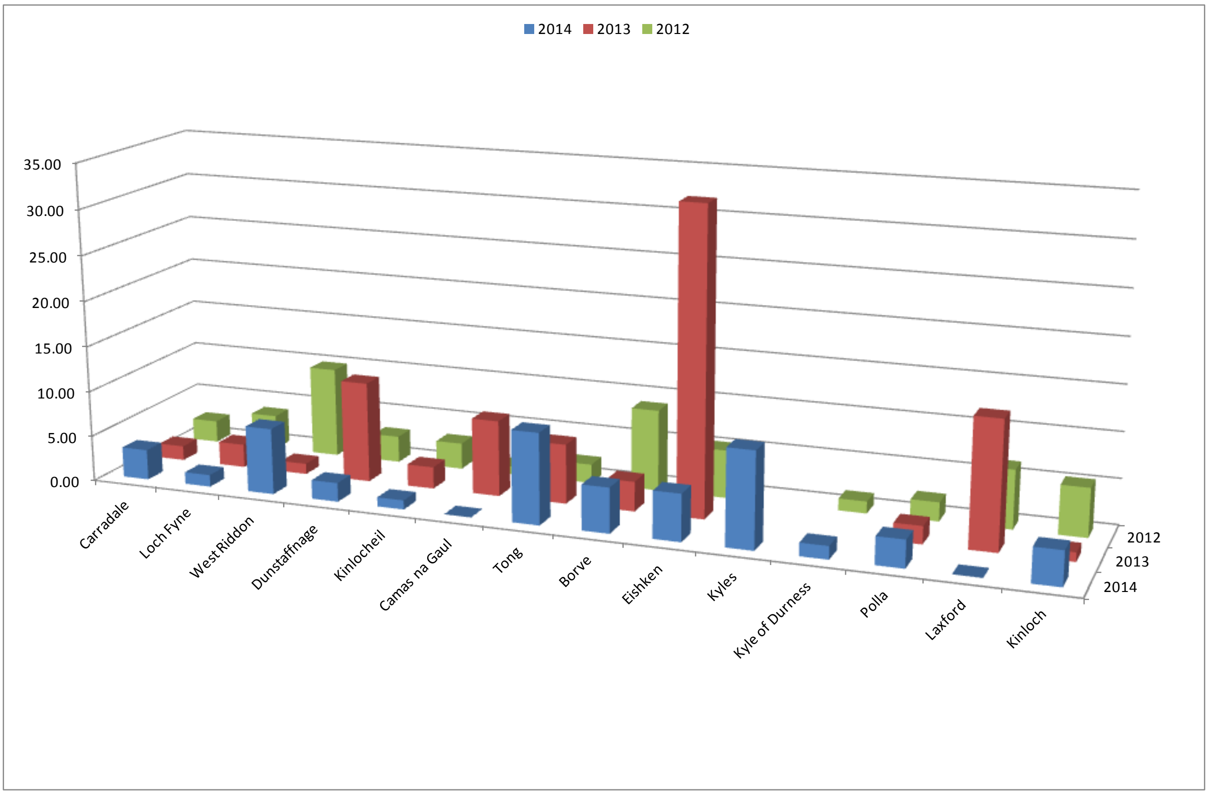


*Figure 10: Back Transformed Intensity for all L. salmonis stages at each monitoring site for 2012, 2013 and 2014.*

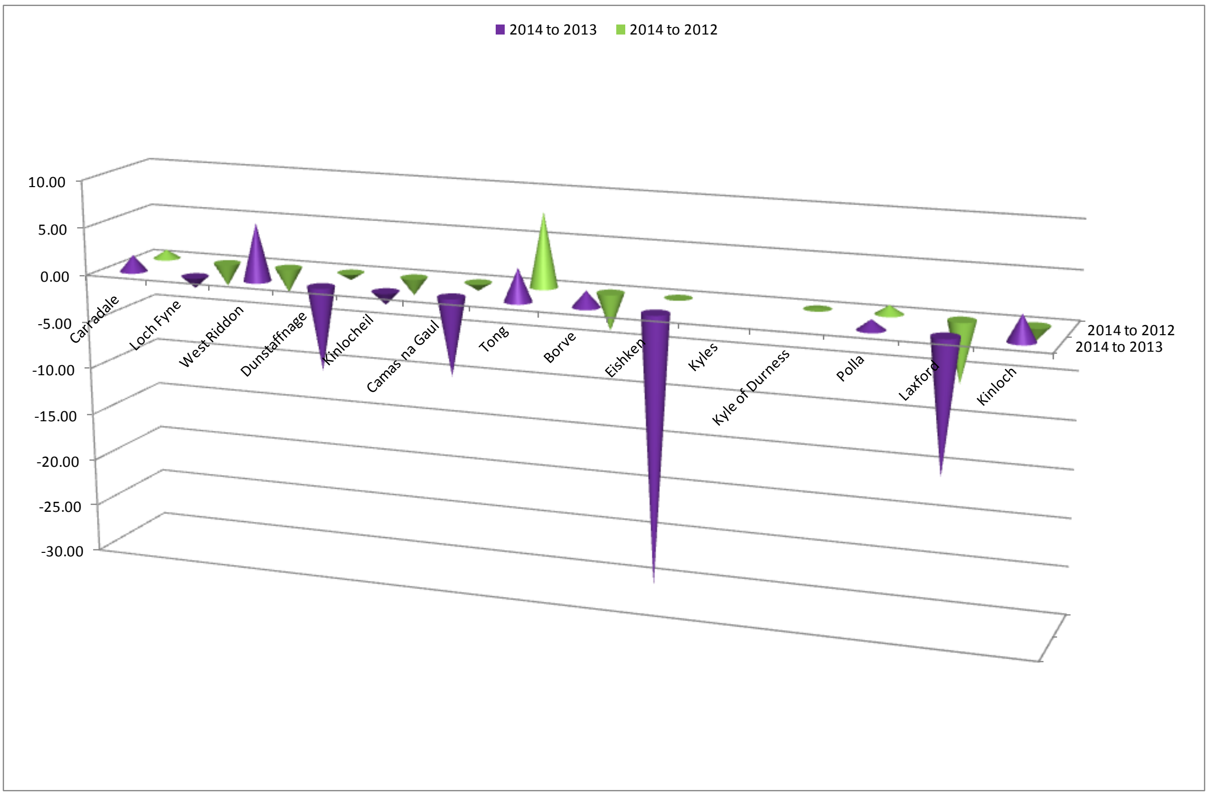


*Figure 11: Variation in intensity between 2014 and 2013, and 2014 and 2012 data.*

### 3.2.2 *C. elongatus*

*Caligus elongatus* is smaller than *L. salmonis*, 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 fewer 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 salmon 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, for juvenile farmed halibut *Hippoglossus hippoglossu*. As a host generalist there are possibilities in Scotland that if levels become elevated, both farmed and wild fish could experience detrimental problems from *C. elongatus*.

From the data collected across the monitoring sites in 2014 *C. elongatus* was present in four Trust areas, Argyll, Lochaber, Outer Hebrides and West Sutherland. Prevalence and abundance figures were low across all monitoring sites in 2014, and *C. elongatus* was not considered a detrimental factor to sea trout populations in 2014 based on the data collected.

