Draft National Adult Salmon Sampling Project

Marine Scotland and Fisheries Management Scotland

1 Background

Sampling of individual adult salmon is used to collect information on the size, sex and age of the fish. This information feeds directly into the stock assessments used for national and international management of Scottish salmon. Until recently, Scotland, as with other countries, collected scale samples from commercial netting. However with the majority of these fisheries closing in recent years and the consequent lack of sampling information available, an assumption has been made that there has been no change in age or size of salmon returning to Scotland since 2018. This is clearly unrealistic given the large scale demographic changes experienced by salmon populations (ICES (2021); Todd et al. (2008); Bacon et al. (2009); Todd et al. (2012); Bal et al. (2017)). To fill this data gap the options for using existing rod fisheries and targeted scientific sampling as a source of biological information on salmon is investigated.

During 2021 and 2022, a pilot national adult salmon sampling programme was developed by Marine Scotland, Fisheries Management Scotland and local Fisheries Trusts and Boards to develop a pilot national adult sampling programme. The objectives of the programme were:

- To trial different approaches to obtaining biological data on adult salmon (length, weight, age) and to see what approaches work in different settings.
- To inform the design of any future adult sampling programme for use in stock assessments.
- To provide information on the size, sex and age of adult salmon that can be used to inform future stock assessments.

2 Methods

A standard operating procedure was developed detailing a set of agreed shared practices for the sampling (see Annex 1). These were designed to allow the maximum flexibility for local arrangements to be made on, for example, how fish would be collected for sampling. Samplers were encouraged to (where possible) select sites:

- From rivers with historic data collections;
- With the best chance of returning a good number of fish;
- As close to the sea as possible.

Samplers were requested to sample scales from both retained and released fish, where appropriate.

Adult salmon were sampled during July-September 2021 and June-September 2022, with some additional samples being provided from May in both years. Fish were primarily captured by rod angling with some catch and release netting. An on-line GIS-based reporting tool was used to allow easy and standardised data collection. The reporting form collected information on the location of capture, fish biometrics, equipment used, photographs and sampler identification. The tool generated a unique code which was written on scale packets. Scale packets containing the samples were sent to Marine Scotland for pressing, ageing and imaging. Genetic information was extracted from a sub-sample of the provided scales from individual salmon and used to determine the sex of the individual (Quéméré et al. 2014). This was then compared to the sex noted in the field.

The relatively small number of samples gathered from some areas precludes an in-depth investigation of between river differences in the ages and sizes of sampled fish. The results are therefore presented at a regional level, with a further aggregation used to explore within and between year patterns:

- East: East and North East fishery regions
- North: Moray Firth and North fishery regions
- West: North West, West, Clyde Coast and Solway fishery regions

3 Results

A total of 907 adult salmon were sampled during 2021 and 2022 across 29 different rivers (Table 1). There was a wide geographic range in the numbers of salmon sampled in both years with the largest numbers tending to be sampled on large east coast rivers (Figure 3.1) .

Table 1: Summary of the number of adult salmon sampled by month and year

Month	2021	2022
May	3	32
June	1	58
July	45	212
August	184	157
September	92	123
Total	*325*	*582*

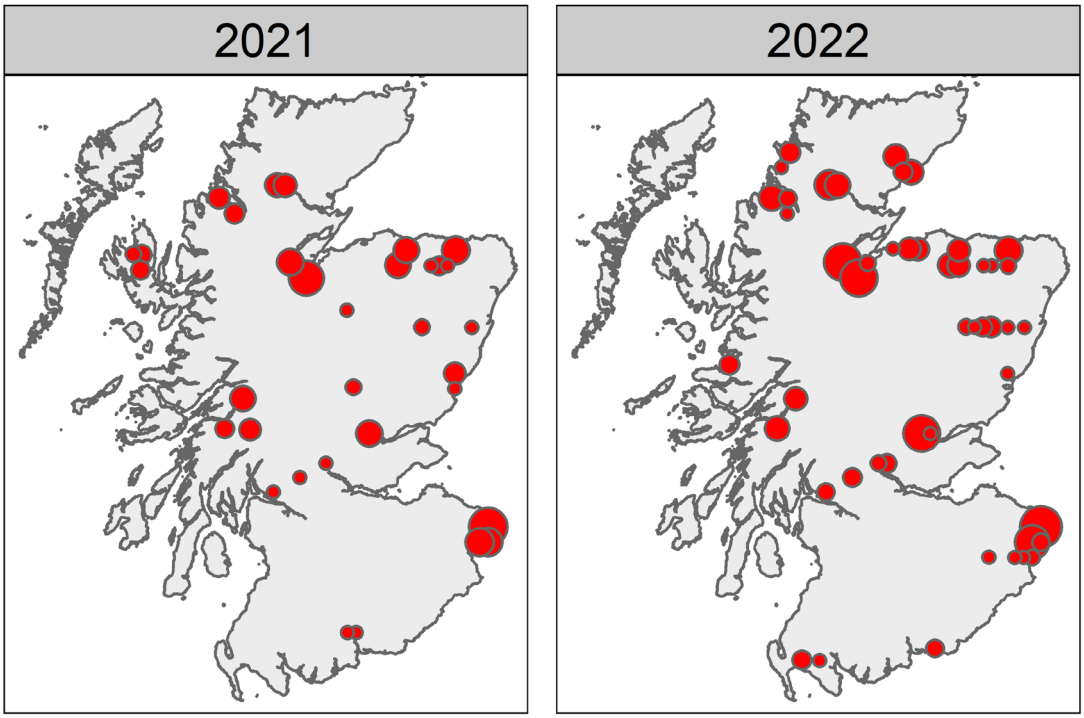

Figure 3.1: Map showing the locations of adult salmon sampled during 2021 and 2022. The size of the point is related to the number of fish sampled in each location.

An overview of the sea ages of salmon sampled during 2021 and 2022 is shown in Figure 3.2. Of the 251 multi-sea winter salmon (MSW) sampled during the project 246 (98%) had spent 2 winters at sea (2SW) with the remaining 5 (2%) being 3SW salmon. The overall pattern of sea ages was similar in 2021 and 2022 with there being a greater number of one sea winter salmon (1SW) in the sample than MSW fish. The exception to this was the West Coast and North East fishery regions where MSW were more prevalent during 2022.

