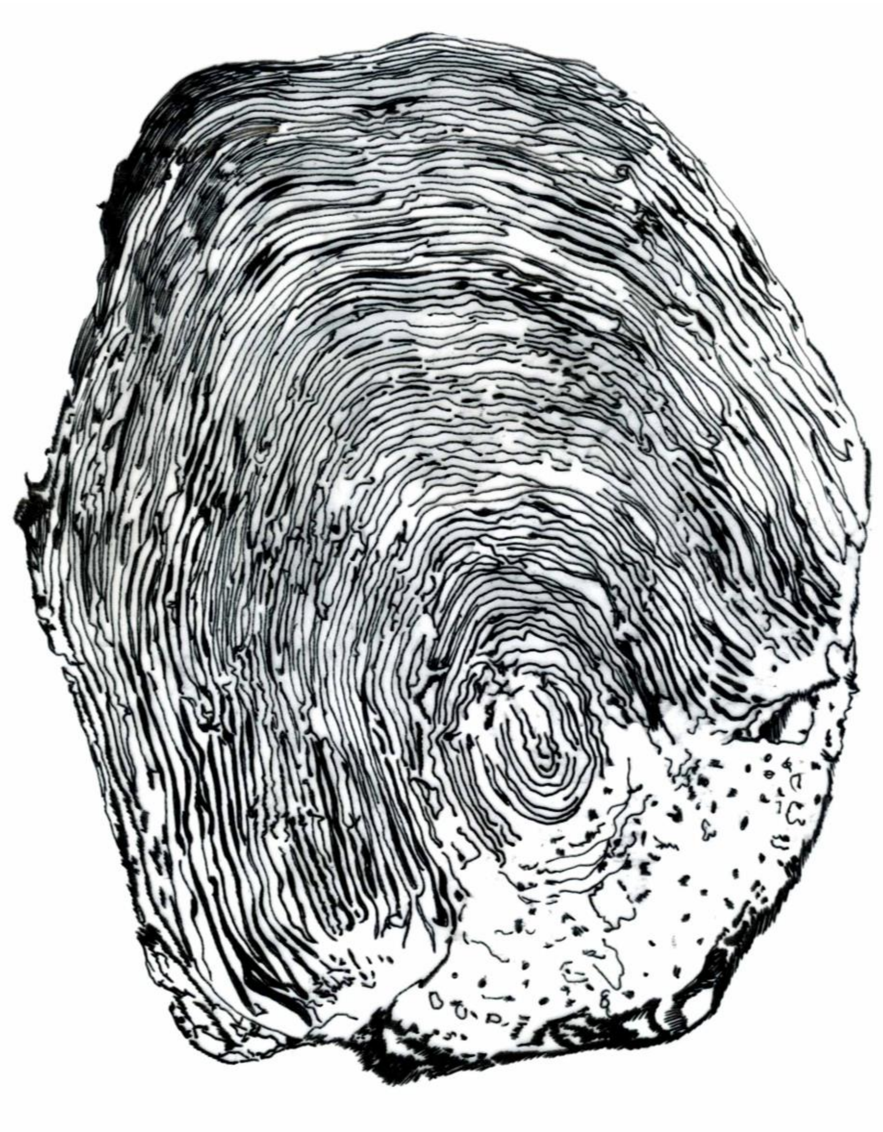
River Oykel Scale Reading 2013-2015



Kyle of Sutherland Fisheries

Report by Keith Williams

1. Introduction

Stock structure and differences in life history are an important consideration when managing a fishery. The Kyle of Sutherland Fisheries Trust collects and collates data for a number of different fish species and utilises such information to inform the management of those species within the catchment. To date, a number of different techniques have been utilised in order to increase the understanding of the life history of the most economically important species present in the Kyle of Sutherland catchment such as salmon, trout and sea trout. Techniques utilised include scale reading, electro-fishing, seine netting, smolt trapping and DNA analyses.

A scale reading programme targeted at the River Oykel catchment was initiated in 2013 with the aim of increasing the understanding of the age profile of juvenile and adult stocks within that system. In addition to scales from the Oykel, some scales from juvenile salmon were also taken from other rivers in order to ascertain if there were any major differences in age profile between the Oykel and other areas of the Kyle of Sutherland district.

Of particular interest in management terms is the age profile of fish emanating from the highest altitude sections of the Oykel catchment. Evidence from telemetry studies undertaken elsewhere suggests that the earliest entrants to a river system tend to migrate the furthest distance upstream. Early-running salmon are considered by many fishery managers within the Kyle of Sutherland district to be disproportionately important economically compared to later running salmon. Anglers visiting the catchment in the months of March and April extend the period in which revenues can be derived from the fishery.

2. Methodology

Sampling of salmon was undertaken at both juvenile and adult life stages. Juvenile sampling was undertaken as part of the routine electro-fishing surveys undertaken by Kyle of Sutherland Fisheries staff in both the Oykel catchment and elsewhere in the Kyle of Sutherland District. Emphasis was placed on collecting samples from juveniles other than those that were ostensibly young-of-the year i.e. salmon parr not salmon fry. Samples were collected in 2013 and 2015. Samples were also collected from adult fish, largely by ghillies employed on the Lower and Upper Oykel fisheries respectively, over the course of the 2013, 2014 and 2015 angling seasons. Samples were taken opportunistically but emphasis was placed on obtaining samples across the fishing season as much as possible. Historical data available for the Oykel catchment and elsewhere in the Kyle of Sutherland area such as the River Carron has also been utilised wherever possible for the purposes of this report. A limited amount of rod catch information specific to the Oykel is available from the 1976 season. Additionally, age data derived from the Bonar Bridge net fishery over a period of several years has been made available from Marine Scotland Science. Although such data is not Oykel specific, results have been incorporated into this report for illustrative purposes.

3. Nomenclature

For the purposes of this report juvenile salmon are aged by the number of winters that they have spent in fresh water with the use of a plus sign denoting that the individual fish is older than the age given and has spent further time in fresh water. Fish captured in the electro-fishing surveys would almost certainly not enter the marine environment until the spring following their capture at the earliest. Thus a salmon that was in the gravel as an egg in the autumn of 2013 would have hatched in the spring of 2014. If the juvenile salmon was captured in 2014 summer electro-fishing surveys it would be denoted as a 0+ fry. If the fish was subsequently caught in an electro-fishing survey in the summer of 2015 and had its scales read it would be denoted as a 1+ salmon parr. If it was subsequently recaptured in 2016 it would be denoted as a 2+ parr, and so on.

For simplicity, the river age of returning adult salmon is denoted as the number of winters spent in the freshwater environment prior to undergoing smoltification and leaving the river for the marine environment. For the purposes of this report the freshwater age at smoltification is often termed the smolt age of the individual fish.

The sea age of the fish captured is also denoted by the number of winters that the individual fish has spent at sea. Thus a fish that left the Oykel as a smolt in the spring of 2013 and returned as an adult in the summer of 2014 would have a sea age of one. A fish that smolted at the same time but did not undertake its return migration until 2015 would have spent two winters at sea and would be denoted as a fish having a sea age of two. Atlantic salmon that have spent only one winter at sea prior to returning to their natal river are often referred to as grilse whereas those that are returning after having spent two or more winters at sea are, somewhat confusingly, termed salmon. For the purposes of this report the use of the word salmon in relation to fish captured in the rod or net fisheries can be taken to mean both grilse and salmon except in sections of the report where the distinction between the two has been specifically highlighted.

Atlantic Salmon are iteroparous i.e. they have the ability to undertake more than one spawning migration, unlike many Pacific salmon species. Fish undertaking their second spawning migration, often termed repeat spawners, are present in the Oykel catchment. For the purposes of this report the sea age of such fish has been taken as the number of winters spent at sea prior to the initial return spawning migration.

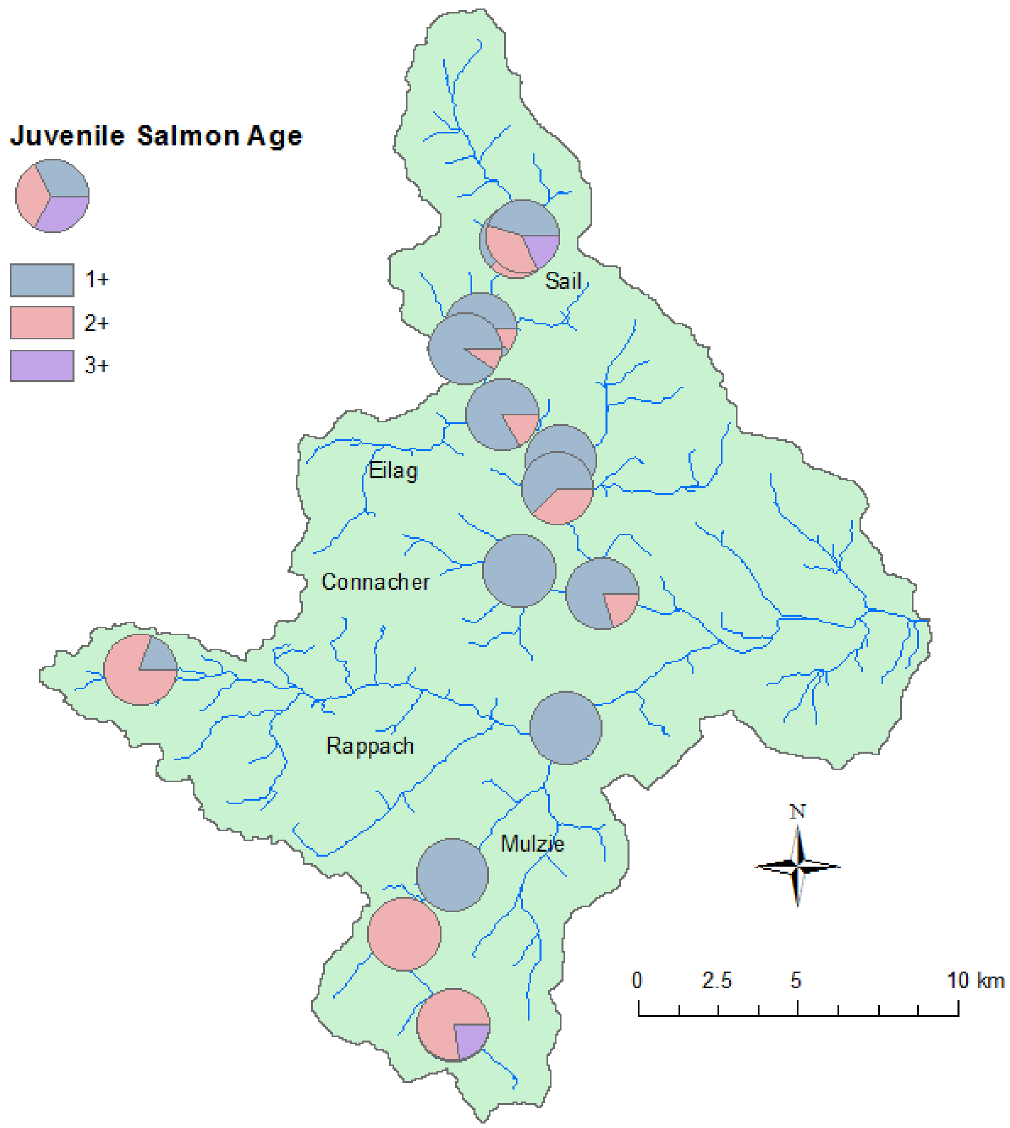
Other information such as evidence of growth in the marine environment following the final winter in the sea and evidence of erosion of the scales resulting from their absorption by fish when they return to a fresh water environment are not considered in this report.

