National Adult Salmon Sampling Project

August 2025

Scottish Government
Riaghaltas na h-Alba

National Adult Salmon Sampling Project

Marine Directorate and Fisheries Management Scotland

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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. Sampling of individuals can also provide information on their condition, while examination of scale samples allows their growth history to be investigated.

In Scotland, and other countries, scale samples were historically collected from commercial netting but most of these fisheries have closed in recent years. Due to a lack of sampling information, it has been necessary to assume that there have been no changes in age or size of salmon returning to Scotland since 2018. This is clearly unrealistic given previously documented long-term shifts in the size and demography of salmon in Scotland (Bacon et al. 2009; Todd et al. 2008; Todd et al. 2012) and more widely in the North Atlantic (Bal et al. 2017; ICES 2023). To fill this data gap the options for using existing rod fisheries and targeted scientific sampling as a source of biological information on returning adult salmon were investigated.

During 2021-2023, a national adult salmon sampling programme was developed by the Marine Directorate, Fisheries Management Scotland and local District Salmon Fisheries Boards and Trusts. 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 to obtaining samples worked 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 could 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 maximum flexibility for local arrangements to be made regarding, for example, how fish would be collected for sampling. Samplers were encouraged to (where possible) select sites:

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

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

Adult salmon were sampled during July-September 2021, June-September 2022 and June-October 2023, with some additional samples provided from May in all three years. Sampling effort was not uniform across the three years but was a function of available funding, with most effort occurring in 2022, followed by 2021 then 2023. 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 were sent to Marine Directorate for pressing, ageing and imaging. Genetic information was extracted from a sub-sample of the scales and used to determine the sex of the individual. 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 differences in the ages and sizes of fish sampled in different rivers. The results were therefore aggregated to a regional level (Salmon Fishery Statistical Regions; Figure 1). Further levels of aggregation were used to explore within and between year patterns (Table 1).

Table 1: Groupings used to explore patterns in the adult sampling data. Regions are from Figure 1).

Coast	**Area**	**Regions**
East	East	East
		North East
	North	Moray Firth
		North
West	West	North West
		West
		Clyde
		Solway

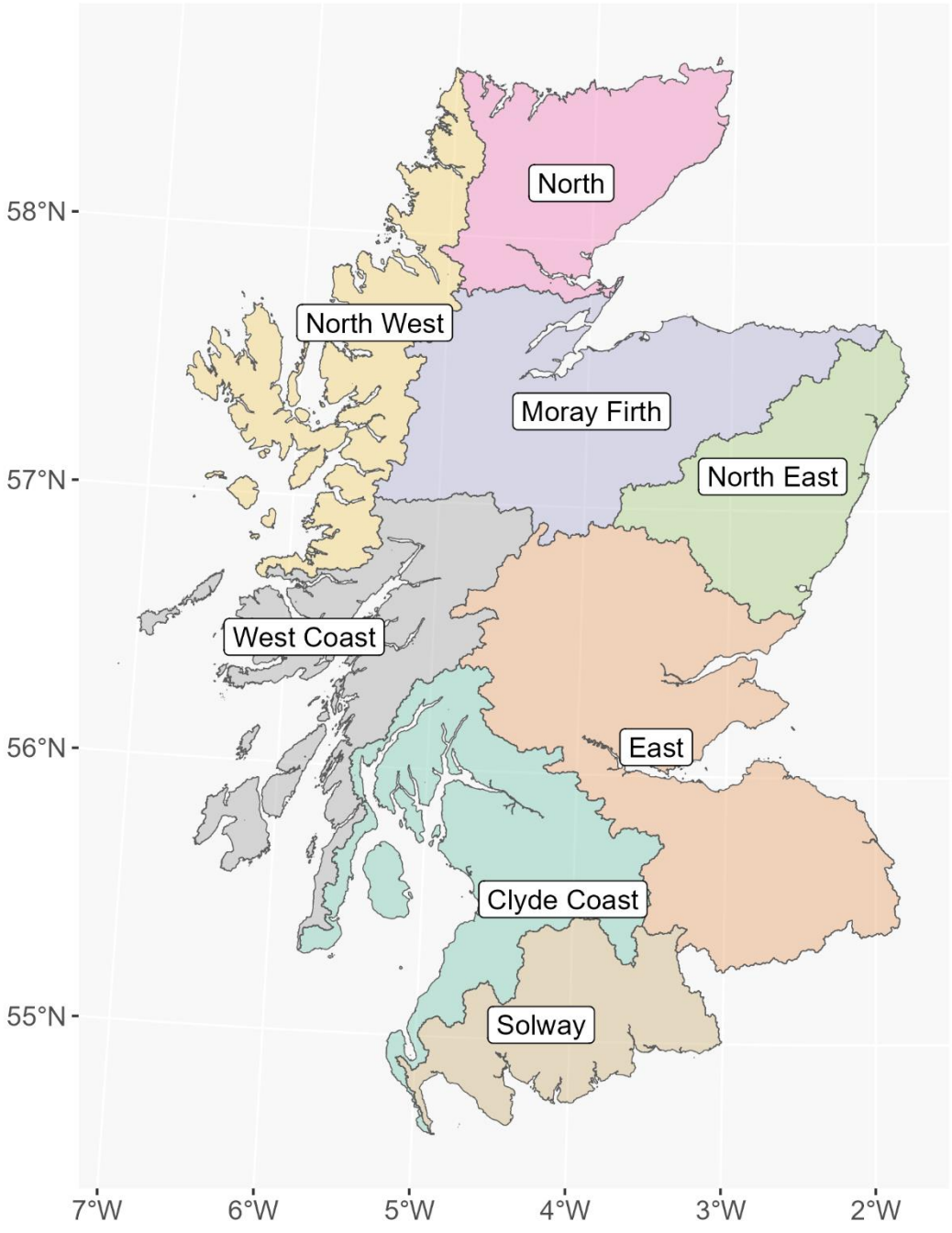

Figure 1: Map showing the fishery regions used to aggregate samples in the report. No sampling took place outwith the mapped regions.

3. Results

A total of 1119 adult salmon were sampled during 2021-2023 across 31 different rivers between May and October, with most samples in July and August (Table 2). The numbers sampled were a function of effort and were highest in 2022. There was also a wide geographic range in the numbers of salmon sampled with the largest numbers tending to be sampled on large east coast rivers (Figure 2).