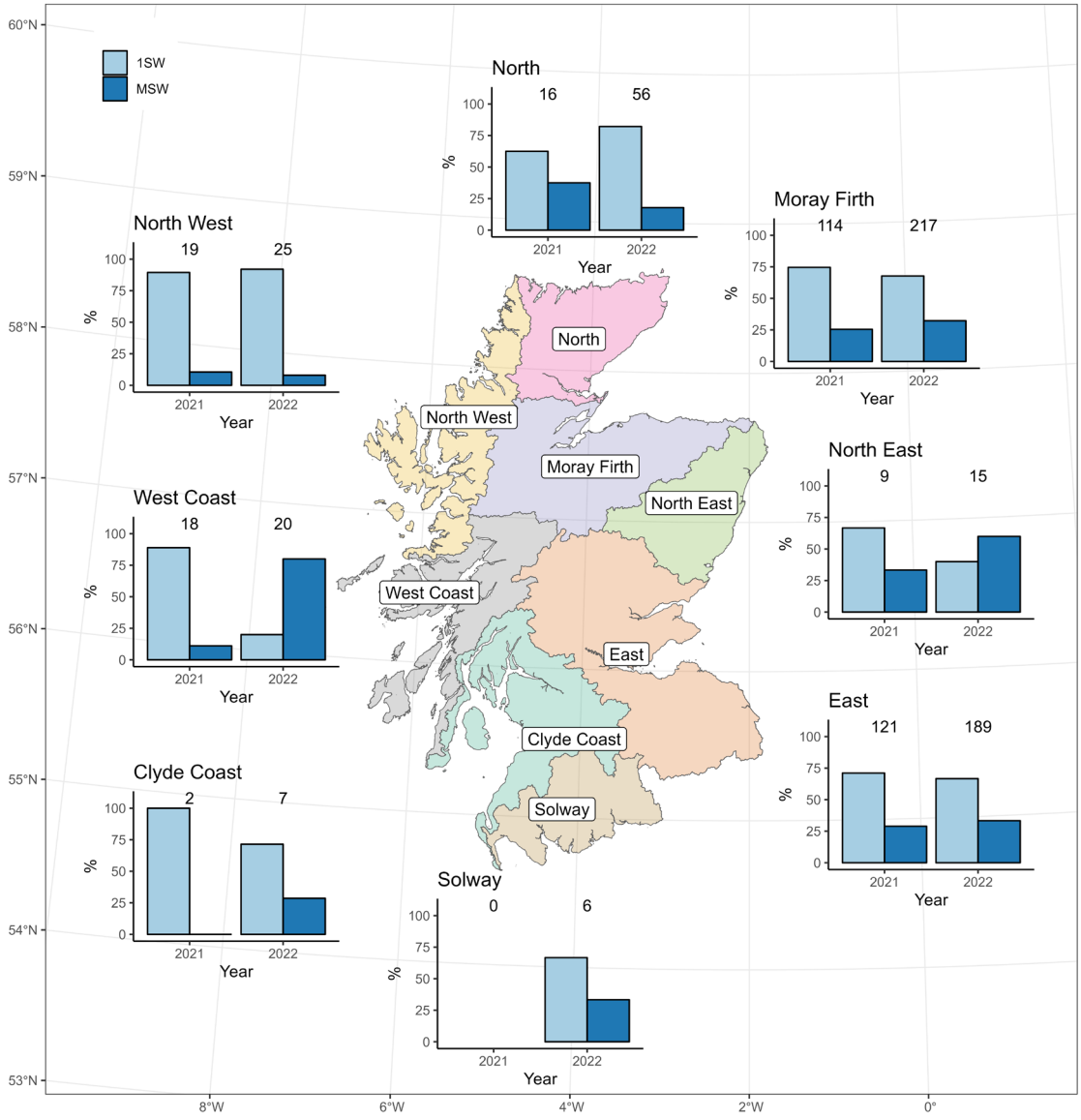

Figure 3.2: Percentage of salmon sampled belonging to different sea age classes broken down by fishery region in 2021 and 2022 (regions indicated on map). 1SW salmon are shown in lighter blue, MSW in the darker shade with the numbers of salmon sampled given above the bars.

The smolt ages of the sample fish were similar between the 2 years (Figure 3.3). Generally S2s (two year old smolts) were the dominant age class, except in the East and Solway regions where S1s (one year old smolts) salmon were the most common age class.