4. Results

4.1 Juvenile Salmon Age

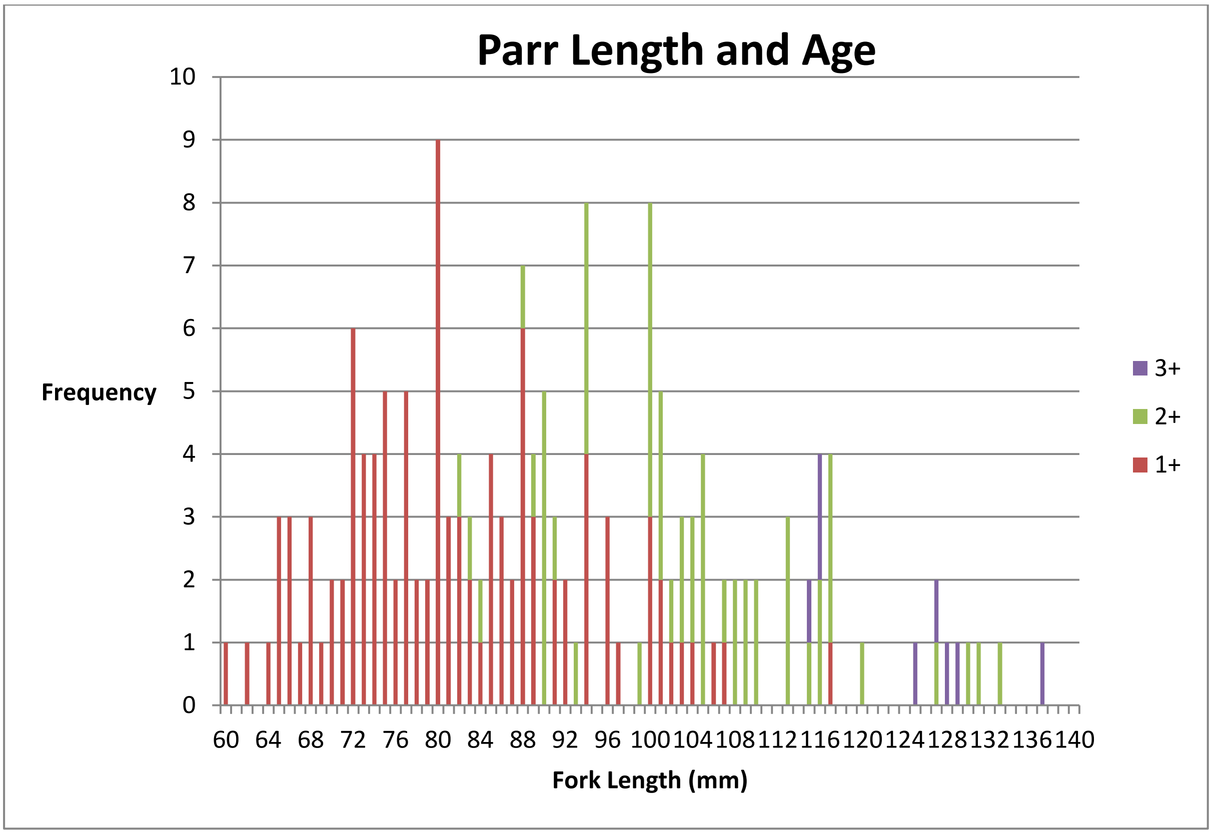
A total of 172 juvenile salmon scales were sampled in 2013 and 2015 within the Oykel catchment. Surveys were undertaken during the summer months. Figure 1 illustrates the proportion of salmon by age at the sites electro-fished. It should be noted that scale data from several sites on the upper reaches of the Mulzie tributary have been pooled for illustrative purposes.

Figure 1 Age of salmon at Oykel electro-fishing sites.



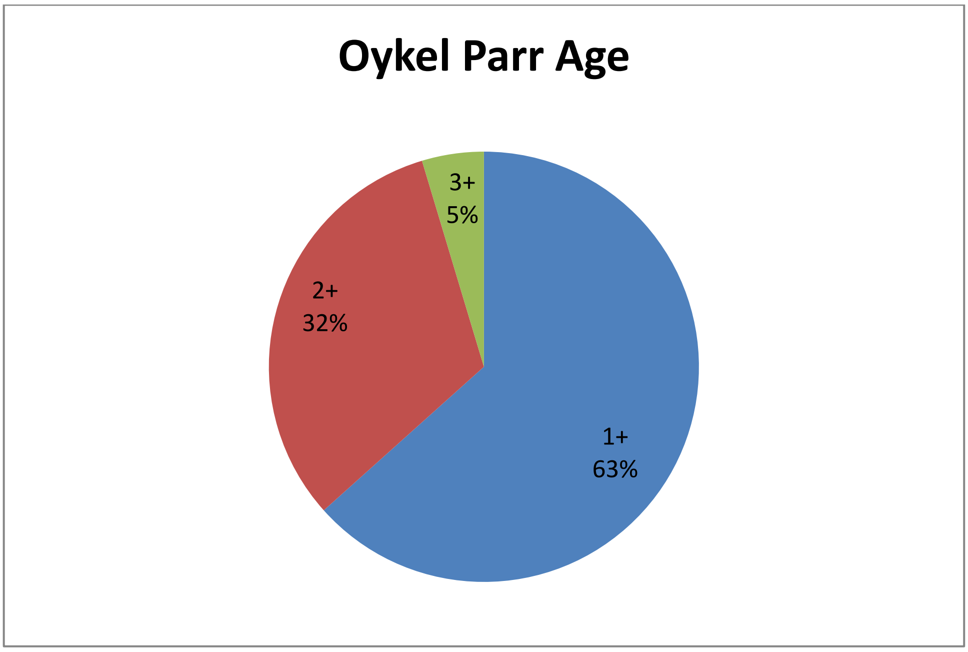
Three age classes of parr were captured during the surveys in addition to 0+ salmon fry which are not considered in this report. As all the salmon captured would spend a minimum of one additional winter in fresh water prior to smolting this suggests that Oykel smolts are aged 2, 3 and 4 although the presence of one year old smolts and smolts older than four years cannot be ruled out as a result of the surveys undertaken. It is likely that there are considerable variations in the age profile of smolts as a result of environmental and other factors. As anticipated, older age classes of juvenile salmon were more prevalent in the geographical extremities of the Oykel catchment although the relatively small sample size and limited number of sites fished precludes firm conclusions in this regard. Notable locations for older age classes of parr include the upper reaches of the Rappach, the Mulzie catchment and the Sail Burn at Benmore. Figure 2 illustrates that when the data from all sites is pooled there is considerable overlap of the length of parr at a given age. This is likely to be the reflection of differences in key variables such as water temperature and competition at individual sites.

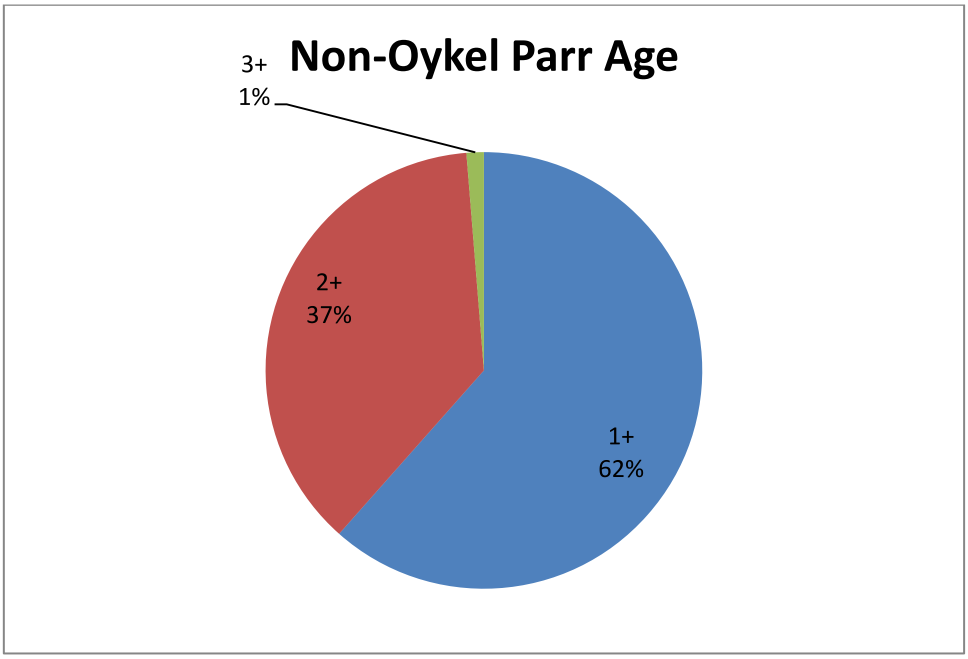
Figure 2 Salmon fork length frequency for pooled electro-fishing data. Different colours represent different age classes of salmon.



The overall age composition of salmon parr captured in the Oykel surveys is illustrated in Figure 3. As may be expected, the predominant age of the salmon parr sampled was 1+. In addition to the Oykel scale samples, a further 78 samples were taken during surveys in other parts of the Kyle of Sutherland catchment. Ostensibly similar results were obtained with 1+parr dominating the age composition. Only one 3+parr was captured out with the Oykel catchment although this may be an artefact of sampling location rather than the lack of older age classes of salmon parr present in the other Kyle of Sutherland rivers.

Figure 3 Proportions of age classes present at sites on the Oykel (upper chart) and elsewhere in the Kyle of Sutherland catchment (lower chart).

