

2022 Survey of Juvenile Salmonids in Caithness Rivers

Caithness District Salmon Fishery Board

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March, 2023



Falls of Forss

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1. Summary

In 2022 the condition of young salmon in the Caithness rivers continued to vary widely. Thurso River remained robust to the changes affecting the other rivers and the juvenile population was again at saturation, or near saturation, levels throughout. In contrast, the Forss River continued its decline. In particular, fry levels in 2022 were trivially low for the first time - a pressing indication that intervention is required. In response, a Forss Recovery Plan is being developed. The recent decline in the status of juvenile populations of salmon in Wick River continued into 2022. The pattern of decline within the river is patchy with the Strath Burn proving most resilient. At some locations, there is circumstantial evidence that survival rate between the fry and parr stages is being reduced by water quality issues caused by summer drought - although direct evidence for this is lacking. In response, WAA has introduced changes to its rules to further reduce angling pressure on the river and it has commissioned work to directly assess water quality if and when summer drought recurs. Two sites were surveyed on Dunbeath Water; fry densities were good in the middle catchment but poor at the higher altitude site. On Berriedale/ Langwell, fry densities were mostly good but (as for Dunbeath Water) poor at the highest altitude site.

2. Introduction

In recent years, populations of juvenile salmon in the Caithness rivers have changed in complex ways driven by a range of new pressures. The primary pressure probably results from the recent succession of summer droughts extending back to 2018. The effects of reduced flows and high water temperatures affect the physiology and behaviour of fish in many ways as well as affecting all of the organisms that they prey on or are preyed by.

Some rivers appear to be more susceptible to the resulting changes than others. Thus, the Thurso, the largest of the Caithness rivers, has proven most resistant to the effects of low summer flows while the smaller rivers seem to have been affected disproportionately more by, for example, reductions in spawner numbers and the increased incidence and severity of disease (RSD/ *Saprolegnia*) among river entrants. Juvenile salmon in survey sites in agricultural settings on small rivers appear to have been susceptible to reduced juvenile survival attributable, perhaps, to water quality issues during hot, dry interludes. Because of all this variation, this report has again been split into five main sections dealing separately with each of the Caithness catchments.

The Board's survey was carried out in exactly the same way as in all previous years in order to continue to generate standardised data for defined survey sites. The 2022 survey was the tenth in the current series of surveys and as the Board's data series has built up it has become possible to extract more information using new approaches. In particular, the availability of long time series for the so-called key sites on every river has made it possible to consider the link between fry and 1+ parr densities in consecutive years and to search for disparities.

The use of biomass density proved extremely informative when fish densities were high. Under present conditions, however, when fish are less numerous in some locations, biomass density ceases to be so useful. Instead, the body sizes of the fish become more directly relevant since low densities (which are inherently hard to measure accurately) tend to be associated with enhanced growth and therefore with large body size which can be measured more easily. So, the emphasis placed on density, biomass density or body size at particular sites has gradually altered to accommodate changing circumstances.

It is always necessary to consider survey data by comparing it with something else. Thus, sites can be compared with other sites for which comparable data is available, or more tellingly, site data for single

years can be compared with comparable data obtained for the same site in previous years. The latter approach was adopted by the Board from the outset. Formerly, Godfrey’s report was used to place the Caithness data in a wider regional context, as described in previous Board reports. More recently, as part of the NEPS exercise, Marine Scotland Science has re-worked archives of regional and national electric fishing data in the context of river size, altitude and surrounding land-use using modelling techniques to predict site-specific benchmark values for fry and parr. It is now possible to access these benchmark values, knowing the coordinates of the site in question, using the on-line resource posted by MSS. The NEPS benchmark values have been used for comparative purposes in some of what follows.

Finally, as previously, all the axis dimensions in the figures that follow have again been held constant in the usual format to aid visual comparisons among site and years. Biomass densities have been estimated from fish lengths using Shackley’s formula, as described in previous reports.

3. Forss

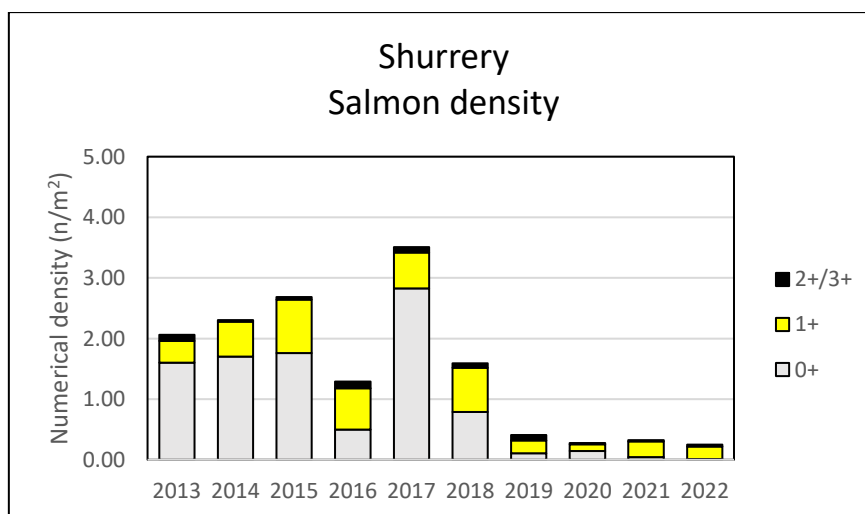
As detailed in previous reports, Forss salmon have been beset by a number of problems in recent years. These have mostly related, in one way or another, to the succession of summer droughts in Caithness since 2018. The overall effect of the various impacts has been to reduce the density of juvenile fish.

These reductions will have had knock-on effects on the number of smolts going to sea and, to make matters worse, since 2019 many of the dwindling number of returning adults have succumbed each year to RSD/ *Saprolegnia* soon after river entry. These mortalities have reduced egg deposition leading to further reductions in the juvenile stock.

A denouement was reached in 2022 when fry were more-or-less absent from the electric-fishing survey sites at Shurrery and Lythmore.

3.1 Shurrery

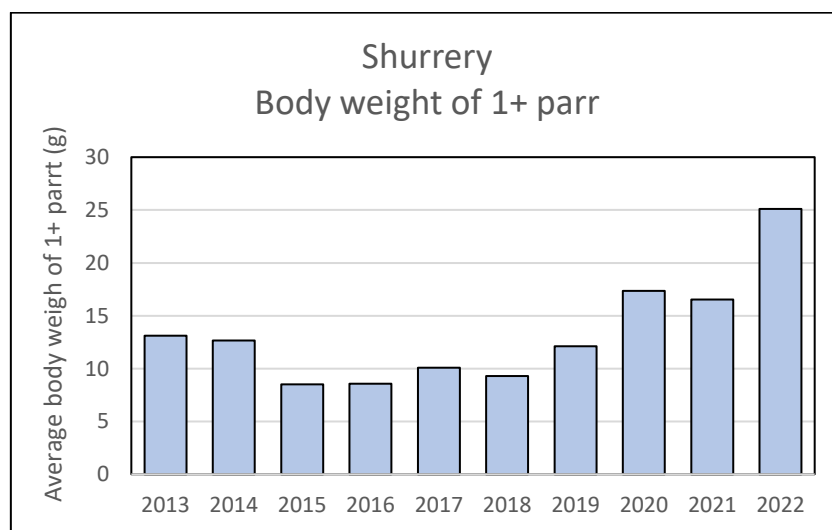
Before 2019, fry densities at Shurrery were high by any standard at an average value around 1.5/m². Densities of 1+ parr were also very high with an average value of around 0.6/m². Older parr were very few in number, indicating that most Shurrery smolts leave for the sea at two years of age.



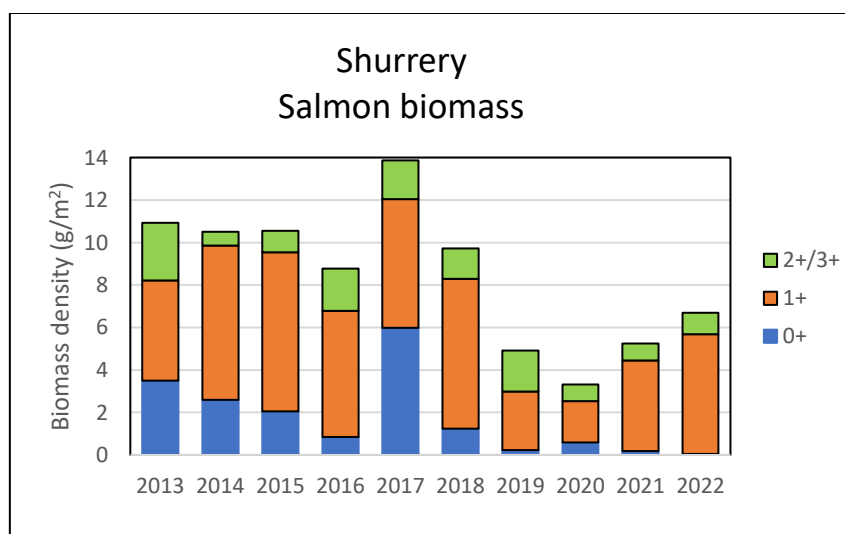
From 2019 onwards, fry densities were much lower and declined progressively; all the annual values were less than 10% of the pre-2019 average. By 2021, fry density was only 0.04/m² (about 3% of the pre-2019 average). In 2022 only a single fry was captured giving an indicative density of 0.01/m² - less than 1% of the pre-2019 average.