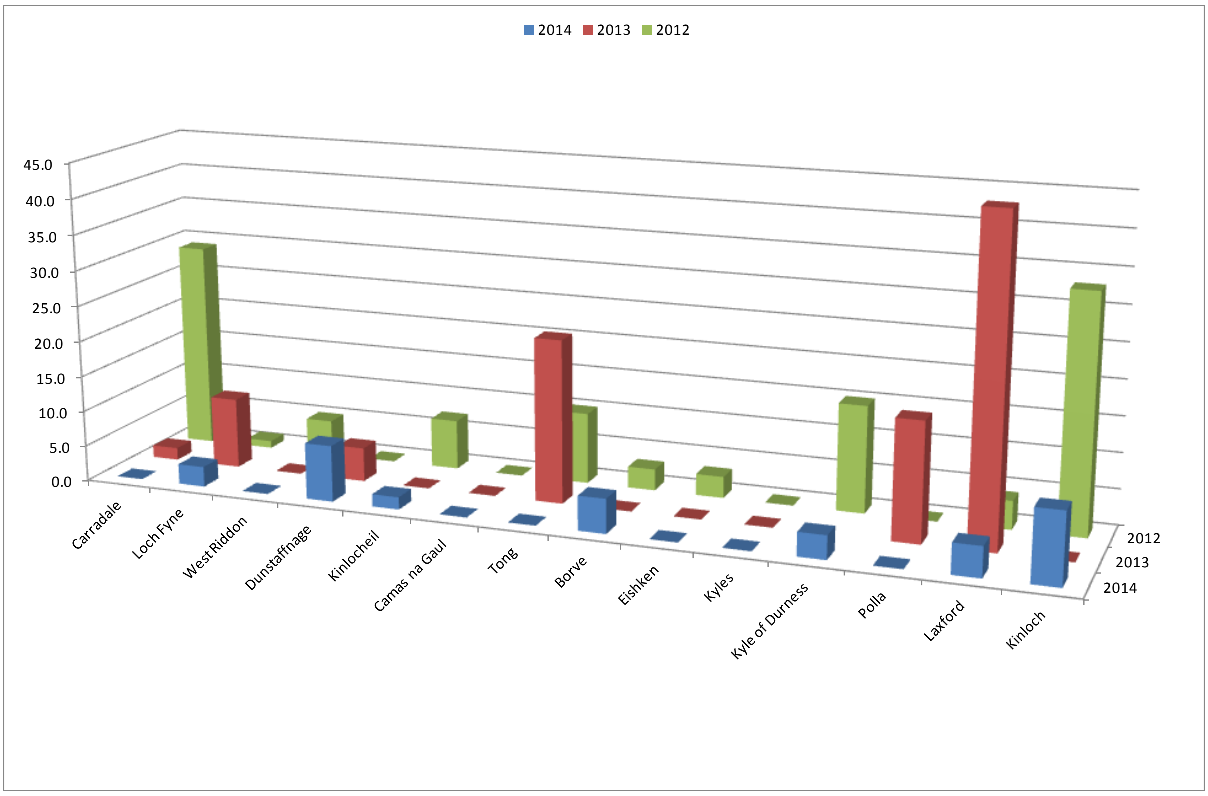


*Figure 12: Caligus elongatus prevalence for 2012, 2013 and 2014.*

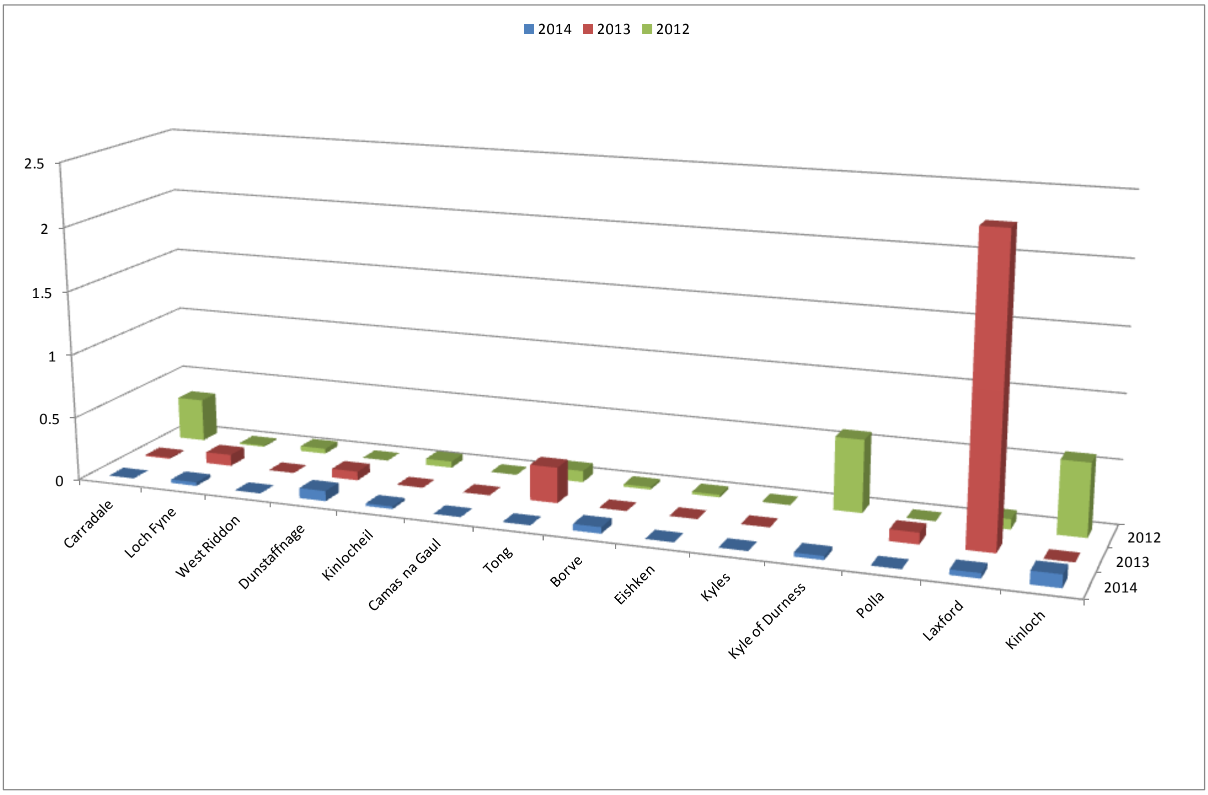


*Figure 13: Caligus elongatus abundance for 2012, 2013 and 2014.*

**3.3 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. Fish which have succumbed to heavy infestation loads will not have been 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 mass fatal infestations of the earliest life-stages of salmon lice, 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 2014 results, only one site recorded prevalence greater than 60% and abundance greater than 5 lice per fish, which was Kyles (Outer Hebrides). However, the site at West Riddon (Argyll) recorded prevalence of over 80% and with an abundance of 4.5 and intensity of 8, was therefore worthy of investigation. Identifying potential epizootics 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.

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.

In 2014, there were insufficient fish sampled at the Kyles site under 198mm (Table 1) to conduct a robust analysis. However, at West Riddon, sufficient fish under 198mm were sampled. Analysis of the results showed that 12.9% of sea trout carried a mobile sea lice burden in excess of 13. No other sites with a valid statistical sample size recorded fish carrying detrimental lice loadings.

### 3.4 Difference between sea lice levels at sampling events

The data displayed above are averages of the sea lice counted from all sea trout caught at the monitoring sites, and the results do not take into account differences between the sampling visits. If the numbers of sea lice counted on sea trout were significantly higher in the second or third visit, compared to the first visit, then the impact of sea lice on a sea trout populations may be underestimated. By the time of the first sampling event, post smolt sea trout will not have been in the marine environment for very long, and the potential for sea lice infestation will be less significant. By the time of the second or third sampling event in June or July, post smolt sea trout will have been in the marine environment for longer, increasing the likelihood of sea lice infestation. Calculating prevalence and abundance based on all sea trout caught at a monitoring site has the potential to underestimate the impact, as it is hypothesised that fewer sea lice will be seen on fish caught on the first visit. Not taking into account the influence of the sampling event on the analysis has the potential to miss harmful levels of sea lice infestation at the population level, as the Costello (2009) threshold for identifying epizootics uses both prevalence and abundance.

Figure 14 describes the differences in median sea lice counts between the first and consecutive visits, with any positive figure showing an increase in sea lice from the first to the second/third visit. It can be seen that more sea lice were counted at the second/third visit at 5 of the 14 monitoring sites. At no sites did the sea lice counts decrease from the first to second/third visit recorded. To provide an initial indication if there are significant statistical differences in these counts, a Wilcoxon Rank Sums test was undertaken in Excel. This test was selected as it uses non-parametric data, and is useful for sample sizes greater than 20, such as was found with this dataset. This test did not show any significant differences in sea lice counts between sampling events. However, it is recognised that the Wilcoxon Rank Sums test is not a powerful test, and the statistical analysis was only undertaken on individual monitoring sites. To provide a robust answer to the question of statistically significant differences between sea lice counted at sampling events, it is recommended that an analysis is undertaken on the dataset as a whole, rather than as individual monitoring sites. This analysis should also be undertaken on data collected in 2011, 2012 and 2013.

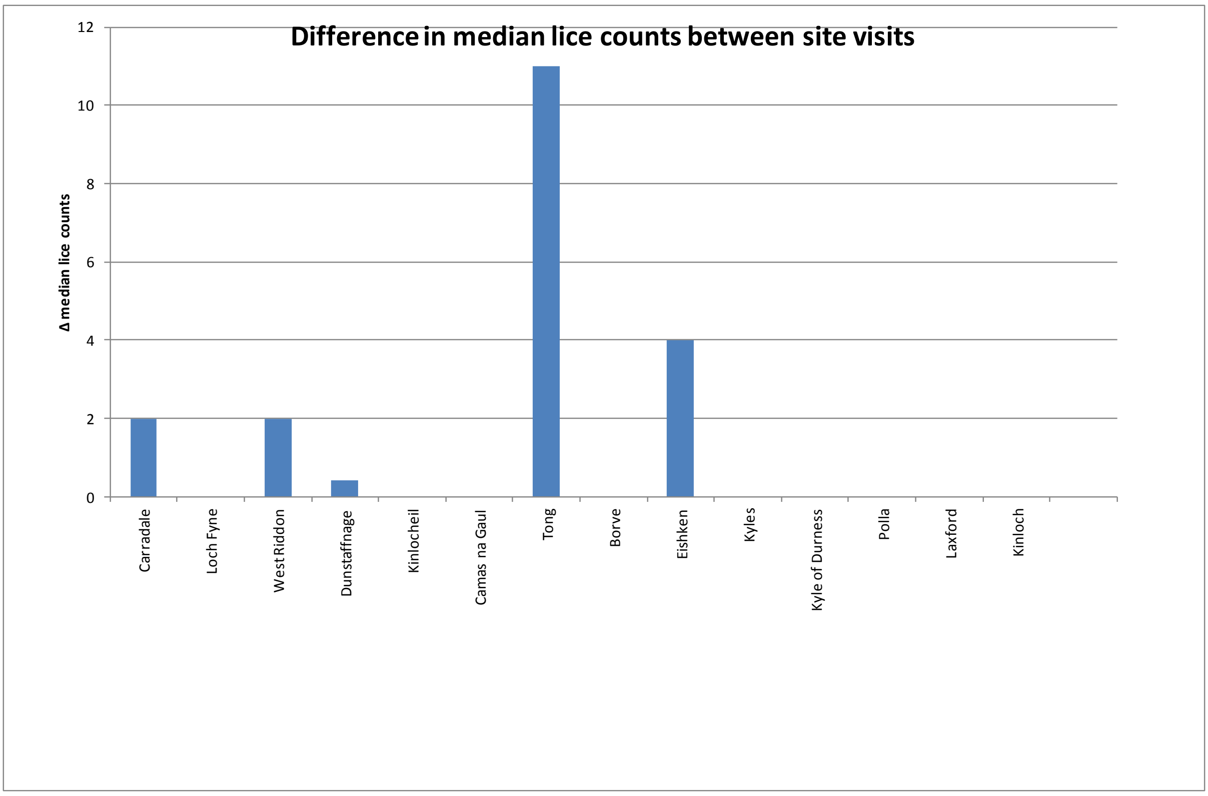


*Figure 14: Differences in median sea lice counts between sampling events for 2014.*