Table 2: Summary of the number of adult salmon sampled by month and year

Month	2021	2022	2023	Total
May	3	32	6	41
June	0	60	6	66
July	45	212	107	364
August	184	157	84	425
September	92	123	7	222
October	0	0	1	1
Total	324	584	211	1119

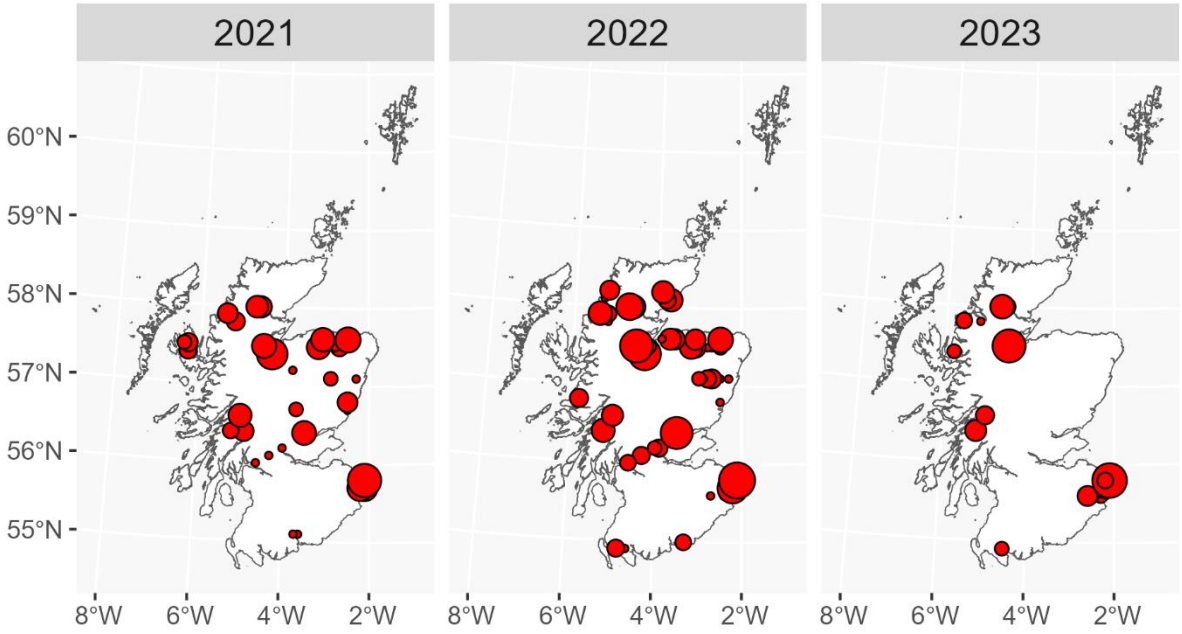

Figure 2: Map showing the locations of adult salmon sampled during 2021-23. The size of the point is proportional to the number of fish sampled in each location.

It was possible to identify the sea ages of 1037 of the 1119 (93%) salmon sampled, with fish becoming more difficult to age later in the season as the scales started to show greater levels of erosion. An overview of the sea ages of salmon sampled during 2021-23 is shown in Figure 3. The overall pattern of sea ages was similar in the three years with 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. Of the 311 multi-sea winter salmon (MSW) sampled during the project 306 (98%) had spent 2 winters at sea (2SW) while only 5 (2%) were 3SW salmon (all within the Moray Firth region).

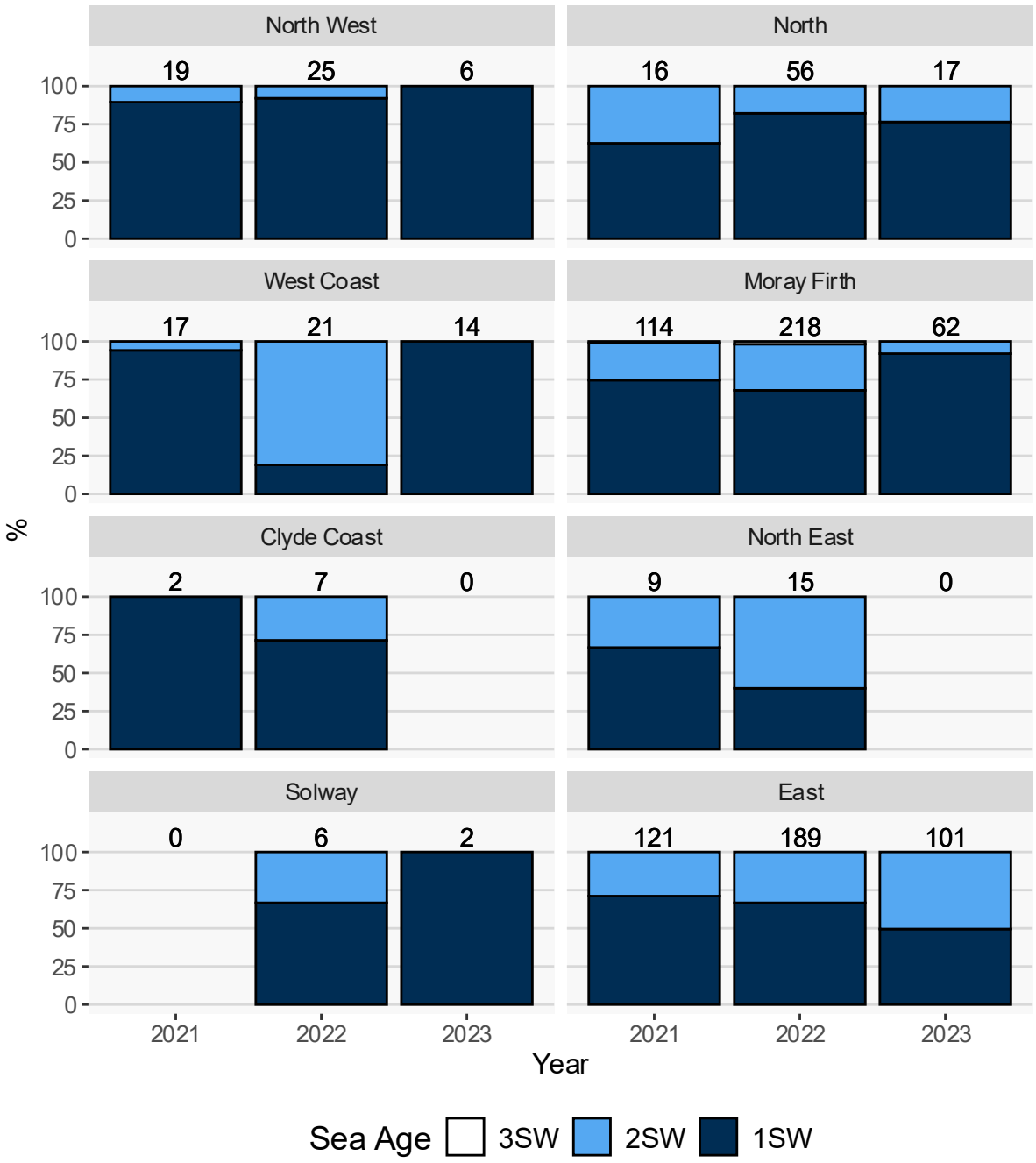

Figure 3: Percentage of salmon sampled belonging to different sea age classes broken down by fishery region in 2021-23. 1SW salmon are shown in darker blue, MSW (2SW and 3SW) in the lighter shades with the total number of salmon sampled given above the bars.