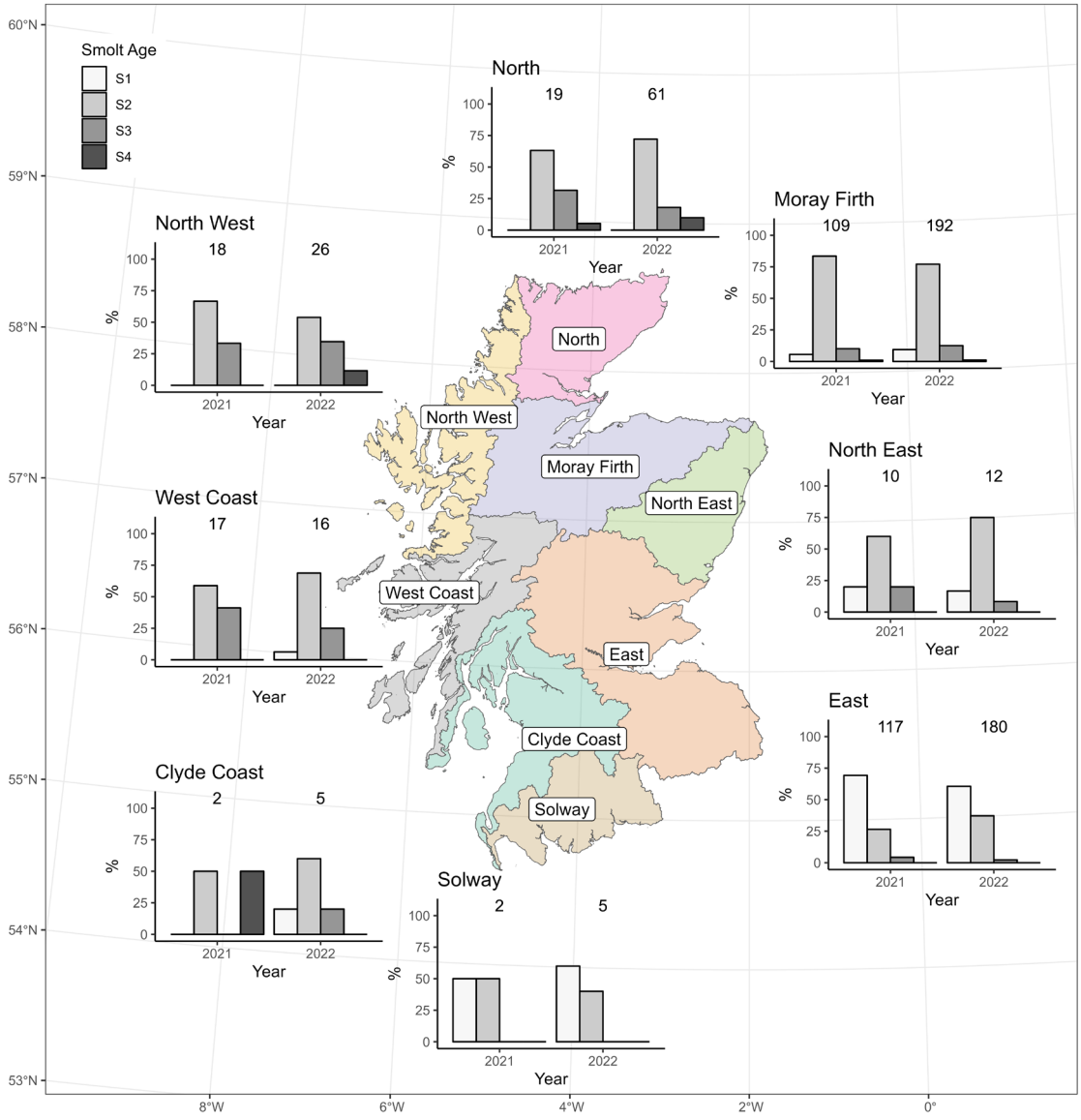

Figure 3.3: Percentage of salmon sampled belonging to different smolt age classes broken down by fishery region in 2021 and 2022 (regions indicated on map).. The numbers of salmon sampled are given above the bars.

3.1 Sea Age

In order to examine how the sea age of salmon changed through the season the samples were first grouped into the East, North and West areas. The incidence of 1SW salmon increased through the year in all three areas; from few 1SW salmon being sampled during May/June to them being the most prevalent age class during August/September (Figure 3.4). Beyond this there do not appear to be any consistent patterns in the data. For example, while the percentage of 1SW salmon was higher in the 2022 samples from the North compared to 2021 the opposite was true for the West.

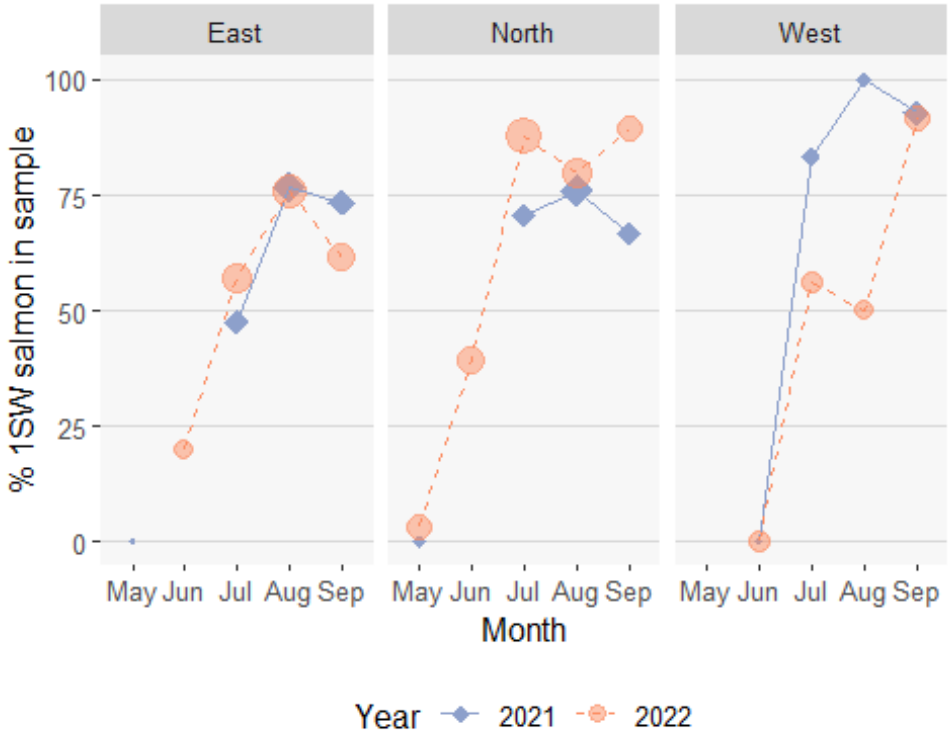

Figure 3.4: Monthly changes in the percentage of 1SW salmon in samples taken from the East, North and West of Scotland in 2021 and 2022

3.2 Smolt Age

Examination of the mean smolt age shows little difference between years or sea ages (Figure 3.5). However, age does vary among areas and there is a suggestion that smolt age may decline through the season.

Mean smolt age varied with latitude on both East and West coasts of Scotland, with some evidence for a higher mean smolt age on the West compared to the same latitude on the East Coast (Figure 3.6). The percentage of S1s was found to be highest in the south of the country, becoming less prevalent moving northwards (Figure 3.7).