The recent lack of fry has reduced the density of 1+ parr in the year that follows. The reduction in 1+ parr density has not been as severe as the corresponding reduction in fry density, probably because of low levels of competition and reduced mortality rate among the few fish present. In 2022 the density of 1+ parr was still 0.21/m² (about 35% of the pre-2019 average), despite the low density of fry in 2021.

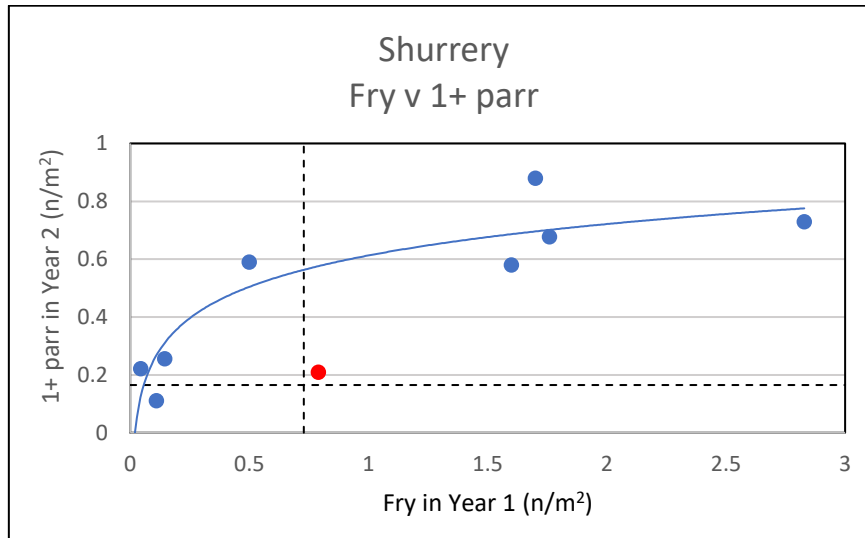
Looking forwards to 2023, however, it is self-evident that the density of 1+ parr is likely now to collapse because fry density in 2022 was below the level at which any compensatory buffer might apply. In other words, the single fry detected in 2022 cannot generate more than a single 1+ parr for 2023.



In 2022, the average body weight of 1+ parr was 25g - more than twice the average value for the years before 2019. This was due to a compensatory increase in the growth and body size of individuals due to their low overall numbers and consequent low levels of competition for abundant resources.



The large size of the few fish that were present made good a surprisingly large part of the potential deficit in total biomass. Before 2019, total biomass density at Shurrery was among the highest values in Caithness at around 10g/m². In 2022, despite the dearth of parr and the imperceptibly small contribution made by the fry, biomass density was still relatively high at around 6.5g/m². This was because the parr were so large.



The graph above shows the stock-recruitment relationship that underpins the functioning of the Shurrery site. The relationship between fry and 1+ parr in the following year is derived from the 10-year series of data that is now available.

The graph plots the density of fry each year (along the horizontal axis) against the density of 1+ parr in the following year (the vertical axis). Nine points are shown matching fry density for the years 2013-2021 with the corresponding value for 1+ density in the years 2014-2022.

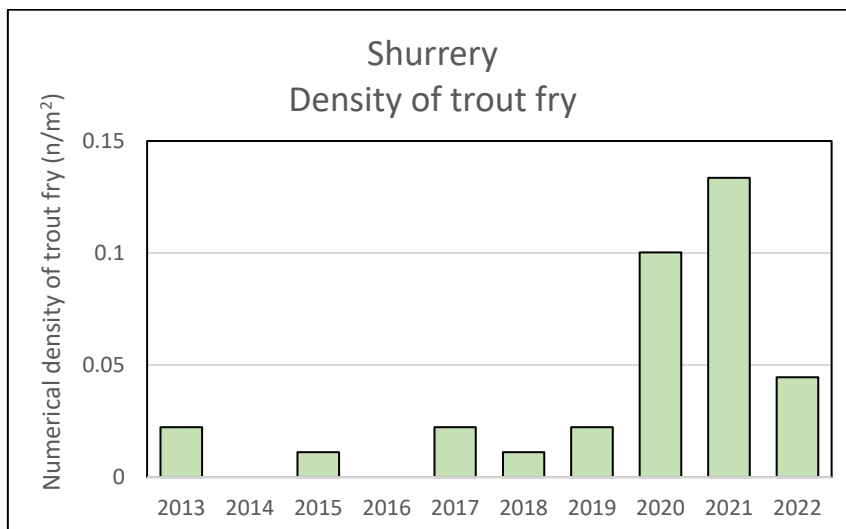
The line showing the overall relationship between the values represented by the blue points is also shown in blue. The red point is for 2018-19 when the inadvertent closure of Shurrery Dam several days after the completion of the 2018 survey killed fish in the river below the dam including some of those around the Shurrery survey site. As can be seen, this resulted in an anomalously low density of 1+ parr in 2019.

The dashed lines on the figure indicate the NEPS benchmark values for the Shurrery site. These have been adopted as reference points, replacing the colour-coded system based on values generated by Godfrey and cited in previous reports. The NEPS benchmarks are for parr of all ages but, since 2+ parr are so infrequent, the NEPS value is used here – conservatively - to benchmark 1+ parr only. The NEPS benchmark values for fry and parr are 0.73/m² and 0.16/m², respectively.

It can be seen that five of the nine points lie to the right of the vertical dashed line and therefore exceed the NEPS benchmark value for fry; eight of the nine points lie above the horizontal dashed line, showing that these values exceed the parr benchmark. The cluster of three values nearest to zero represent the most recent fry years, 2019-21, for which matching data for 1+ parr is available (2020-22).

Fry density in 2022 was only 0.01/m² indicating that when matching data is obtained in 2023 for the 1+ parr, the paired data point will add to the cluster of low values.

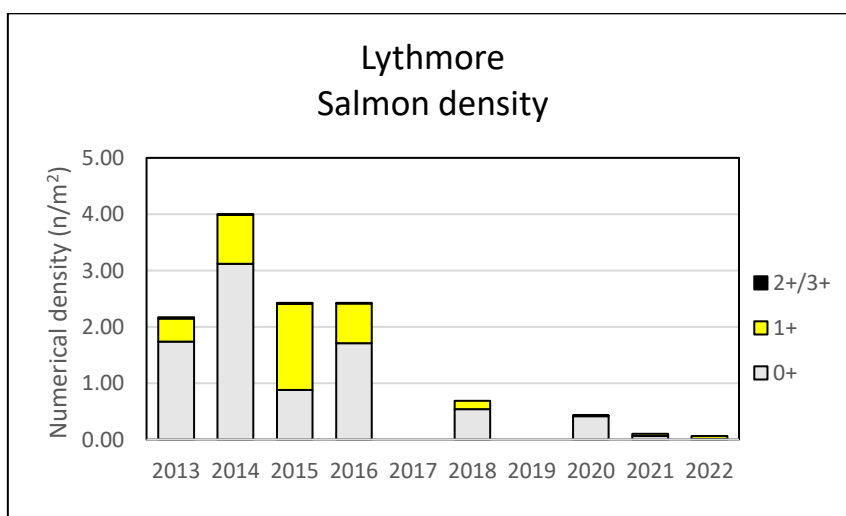
However, as a caveat, it is also evident from the points representing the lowest fry-years that low fry values can generate unexpectedly high values for 1+ parr. So, for example, for each of the four points closest to the vertical axis, the density of 1+ parr was actually greater than the density of fry the previous year. This must be due to errors in the survey estimates when small numbers of fish are involved, to unusually high survival rates between the fry and 1+ parr stages when density is low, to net in-migration of fish from outside the Shurrery site, or to a mixture of all these effects. Any residual doubt about the outcome of the 2022 fry-year will be resolved when electric-fishing is repeated in 2023.



Brown trout were infrequent at Shurrery before 2020. Densities of trout fry were higher than previously in 2020 and 2021 suggesting that, with reduced competition from young salmon, trout fry might be beginning to exploit stream resources that they could not previously access. In 2022, the density of trout fry at Shurrery was 0.05/m², lower than in either 2020 or 2021 although still higher than pre-2020 values. This aspect of the site’s salmonid population should be monitored and updated in coming years.

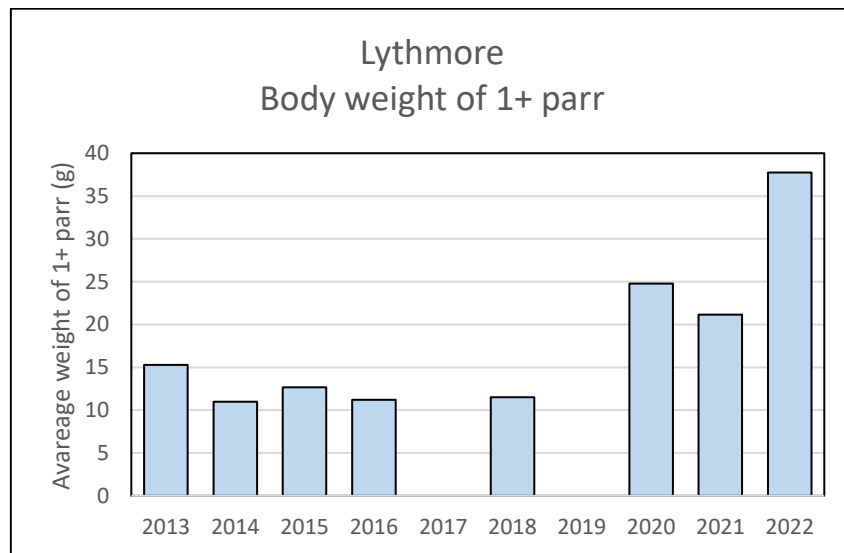
3.2 Lythmore

Lythmore has been surveyed less frequently than Shurrery. Due to competing priorities, survey data were not obtained for 2017 and 2019. Otherwise, a substantial body of information is now available spanning the period 2013-2022.