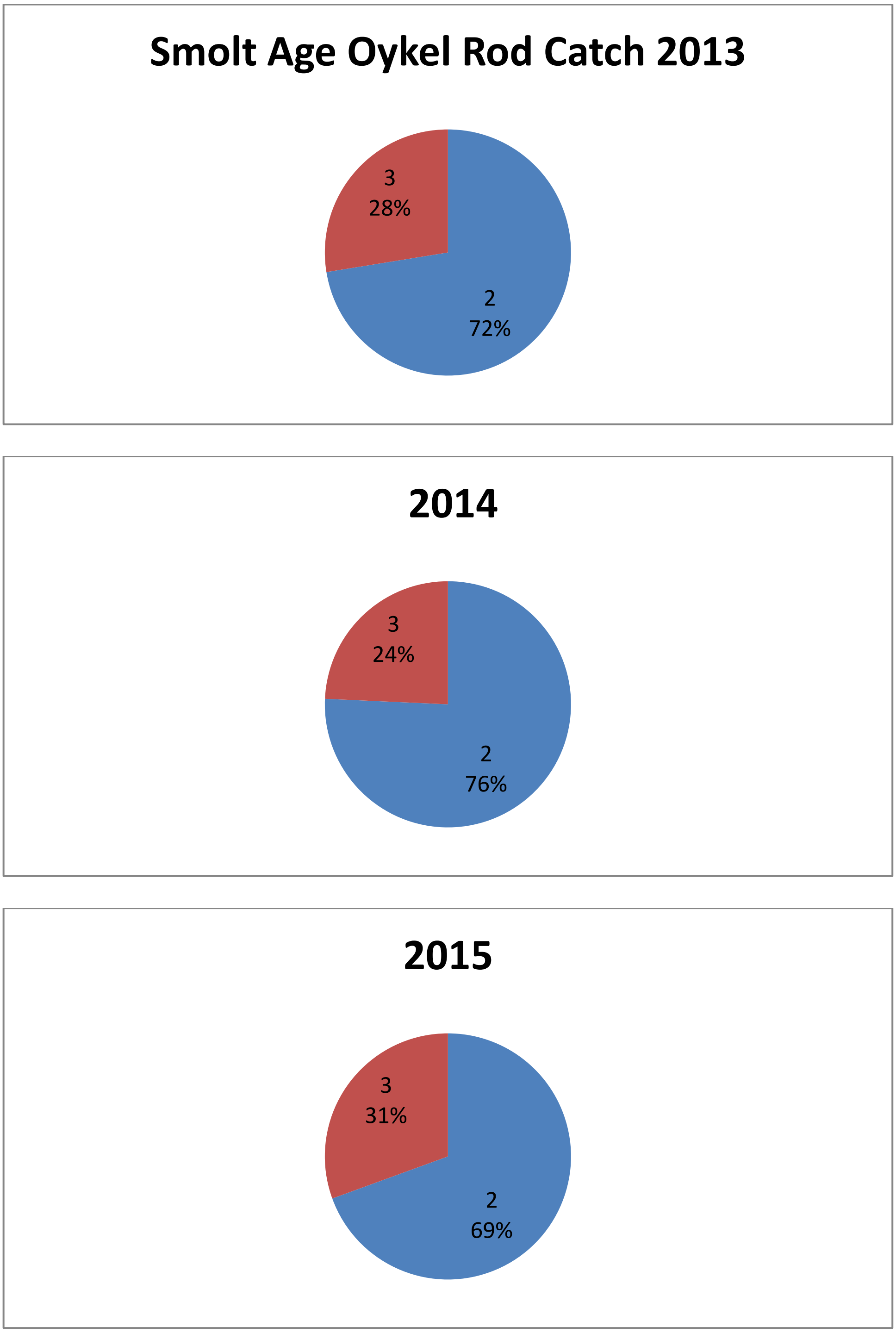




4.2 River Age of Returning Adult Salmon

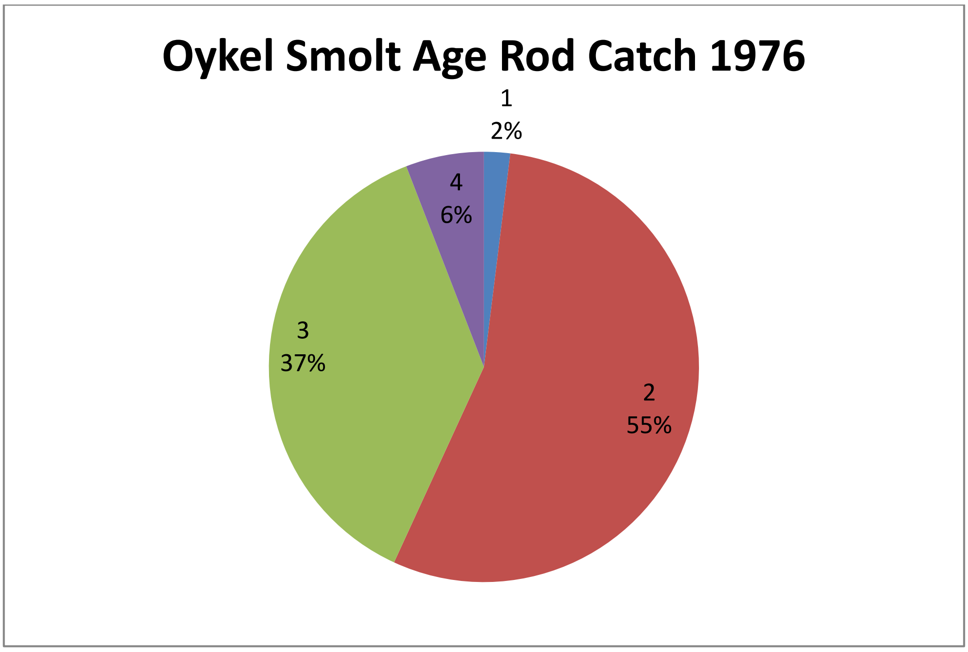
Data collected from electro-fishing sites is useful in obtaining some insights into the structure of stocks within the freshwater environment. However, it can also be considered limited in that it does not provide information on the age at which fish go to sea or the degree to make male salmon parr mature in freshwater and potentially complete their life cycle without entering into the marine environment. In order to obtain a better understanding of the present contribution of different age classes of smolts to the adult salmon fishery, and potentially by inference to the spawning stock of the Oykel, consideration is given to the age at smolting of the salmon sampled from the rod fishery in 2013, 2014 and 2015. Figure 4 illustrates the river age at smoltification of rod caught salmon on the River Oykel in the aforementioned years. A total of 453 adult salmon were sampled during the period (196 in 2013; 82 in 2014; and 175 in 2015), although river age at smoltification was not available for all fish. This is a common phenomenon due the presence of replacement scales or uncertainties associated with the reading of individual scales.

Figure 4 Age at smoltification of adult salmon captured in the Lower Oykel fishery.



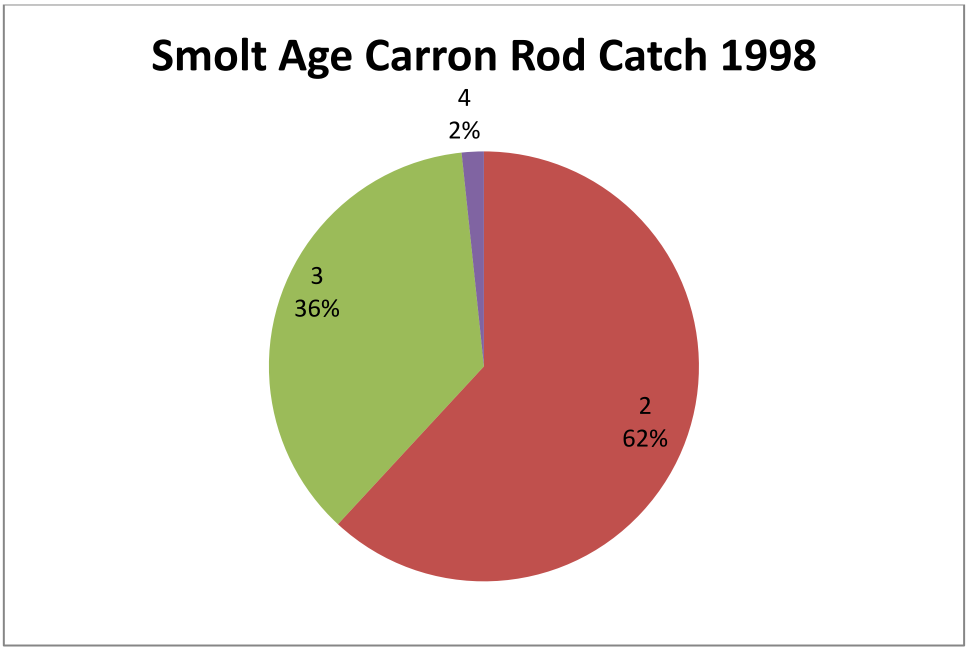
It can be seen from Figure 4 that all of the salmon sampled from the Lower Oykel in 2013-2015 were aged either two or three at smoltification, with two year old smolts predominating. The presence of only two age classes in the sampled adults is somewhat surprising given the presence of 3+ parr in the electro-fishing surveys plus the potential for smolts aged only one year to be produced from the Oykel. Only limited historical scale data for Oykel adult salmon appears to exist. In 1976 scales for 62 salmon angled from the River Oykel in the months April to September were obtained. It can be seen from Figure 5 that four river age classes of fish were represented in the salmon captured although predominately two and three year at smolt age were observed. This contrasts with the absence of one year and four year old smolts from the 2013, 2014 and 2015 rod catch samples. The proportion of three year old smolts in 1976 appears to be higher than that seen in the 2013-2015 sampling programme.

Figure 5 Age at smoltification of adult salmon captured in the rod fishery during the 1976 season.



During 1998 scales were sampled from the River Carron fishery, co-ordinated by Morgan Fisheries Consultancy, as part of investigations into the structure of salmon stocks present in that river system. A total of 193 scale samples were examined. Age at smoltification was readable for 183 of the scales available. The sample contained four age classes of salmon at smoltification although the two salmon that were one year old at smoltification were deemed to be of farm origin rather than wild. These have been excluded from subsequent analyses.The proportion of three year old smolts in the Carron sample (see Figure 6) appears to be higher than that found in the 2013-2015 Oykel rod catch samples and is more similar to the results obtained in the 1976 Oykel rod catch sample and the 1986, 1993 and 1994 Bonar Bridge netting samples (see Figure 7).

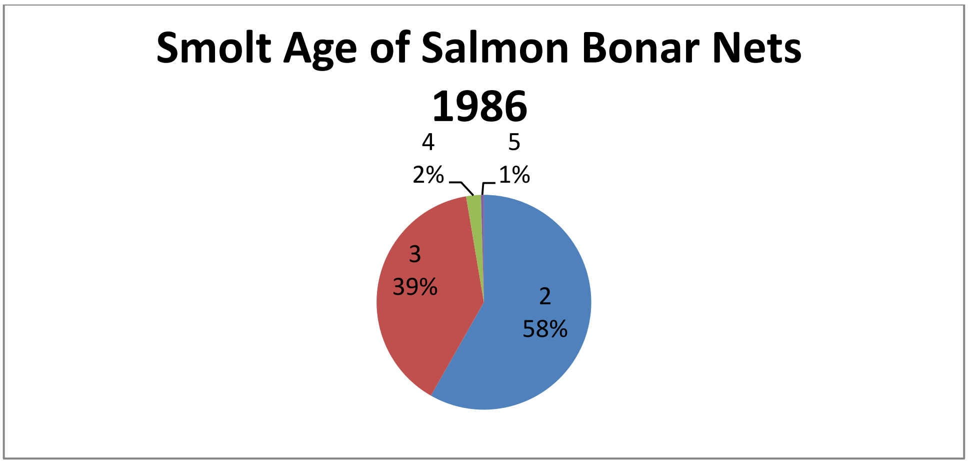
Figure 6 Smolt age data from The Morgan Fisheries Consultancy report on Carron salmon.