# 4 Discussion

## 4.1 Managing Interactions

The 2014 data provide a snapshot of the levels of sea lice on post-smolt sea trout of the West Coast of Scotland. The current sampling strategy is designed to explore the relationship between sea lice burdens on post-smolt sea trout and the distance to the nearest salmon aquaculture site to build upon the analysis conducted by Middlemas *et al.* (2012). For this project, no attempt is made to link sea lice levels found on wild sea trout to the nearest salmon fish farm, however the data are viewed in the context of fish farming. Attempting to link sea lice levels on wild sea trout to the nearest fish farm may not be appropriate, as prevailing wind direction and sea currents may transport fish farm derived sea lice away from salmonid rivers (Adams *et al*. 2012), and sea trout in the marine environment are mobile and can interact with more than one fish farm. However, sea lice epizootics are rare in areas without salmon aquaculture (Revie *et al.* 2008).

The only site in 2014 with the required sample size that was indicative of an epizootic was at West Riddon in Argyll, where 12.9% of fish sampled had a harmful level of sea lice. However in 2013 this site only recorded a prevalence of 17% with abundance of 0.14, and 2012 results were a prevalence of 98% and abundance of 9.5 sea lice per fish sampled. In 2013, three sites indicated a potential epizootic; Eishken, Camas na Gaul and Kannaird, yet none of these sites were indicative of an epizootic in 2014 (albeit the site at Eishken had a prevalence figure in excess of 80%, however abundance was less than 3.5 lice per fish). These results indicate that the pressures on wild salmonids from sea lice vary temporally as well as spatially.

When considering the epizootic threshold (Costello, 2009) and the *L. salmonis* mobile threshold (Wells *et al,* 2006), it is possible to identify the sea trout populations in the study areas that are under pressure from detrimental sea lice loadings. It is important that management strategies are developed to support the reduction of sea lice burdens on such post smolt populations.

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

"*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 is continuing to achieve this aim.

The interactions between sea lice levels on wild sea trout populations and those observed at active fish farm sites is a highly complicated issue. There are many factors potentially influencing the interactions between wild salmonids and salmon aquaculture, and understanding those interactions is vital for the ongoing management of wild salmonid rivers and for aquaculture.

**4.2 Farmed fish sea lice counts.**

Every active fish farm in Scotland is required to conduct regular counts of sea lice on the farmed salmon. The Scottish Salmon Producers Organisation (SSPO) collates and aggregates the data, which are published in publicly available reports on their website for 30 management regions across Scotland (reports can be downloaded from http://www.scottishsalmon.co.uk/science/sea_lice/regional_reports%281%29.aspx ).

The lice counts are for adult female sea lice, and therefore do not include chalimus, pre adult or adult male stages, which are included in the post smolt sweep netting counts. The values provided are averages for all active farms within a production area and do not give details of sea lice levels on individual farms. The SSPO Code of Good Practice suggests treatment thresholds for female adult lice of an average of 0.5 louse per fish during the wild smolt run (February to June inclusive), and an average of 1 louse per fish at other times (July to January inclusive). It should be noted that these limits are treatment thresholds, and do not state what the maximum permitted lice loadings on farmed fish should be.

**5. Conclusions**

In 2014 at 21 monitoring sites across the West coast and islands of Scotland nearly one thousand sea trout were evaluated and essential data recorded. Of the 21 monitoring sites, fourteen sampled the required number of sea trout to enable analysis to take place.

The 2014 data indicate that one site experienced sea lice infestations that could impact at a population level. 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 critical threshold level indicates that one of the monitoring sites had elevated levels of sea lice presence within the fish population that potentially could be having a critical detrimental impact.

This report is intended to simply present the data, and does not attempt to draw conclusions about the impact of salmon aquaculture on the wild fish populations of the West Coast of Scotland. It is recommended that a robust statistical analysis be conducted on all data collected for this project since 2011 to answer some of the fundamental questions relating to interactions between wild salmon and aquaculture, such as is aquaculture having an effect on wild salmonid populations.

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## 7. Appendices

### Appendix 1

*Table A1: Monitoring Site Mean Environmental Conditions over sample period in 2014.*

| Site ID | Site Name | Date | Water Temp (°C) | Salinity (PSU) | Date | Water Temp (°C) | Salinity (PSU) |
|---|---|---|---|---|---|---|---|
| 1 | Carradale | 05/06/2014 | 12.6 | 24 | 25/06/2014 | 15.4 | 25 |
| 2 | Loch Fyne | 21/05/2014 | 13.5 | 11 | 21/06/2014 | 19.6 | 18 |
| 3 | West Riddon | 20/05/2014 | 13.7 | 25 | 18/06/2014 | 15.7 | 27 |
| 4 | Dunstaffnage | 14/05/2014 | 12.5 | 21 | 20/06/2014 | 13.1 | 22 |
| 5 | Goil | 19/05/2014 | 12.9 | 23 | 21/06/2014 | 14.8 | 22 |
| 6 | Kinlocheil | 15/05/2014 | 11 | 15.6 | 03/07/2014 | 13 | 22.2 |
| | | 24/06/2014 | 14 | 17.4 | | | |
| 7 | Camas na Gaul | 22/05/2014 | 11 | 26.5 | 20/06/2014 | 13 | 28.9 |
| | | 03/06/2014 | 10 | 24 | | | |
| 9 | Borrodale | 04/06/2014 | 13 | 25.6 | 25/06/2014 | 13 | 20.1 |
| | | 17/06/2014 | 14 | 25.8 | 04/07/2014 | 13 | 27 |
| | | 22/06/2014 | 13 | 23.1 | 08/07/2014 | 13 | 27.4 |
| 10 | Tong | 14/05/2014 | 12.5 | 35 | 17/06/2014 | 19.5 | 35 |
| 12 | Borve | 16/05/2014 | 12.2 | 32 | 02/06/2014 | 13.6 | 35 |
| 13 | Eishken | 15/05/2014 | 13.6 | 35 | 18/06/2014 | 15.4 | 35 |
| 14 | Kyles | 27/05/2014 | 17.7 | 35 | 26/06/2014 | 23.4 | 35 |
| 15 | Malacheit | 28/05/2014 | 22.6 | 35 | 25/06/2014 | 15.6 | 35 |
| | | 29/05/2014 | 14 | 35 | 28/07/2014 | 19.2 | 35 |
| 16 | Kyle of Durness | 28/05/2014 | 8 | 12 | 12/06/2014 | 16.6 | 10 |
| 17 | Polla | 29/05/2014 | 14.7 | 4 | 16/06/2014 | 14.1 | 1 |
| 18 | Laxford | 16/05/2014 | 11.2 | 2 | 13/06/2014 | 15 | 1 |
| 19 | Kinloch | 28/05/2014 | 10 | 8 | 08/07/2014 | 17.9 | 2 |
| | | 12/06/2014 | 12.7 | 4 | | | |
| 20 | Kannaird | 16/06/2014 | 15 | 15 | 14/07/2014 | 15 | 15 |
| 21 | Boor Bay | 13/06/2014 | 12 | 33 | 11/07/2014 | 13 | 30 |
| | | 27/06/2014 | 14 | 33 | | | |
| 22 | Flowerdale | 12/06/2014 | 13 | 30 | 10/07/2014 | 13 | 30 |
| | | 28/06/2014 | 14 | 20 | | | |
| 23 | Loch Slapin | 17/06/2014 | 14 | 15 | 17/07/2014 | 14 | 15 |
| | | 02/07/2014 | 14 | 15 | | | |