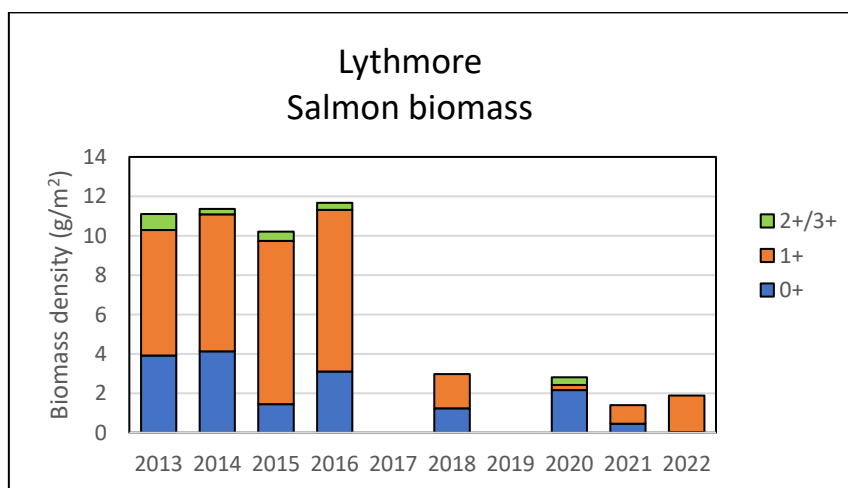


As at Shurrery, the salmon population at Lythmore has collapsed over recent years. Only a single salmon fry was captured at Lythmore in 2022, giving an indicative density of 0.01/m² - less than 1% of the equivalent pre-2017 average. The density of 1+ parr (0.05/m²) in 2022 was less than 10% of the pre-2017 average.

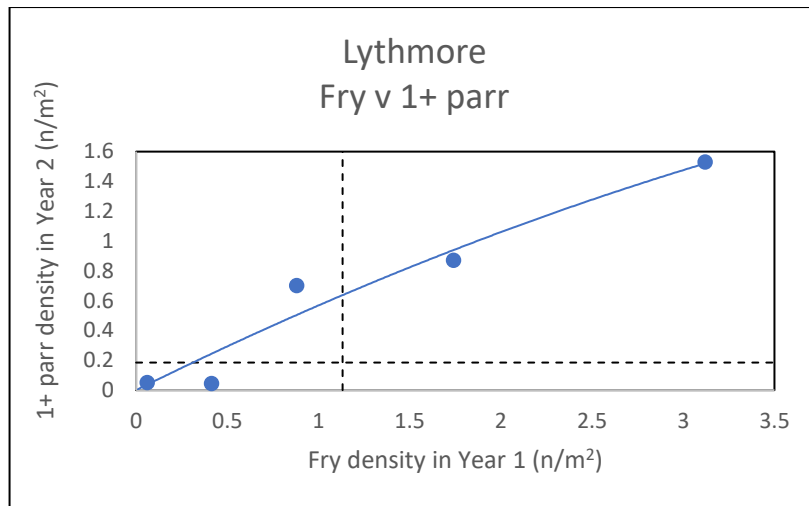
As for Shurrery, a further collapse of 1+ parr density to trivial values in 2023 is seemingly inevitable since only a single fry was captured in 2022.



The average body weight of 1+ parr was 38g - much larger than in previous years and much larger than the equivalent 2022 value for the Shurrery site. Again, the parr's large size is attributable to reduced competition for abundant stream resources.

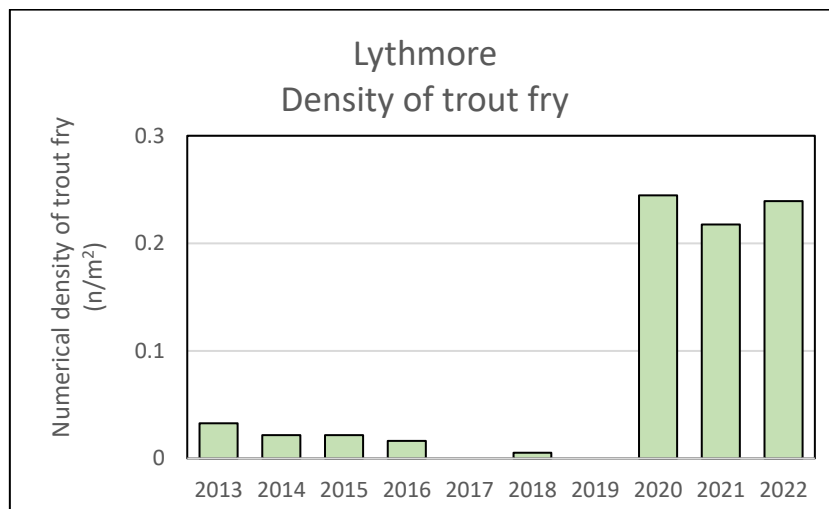


Total biomass density was attributable almost solely to the contribution of 1+ parr and, despite their very large size and because of their very low density, the value for 2022 was only around 20% of the pre-2017 average



The stock-recruitment diagram for Lythmore is based on the matching density values for fry and 1+ parr that are available for five pairs of consecutive years. Until the recent decline, fry numbers and parr numbers far exceeded the NEPS benchmark values indicated by the broken lines.

In 2014-15 a fry crop of 3.1/m² generated a huge crop of 1+ parr (1.5/ m²). Even then, and although the data are sparse, there is no indication of a levelling off of the blue line, suggesting that the full capacity of Lythmore has not been realised at any point during the current sequence of annual surveys.



The density of brown trout fry rose abruptly around the time that the densities of salmon fry declined. This pattern continued into 2022 when trout fry were present at 0.24/m², about the same value as in the preceding two years.

3.3 Conclusions

SEPA carried out a parallel, independent electric-fishing survey of five sites in Forss in 2022 – at Westfield, at two sites near Broubster and at Torran and Cnoc-glas above Loch Shurrery.

Although the SEPA survey was by 1-pass only and the data are not directly comparable with the results of the Board’s 3-pass survey, the SEPA team’s findings and the Board’s findings generally align, adding greater confidence to what follows.

1. In 2022, the density of salmon fry continued the decline of recent years reaching new lows that will almost certainly be insufficient to generate 1+ parr for 2023 in any more than trivial numbers. If this is so, the smolt run of 2024 will be similarly insubstantial.
2. Observation of the river and the fishery in 2023 suggests that spawning in 2022 was probably, again, very poor and that a correspondingly poor year for fry will follow in 2023. If this is the case, numbers of 1+ parr in 2024 and the smolt run of 2025 will also prove to be insubstantial.
3. Although the density of 1+ parr was very low in 2022, a substantial number of 1+ parr (potential smolts in 2023) may remain distributed throughout the catchment. Thus, Marine Scotland estimates that there are about 300,000 m² of proven juvenile salmon habitat in the Forss catchment. If the average density of 1+ parr over the whole catchment is assumed to have been 0.05/m² in 2022 (as at the Lythmore survey site), the river will produce about 15,000 smolts in the spring of 2023 (less any over-winter mortalities). If 2% of these return as adults the number of potential spawners resulting will be around 300 individuals, split between the grilse of 2024 and the 2SW fish of 2025.
4. If, instead, the density of 1+ parr at the Shurrery survey site (0.21/m²) was more typical of the catchment as a whole, the corresponding total number of returning adults will be greater at around 1200 fish.
5. The number of returning adults in 2024-25 will be lower than calculated because an unknown part of the total area that is available to juvenile fish will comprise habitat that is less favourable (eg. pools) for smolt production than the Shurrery or Lythmore sites.
6. On the other hand, the 1+ parr of 2022 were, on average, two or three times larger in size (body weight) than in earlier years when parr were abundant and the smolts of 2023 will also be larger than usual. Marine survival for large smolts is reportedly greater than for small smolts (Gregory et al. 2019¹). On this basis, the number of adults returning in 2024 and 2025 may be greater than otherwise expected.
7. Male fish will predominate among the grilse of 2024 and females will predominate among the 2SW fish of 2025. The 2SW fish will be larger than the grilse and because of this the 2SW females will carry more eggs than the female grilse.
8. On balance, therefore, it is likely that the number of eggs available to the river will be greater in 2025 than in 2024.
9. After 2025, the number of returning adults will be much lower due to the very poor fry years now in train.
10. In summary, given the situation that has developed in Forss since 2018, the last foreseeable opportunities to manage the Forss such that a good spawning replenishes the river's juvenile population will be in 2024 and, perhaps especially, in 2025.

A recovery plan has been prepared for the River Forss based partly on the considerations above. In addition, it will be of over-riding importance to find a way to resolve or minimise the disease issues that have recently affected the river before the critical spawnings in 2024 and 2025 take place.