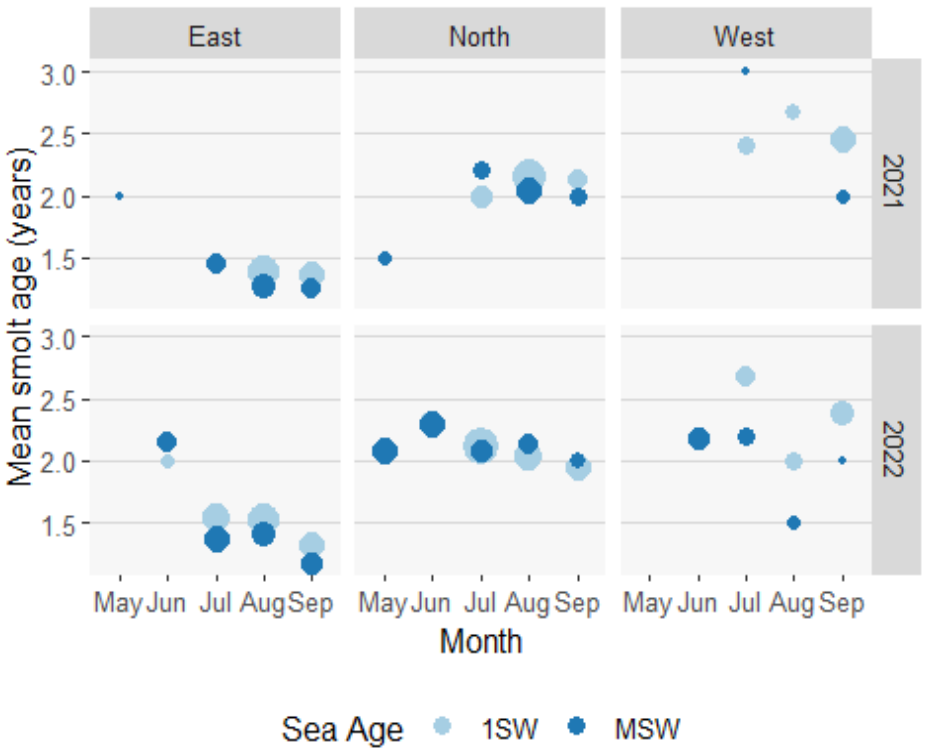

Figure 3.5: Monthly changes in the mean smolt age of 1SW and MSW salmon sampled from the East, North and West of Scotland in 2021 and 2022.

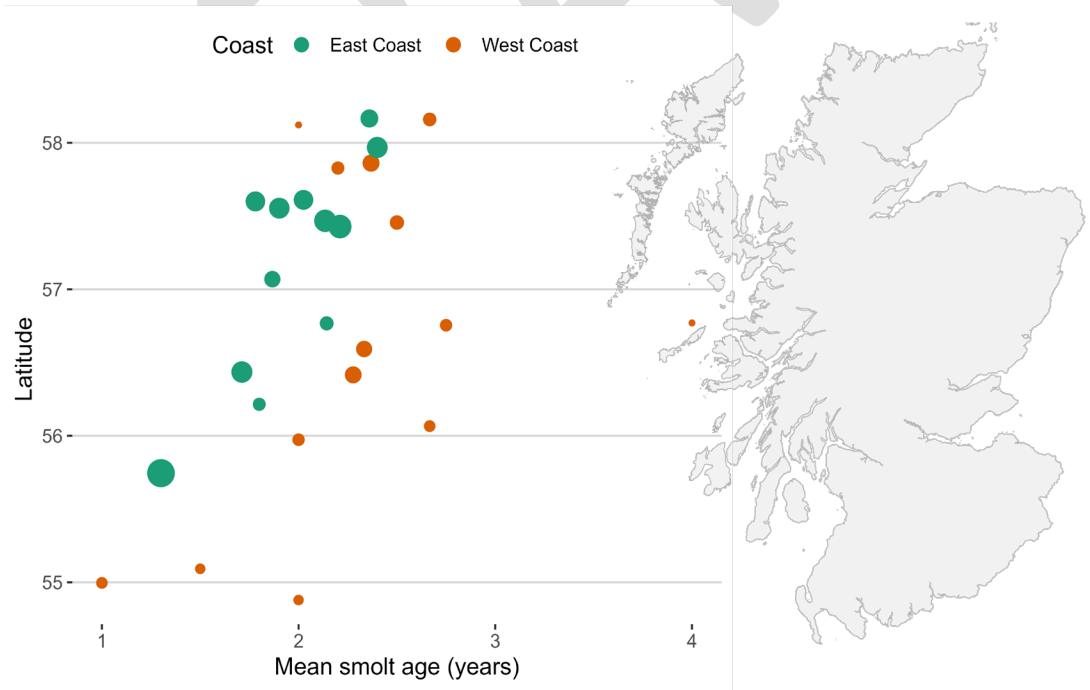

Figure 3.6: The relationship between mean smolt age and latitude shown for samples collected on the East and West Coasts. Map is provided to illustrate latitudes.

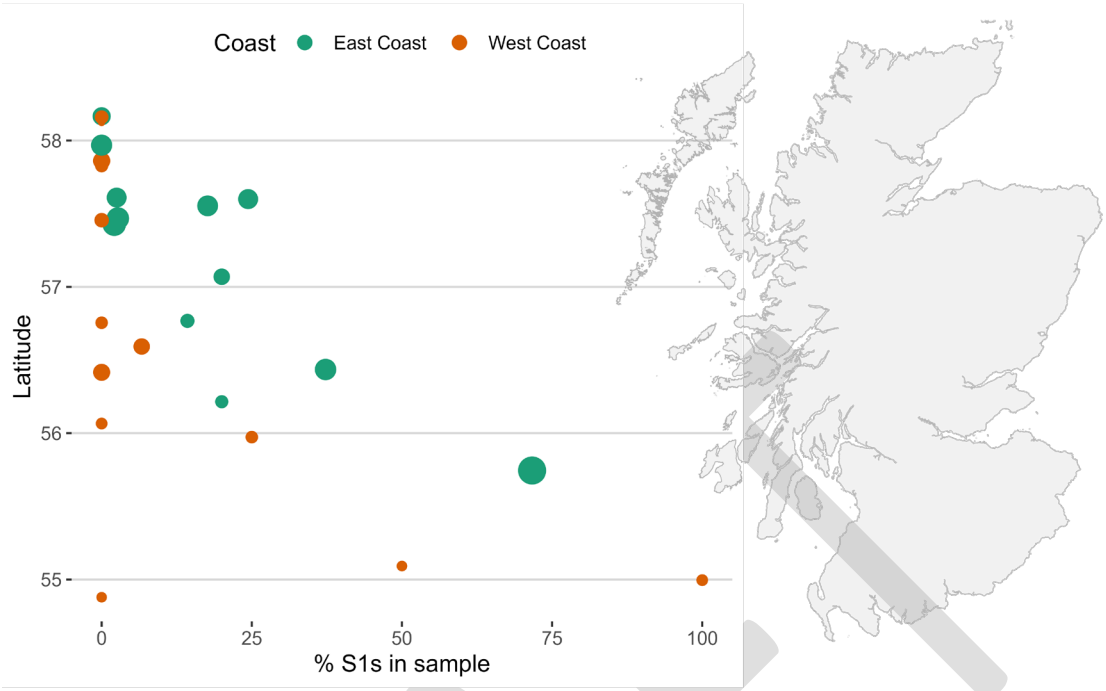

Figure 3.7: The relationship between the percentage of one year old smolts (S1s) in a sample and latitude shown for samples collected on the East and West Coasts. Map is provided to illustrate latitudes.