**Appendix 2**

*Table A2: Prevalence, Abundance, Intensity and Median analysis for Copepodid/Chalimi at each monitoring site 2014.*

| Site ID | Site Name | Total Number of Post Smolts (260mm) within sample | Prevalence | Abundance (± S.D.) | Intensity (± S.D.) | Median |
|---|---|---|---|---|---|---|
| 1 | Carradale | 43 | 9.30 | 0.16 (± 0.65) | 4.0 (± 0.83) | 0 |
| 2 | Loch Fyne | 71 | 1.41 | 0.02 (± 0.18) | 3.0 (± 0) | 0 |
| 3 | West Riddon | 62 | 67.74 | 2.34 (± 1.9) | 4.92 (±1.23) | 2 |
| 4 | Dunstaffnage | 76 | 21.33 | 0.25 (±0.63) | 1.89 (± 0.65) | 0 |
| 5 | Goil | 5 | 60.00 | 2.84 (±2.60) | 8.41 (± 0.67) | 6 |
| 6 | Kinlocheil | 58 | 3.45 | 0.02 (± 0.14) | 1.0 (± 0) | 0 |
| 7 | Camas na Gaul | 59 | 0.00 | 0 | 0 | 0 |
| 9 | Borrodale | 12 | 16.67 | 0.44 (± 1.34) | 7.77 (± 0.38) | 0 |
| 10 | Tong | 46 | 50.00 | 1.45 (± 1.69) | 5.0 (±0.94) | 0.41 |
| 12 | Borve | 62 | 6.45 | 0.13 (± 0.77) | 5.80 (± 3.22) | 0 |
| 13 | Eishken | 50 | 34.00 | 1.22 (± 2.5) | 9.42 (± 1.75) | 0 |
| 14 | Kyles | 40 | 72.50 | 3.64 (± 2.04) | 7.32 (± 0.95) | 5 |
| 15 | Malacheit | 27 | 48.15 | 1.57 (± 2.12) | 6.08 (±1.24) | 0 |
| 16 | Kyle of Durness | 30 | 40.00 | 0.41 (±0.57) | 1.34 (±0.28) | 0 |
| 17 | Polla | 51 | 0.00 | 0 | 0 | 0 |
| 18 | Laxford | 94 | 0.00 | 0 | 0 | 0 |
| 19 | Kinloch | 30 | 16.67 | 0.24 (± 0.69) | 2.68 (±0.58) | 0 |
| 20 | Kannaird | 29 | 62.07 | 4.26 (±3.94) | 13.51 (± 2017) | 6 |
| 21 | Boor Bay | 2 | 100.00 | 2.46 (± 0.23) | 2.46 (± 0.23) | 2.46 |
| 22 | Flowerdale | 20 | 10.00 | 0.09 (± 0) | 1.45 (± 0) | 0 |
| 23 | Loch Slapin | 13 | 100.00 | 6.03 (± 0.86) | 6.03 (± 0.86) | 6 |

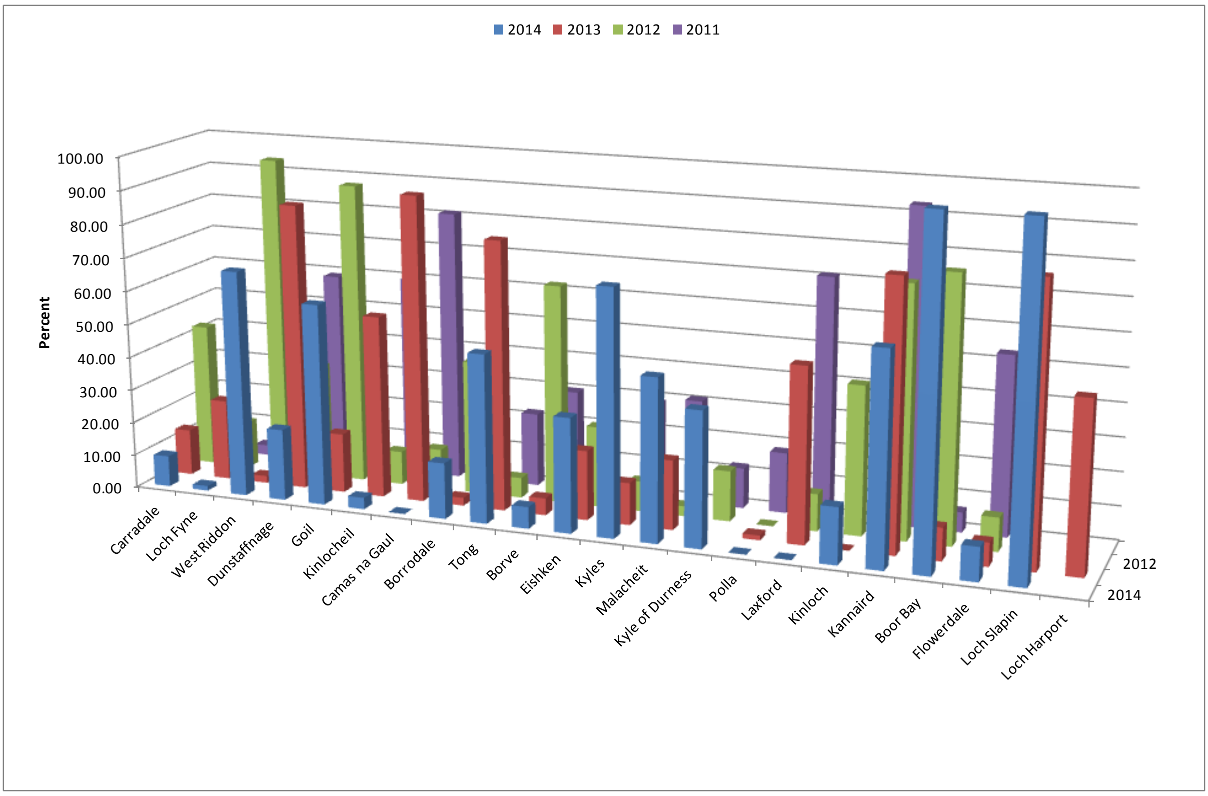


*Figure A. 1. L. salmonis Copepodid/Chalimi Stages Prevalence results for 2012, 2013 and 2014 for all sites.*

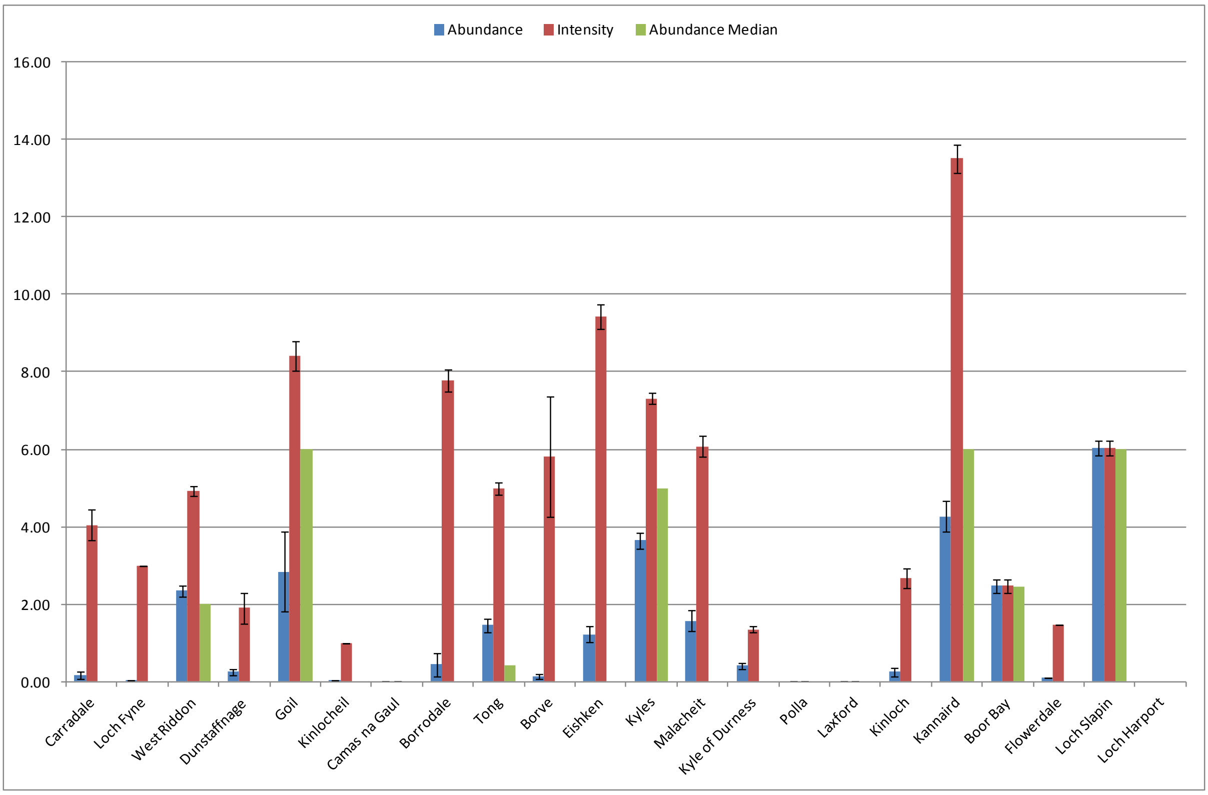


*Figure A2. Back transformed abundance, intensity and median values for L. salmonis Copepodid/Chalimi Stages for 2014.*