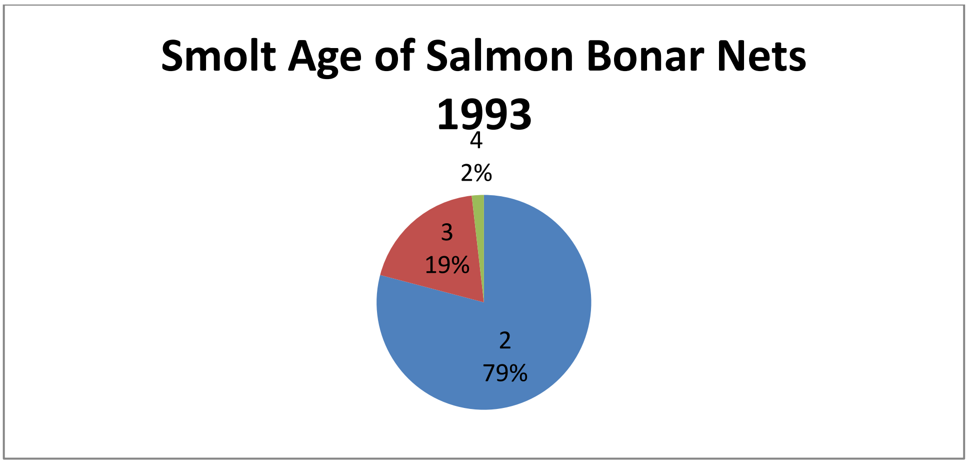


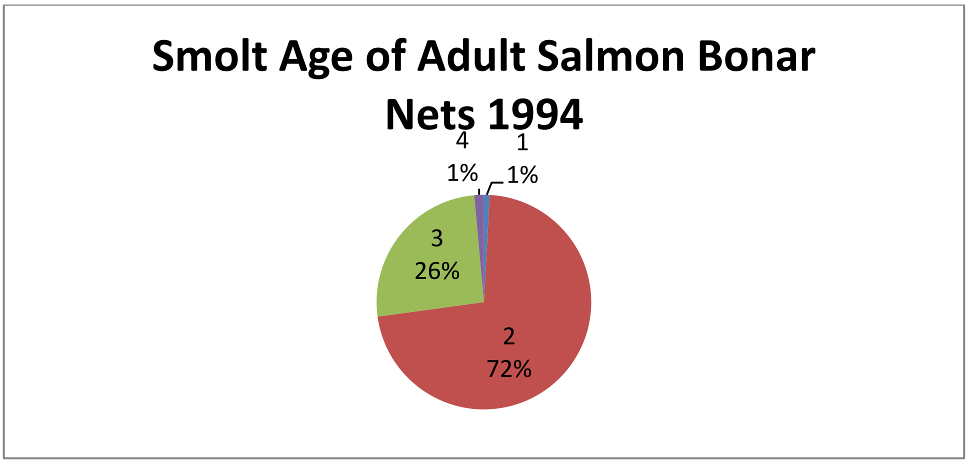
Scale reading data is also available from the Bonar Bridge netting station for the years 1986, 1993, 1994. This data has been made available courtesy of Marine Scotland Science. Total numbers of scales available for the purposes of this report was 232 in 1986 (June and July netting), 113 in 1993 (July only netting) and 354 in 1994 (June and July netting). It would be expected that the nets would capture fish destined for all the major Kyle of Sutherland rivers i.e. Carron, Cassley, Oykel, Shin and Evelix not just salmon destined for the Oykel catchment. Potentially fish destined for other river systems would also feature in the net fishery. As with the Oykel rod catch data from 2013-2015 river ages of two and three predominate. However, as with the 1976 rod catch data there appears to be more diversity in the river age of captured fish. Small numbers of salmon aged four years at smolting were present in the net samples in each of the three years sampled in addition to the presence of a smolt aged five years old at smolting in 1986 and a one year old at smolting in 1994.

It should be noted that the samples obtained from the netting took place over a relatively narrow time period and it is unlikely that the results can be considered to be fully representative of the age structure of the salmon populations as a whole within the Kyle of Sutherland catchment during that time period. However, the data does provide a useful snapshot of the age structure of the fish contributing to the net fishery for comparative purposes.

Figure 7 Smolt ages of salmon sampled by Marine Scotland Science in 1986, 1993 and 1994.





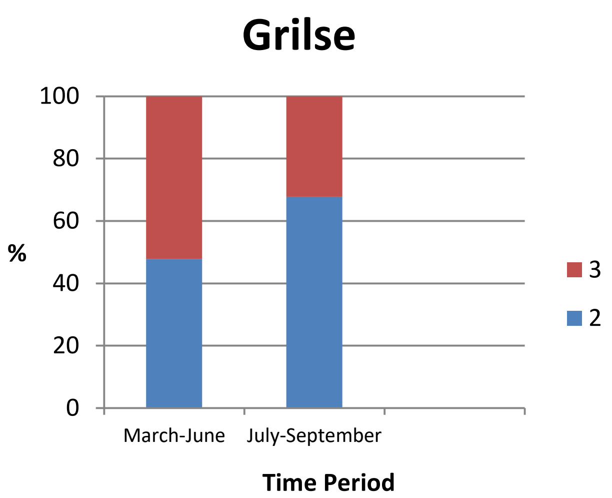


4.3 Timing of Capture of Returning Salmon and River Age

The date of capture of each fish contributing to the 2013-2015 sampling programme was recorded therefore it is possible to examine possible temporal changes in the river age of fish contributing to the fishery across the fishing season. Due to small sample sizes in the early months of the fishing season, data has been combined in order to facilitate a comparison between the initial part of the fishing season and the latter part. Thus data has been grouped into March – June and July - September. It should be noted that few fish were sampled in March (six in total during the three year period). It should be further noted that date of capture does not necessarily equate with date of river entry therefore caution needs to be expressed in assessing run-timing of any individuals captured in the rod fishery. For illustrative purposes the sea age of the fish sampled has also been split in to two categories, namely grilse (fish that have spent a single winter in the marine environment prior to undertaking a spawning migration) and salmon (fish that have spent two or more winters in the marine environment prior to undertaking a spawning migration).

In the three year sample period fish with a river age of two and three were captured across the fishing season. When combined across the three year adult scale sampling period it can be seen that the proportion of fish with a river age of three years declines in the July – September period compared to the March – June period (Figure 8). It is noticeable that the proportion of fish with a river of two years was higher for both salmon and grilse in the July – September period than in the March – June period in each of the three years for both with the exception of grilse in the 2014 season (see Figure 9). In the 2014 season the proportion of grilse with a river age of three increased marginally in the July – September period compared to the March – June period of that year. It may be speculated that the very dry late spring and early summer period which characterised the 2014 season may have influenced the availability of fish to the rod fishery and in turn influenced the timing of samples taken.

Figure 8 Combined 2013-2015 river age data shown by time period of capture.



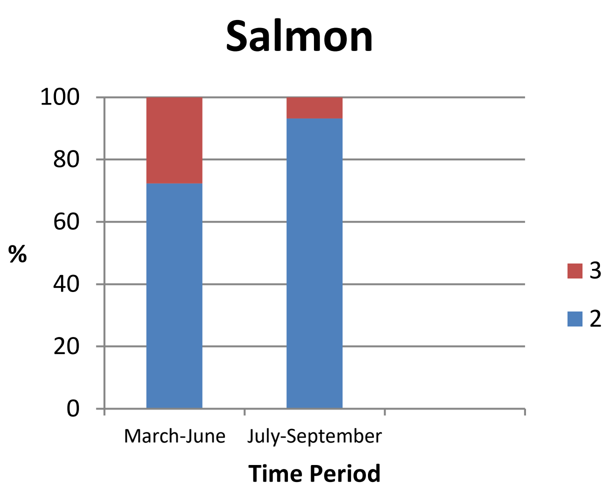
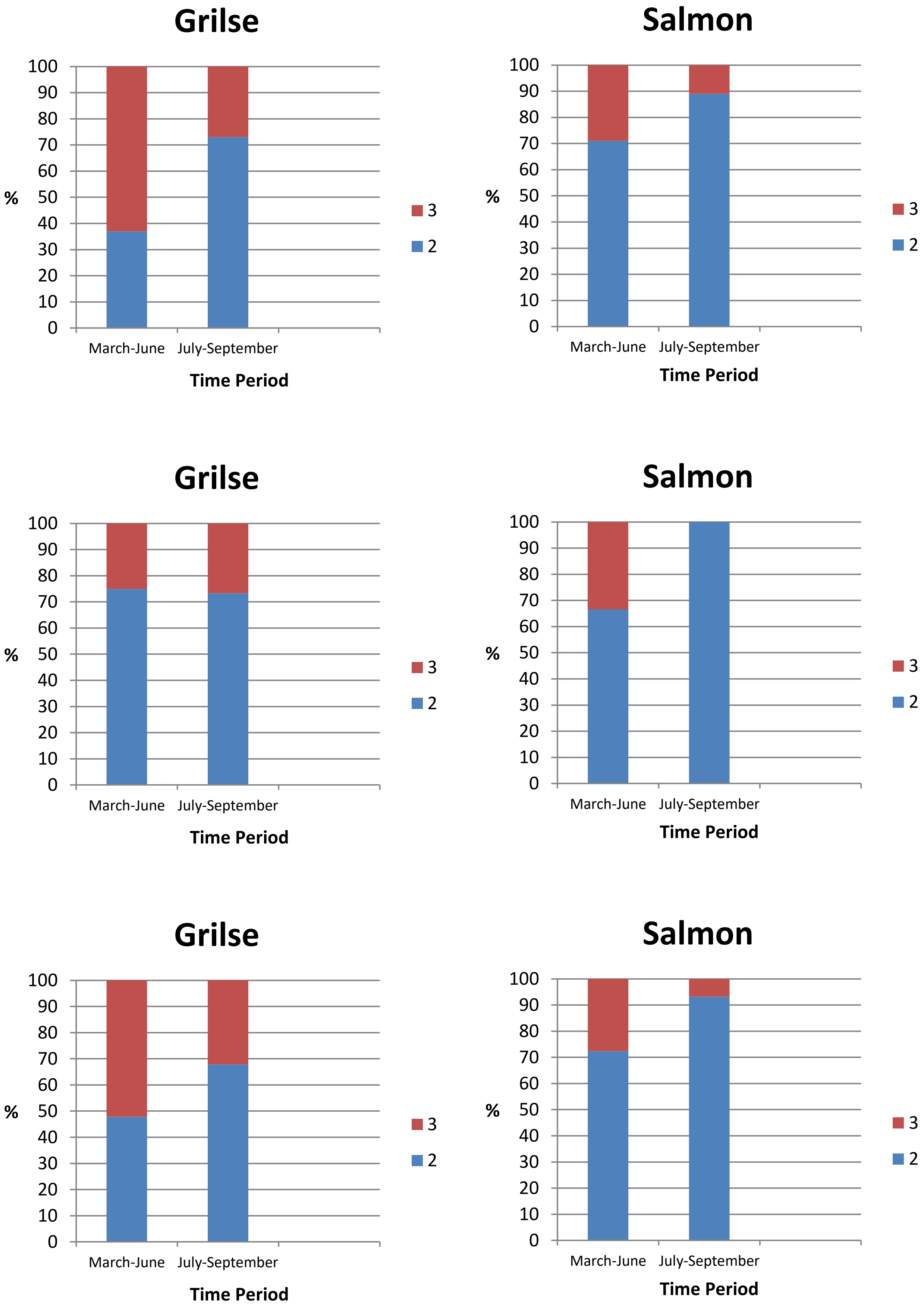