It was possible to identify the smolt ages of 993 (89%) of the salmon sampled over the three years. Smolt age was similar among the sampled years (Figure 4). Generally, S2s (two year old smolts) were the dominant age class, except in the East and Solway regions where S1s (one year old smolts) were the most common age class.

3.1 Sea Age

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 over the season in all three areas, with few 1SW salmon sampled during May/June to them becoming the most prevalent age class during August/September (Figure 5). Beyond this, there were no 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.

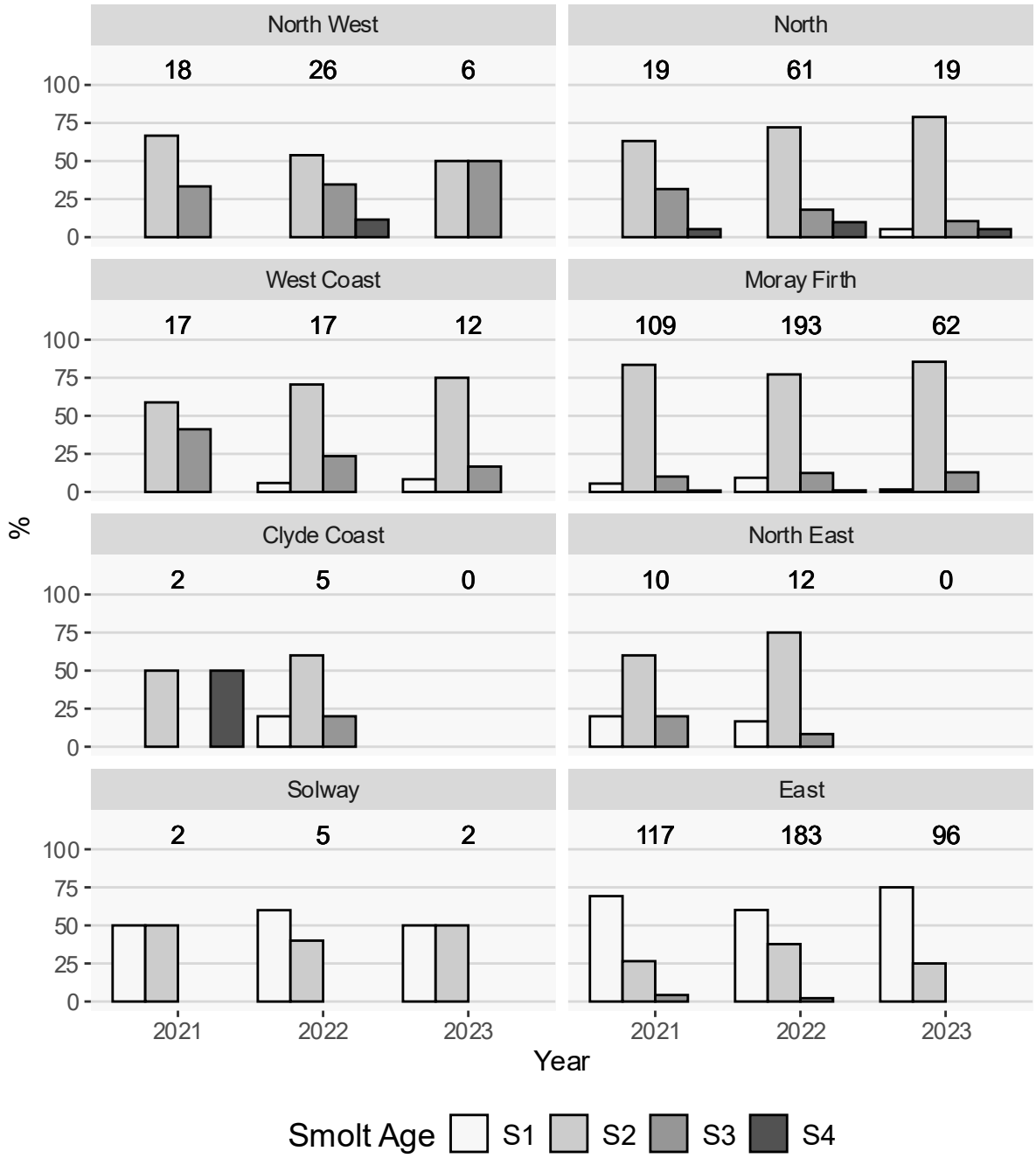

Figure 4: Percentage of salmon sampled belonging to different smolt age classes broken down by fishery region in 2021-23 (regions indicated on map). S1 salmon are shown in white and S4 salmon as dark grey with S2 and S3s as intermediate shades. The numbers of salmon sampled are given above the bars.