3.3 Size

Although sample sizes are limited there are suggestions of consistent patterns among areas, with 1SW salmon tending to be smaller in 2022 than 2021 while 2SW salmon were a similar size (Figures 3.9 and 3.8). However, there are also clear differences in the patterns. For example, while the size of 2SW salmon increases during the season in the East it declined in the North and West.

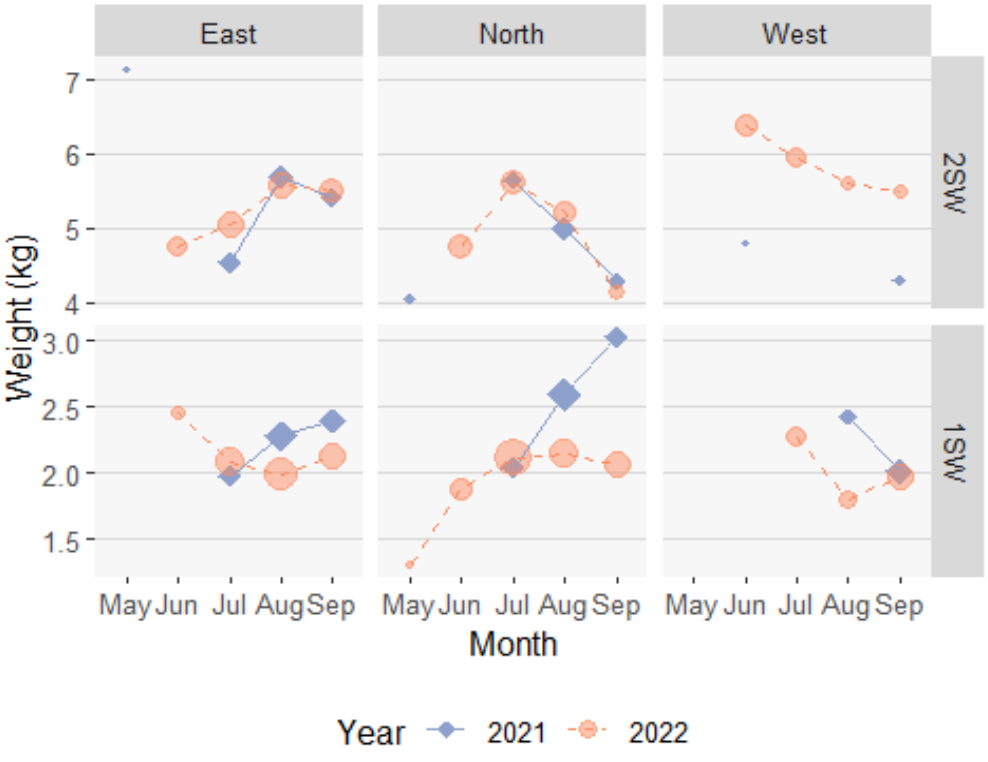

Figure 3.8: Monthly changes in the mean weight of 1SW and 2SW salmon salmon sampled from the East, North and West of Scotland in 2021 and 2022. The size of point is related to the number of fish in each sample.

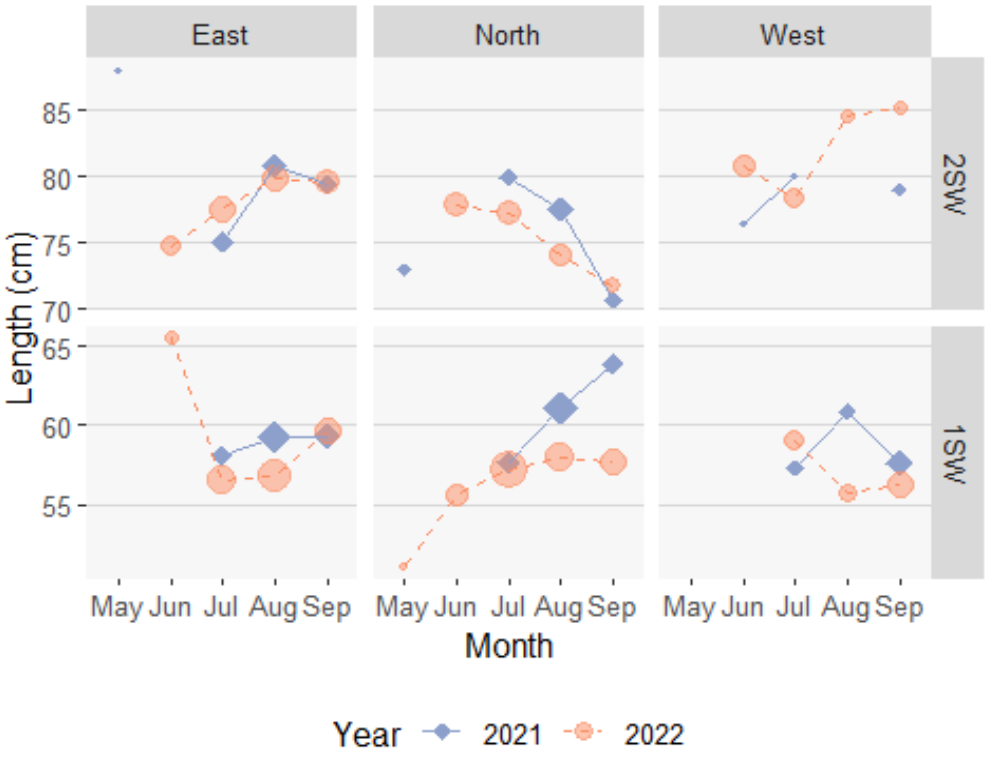

Figure 3.9: Monthly changes in the mean length of 1SW and 2SW salmon salmon sampled from the East, North and West of Scotland in 2021 and 2022. The size of point is related to the number of fish in each sample.