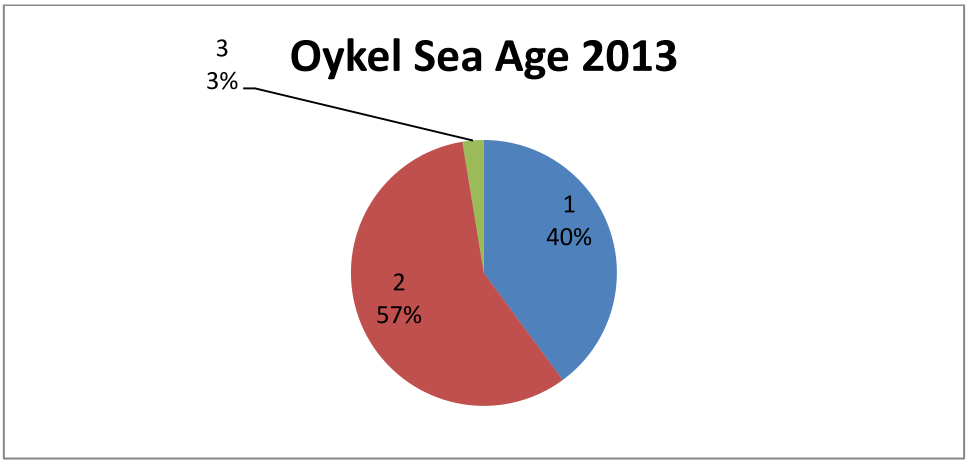
Figure 9 River age data shown for 2013 (top), 2014 (middle) and 2015 (bottom).

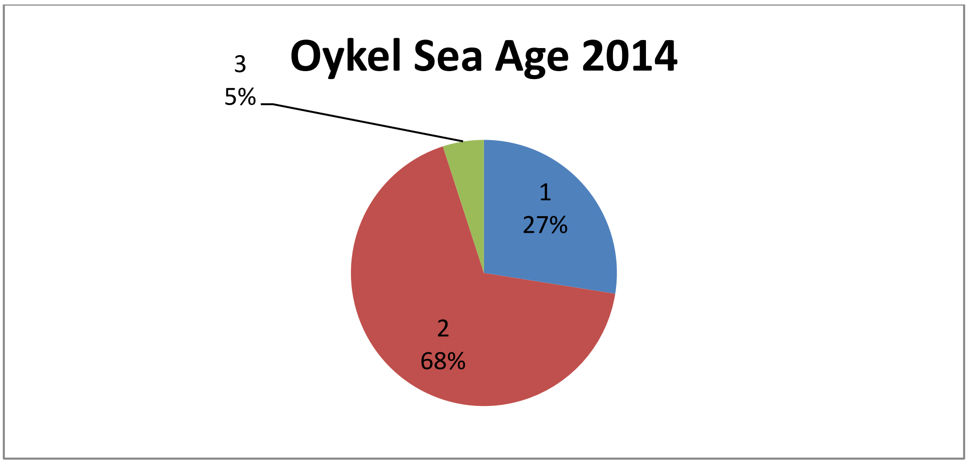


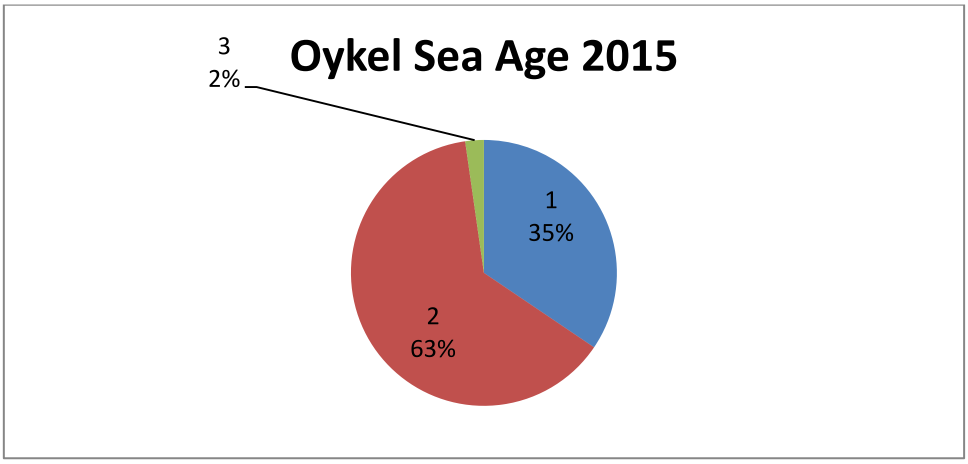
4.4 Sea Age of Returning Adult Salmon

The sea age of salmon sampled during the 2013, 2014 and 2015 seasons appears relatively consistent (Figure10). In each of the three years sampled the largest category was two-sea-winter fish followed by one sea winter. In each of the three years a small number of three-sea- winter fish were also caught.

Figure 10 Sea age of adult fish sampled 2103-2015.



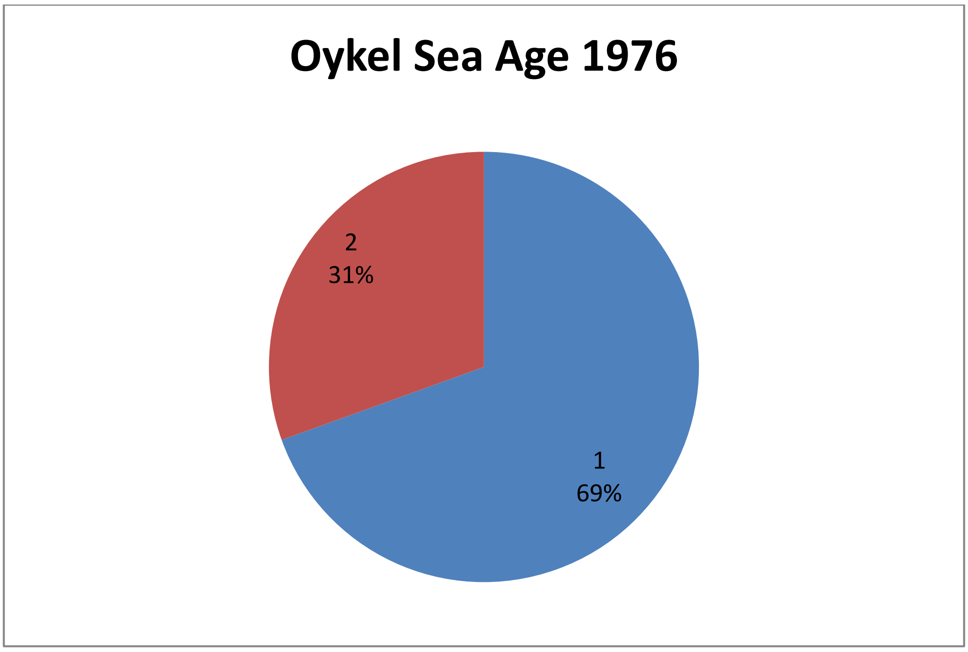




It is not known if sampling bias has been inadvertently introduced into the programme of collection For example, 2014 was characterised by low rainfall during the summer months therefore one-sea-winter fish catches are likely to have been lower than might otherwise have been expected, which may in turn have influenced the numbers of such fish available to be sampled. Not shown in the charts below is the presence of repeat spawning fish, as the ages shown reflect age at first spawning migration. Repeat spawning appears to be a feature of the Oykel stock with seven recorded in the sampling programme (circa 1.5% of the overall sample). Size range of repeat spawners was an estimated 7-16lb with sea age at initial spawning showing that two fish had spent a single winter at sea with the remainder having spent two winters in the marine environment.

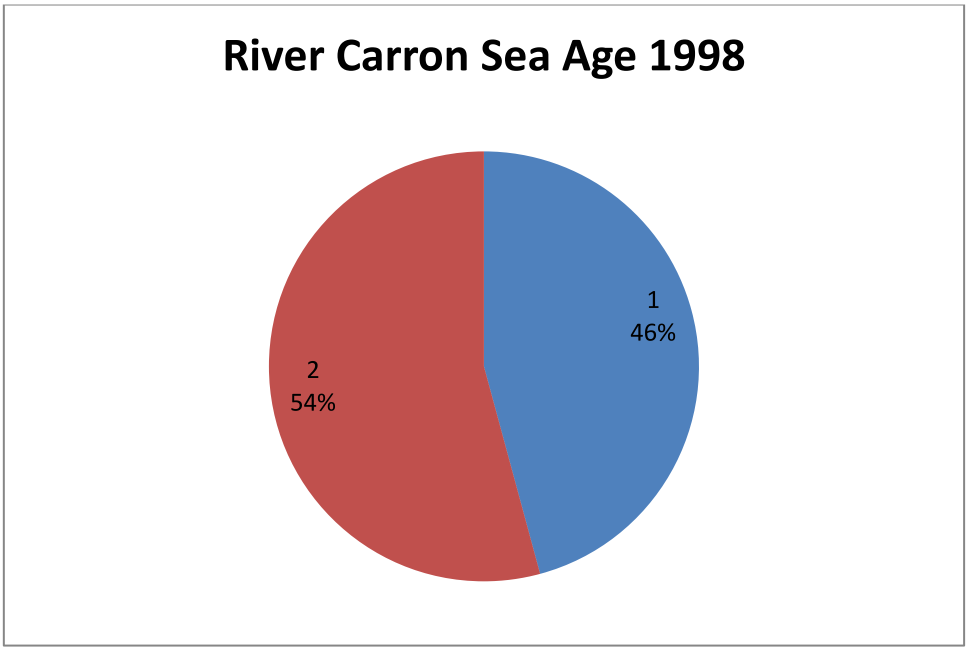
Sea ages of 62 Oykel salmon caught in 1976 are available although a small number could not be successfully read. Only one and two-sea-winter fish were captured as part of the sampling programme with the exception of a single fish that was a repeat spawner. 1976 was characterised by a very dry summer and the lowest recorded rod catch for the Kyle of Sutherland district in the 1952-2016 Marine Scotland Science data set. As such, a cautious approach to the interpretation of the data should be taken.