**Appendix 3**

*Table A3: Prevalence, Abundance, Intensity and Median analysis for Preadult/Adult at each monitoring site 2014.*

| Site ID | Site Name | Total Number of Post Smolts (260mm) within sample | Prevalence | Abundance (± S.D.) | Intensity (± S.D.) | Median |
|---|---|---|---|---|---|---|
| 1 | Carradale | 43 | 6.98 | 0.05 (± 0.2) | 1.0 (± 0) | 0 |
| 2 | Loch Fyne | 71 | 5.63 | 0.03 (± 0.15) | 1.0 (± 0) | 0 |
| 3 | West Riddon | 62 | 74.19 | 1.87 (± 1.44) | 3.14 (±1.09) | 2 |
| 4 | Dunstaffnage | 76 | 21.33 | 0.19 (± 0.43) | 1.29 (± 0.30) | 0 |
| 5 | Goil | 5 | 80.00 | 1.7 (± 1.12) | 2.46 (± 0.80) | 2 |
| 6 | Kinlocheil | 58 | 0.00 | 0 | 0 | 0 |
| 7 | Camas na Gaul | 59 | 0.00 | 0 | 0 | 0 |
| 9 | Borrodale | 12 | 25.00 | 0.28 (± 0.66) | 1.71 (± 0.70) | 0 |
| 10 | Tong | 46 | 52.17 | 1.42 (± 1.60) | 4.84 (± 0.82) | 0.4 |
| 12 | Borve | 62 | 3.23 | 0.03 (± 0.18) | 1.45 (± 0.33) | 0 |
| 13 | Eishken | 50 | 82.00 | 2.25 (± 1.41) | 3.20 (± 1.13) | 2 |
| 14 | Kyles | 40 | 90.00 | 3.18 (± 1.03) | 3.90 (± 0.73) | 3 |
| 15 | Malacheit | 27 | 66.67 | 1.68 (± 1.30) | 3.38 (± 0.72) | 2 |
| 16 | Kyle of Durness | 30 | 0.00 | 0 | 0 | 0 |
| 17 | Polla | 51 | 3.92 | 0.03 (± 0.21) | 3.0 (± 0.0) | 0 |
| 18 | Laxford | 94 | 0.00 | 0 | 0 | 0 |
| 19 | Kinloch | 30 | 6.67 | 0.09 (± 0.45) | 2.74 (± 1.42) | 0 |
| 20 | Kannaird | 29 | 51.72 | 1.10 (±1.40) | 3.19 (± 0.99) | 1 |
| 21 | Boor Bay | 2 | 100.00 | 1.83 (0.63) | 1.83 (0.63) | 1.8 |
| 22 | Flowerdale | 20 | 5.00 | 0.03 (± 0.0) | 1.0 (± 0.0) | 0 |
| 23 | Loch Slapin | 13 | 92.31 | 4.39 (± 1.25) | 5.20 (± 0.94) | 5 |

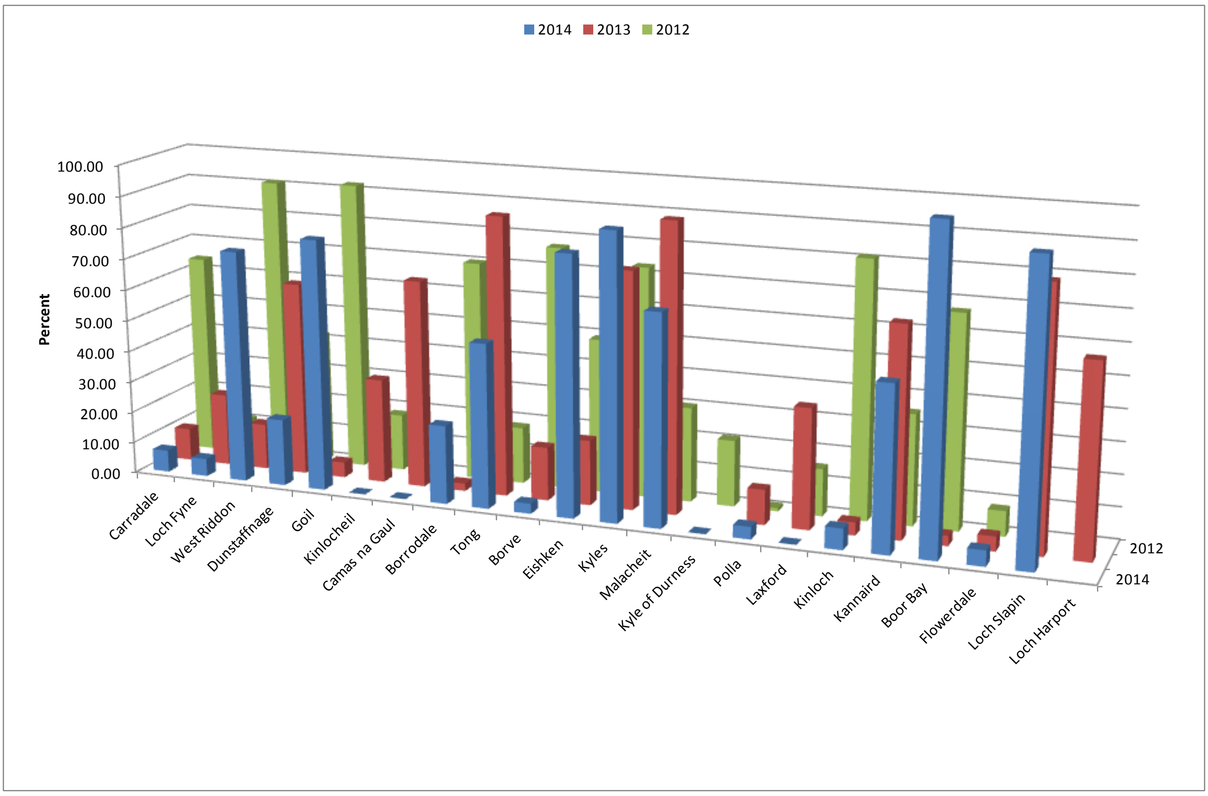


*Figure A3. L.salmonis prevalence for Preadult/Adult for 2012, 2013 and 2014 for all sites.*

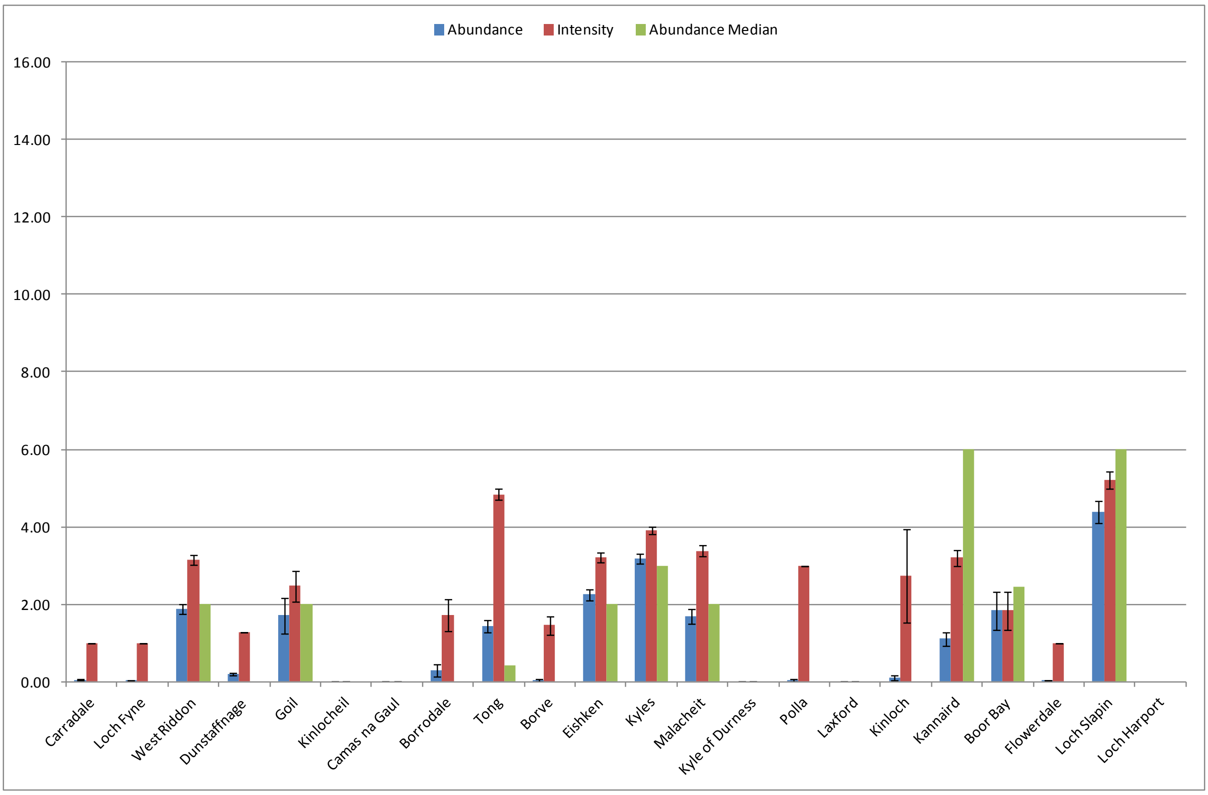


*Figure A4. Back transformed abundance, intensity and median values for L. salmonis Preadult/Adult Stages for 2014.*