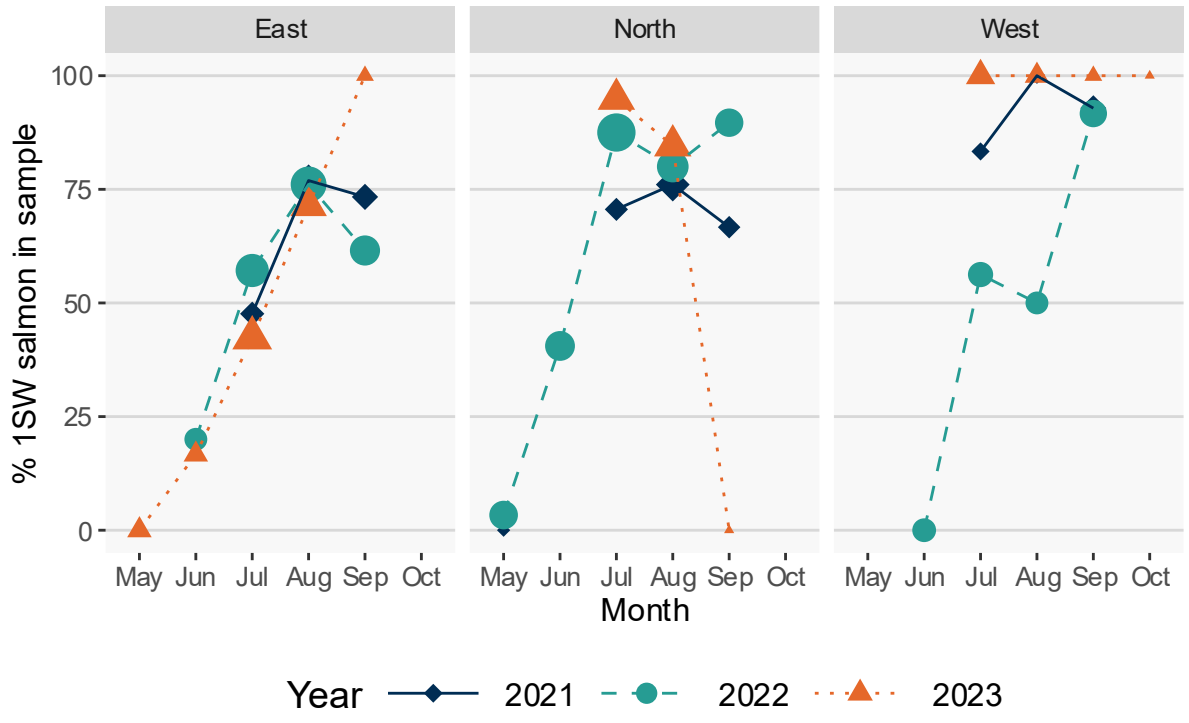

Figure 5: Monthly changes in the percentage of 1SW salmon in samples taken from the East, North and West of Scotland in 2021(purple solid line), 2022 (orange dashed line) and 2023 (green dotted line). The size of the points is proportional to the number of salmon sampled.

3.2 Smolt Age

Examination of the mean smolt age shows little difference between years or sea ages (Figure 6). However, age did vary among areas and there was a suggestion that smolt age declined through the season.

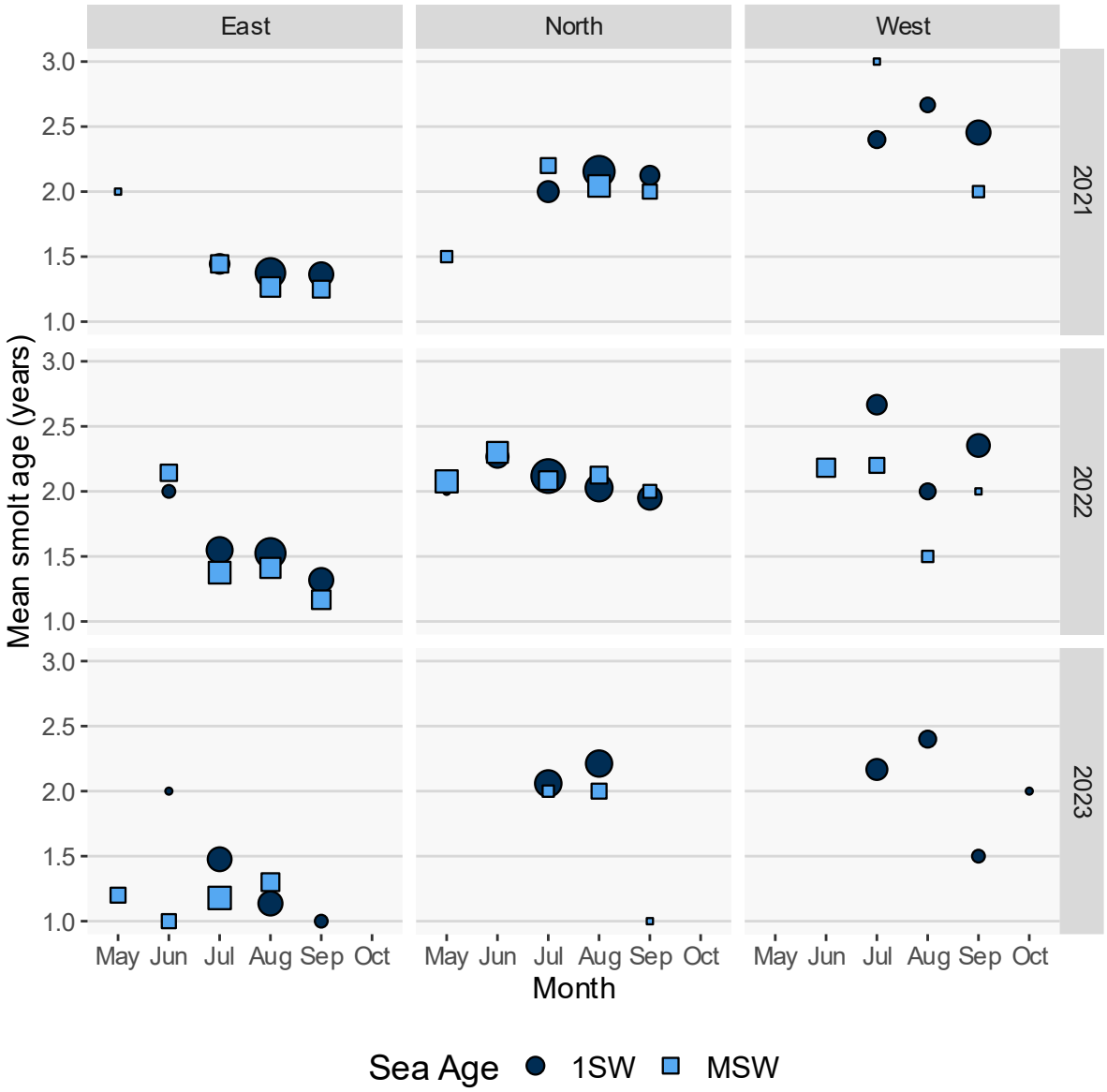

Figure 6: Monthly changes in the mean smolt age of 1SW and MSW salmon sampled from the East, North and West of Scotland in 2021-23. The size of the points is proportional to the number of salmon sampled.

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 7).

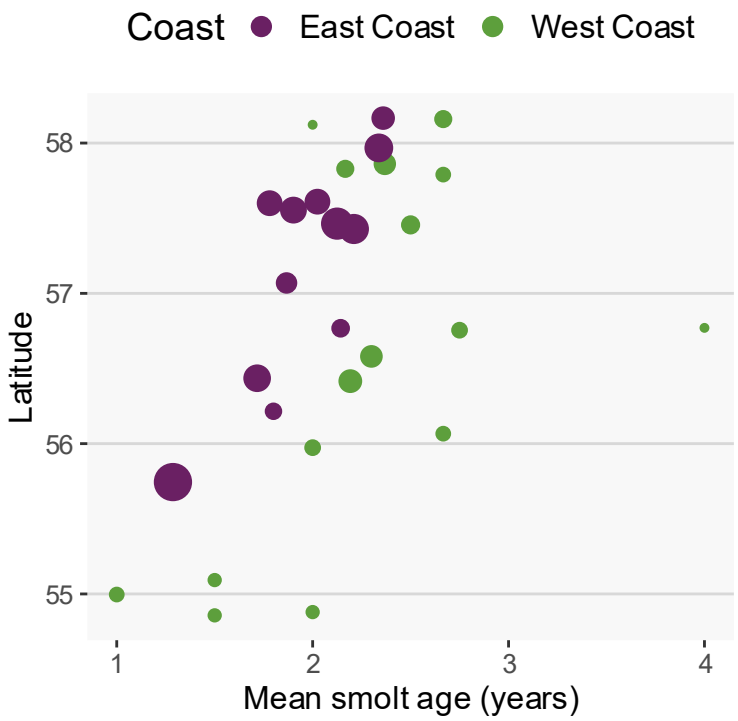

Figure 7: The relationship between mean smolt age and latitude shown for samples collected on the East and West Coasts.