Figure 11 Sea age of the 1976 Oykel rod fishery sample.



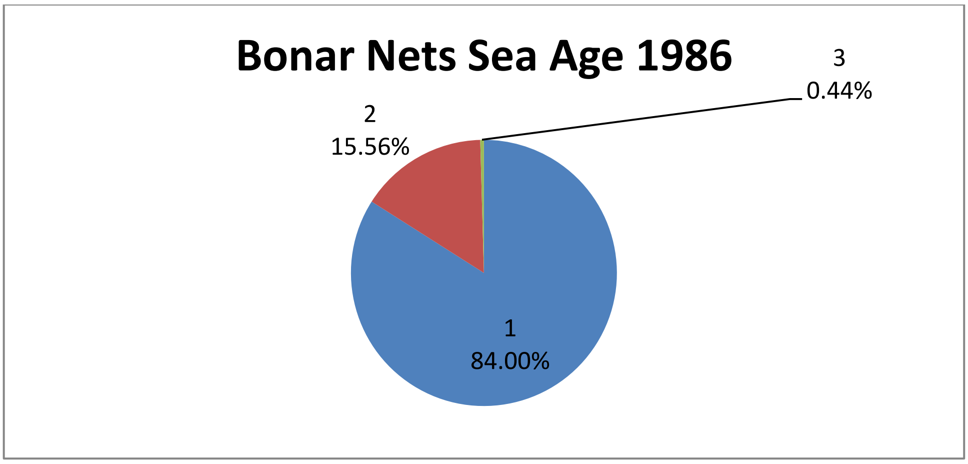
Of the scales of the 193 fish sampled on the River Carron in 1998 by Morgan Fisheries Consultancy, two-sea-winter fish narrowly outnumbered one-sea-winter fish. Three of the sampled fish were repeat spawners giving a percentage occurrence of circa 1.5%, a similar figure to that found on the Oykel in the 2013-2015 rod catch data. As with the Oykel sea age data from 1976, no three or four sea winter fish were present in the samples. Again caution is advised on the interpretation of this data as there is no indication as to whether sampling bias was inadvertently introduced into the collection programme.

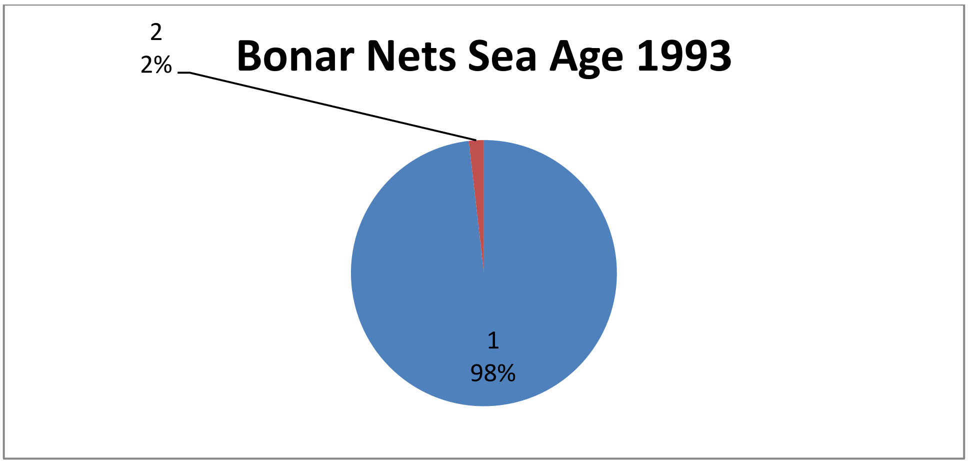
Figure 12 River Carron sea age of fish sampled by Morgan Fisheries Consultancy.

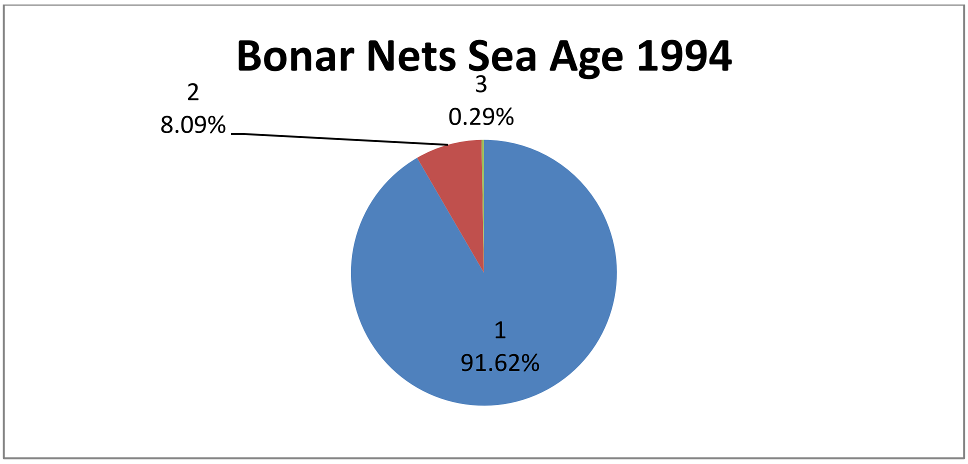


As outlined in Section 4.2 both river and sea ages are available from salmon and grilse netted at Bonar Bridge in 1986, 1993 and 1994. It should be noted that in contrast to the Oykel rod fishery samples from 2013- 2015, the net scale samples were typically taken over a relatively short timescale. In 1986 salmon were sampled on 12th June and 8th July. In 1993 salmon were sampled on 13th July and 28th July. The broadest spread of sample dates was achieved in 1994 when sampling was undertaken on 13th June, 14th June, 28th June, 12th July, 26th July and 28th July. It can be seen that even in 1994 there was a relatively narrow temporal spread of sampling. The results suggest that the fishery as prosecuted during the time of the sampling primarily captured one-sea-winter fish with a relatively small proportion of two-sea-winter fish and a very small proportion of three-sea-winter fish contributing to the total catch. It is understood that the primary reason for examining the age structure of the net catches was to gain greater insight into a phenomenon known as 'grilse error'. The biased nature of the sampling from the net fisheries in terms of the date of capture makes comparison with the rod catch data problematical. However, it is noticeable that three- sea-winter fish were captured in contrast to the 1976 Oykel and 1998 Carron scale sampling programme. The sea ages of the fish sampled in the Bonar Bridge nets by Marine Scotland are illustrated in Figure 13.

Figure 13 Sea ages from Bonar Bridge net caught salmon sampled by Marine Scotland Science.