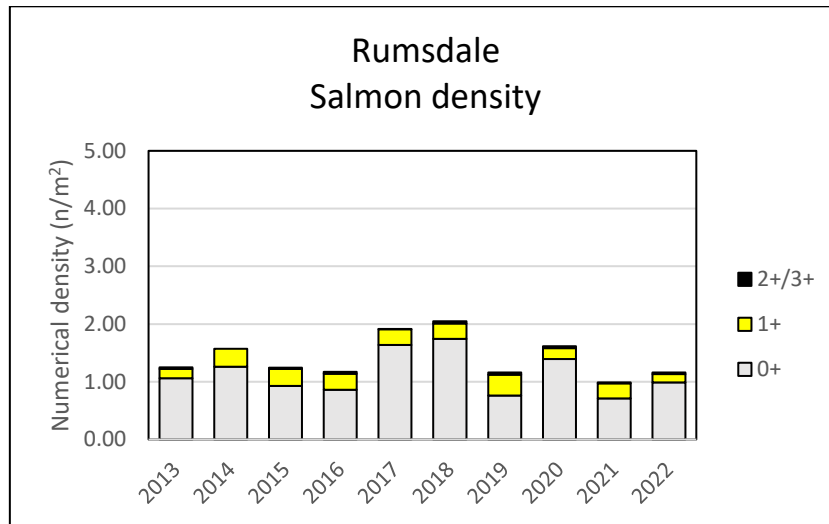
¹ S.D. Gregory et al. (2019). Atlantic salmon return rate increases with smolt length. ICES J. Mar. Sci. 76: 1702-12.

4. Thurso

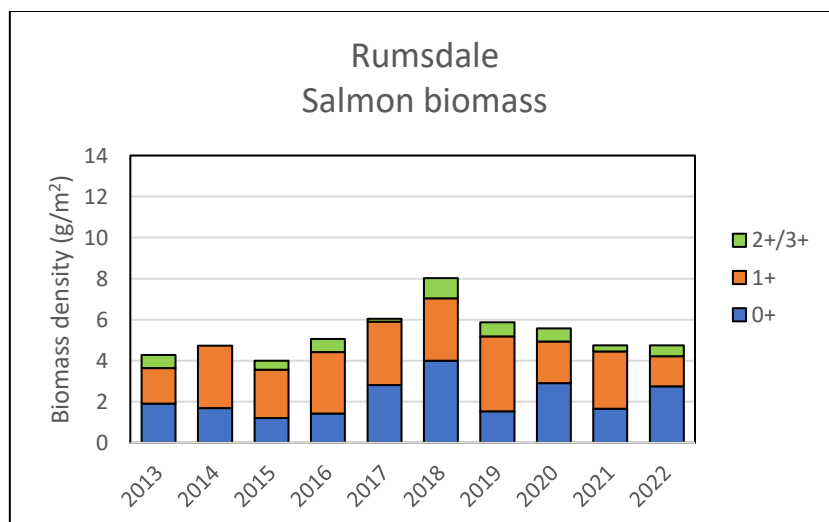
Six sites were surveyed in 2022, including the key site at Rumsdale which has been surveyed every year since 2013.

4.1 Rumsdale

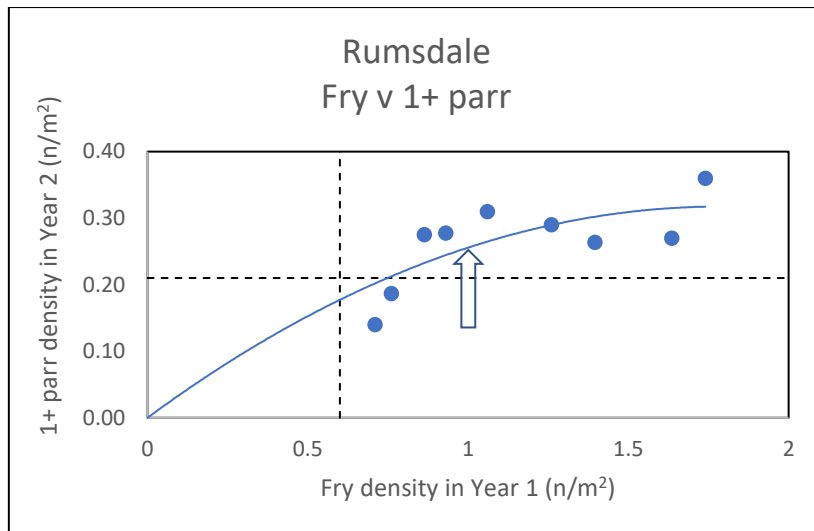
The survey results for Rumsdale were more or less in line with those of previous years reflecting the essential stability of the salmon population in the vicinity of the survey site over the last 10 years.



Fry were present at $1.0/m^2$, close to the average value for previous years. The density of 1+ parr was $0.14/m^2$, lower than the previous average, following on from the (relatively) low crop of fry in 2021. As previously, older parr were not present in significant numbers



The average body length of fry was 66mm (equivalent to 4.8g) the highest value in the time series. The average length of 1+ parr was similar to the long-term average at 98mm (equivalent to 10.7g). The total biomass density was $4.8g/m^2$ which is about average for the site.

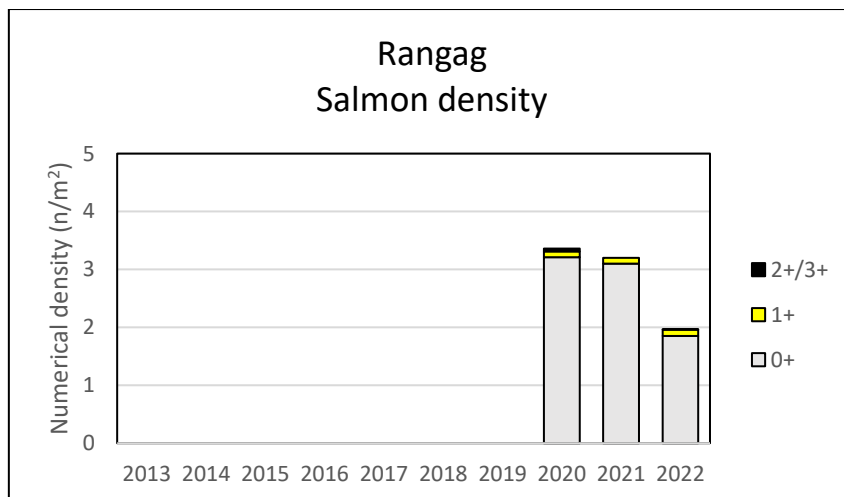


The relationship between fry and 1+ parr has been updated to include data obtained in 2022. Fry densities at Rumsdale exceeded the NEPS benchmark value for fry (the vertical dashed line) in all survey years. The density of 1+-parr mostly exceeded the NEPS benchmark value for parr (horizontal dashed line) with two exceptions. One of the exceptions was for 2021-2022 when a density of 0.71 fry/ m² in 2021 was followed in 2022 by a density of 1+ parr of 0.14/m².

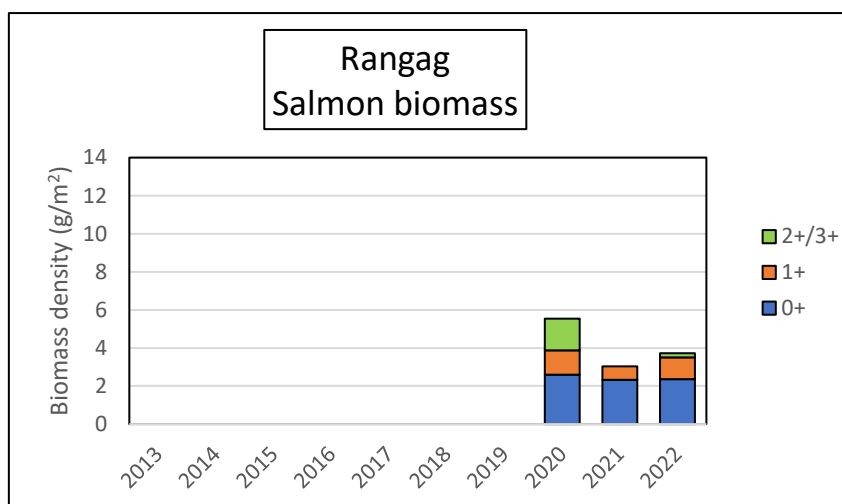
The stock-recruitment relationship is represented by the blue line which is the best overall representation of the values corresponding to the blue points. The stock-recruitment line can be used to predict 1+ parr values for 2023 knowing the density of fry in 2022. The density of fry in 2022 (1.0/m²) as indicated by the arrow is expected to saturate the Rumsdale site with 1+ parr in 2023 at a density in the range around 0.26-0.28/m².

4.2 Rangag

Rangag lies towards the upper limit of the part of the Little River catchment that is accessible to salmon. The site has been surveyed only since 2020.