3.3 Size

Although sample sizes were limited there were suggestions of consistent patterns in size among areas, with 1SW salmon tending to be larger in 2021 than in 2022 and 2023 while 2SW salmon were a similar size (Figures 8 and 9). 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.

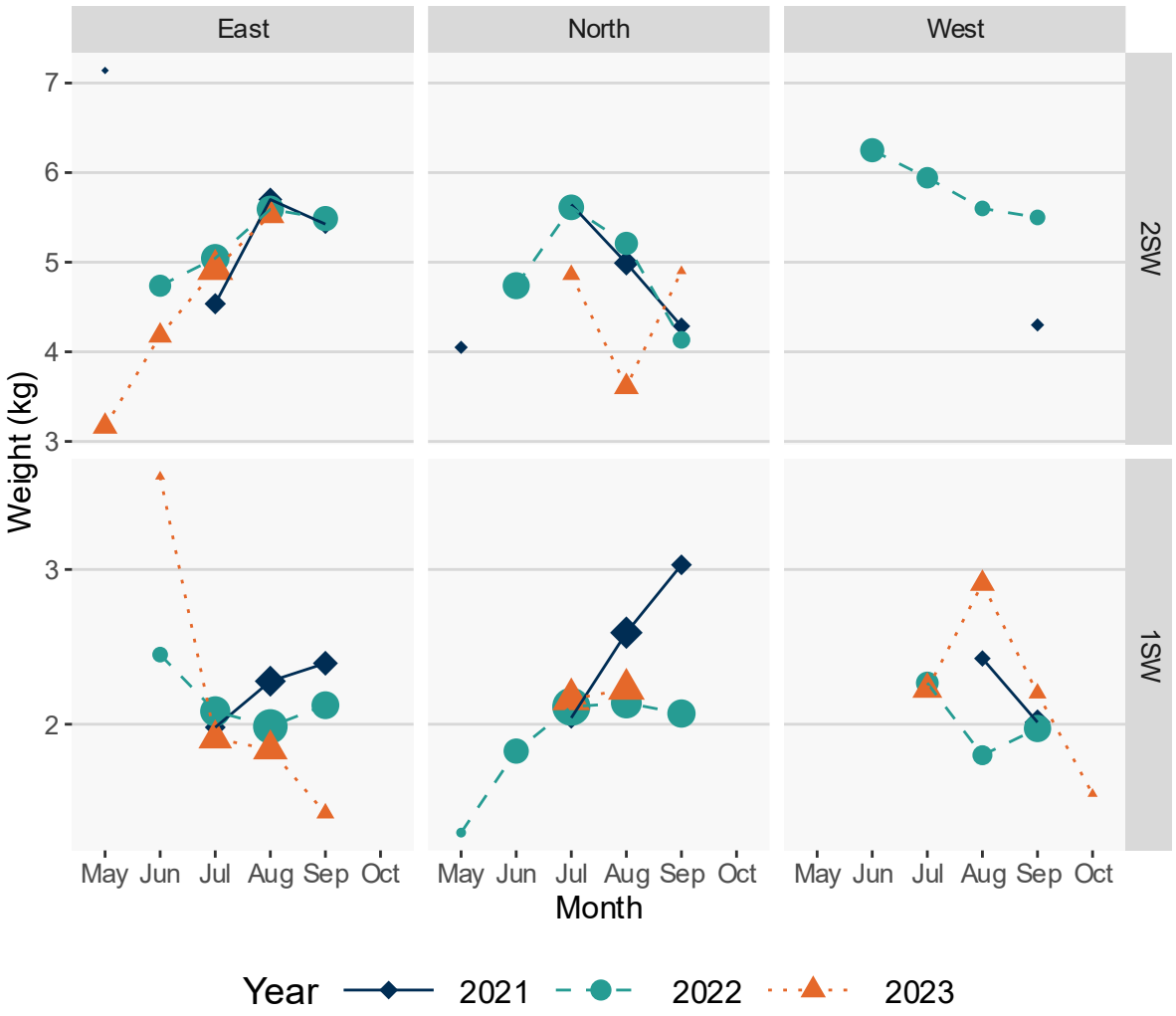

Figure 8: Monthly changes in the mean weight of 1SW and 2SW salmon sampled from the East, North and West of Scotland in 2021 (purple solid line), 2022 (orange dashed line) and 2023 (green dotted line). The size of point is proportional to the number of fish in each sample.