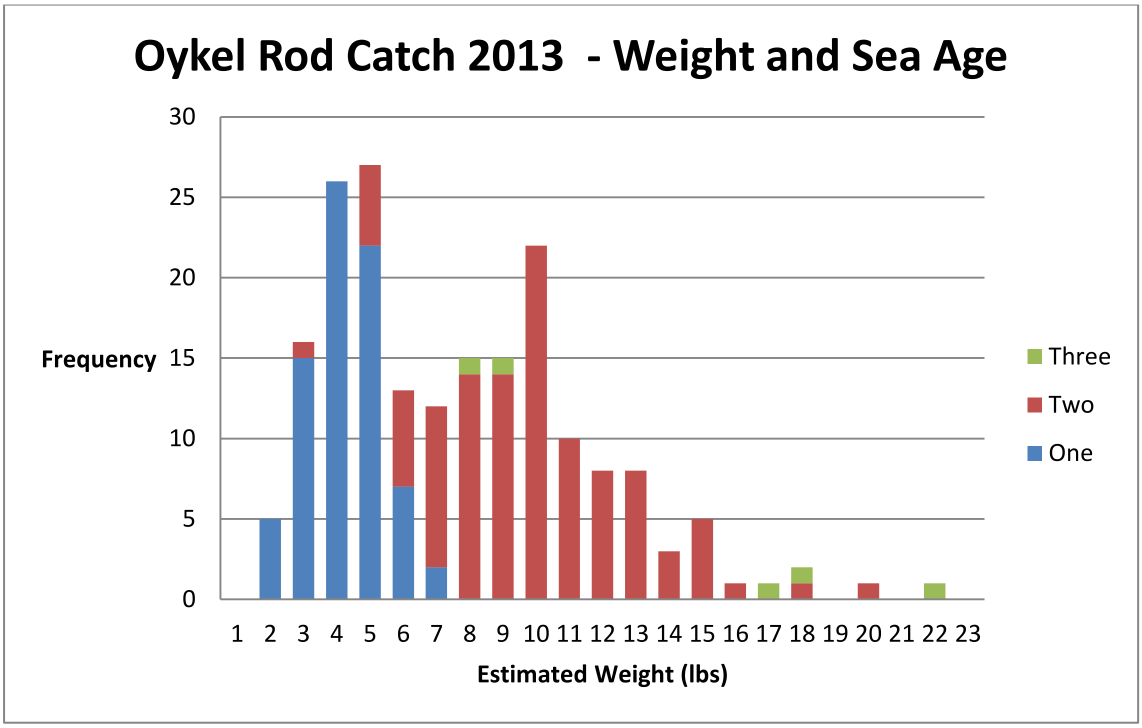


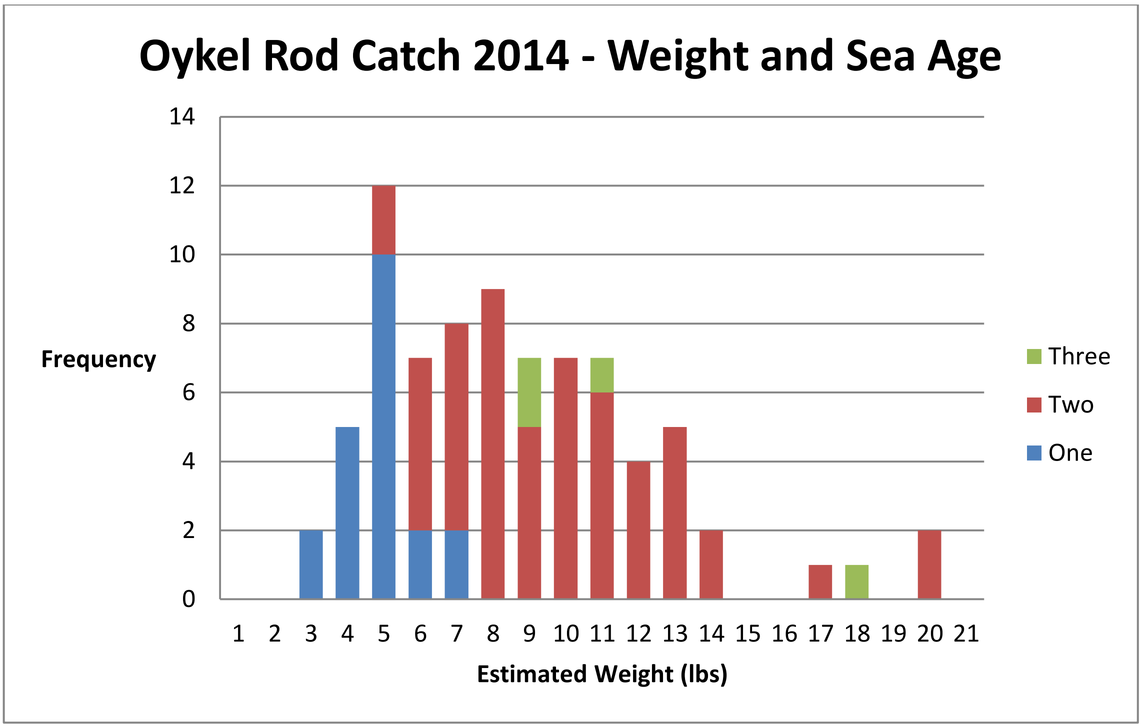
4.5 Weight and Sea Age

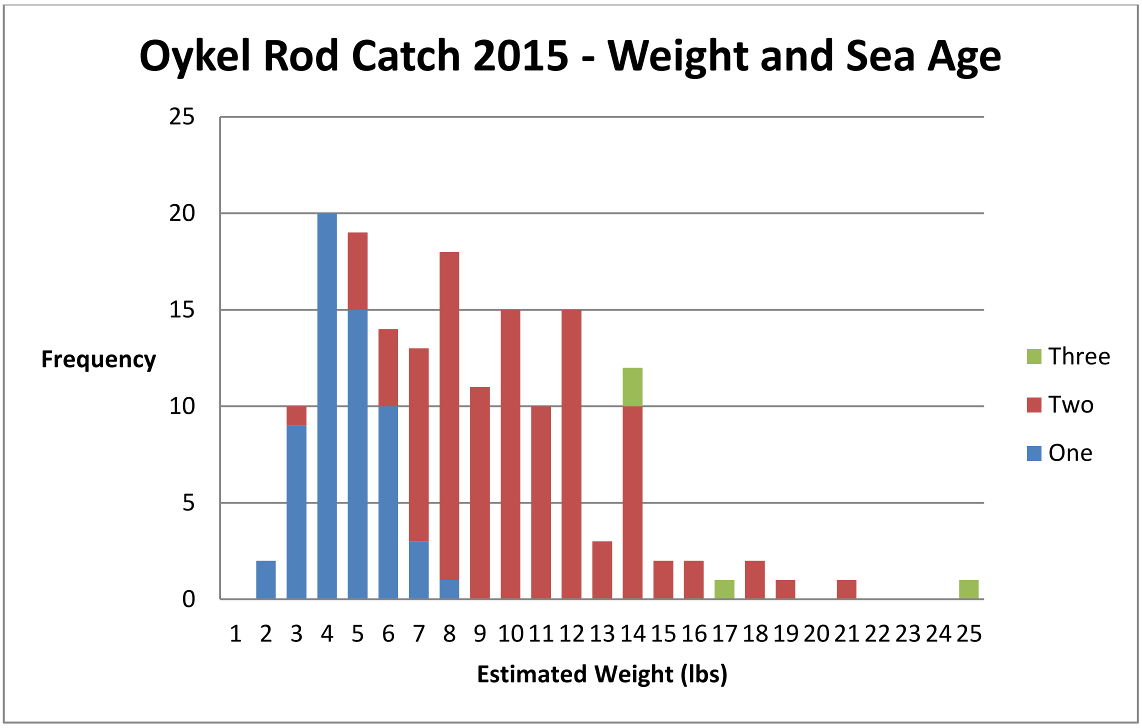
Estimated weight data is available for each of the salmon and grilse sampled from the Oykel rod fishery in 2013-2015. In most cases the weight has been estimated to the nearest pound, but in a small number of cases weight has been estimated to the nearest half pound. In order to illustrate the weights and sea age of fish graphically, estimated weights have been rounded down to the nearest pound. Figure 14 illustrates in each year of the sampling programme the frequency of individual estimated weights and the age classes of fish at those estimated weights. Although statistical analyses was not undertaken to assess if there were differences between years, the final chart in the sequence represents the amalgamated data for the overall 2013-2015 period. Of particular interest is the overlap of estimated weights between different sea ages. This has important implications for assessing stock structure which in turn has, for example, implications for issues such as the setting of conservation limits.

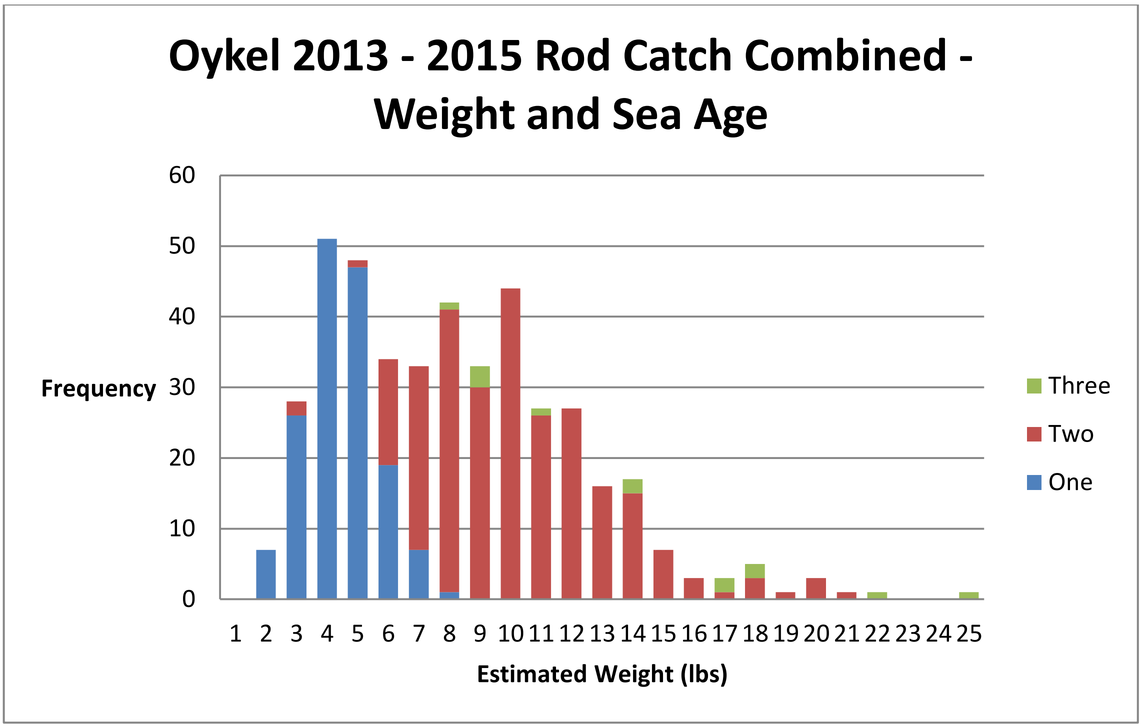
It can be seen from the amalgamated data that, in particular, there is considerable overlap in the weight of one-sea-winter fish and two-sea-winter fish. Thus one-sea-winter fish sampled weighed between 2lbs and 8lbs; two-sea-winter fish weighed between 3lbs and 21lbs; and three-sea-winter fish between 8lbs and 25lbs. The overlap between one-sea-winter and two-sea-winter fish is particularly significant given that fishery managers are obliged to attempt to differentiate between grilse and salmon when completing a statutory catch return to Marine Scotland Science.

Figure 14 Weights and sea ages of the adult Oykel fish sampled in 2013-2015. The final chart shows amalgamated data for the whole time period.




Oykel Rod Catch 2014 - Weight and Sea Age
Frequency
Estimated Weight (lbs)
Three
Two
One
0
2
4
6
8
10
12
14
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21


Oykel Rod Catch 2015 - Weight and Sea Age
Frequency
Estimated Weight (lbs)
Three
Two
One
0
5
10
15
20
25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25



5. Discussion

Diversity in river and sea age of returning salmon is likely to be important for a number of reasons. Shearer (1992) states that salmon from the 1978 spawning on the North Esk catchment were captured as adults in the net and coble fishery situated in the lower reaches of the river in each of the years from 1981 to 1985. This was due to a combination of differences in river and sea age. This was considered by the author to demonstrate, for example, that a natural 'insurance policy' is in place for both natural and anthropogenic negative influences on survival. Thus poor marine feeding conditions in a given year would not necessarily result in proportionate reductions in spawning fish numbers due to other fish experiencing different marine conditions in different years. Diversity in Atlantic salmon populations is considered to be important in ensuring the survival of the species, particularly in respect of adaptation to changes in environmental conditions (e.g. de Leaniz *et al.*, 2007). Perceived issues such as rapid climate change may make such diversity more important in future years in allowing salmon populations to adapt to the changes in environmental conditions.

The capture of salmon parr aged 1+, 2+ and 3+ in the electro-fishing surveys undertaken as part of the sampling strategy for this project suggests that the Oykel juvenile salmon populations remain diverse and complex in age structure. It is noticeable, but not unexpected, that the older age classes of parr tended to be captured in the higher altitude sections of the Oykel catchment, in particular the upper reaches of the Einig catchment and its associated tributaries plus the tributaries of the Oykel in the Benmore area. Growth, maturity of precocious male salmon parr and age at smolting are considered to be largely a function of water temperature (e.g. Baum *et al.*, 2004, 2005). Thus it was anticipated that older age classes of salmon parr would be proportionately more prevalent in the higher altitude sections of the catchment where lower mean water temperatures would be expected in comparison to the more lowland areas. However, caution should be taken in assessing the age composition in age structure of salmon parr at any individual site given the potential lack of site fidelity by juvenile salmon. The degree of overlap in the ages of parr at a given length suggests that growth is variable across the catchment presumably as a result of local environmental factors. The influence of genetic factors in relation to variations in growth also cannot be ruled out as studies have demonstrated that genetics can play a key role in explaining variations in growth rates (e.g. McGinnity *et al*., 1997).