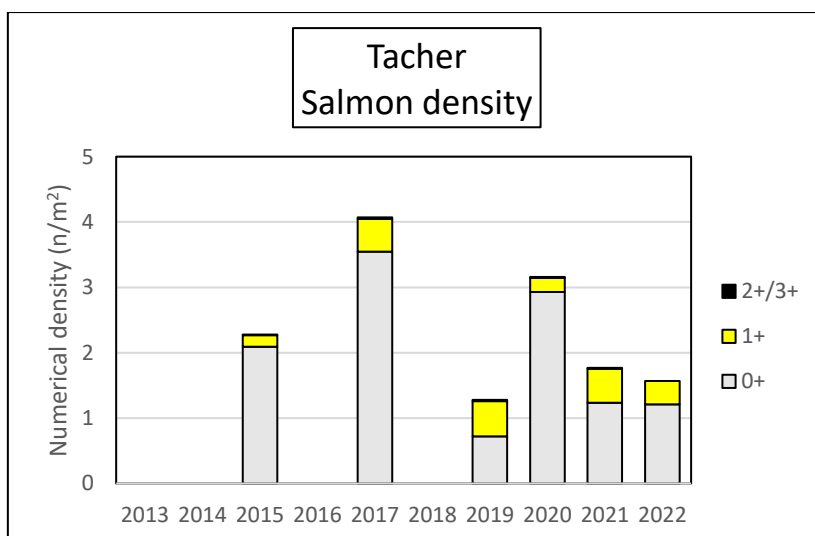
The density of salmon fry was lower than in previous years but fry were still very abundant at 1.85/m². As previously, parr were few in number, reflecting the stream's small size and its fine substrate. Over the interval between annual surveys fry probably disperse from Rangag to take up territory in more complex habitat further downstream.



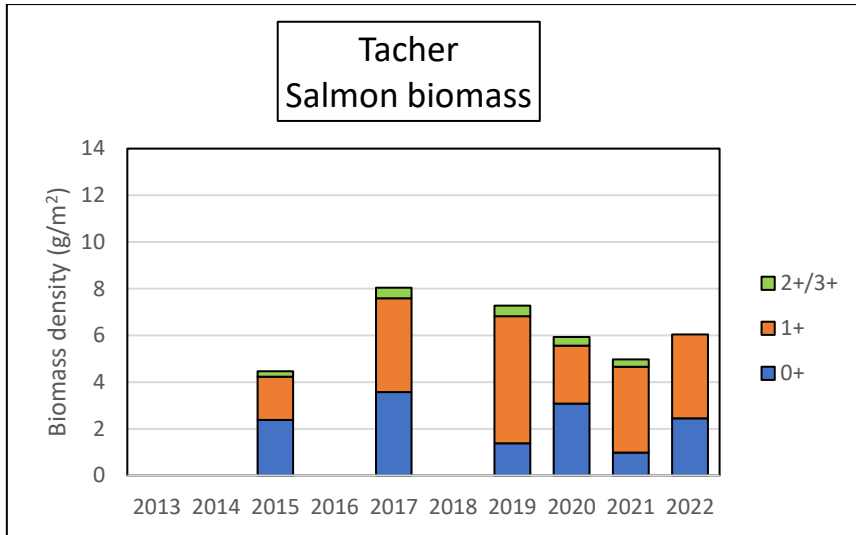
The total biomass of salmon was similar to previous values driven by the large average size of the fry (1.3g) relative to previous years when their density had been greater.

4.3 Tacher

As a result of a mishap, the 2022 Tacher survey data is not strictly comparable with those obtained in previous years. The 2022 survey site overlapped the upper limit of the standard site area by 50% by area but includes a further 50% by area located adjacent to the upper limit of the formal site.

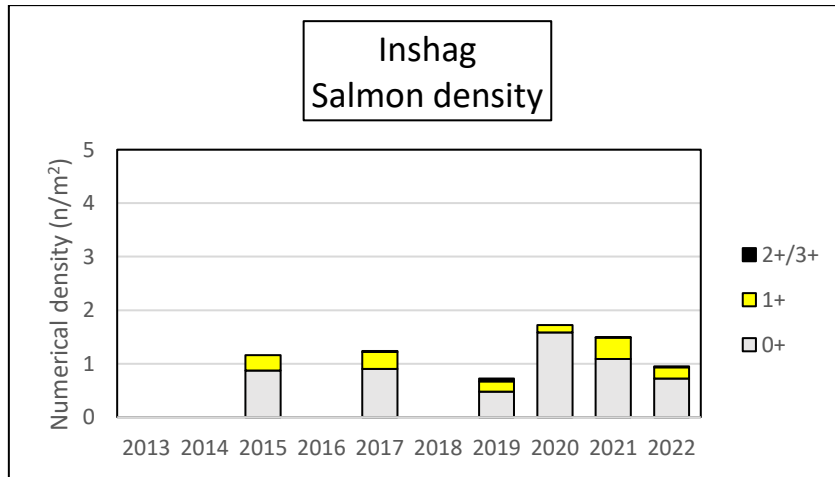


The densities of fry and 1+ parr were in broadly in line with previous years. Fry were again abundant at 1.2/m². Parr were present at 0.36/m².

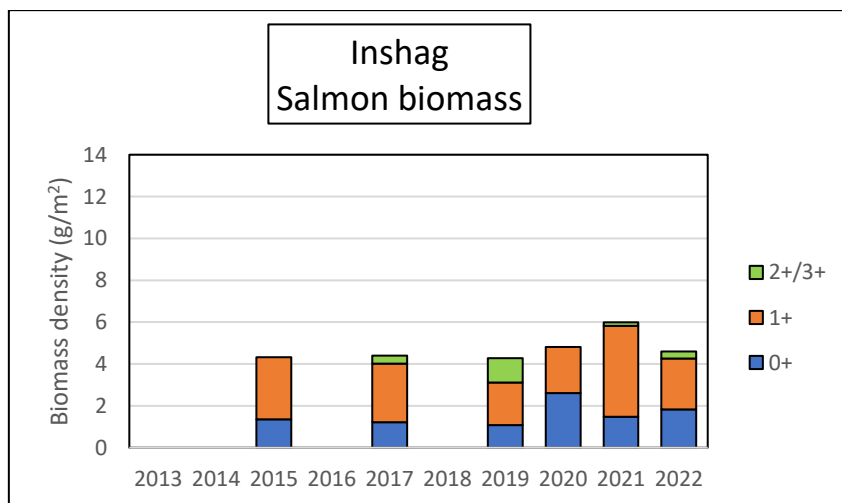


Total biomass density was about average for the location at 6g/m².

4.4 Inshag



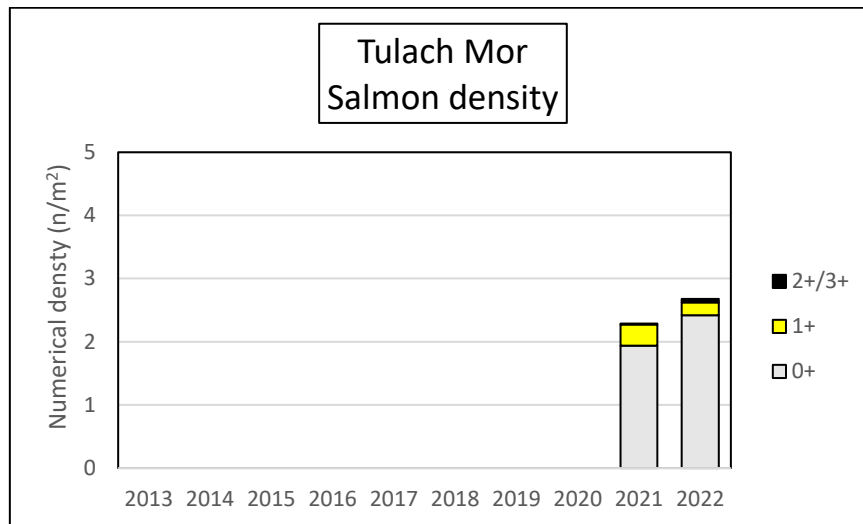
Fry density at Inshag was about average for the site at 0.72/m². The density of 1+ parr was slightly less than average at 0.21/m²s.



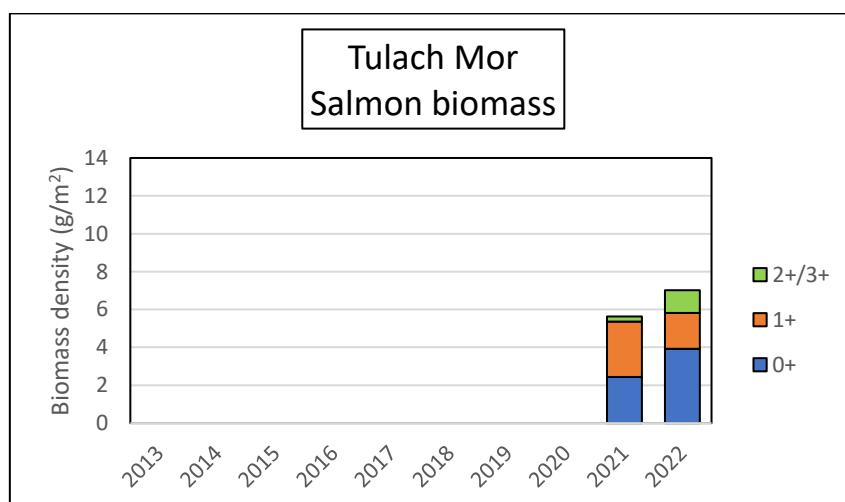
Total biomass density was about average for the site at 4.60g/m².

4.5 Tulach Mor

Tulach More is a mainstem site located on Beat 9. It is fished using the arrangement of stop-nets shown on the cover photograph of the 2020 Electric-fishing Report. The site area is measured at the time of sampling because the position of the nets varies slightly between years according to the height of the river and its flow.