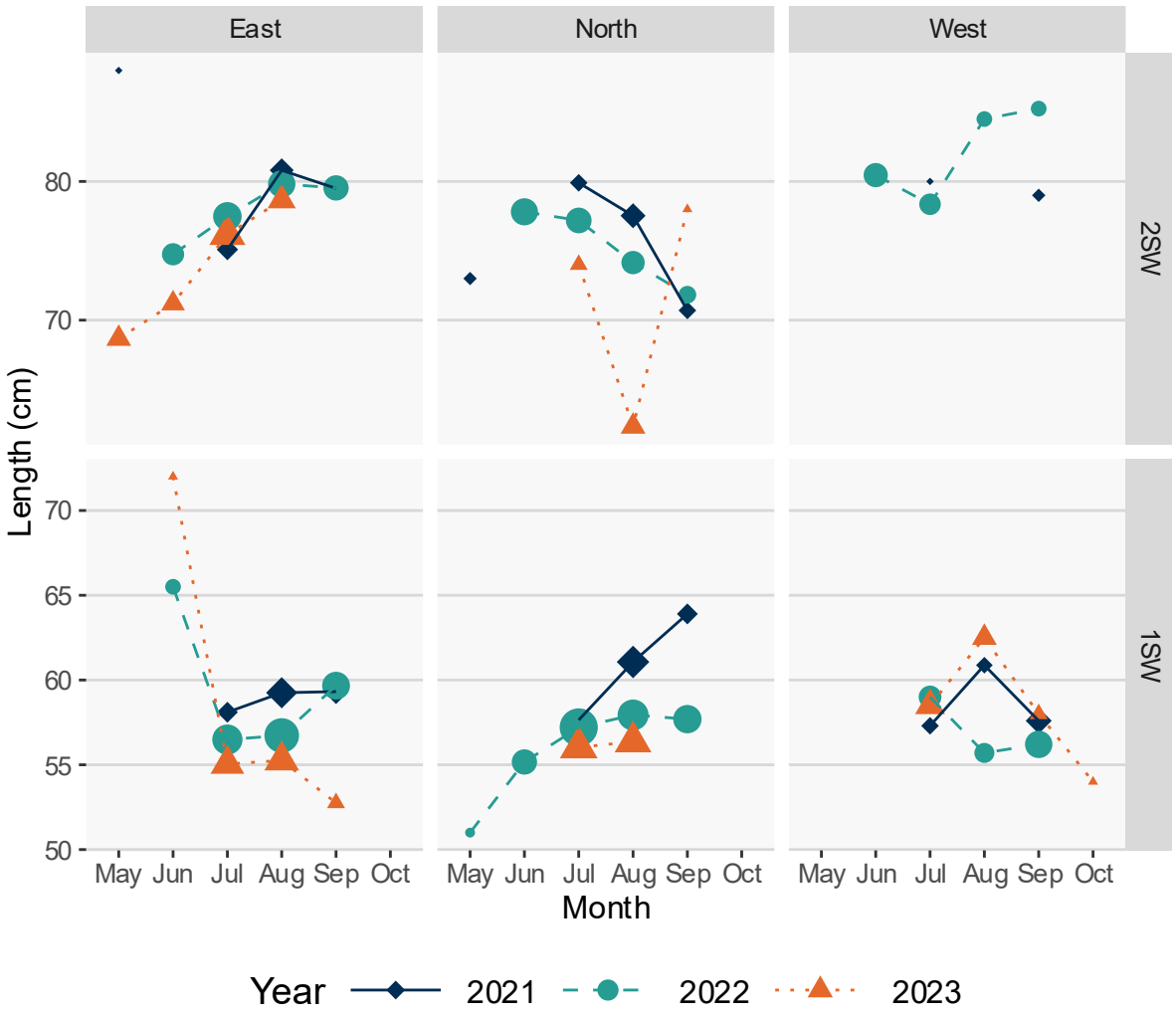

Figure 9: Monthly changes in the mean length of 1SW and 2SW salmon salmon sampled from the East, North and West of Scotland in 2021 (purple solid line), 2022 (orange dashed line) and 2023 (green dotted line). The size of point is proportional to the number of fish in each sample.

3.4 Sex

Results from the genetic determination of sex were available for 924 of the salmon where it was possible to determine a sea age from the scales. The reported (visual) percentage of females for both 1SW and MSW salmon was found to be lower than that determined using the genetics method in 2021 and 2023 but similar in 2022 (Figure 10).

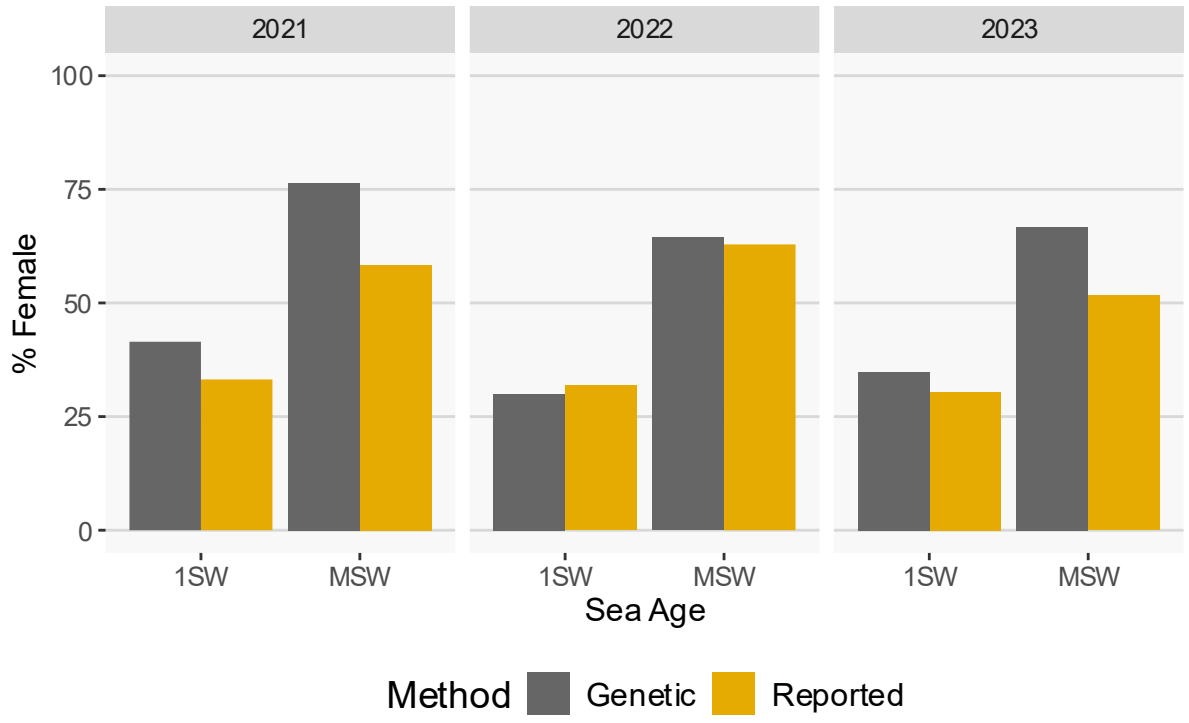

Figure 10: The percentage of female salmon by sea age sample in 2021-23 as reported using visual assessment and genetic assignment.

Overall the visual and genetic methods agreed in 69.1% cases for genetically assigned females (n = 408) compared to 83.5% of genetic males (n = 516). Closer examination of where the visual sex agreed with the genetic sex highlights that the level of disagreement differs between years, sea ages and genetic sex (Figure 11).