There is an apparent paucity of historical information with which to compare the spatial distribution of older age classes of salmon parr observed in the 2013 and 2015 surveys. Thus the geographical extent of historical usage of the catchment by older age classes of salmon parr is not known and comparison with the pattern observed in 2013 and 2015 is not possible. Historical data is also likely to have been biased by the stocking of juveniles in many parts of the catchment. Temporal changes to juvenile salmon growth, age at smolting and run-timing of smolts is particularly pertinent due to the recently observed shortening of freshwater residence of juveniles prior to migrating to sea in many regions of the range of Atlantic salmon. (Russell *et al*., 2012). Concerns have additionally been raised, for example, that earlier smolt emigration in a given year, even by a few days, may result in a mismatch with the 'smolt window', as described by McCormick *et al*. (1998), of optimal entry into the marine environment i.e. the period when food availability in transitional waters and the marine environment is optimal for smolt survival (Russell *et al*., 2012). Shearer (1992) noted that alterations to the age profile of smolts resulting from water temperature changes, for example, may in turn impact on the timing of availability of adult fish to a rod or net fishery. The reduction in the proportion of Oykel returning adults with the oldest river ages in the 2013-2015 samples compared to the 1976 sample is consistent with the perceived decline in the contribution of early-running salmon to the Oykel rod fishery.

The lack of diversity in respect of the river age of returning Oykel adult salmon in the 2013-2015 sample data is somewhat surprising as this appears to differ from the situation illustrated by historical scale reading data both from the Oykel and elsewhere in the Kyle of Sutherland catchment. Only fish with a river age of two or three featured in the rod catch samples for 2013-2015, although it should also be noted that these age classes also dominated the limited historical data that is available. It must also be remembered that other factors such as inadvertent sampling bias and relatively small sample size may also play a part in the results observed. The lack of smolts that migrated at ages one and four, although historically contributing a modest proportion of the overall samples can be considered to be concerning. A reduction in the diversity of river or sea ages of returning salmon has the potential to reduce the natural 'buffering' capacity of Oykel salmon populations to cope with catastrophic events or large reductions in survival in either or both the marine and freshwater environments. It must also be remembered that the samples from the rod fishery do not necessarily encapsulate the entirety of the fish migrating into a river system as it is likely that salmon will return out with the fishing season. It may be speculated that changes in water temperature in both the freshwater and marine environments may be influencing the age profile of Oykel salmon.

Salmon that had spent two or more winters at sea featured in the samples throughout the fishing season although it was particularly noticeable that few multi-sea-winter salmon with a river age of three featured in the samples taken after June – only three in the entire 2013-2015 study period. Shearer (1992) noted that in the North Esk trap catches between 1963 -1970 smolt age composition was subject to variation depending on the time of year, as was the case in the net and coble fishery samples between 1963 – 1988. More specifically, the mean river age of salmon and grilse captured declined as the fishing season progressed. These observations were based on large sample sizes which were made possible because of the nature of the fisheries of the North Esk and the ability to trap salmon out with the main fishing season. In order to assess if a similar pattern could be observed on the Oykel during the sampling programme, data was combined across months in order to facilitate a rudimentary comparison of the river age of fish captured in the early part of the season with the river age of fish in the latter part of the season. With the exception of one-sea-winter fish in 2014 it would appear that the proportion of one-sea-winter fish and multi-sea-winter fish with a river age of three declined as the fishing season progressed. Although the choice of months in which the data has been grouped is somewhat arbitrary in nature, the results suggest that a similar relationship between date of capture and river age may exist on the Oykel to that observed on the River Esk fishery and elsewhere. In the 2013-2015 Oykel samples, no one-sea-winter fish were captured prior to the start of June and numbers of such fish sampled in June were also low. One-sea-winter fish are known to feature in the rod fisheries of the Kyle of Sutherland catchment as early as May, though, in some years. Little is presently known with regard to the origin of the early-running component of the grilse stocks. Information from the River Dee catchment suggests that exploitation of early-running grilse by rod fisheries and net fisheries is typically low due to the tendency of such fish to migrate rapidly through the river system (John Webb, personal communication).

The spatial distribution of the older age classes of salmon parr captured as part of the juvenile scale reading programme suggested that the areas of the Oykel catchment furthest from the sea were typically utilised. Radio tracking data from large east coast of Scotland river systems such as the Dee and the Spey have indicated that salmon destined to spawn in the upper reaches of the catchment tend to enter their natal rivers in the early months of the season (e.g. Laughton and Smith, 1992). Thus it would appear logical that in the Oykel catchment those fish destined to travel the furthest will be more likely to enter the river the river in the earliest months of the year. However, it should also be noted that other factors such as marine feeding conditions can also influence the timing of spawning migrations (Todd *et al.,* 2012). It is likely that, as with many traits displayed by salmon, run-timing is a product of both heritable genetic and environmental factors. Common garden experiments such as those undertaken by Stewart *et al*. (2002) suggest that run-timing is a heritable trait, however genetic markers have yet to be identified that would allow a greater understanding of this phenomenon. Recent studies have highlighted variations in circadian clock genes as one possible explanation of variations of run-timing of Atlantic salmon (O'Malley *et al*., 2014). Should reliable genetic markers for run-timing be developed then it is suggested that greater spatial resolution in respect of identifying those areas of the Oykel catchment predominately utilised by the early-running stock component may be achieved.

In the 2013-2015 study period it would appear that fish with diverse sea ages contributed to the rod fishery although by far the largest contributors to the samples spent either one or two winters at sea. More modest numbers of maiden three sea winter salmon and repeat spawners featured in the samples taken. In each of the three years of the study, fish with a sea age of two or more contributed the most to the overall sample although it should be noted that fish of one-sea-winter contributed to the fishery more as the season progressed. Contributions by both one sea winter and multi sea winter fish to the overall fishery appeared ostensibly similar in each of the three fishing seasons when samples were taken. It may be speculated that an apparent increase in the number of three-sea-winter salmon in the Oykel catch compared to 1976 may be the result of reductions in high seas and coastal netting. It has been suggested by a number of authors including Shearer (1992) that such fisheries had a disproportionate effect on the numbers of three-sea-winter and older salmon available to a rod fishery. Considerable variation is likely over time in respect of the relative contributions between one and multi-sea-winter salmon to the overall fishery. On the North Esk Shearer (1992) noted that the dominance of one versus two-sea-winter fish varied considerably during the 1963 -1988 period, a pattern that has been observed in a number of other fisheries.

Repeat spawning can be an important feature in reducing the impact of stochastic events on salmon populations and this study provides evidence that this phenomenon exists on the Oykel, albeit at a modest level. Fleming (1996) notes that typically the incidence of survival to spawn for a second time in Scottish rivers is less than 10% although in some rivers within the geographical range of Atlantic salmon it can be as high as 40%. In summarising recent data from Ireland de Eyto *et al.* (2015) note that on the Burishoole system repeat spawning percentage was 0.9 – 2.3% between 2009-2013; on the the Bush system it was less than 2% between 2000- 2012; and that examination of 626 salmon and grilse on the Erriff and Corrib system in 2005 found no repeat spawners. Typically, repeat spawners are female with only circa 5% of the repeat spawners on the North Esk being male (Shearer 1992). The numbers of repeat spawners sampled in the Oykel system would ostensibly appear reasonable, particularly given the similar results found in the 1998 Carron study.

It is understood that the distinction between salmon and grilse is considered important for a number of reasons, in particular that sex ratios and in turn egg deposition rates from a given number of fish may differ significantly between grilse and multi-sea-winter salmon. During the months when one-sea-winter fish are most likely to be present, the fishery manager of the Lower and Upper Oykel fishings typically records fish of 5lbs and under as grilse (Steven Mackenzie, personal communication). The data for the combined 2013 – 2015 Oykel sample programme indicates that a relatively small proportion of the fish estimated to be 5lbs in weight were multi-sea-winter salmon and likely to be classified as grilse in error. More interestingly, however, fish estimated at 6lbs in weight, which would typically be recorded as a salmon, were predominately grilse albeit by a small margin.

This phenomenon is often known as 'grilse error' and needs to be accounted for in the construction of conservation limits and general analyses of stock structure within a fishery. It should be noted that there is no obvious way to fully remedy this situation as it is not possible to easily identify differences between salmon and grilse on the river bank. However, it is unlikely that fish will be classified as grilse by river managers if captured prior to the end of April and in many cases the end of May.

Whilst grilse do feature in some fisheries in May, this was not the case in the fish sampled on the Oykel between 2013-1015. On the evidence of the present study, classifying fish caught in April and May which weighed 5lbs and 6lbs as salmon and not grilse reduces the chance of errors in classification being made. In this data set nine fish with an estimated weight of 5lbs which were subsequently identified as multi-sea-winter salmon by scale reading were captured prior to the end of May and a further 11 fish with an estimated weight of 6lbs which were subsequently identified as multi-sea-winter salmon by scale reading were captured prior to the end of May. However, two multi-sea-winter salmon estimated at 3lb in weight were recorded in the sample which were described as fresh fish and were captured in June (25th June 2013 and 22nd June 2015 respectively). Therefore misclassification of salmon as grilse may to some degree counterbalance grilse being classified as salmon. Grilse captured in June during the sample period typically were estimated at 3-4lb in weight. It is thus suggested that fish with an estimated weight of 4lbs and under be considered to be grilse in May and June with all fish 6lbs and under being classified as grilse from July onwards. However, periodically further sampling to ensure that the relationship observed in 2013-2015 remains stable would be desirable.

It is suggested that the present study has highlighted a number of key issues for further consideration. In particular it would appear that the uppermost reaches of the Oykel catchment are likely to be disproportionately important for the production of older age classes of salmon parr, and in turn the early-running component of the salmon stocks. Attention should be paid to the physical condition of such areas, particularly where it is understood that there has been considerable anthropogenic perturbation to river and riparian habitat. For example, it is known that considerable portions of the Oykel catchment were the subject of large scale hill drainage schemes in the past and that remedial action can be directed to such areas. Should genetic markers for run timing be identified in the future then it is suggested that the management of the Oykel fishery would likely be enhanced by targeted sampling of the juvenile salmon populations. One option to better explore the age structure of Oykel salmon smolts would be the use of a smolt trap or multiple smolt traps in the catchment. The presence in the adult samples of fish limited only to river ages of two and three is concerning as this potentially reflects a loss of important diversity that could render the salmon populations of the Oykel less robust to future environmental changes, for example increasing river temperatures as a result of climate change. This observation of lack of diversity in the river ages of returning salmon may just be an artefact of the relatively small sample size, however it is suggested that this subject should be revisited in future years. In the light of the recent implementation of conservation limits and river classifications by the Scottish Government it is further suggested that as much effort as is possible is made to increase the levels of understanding of the structure of both juvenile and adult salmon populations within the Oykel catchment.

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