3.4 Sex

Results from the genetic determination of sex were available for 277 of the salmon sampled in 2021. The reported sex agreed with the genetic assignment in 80.5% of cases. Examination of the data shows that these differences were not random and there is a bias towards reporting fish to be male with the methods assessment agreeing in 70% cases for genetically assigned females (n = 140) compared to 91.2% of genetic males (n = 137). The consequence of the bias of visual sexing towards males can be seen in Figure 3.10 where the reported (visual) percentage of females for both 1SW and MSW salmon is lower than that determined using the genetics method.

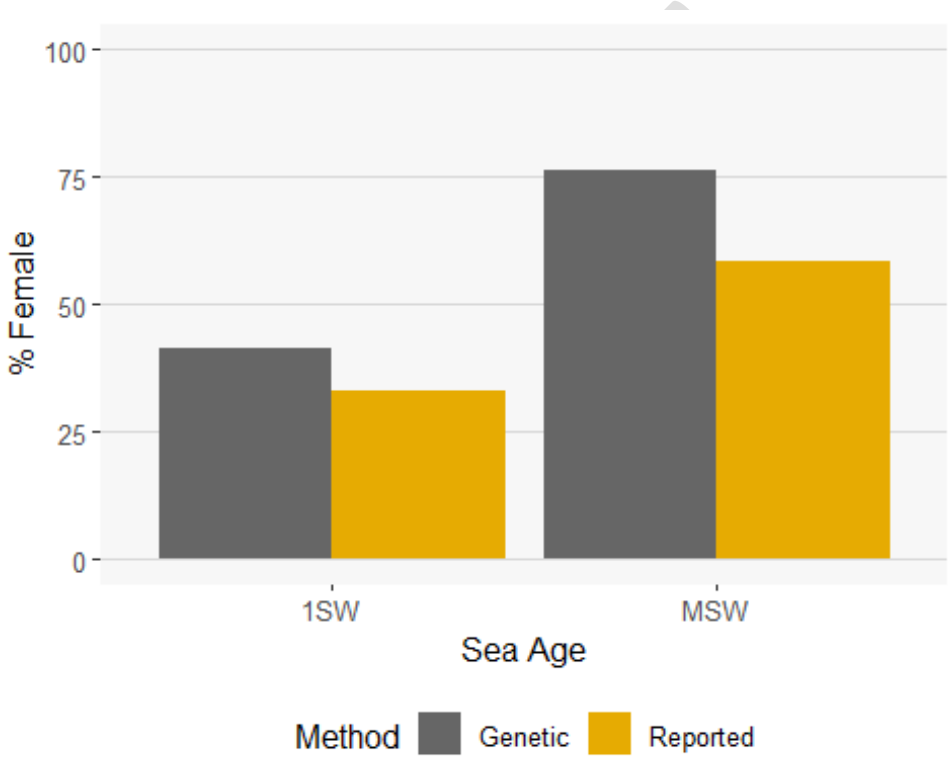

Figure 3.10: The percentage of female salmon by sea age sample in 2021 as reported using visual assessment and genetic assignment.

In the 2021 samples there is a difference between the East and West Coasts with a greater percentage of 1SW salmon on the West Coast being female (72.4%; n = 29) compared to the East (36.4%; n = 176). This results needs to be confirmed once the genetic analysis of the 2022 samples is available when a more detailed look at geographic and temporal trends in the sex ratio will be possible.

3.5 Long Term Patterns

There are long term data available from sampling of commercial catches on the River Tweed. These allow the 2021 and 2022 samples to be placed into a wider context. To account for within season changes the percentage of 1SW fish and the weights of 1SW and 2SW fish sampled during August were compared (Figure 3.11). There are clear long-term fluctuations in the ages and lengths of salmon sampled on

the River Tweed. The percentage of 1SW sampled has generally been around 80%, with the occasional periods where they were less common. In 2021 and 2022 the percentage of 1SW salmon has recovered from a period of lower occurrence during the 2010s (Figure 3.11A). The weights of both age classes have recently increased from the low values seen from the mid-2000s, but have not returned to the values seen during the earlier part of the dataset (Figure 3.11B).