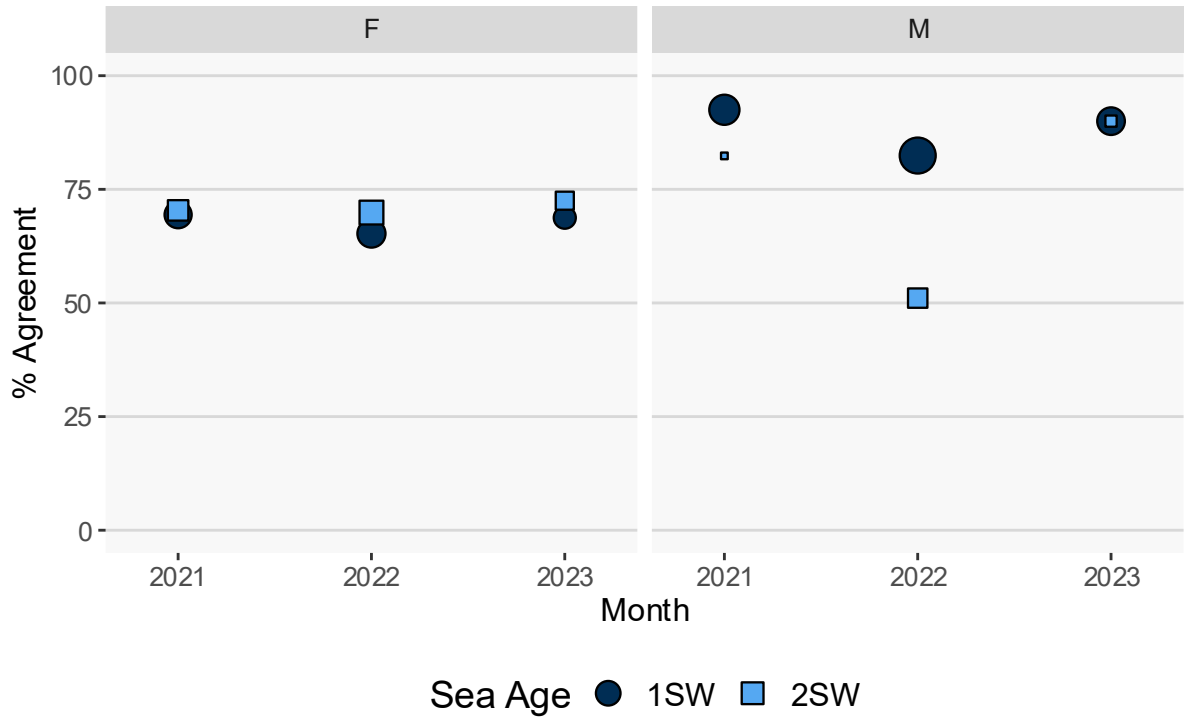

Figure 11: The percentage of genetically female and male salmon where the visual sex agrees with the genetic sex in 2021-23. Information is presented for 1SW and 2SW salmon with the size of the point proportional to the number of samples (range of 17-222).

A greater percentage of 2SW salmon were found to be female compared to 1SW fish. In addition, there was a difference in the sex ratio between the East and West Coasts with a greater percentage of salmon on the West Coast being female for both 1SW and 2SW age classes (Figure 12).

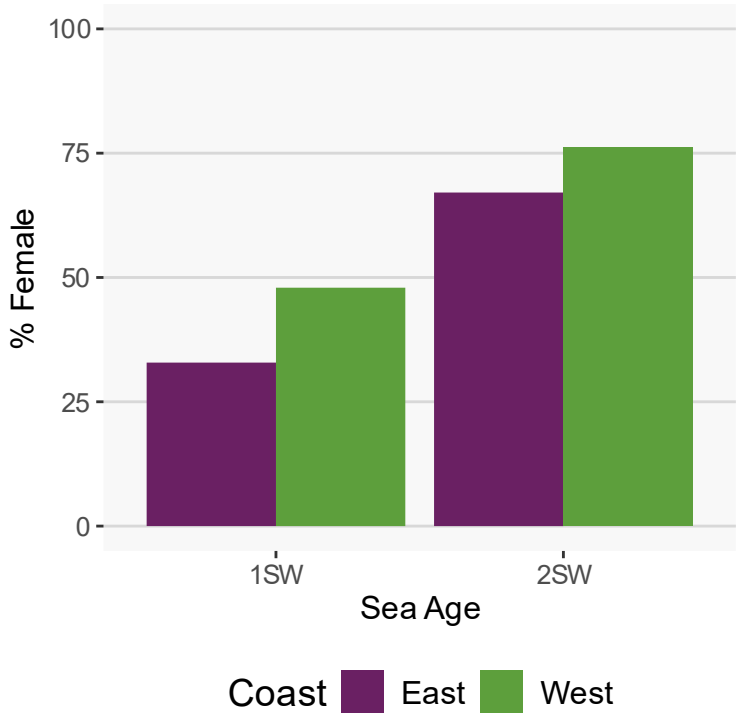

Figure 12: The percentage of genetically female 1SW and 2SW salmon by coast 2021-23.

3.5 Long Term Patterns

There are long term data available from sampling of commercial net catches on the River Tweed. These allow the 2021-23 samples to be placed into a wider context. To account for seasonal change in age and size, the percentage of 1SW fish and the weights of 1SW and 2SW fish sampled by net during the month of August were compared (Figure 12). There are clear long-term fluctuations in the ages and lengths of salmon sampled on the River Tweed. Compared to the early 2010s there were more 1SW fish in the 2021-23 samples (Figure 13A), while the weights of both age classes have recently increased from the low values seen from the mid 2000s (Figure 13B).