## Appendix 4

*Table A4: Prevalence, Abundance, Intensity and Median analysis for Ovigerous Females at each monitoring site 2015.*

| Site ID | Site Name | Total Number of Post Smolts (260mm) within sample | Prevalence | Abundance (± S.D.) | Intensity (± S.D.) | Median |
|---|---|---|---|---|---|---|
| 1 | Carradale | 43 | 6.98 | 0.05 (± 0.19) | 1.0 (± 0) | 0 |
| 2 | Loch Fyne | 71 | 0.00 | 0 | 0 | 0 |
| 3 | West Riddon | 62 | 19.35 | 0.18 (± 0.51) | 1.40 (± 0.68) | 0 |
| 4 | Dunstaffnage | 76 | 13.33 | 0.15 (± 0.47) | 1.84 (± 0.67) | 0 |
| 5 | Goil | 5 | 20.00 | 0.15 (± 0.36) | 1.0 (± 0) | 0 |
| 6 | Kinlocheil | 58 | 0.00 | 0 | 0 | 0 |
| 7 | Camas na Gaul | 59 | 0.00 | 0 | 0 | 0 |
| 9 | Borrodale | 12 | 0.00 | 0 | 0 | 0 |
| 10 | Tong | 46 | 32.61 | 0.38 (± 0.64) | 1.70 (± 0.44) | 0 |
| 12 | Borve | 62 | 1.61 | 0.01 (± 0.09) | 1.0 (± 0) | 0 |
| 13 | Eishken | 50 | 0.00 | 0 | 0 | 0 |
| 14 | Kyles | 40 | 40.00 | 0.69 (± 1.08) | 2.69 (± 0.75) | 0 |
| 15 | Malacheit | 27 | 33.33 | 0.38 (± 0.65) | 1.65 (± 0.37) | 0 |
| 16 | Kyle of Durness | 30 | 3.33 | 0.02 (± 0.13) | 1.0 (± 0) | 0 |
| 17 | Polla | 51 | 0.00 | 0 | 0 | 0 |
| 18 | Laxford | 94 | 0.00 | 0 | 0 | 0 |
| 19 | Kinloch | 30 | 6.67 | 0.06 (± 0.26) | 1.45 (± 0.33) | 0 |
| 20 | Kannaird | 29 | 20.69 | 0.26 (± 0.64) | 2.02 (± 0.58) | 0 |
| 21 | Boor Bay | 2 | 50.00 | 0.41 (± 0.63) | 1.0 (± 0) | 0.41 |
| 22 | Flowerdale | 20 | 0.00 | 0 | 0 | 0 |
| 23 | Loch Slapin | 13 | 53.85 | 0.77 (± 0.87) | 1.89 (± 0.53) | 0.86 |

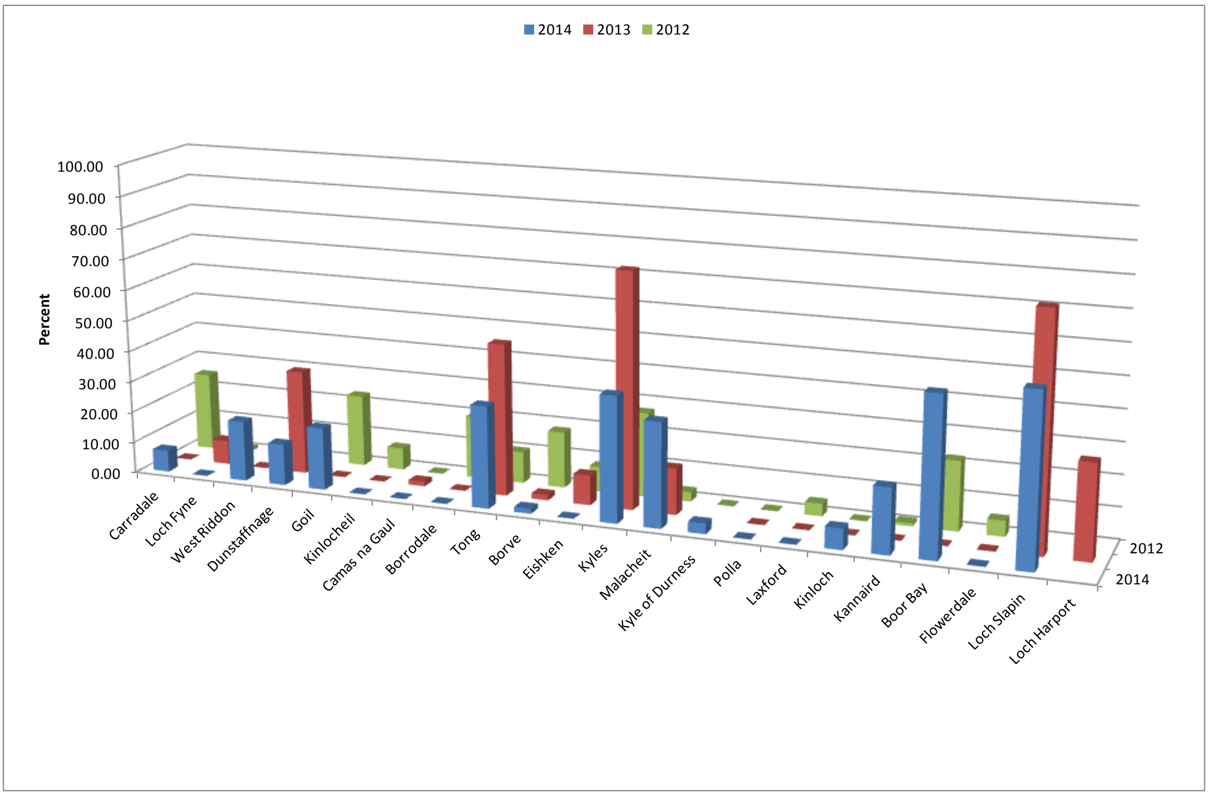


*Figure A5.L .salmonis prevalence for Ovigerous females for 2012, 2013 and 2014 for all sites.*

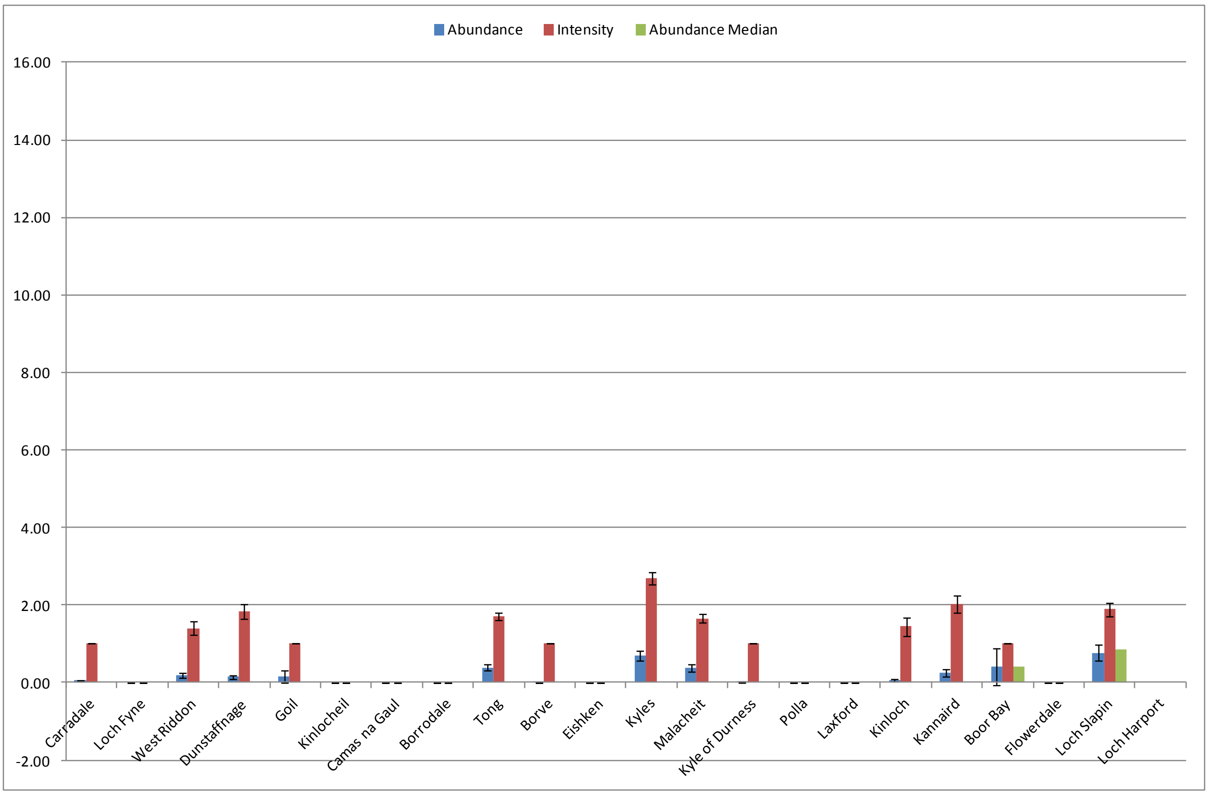


*Figure A6. Back transformed abundance, intensity and median values for L. salmonis Ovigerous female Stage for 2014*