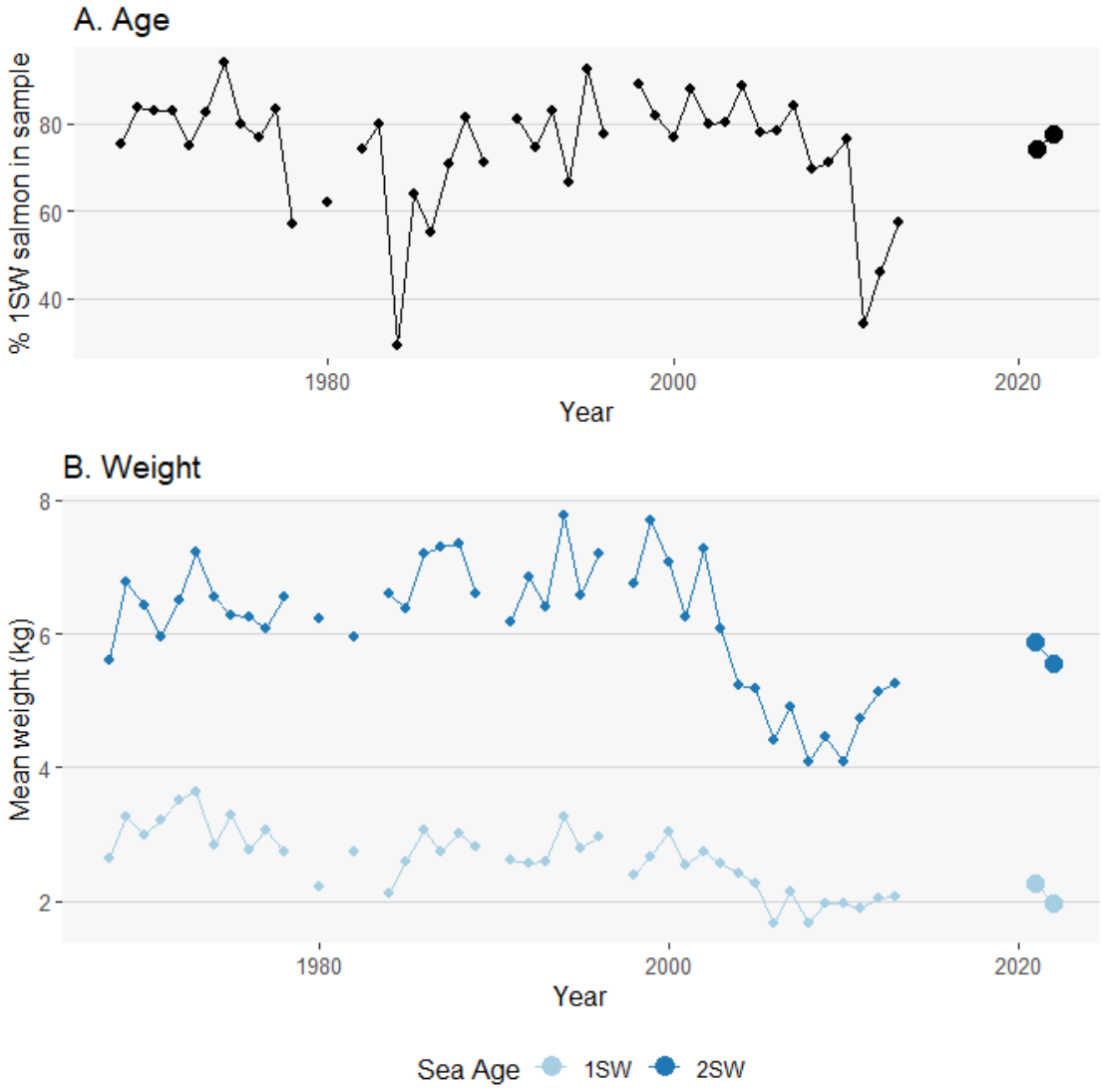

Figure 3.11: Long term changes in salmon sampled during August in the River Tweed (1968-2022). A: Changes in the percentage of 1SW salmon in the samples. B: Changes in the mean weight of 1SW and 2SW salmon.

4 Discussion

The fundamental data pillars for wild Atlantic salmon stock assessment in Scotland are catches, counts, sex ratios, fecundities, sizes and ages. The National Adult Salmon Sampling Project demonstrated the potential for local managers to contribute valuable information on the ages, size and sex of returning stocks that can be used within population dynamics models to estimate stock status.

Previous work has shown long term changes in the balance between the different sea age classes (George (1982); Summers (1995)) and fluctuations in the sizes of salmon returning to Scottish coasts (Summers (1993)). Although there is some evidence of a relationship between the size of adult salmon returning from the sea and climatic variables it is not possible to use this to predict size or age of returning fish (Todd et al. (2008); Bacon et al. (2009); Bal et al. (2017)).

In contrast to long term temporal changes there has been less focus on geographic changes in life history parameters of salmon around Scotland. This is a function of the greater size of the stocks and fisheries in the east and north of Scotland affording greater sampling opportunities than on the west. This imbalance is also shown in the number of samples collected during 2021 and 2022. Despite this imbalance the samples were able to demonstrate some important geographic patterns, particularly in the age and sex of salmon. The link between smolt age and latitude, previously shown on a range wide scale (Metcalfe and Thorpe (1990)) was shown within Scotland. For sea age the higher occurrence of 1SW salmon on the west compared to the east, highlighted in the reported catches, can be seen in the samples. Geographic comparisons of the sex ratio of salmon are likewise limited with Shearer (1992) noting that for the River North Esk “most grilse are male and most 2SW fish are female. However, in ‘grilse only’ rivers, the proportions of male and female grilse are about equal.” This general pattern accords with the preliminary results presented here where grilse from the east were more likely to be male and those on the west (equivalent to ‘grilse only’ rivers) female.

There is limited information on the sex ratio of Scottish salmon, with the majority being collected using visual observations (e.g. Bacon et al. (2009)). However, the use of visual methods of sexing were found to underestimate the occurrence of females, both in this study and on the River Tamar (King, Toms, and Stevens (2023)). King, Toms, and Stevens (2023) found that error varied throughout the season and highlighting the issues with depending on visual sex identification for stock assessment, and other analyses.

The project highlights how sampling of adult salmon can be used to gather information on the age, size and sex of adult salmon returning to Scottish coasts. The geographic and temporal differences shown here are not just academically interesting but have real practical implications for management:

- *Sea Age*. The sea age of salmon in a given stock is related to the size of individuals and the sex ratio and will therefore impact on the estimated egg deposition used to assess stock status. Underestimating the proportion of 1SW salmon (for example Figure 3.11A) would lead to an overestimation of egg deposition.

- *Smolt Age*. Differences in the smolt age of fish also impact on egg deposition, with females having a lower smolt age tending to contain a greater number of eggs (Hanson et al. (2020)).
- *Size*. Large fish contain more eggs so not using accurate size information could lead to biased stock assessments (Hanson et al. (2020)).
- *Sex ratio*. Currently the sex ratio of 1SW and MSW salmon are treated as fixed when assessing Scottish stocks. This project has provided the first geographic data on these ratios to allow these patterns to be accounted for in the assessments.

Although the current stock assessment methods do account for geographic changes (e.g Anon), further information is required, particularly to account for changes over time (e.g. Figure 3.11).

The project highlights the utility of national and local bodies working together to collect the information required for management of salmon in Scotland. The sampling relies on the network of trusts and boards spread throughout Scotland, their presence on the ground and their relationships with their local fisheries. On the other hand the national bodies (Fisheries Management Scotland and Marine Scotland) are able to provide funding, project management, quality assurance and consistent reading of scales.

The next step with this process will be to use the experience gained over these first two years to produce an updated sampling design. Any new design will have to balance extending the sampling season, maximising the number of fish sampled and maintaining good round Scotland coverage. Given finite resources it is possible that there will have to be a reduction in the overall number of rivers that can be sampled, although this will depend on funding. It will also be important to investigate how the information from the sampling may be integrated with other data to feed into stock assessments, particularly rod catch data. Rod catches have very good spatial and temporal coverage but there are known inaccuracies in, for example, the reported proportion of 1SW in the catches (MacLean, Smith, and Laughton (1996)). Further work is require to determine if the two sources can be integrated to provide a more complete picture of adult salmon returning to Scotland.