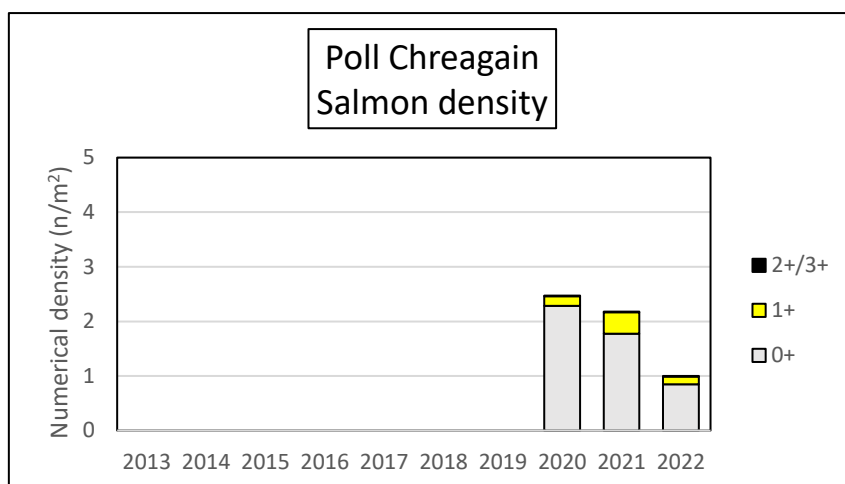
Fry density was $2.42/m^2$ similar to the value observed in 2021, the only previous year in which the site was surveyed. The density of 1+ parr ($0.20/m^2$) was less than previously but a greater number of older parr ($0.06/m^2$) were present.



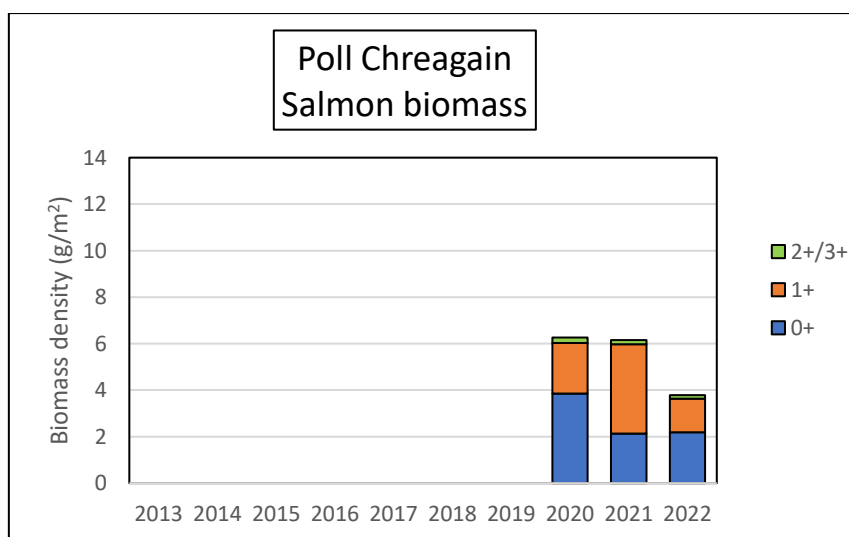
Total biomass density was $7.0g/m^2$, marginally greater than in 2021, due to the larger contribution made by the older parr.

4.6 Poll Chreagain

Poll Chreagain is also a main river site, also on Beat 9, where stop-nets are deployed in the same way as for Tulach Mor.



The density of fry was 0.85/m², less than in 2020 or 2021. The density of 1+ parr was also lower than previously at 0.14/m².



Total biomass density was about 4g/m², less than previously and in line with the lower numerical densities of fry and parr.

4.7 Conclusions

All the evidence from the six sites surveyed in 2022 indicates that the Thurso was again saturated, or nearly saturated, with fry. Across all sites, the density of fry was very high relatively to sites in any of the other Caithness rivers, ranging from 0.72/m² at Inshag to 2.42/m² at Tulach Mor. The average value across all sites was 1.34/m². This is roughly equivalent to the situation in 2021 when the corresponding average was 1.64/m², ranging from 0.71/m² (at Rumsdale) to 3.10/m² (at Rangag).

5. Wick River

In the annual survey report for 2021, it was noted that “*In previous years, survey sites on the Scouthal and Strath Burns in the upper part of the catchment of the Wick River have proved extremely productive. Fry densities have frequently been greater than 2/m², parr densities greater than 0.5/m² have been common and biomass densities often exceeded the 8-10g/m² range. This was not the case in 2021 when juvenile populations at Clow and Acharole1 on the Scouthal Burn and Sheriffs on the Strath Burn were in a very depleted condition*”.

With regard to the fry of 2021, specifically, the poor spawning in 2020, as reported by the Wick hatchery team, is likely to have been part of the cause. In addition, however, densities of 1+ parr in 2021 were much lower than expected from the fry densities observed in 2020. This suggested that water quality issues during the low water and high temperatures experienced over the summer of 2021 had resulted in atypically high rates of mortality in the period before the survey was carried out.

Given this complex background and in order to best target the 2022 survey, a preliminary survey of four sites was carried out in July, 2022 – two months in advance of the standard survey in September – and before any seasonal issues with water quality were likely to recur.

5.1 Preliminary (July) survey of Acharole, Sheriffs1, Achairn and Newton survey sites

The preliminary survey was, as usual, by 3-pass depletion fishing with Zippin correction for capture efficiency. Sites were chosen to avoid overlap with the follow-up survey sites scheduled for September. The sites chosen had all been surveyed in a previous year.

Tables 1 and 2 show the values for fry and parr, respectively, from the four sites - Acharole on the Scouthal Burn, Sheriffs1 on the Strath Burn, Achairn on the Haster Burn and a site on the Newton Burn which drains Loch Hempriggs near Wick.

Table 1. Preliminary survey results for salmon fry density: 3-pass fishing.

Fry				
Site	Date	Area	Number	Density (n/m ²)
Acharole	9/7/22	133	9	0.07
Sheriffs1	9/7/22	136	236	1.74
Achairn	9/7/22	120	20	0.17
Newton	10/7/22	92	0	0.00

Expressed in very general terms, fry density was low at Acharole and Achairn and fry were absent from the Newton Burn near Wick. However, fry density was high at Sheriffs1 (a new site on the Strath Burn 100m upstream of the standard Sheriffs site).

Table 2. Preliminary survey results for salmon parr density: 3-pass fishing.

Parr				
Site	Date	Area	Number	Density (n/m ²)
Acharole	9/7/22	133	16	0.12
Sheriffs1	9/7/22	136	30	0.22
Achairn	9/7/22	120	20	0.17
Newton	10/7/22	92	6	0.07

Considered in the same general terms, parr density was moderate at Sheriffs1 and Achairn but low at Acharole and Newton.

These values were compared with data for previous years for the same survey sites. Comparison was based on 1-pass data because only 1-pass data was available from those of the sites which had been previously surveyed as part of the Scottish Government's NEPS programme. The 1-pass values are shown in Table 3.

Table 3. Comparison of densities (n/m²) of fry and parr between years based on 1-pass fishing, only.

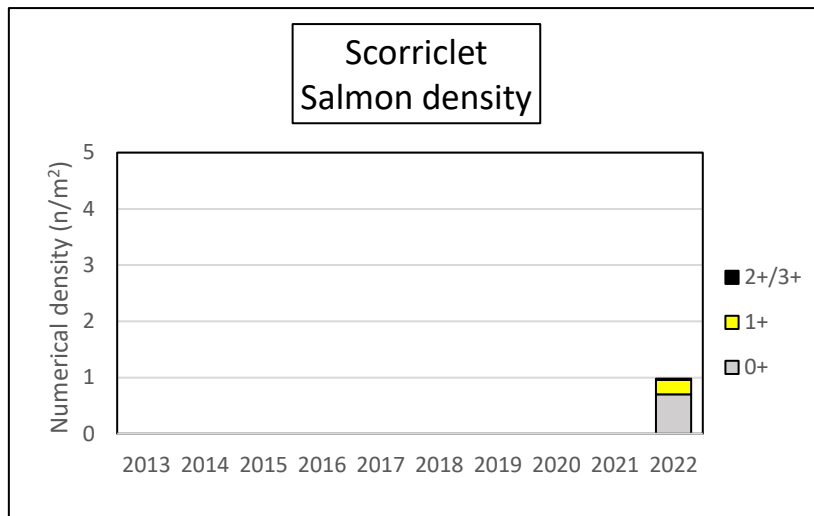
Location	2018		2021		2022	
	Fry	Parr	Fry	Parr	Fry	Parr
Acharole	1.14	0.08			0.05	0.06
Sheriffs1			*0.18	*0.12	1.01	0.18
Achairn			0.85	0.11	0.11	0.13
Newton			0.52	0.00	0.00	0.05

*Values for standard Sheriffs site.

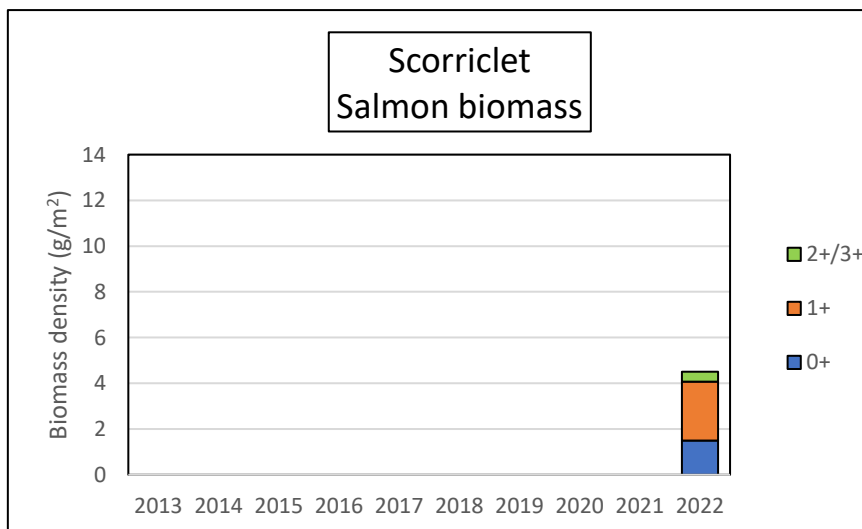
In 2022, 1-pass fry density at Sheriffs1 was much higher than the corresponding value in 2021 at the nearby Sheriffs site. However, at Acharole, Achairn and Newton fry densities were markedly lower than previously, supporting the observation by the Wick hatchery team that spawning in 2021, as in 2020, had been relatively poor. Parr densities by 1-pass fishing were generally as expected based on previous values all four sites.