## Appendix 5

*Table A5: Prevalence, Abundance, Intensity and Median analysis for total L. salmonis at each monitoring site 2014.*

| Site ID | Site Name | Total Number of Post Smolts (260mm) within sample | Prevalence | Abundance (± S.D.) | Intensity (± S.D.) | Median |
|---|---|---|---|---|---|---|
| 1 | Carradale | 43 | 13.95 | 0.23 (± 0.75) | 3.32 (± 0.91) | 0 |
| 2 | Loch Fyne | 71 | 7.04 | 0.06 (± 0.25) | 1.30 (± 0.36) | 0 |
| 3 | West Riddon | 62 | 80.65 | 4.48 (± 2.10) | 7.23 (± 1.33) | 5.5 |
| 4 | Dunstaffnage | 76 | 40.00 | 0.56 (± 0.91) | 2.07 (± 0.72) | 0 |
| 5 | Goil | 5 | 100.00 | 5.32 (± 1.68) | 5.32 (± 1.68) | 6 |
| 6 | Kinlocheil | 58 | 3.45 | 0.02 (± 0.14) | 1.0 (± 0) | 0 |
| 7 | Camas na Gaul | 59 | 0.00 | 0 | 0 | 0 |
| 9 | Borrodale | 12 | 25.00 | 0.59 (± 1.57) | 5.41 (± 1.75) | 0 |
| 10 | Tong | 46 | 56.52 | 2.86 (± 2.54) | 9.93 (± 0.71) | 5 |
| 12 | Borve | 62 | 8.06 | 0.15 (± 0.82) | 4.93 (± 2.87) | 0 |
| 13 | Eishken | 50 | 82.00 | 3.42 (± 2.39) | 5.13 (± 2.02) | 2 |
| 14 | Kyles | 40 | 92.50 | 8.55 (± 1.52) | 10.47 (± 0.98) | 9 |
| 15 | Malacheit | 27 | 77.78 | 3.53 (± 2.20) | 5.97 (± 1.55) | 4 |
| 16 | Kyle of Durness | 30 | 40.00 | 0.43 (± 0.60) | 1.43 (± 0.29) | 0 |
| 17 | Polla | 51 | 3.92 | 0.03 (± 0.21) | 3.0 (± 0) | 0 |
| 18 | Laxford | 94 | 0.00 | 0 | 0 | 0 |
| 19 | Kinloch | 30 | 16.67 | 0.30 (± 0.91) | 3.74 (± 1.08) | 0 |
| 20 | Kannaird | 29 | 65.52 | 5.09 (± 4.16) | 14.78 (± 2.29) | 6 |
| 21 | Boor Bay | 2 | 100.00 | 4.66 (± 0.63) | 4.66 (± 0.63) | 4.7 |
| 22 | Flowerdale | 20 | 10.00 | 0.11 (± 0) | 1.83 (± 0) | 0 |
| 23 | Loch Slapin | 13 | 100.00 | 11.46 (± 0.96) | 11.46 (± 0.95) | 16 |

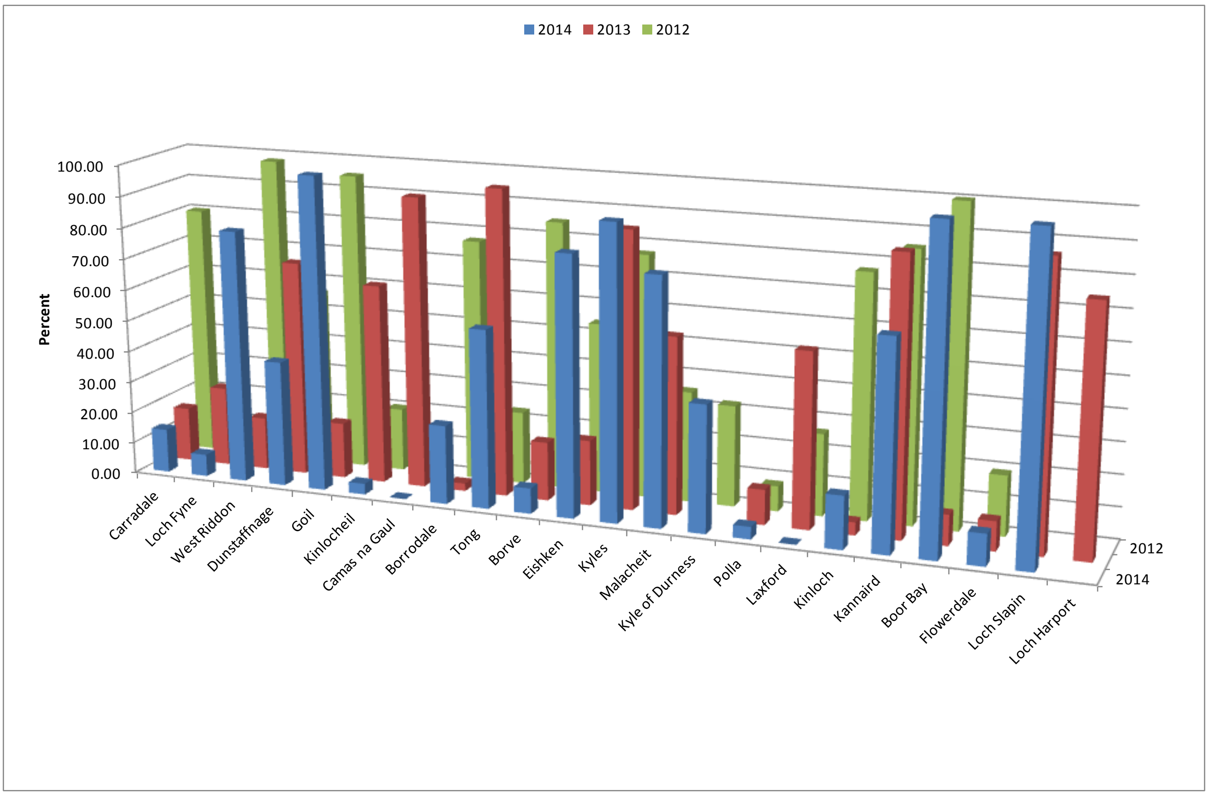


*Figure A7. L .salmonis prevalence all stages for 2012, 2013 and 2014 for all sites*

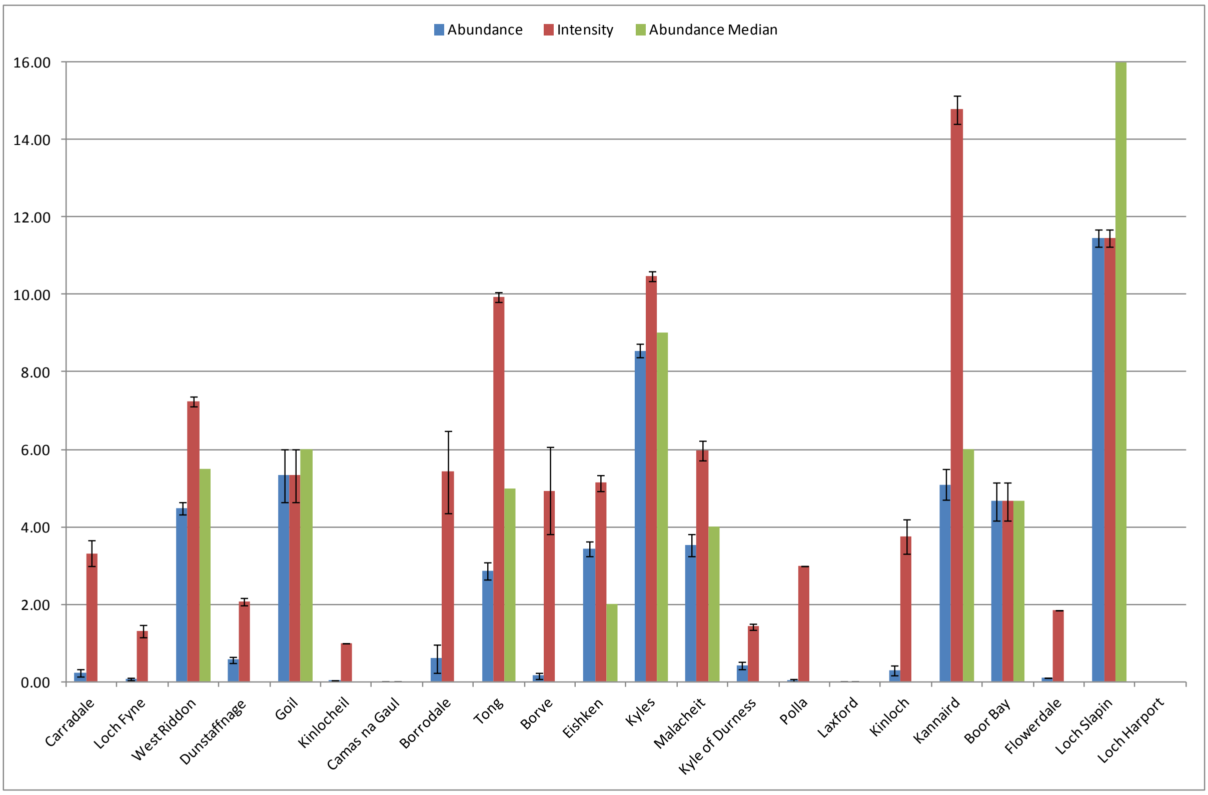


*Figure A8. Back transformed abundance, intensity and median values for L. salmonis all stages for 2014*