References

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Annex 1 – Standard Operating Procedure

Minimum reporting requirements:

- Minimum data requirements:
  - Date
  - Location (using online GIS tool)
  - Method of Capture
  - Length (cm)
  - Weight (kg)
  - Digital balance used
  - Sex (male/female/unknown)
  - Fish state (live/dead, sedated/un-sedated)
  - Sea lice (presence/absence)
  - Scale sample taken

- Fork length (Figure 1) of the fish should be recorded **in centimetres** to the nearest 0.5 cm either using a measuring board or a tape measure.
- Weight of the fish (ungutted) should be measured **in kilograms** to the nearest 0.1 kg using a digital balance.
- Presence or absence of sea lice noted.
- For consistency, **scales should be taken from the left flank of the fish**, from an area immediately behind the dorsal fin and midway between the back of the fish and the lateral line (see Figure 1). Occasionally, in situations where fish may have been sampled previously, consideration instead, should be given to take scales from the right flank, where a higher proportion should be originals.

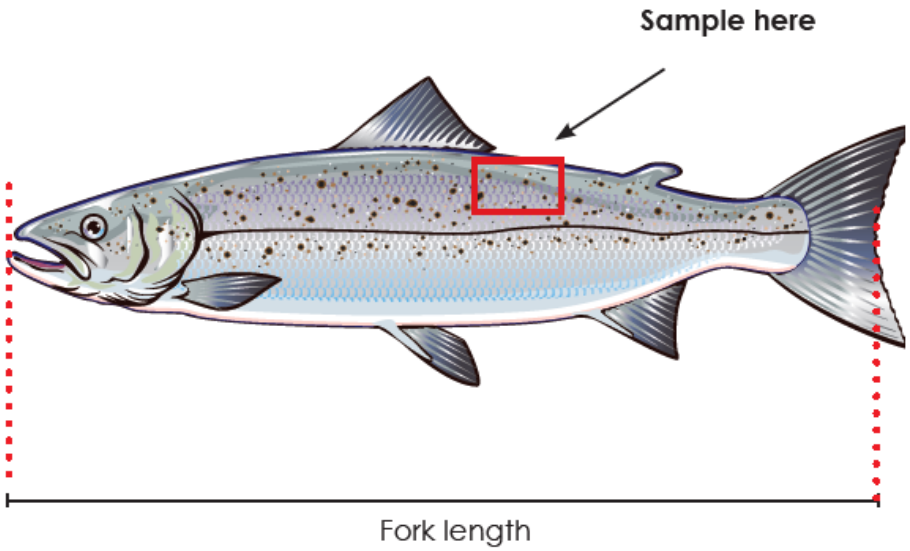

Figure 1: Measurement of fork length and scale sample location for adult Atlantic salmon (Source: Inland Fisheries Ireland)

- A blunt scalpel or a knife blade is used initially in a head to tail direction to remove excess mucus. Then, working in the opposite direction, and by applying more pressure, scales are scraped loose from the fish. Scales may also be removed using

forceps. In general, a relatively large sample (10+ scales) is likely to provide more useable scales. Alternatively, for larger fish, dissection forceps can be used to remove individual scales. Scales are transferred from the blade/forceps to a paper scale packet, taking care to clean the instrument between samples.

- For **dead fish**, a relatively large sample (**10+ scales**) should be collected.
- For fish that will be **returned live** to the water, fewer scales should be taken (**6-8**).
- Each scale packet should be clearly labelled to identify the sample it contains, with details that will help a scale reader interpret growth (length, weight, date, place, sex if known). A unique scale sample identification number will be provided by the online reporting tool when submitting a record; this must be transcribed onto the scale packet to enable linking of the physical and digital record. Scale packets should be allowed to dry fully in open air before being stored and returned to:

  National Adult Salmon Sampling Programme
  Marine Scotland Science
  Freshwater Fisheries Laboratory
  Faskally, Pitlochry
  PH16 5LB

- OPTIONAL: while not required for the National Adult Salmon Sampling Programme, you may wish to take photographs of the fish and there is an option to upload these to the online reporting tool
- Submit data to the online reporting tool available at: National Adult Salmon Sampling Project (Survey123)

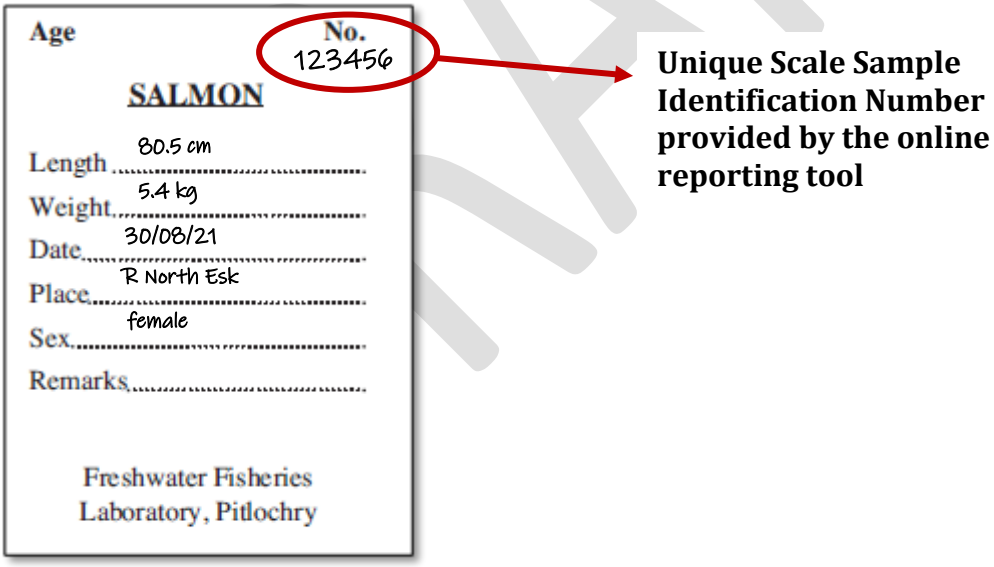

Figure 2 Example scale packet with necessary required data