5.2 Scoriclet

In September, a new site was surveyed at Scoriclet about 3.5km upstream of the Sheriffs site in order to extend surveillance of the Strath Burn, specifically.



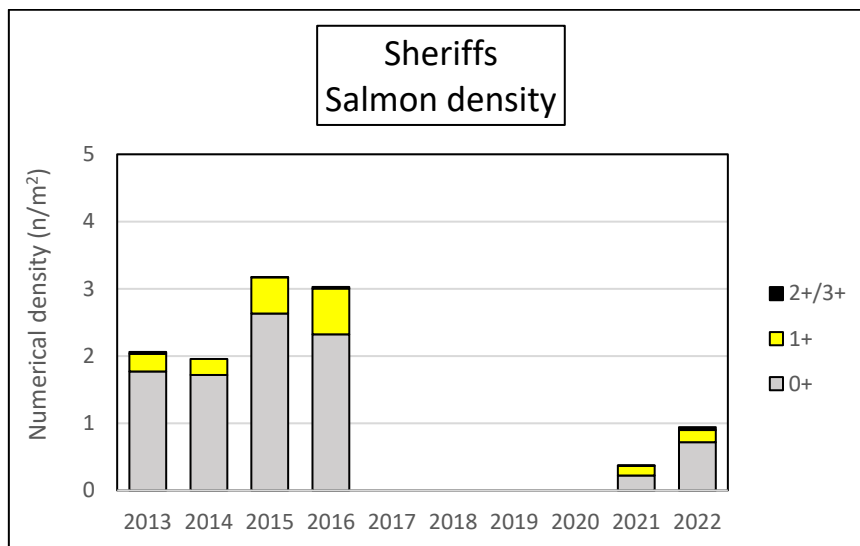
The density of fry was 0.70/m² and the density of 1+ parr was 0.26/m². The NEPS benchmark values for fry and parr at Scorriclet are 0.75/m² and 0.18/m², respectively. The observed values for fry and parr can both, therefore, be considered adequate in general terms but, based on previous surveys of the Strath Burn, the values were rather less than might have been expected for a site of Scorriclet's quality



The average body lengths of fry and 1+ parr were unremarkable at 60mm and 95mm, respectively – equivalent to average body weights of 2.1g and 9.8g. Total biomass density was also unremarkable at 4.51g/m².

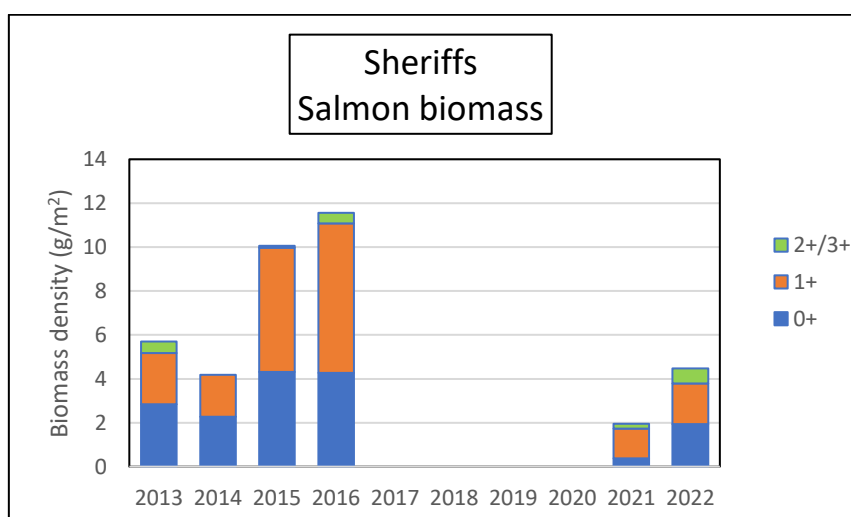
5.3 Sheriffs

The Sheriffs site has been surveyed on several occasions over the years including 2021.



In 2022 the density of fry was $0.72/m^2$ and the density of 1+ parr was $0.18/m^2$. Both values were higher than in 2021 but much lower than the values observed in the earlier years of the survey series.

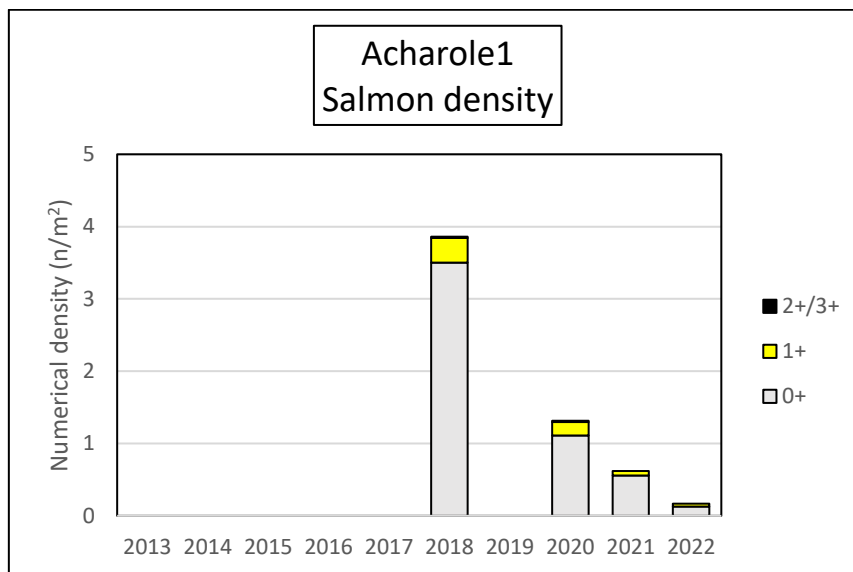
In 2022, the values observed at Sheriffs were broadly in line with those at the new site at Scorricket (as surveyed in July). The observed values were also broadly in line with the NEPS benchmark values for Sheriffs which are $0.91/m^2$ and $0.20/m^2$ for fry and parr, respectively. The values observed in 2022 can therefore be regarded as adequate and an improvement on 2021. However, the values are still sub-optimal relative to earlier survey years when much higher densities of fry tended to produce larger crops of parr.



The average body lengths of fry and 1+ parr were 64mm and 97mm, respectively. The total biomass was $4.47g/m^2$, higher than in 2021 and similar to values observed in 2013 and 2014 when much smaller fish were present at greater densities. Total biomass density at Sheriffs was similar to the value observed at the new site at Scorricket.

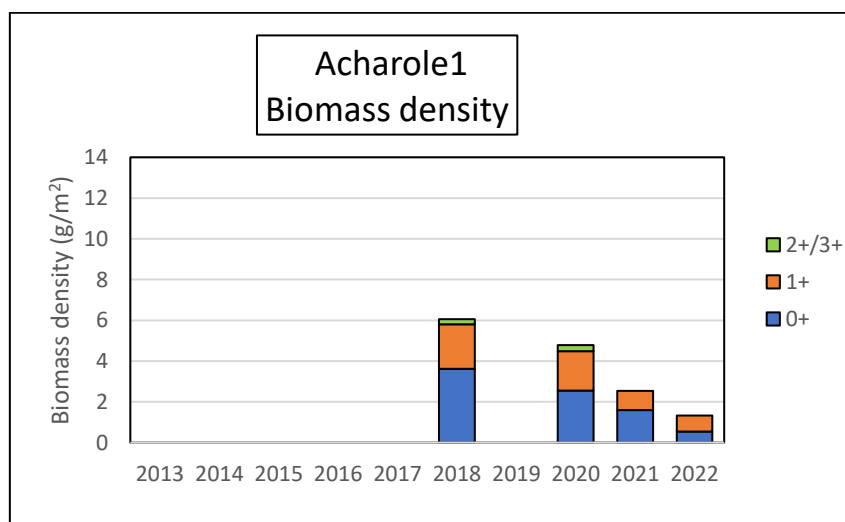
5.4 Acharole1

Acharole1 is located 600m upstream of the key site at The Clow on the Scouthal Burn.



The densities of fry ($0.13/m^2$) and 1+ parr ($0.04/m^2$) at Acharole1 continued the progressive decline noted after 2018. In particular, fry density dropped to a trivial value in 2022 for the first time.

The density of 1+ parr was unexpected low. In general, 1+ parr density is expected to be about 30% of the fry density in the preceding year (see 2021 report). However, the density of 1+ parr in 2022 was only 7% of the value for fry density in 2021 ($0.56/m^2$). This was a repeat of the pattern first observed at Acharole1 in 2021 when the density of 1+ parr was only 5% of the fry density value for 2020. The atypically low yield of 1+ parr in 2022 from the fry crop observed in 2021 suggests that summer water quality had, again, been an issue in 2022 at some point before the survey was carried out.