**Appendix 6: Long term data series**

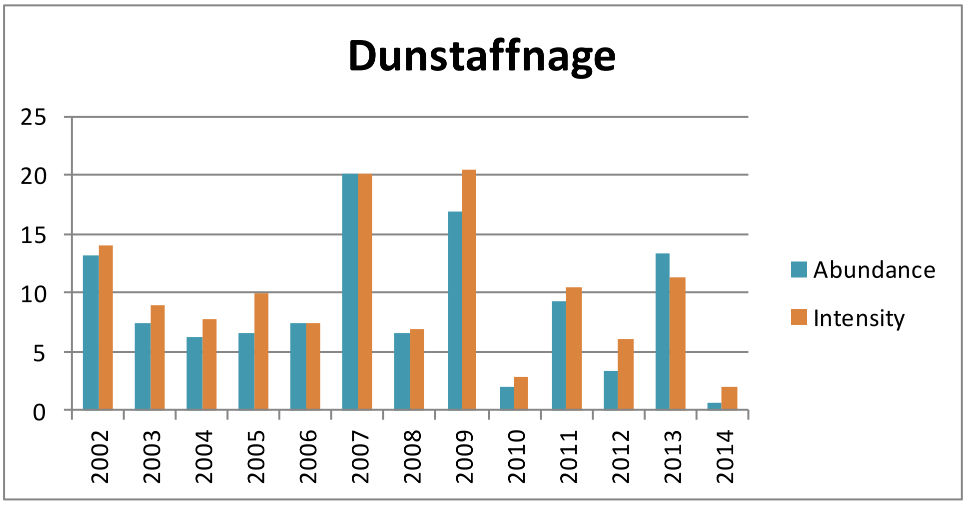


Figure A9: Abundance and intensity values for Dunstaffnage from 2002-2014

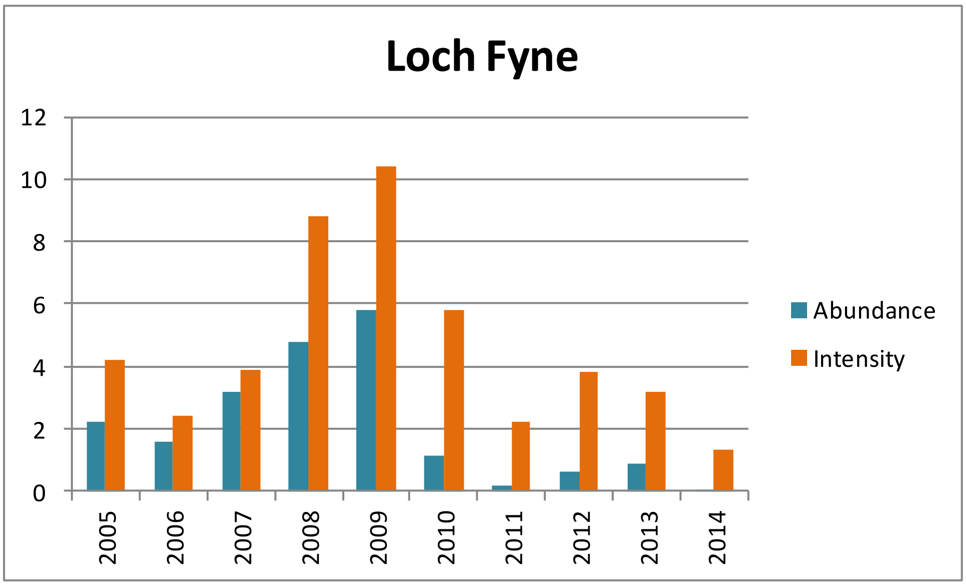


Figure A10: Abundance and intensity values for Loch Fyne from 2005-2014

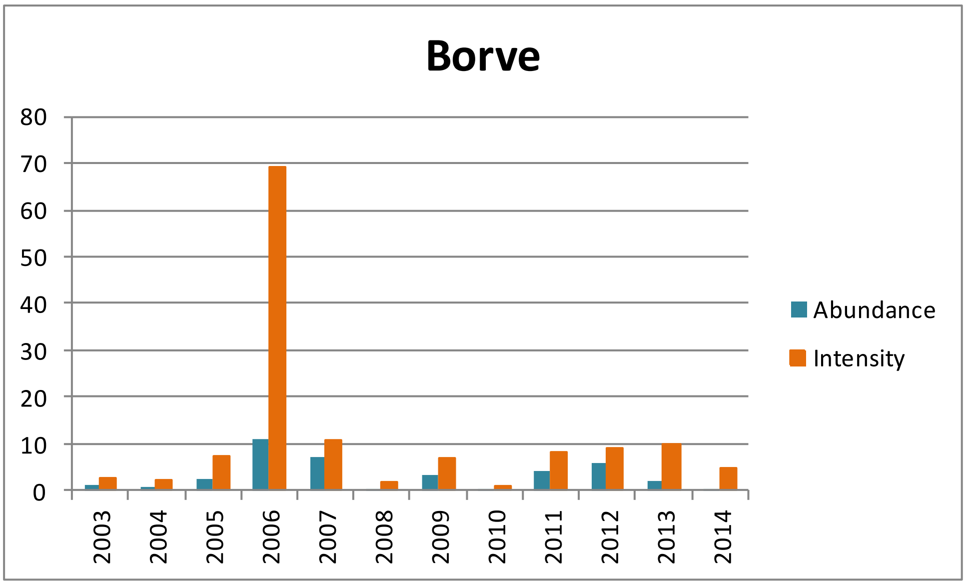


Figure A11: Abundance and intensity values for Borve from 2003-2014

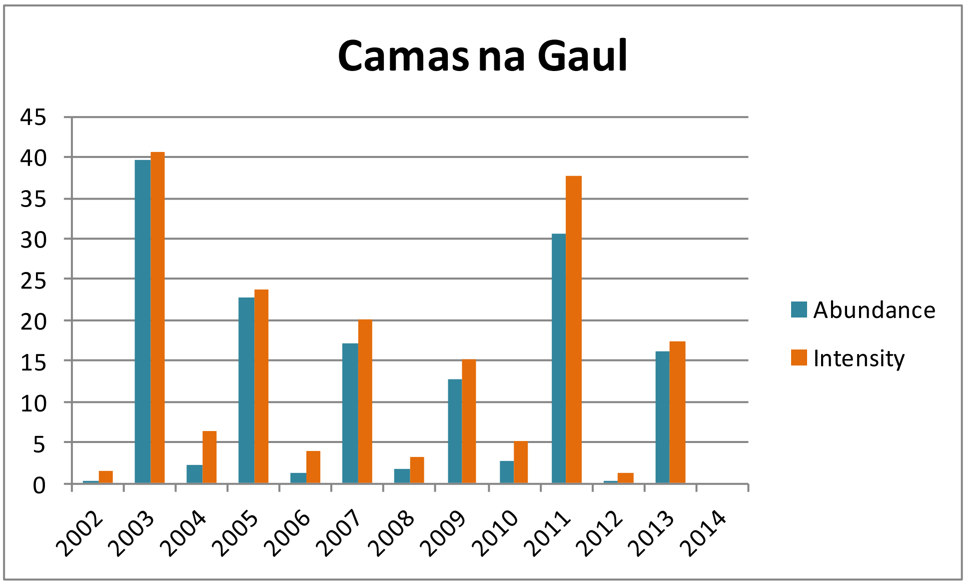


Figure A12: Abundance and intensity values for Camas na Gaul from 2002-2014

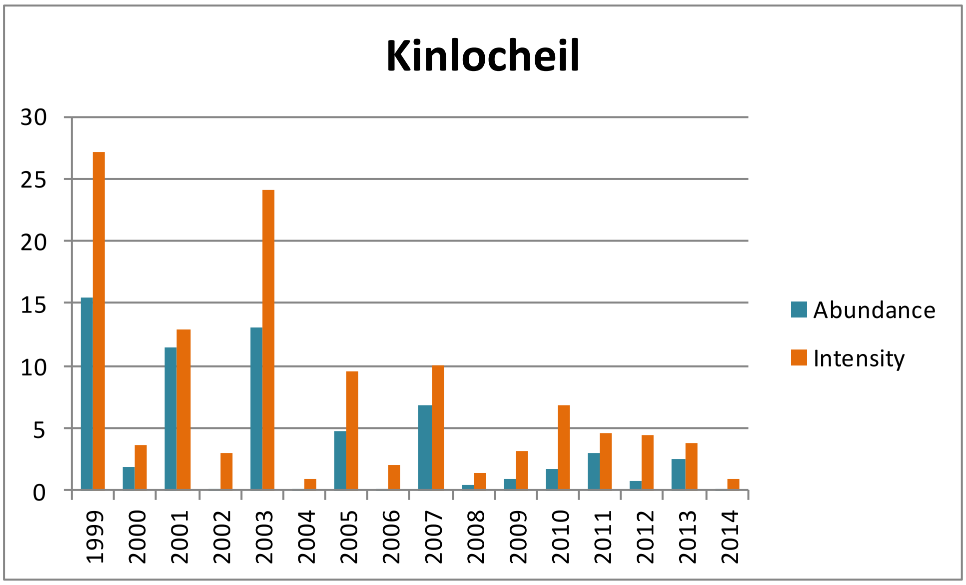


Figure A13: Abundance and intensity values for Kinlocheil from 1999-2014