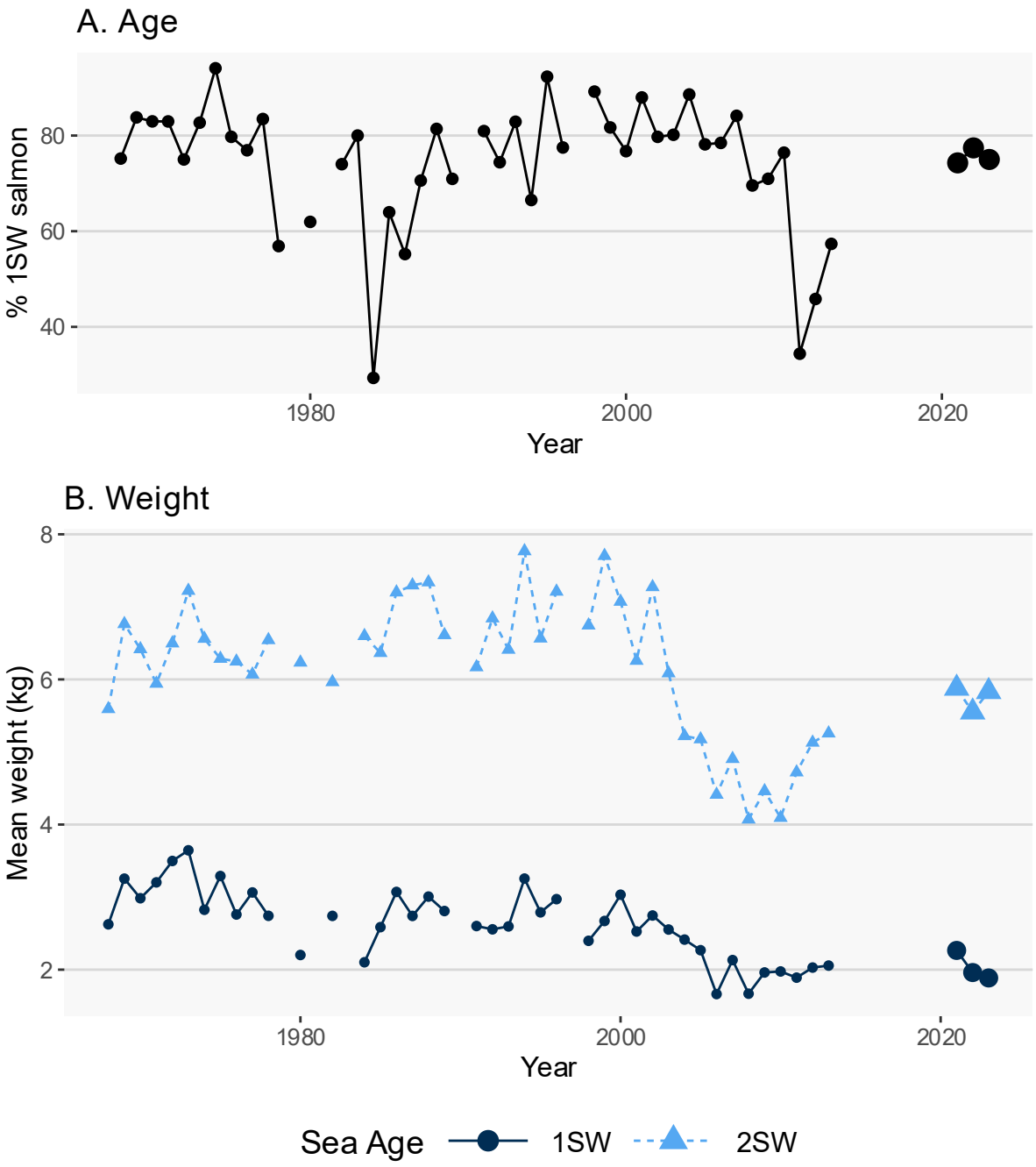

Figure 13: Long term changes in salmon sampled during August in the River Tweed (1968-2023). A: Changes in the percentage of 1SW salmon in the samples. B: Changes in the mean weight of 1SW and 2SW salmon.

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 Programme 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 differences 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 2021-23. Despite this imbalance, the samples obtained demonstrated some important geographic patterns, particularly in the age and sex of salmon. The link between smolt age and latitude, previously shown at a range-wide scale (Metcalfe & Thorpe 1990), was also shown within Scotland. For sea age, the higher occurrence of 1SW salmon on the west compared to the east (also seen in reported catch statistics; Marine Directorate, 2024) 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 [1SW] 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 results presented here where 1SW salmon from the east were more likely to be male and those on the west female (where rivers are equivalent to the ‘grilse only’ rivers noted by Shearer (1992)).

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 et al. 2023). Similar to the present study, King et al (2023) found that error varied within and among years highlighting the issues with depending on visual sex identification for stock assessment, and other analyses.

This report highlights how coordinated sampling of adult salmon in recreational or scientific fisheries 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 3.13A) 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, further information is required - particularly to account for changes over time (e.g. Figure

3.13). If an annual sampling programme can be maintained, it will provide this invaluable information as it matures.

The programme highlighted 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 at the river bank and their relationships with local fisheries. The national bodies (Fisheries Management Scotland and Marine Directorate) are able to provide funding, project management, coordinated data collection, quality assurance and consistent reading of scales.

Given finite resources available for monitoring salmon populations, the next step will be to investigate the potential of other data sets to provide complementary information to targeted sampling of adult salmon. Rod catches provide some information on the sea age and size of salmon and have very good spatial and temporal coverage. However, there are known inaccuracies in, for example, the reported proportion of 1SW in the catches (MacLean et al. 1996). Further work is therefore required to determine if the two sources can be integrated to provide a more complete picture of adult salmon returning to Scotland.

Data availability

Data collected during the National Adult Salmon Sampling Project are available.

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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.

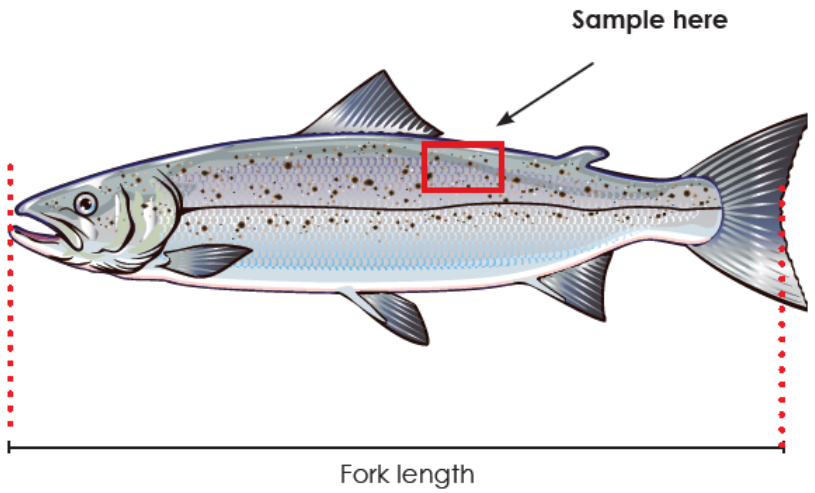

Figure 1: Measurement of fork length and scale sample location for adult Atlantic salmon (Source: Inland Fisheries Ireland)

- 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)

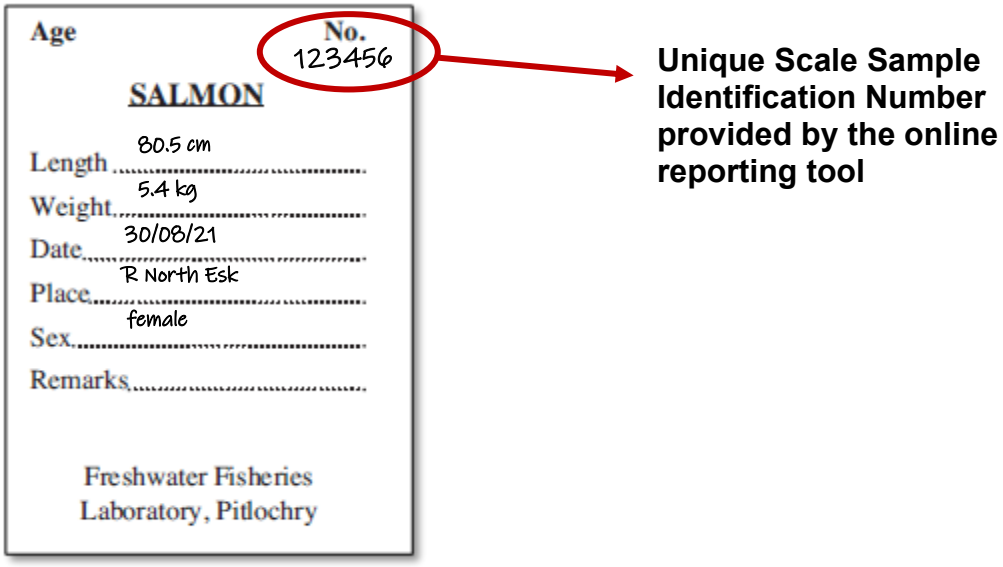

Figure 2 Example scale packet with necessary required data

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