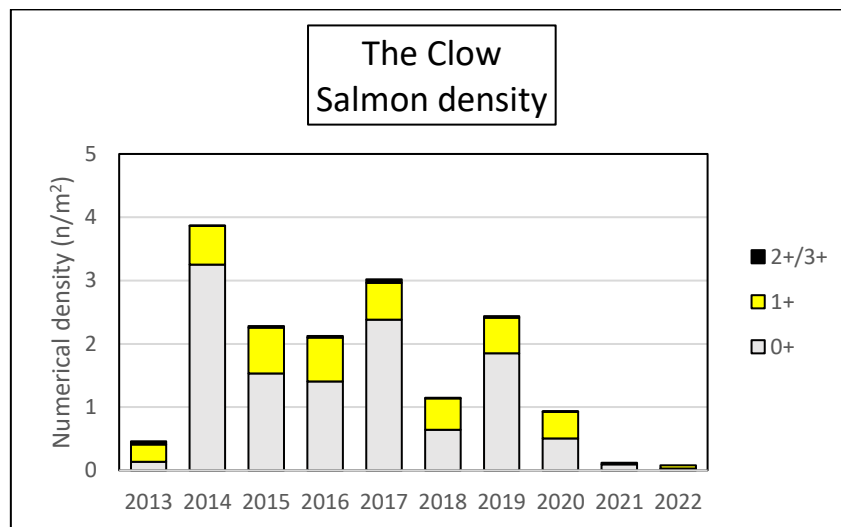


The few fish present at Acharole1 were large for their age. The average length of fry was 74mm equivalent to a body weight of 4.3g. The body length of 1+ parr was 120mm, equivalent to a weight of 21g.

As a consequence of the fishes' large size, total biomass density was relatively maintained at $1.3g/m^2$ but the value was still much lower than in previous years.

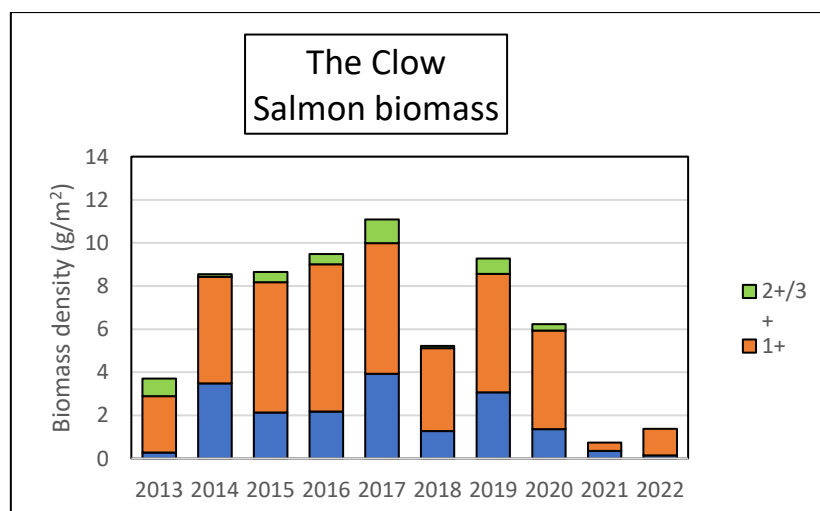
5.5 The Clow

The Clow is a key site that has been surveyed every year since 2013. The site is located about 600m downstream of Acharole1.



As for 2021, the numbers of fish present were very low. Fry density was 0.03/m² and the density of 1+ parr was 0.05/m²; no older parr were captured.

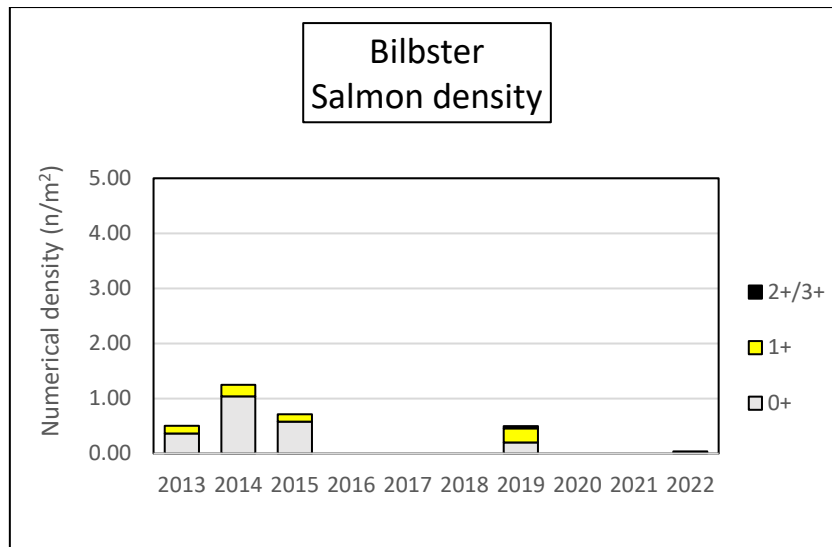
Because so few fry were present in 2021, it is not possible to calculate the yield of 1+ parr for 2022 and, therefore, evidence for any water quality issues at Clow is lacking.



The few fish present at Clow were large for their age. The average body length of fry was 78mm (equivalent to 4.9g); the average body length of 1+ parr was 126mm (equivalent to a body weight of 24.5g). Total biomass density was 1.4g, marginally greater than in 2021 but much less than in previous years.

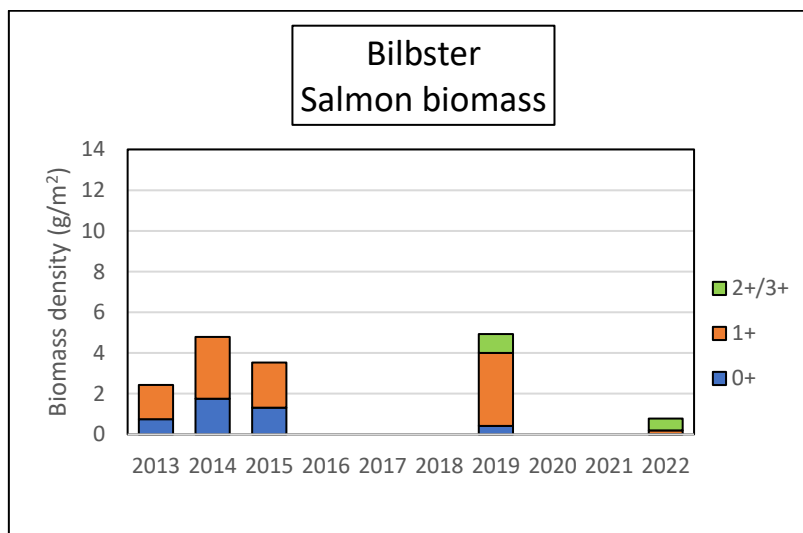
5.6 Bilbster

The site at Bilbster, on the main river between Watten and Wick was re-visited in 2022 in order to further examine the seeming discrepancy between the condition of the salmon populations on the twin arms of the Wick River above Watten village - the Scouthal Burn and the Strath Burn. The Bilbster site was previously surveyed between 2013 and 2015.



Very few fish were present at Bilbster in 2022. A single fry was detected, only five 1+ parr were present at a notional density of 0.01/m² and 2+ parr were present at 0.03/m².

When Bilbster was surveyed earlier in the annual survey series its salmon population was always found to be modest relative to sites elsewhere in the Wick catchment. However, the 2022 values show a substantial decline from the site's former condition. In 2022, the status of the Bilbster site was clearly aligned with the inferior status of fish of the Scouthal Burn sites rather than with the modest condition of the sites on the Strath Burn.



Total biomass density was only 0.77g/m².

5.7 Conclusions

The current situation in Wick River is evidently complex. Since around 2019 there have been substantial overall declines in fry and parr densities relative to earlier years. However, the declines have not been uniform. The complexity emerging across the catchment has made it more difficult to identify the causes of the changes taking place – and even harder to explain them. While it is important to avoid over-interpreting the data, it is also necessary to try to identify the factors driving the changes in order to work out how they might be addressed.

There are several factors to consider –

1. Wick River is particularly susceptible to the effects of the recent succession of summer droughts because it is a spate river that drains a small catchment in a highly modified landscape. It is particularly important to understand the effects of drought years on salmon because NatureScot² predicts that droughts will become more common in Caithness as a result of future climate change.
2. The decline in fry densities in Wick River can be plausibly linked to reduced spawning from the start of the current series of summer droughts in 2018 onwards. Fry density was first noted to falter in 2019 as reported in the Board's Survey Report for that year.
3. Unlike the fry, parr densities in 2019 were still satisfactory following what was demonstrably a good fry-year in 2018. These parr will have smolted in 2020 and they should have sustained correspondingly adequate runs of grilse in 2021. The river fishery proved to be poor in 2021 but that was as expected since low water conditions restricted angling activity. More tellingly, the Wick hatchery team reported poor numbers of spawners on the redds in 2021. This observation was supported later by the generally low densities of fry observed in 2022.
4. It appears, therefore, that that the previously dependable sequence of links between (1) high parr density, (2) high adult numbers, (3) good spawning and (4) high fry density was disrupted at some point in the life-cycle in the years after the start of the current series of the droughts.
5. It is often remarked that when returning adult fish are temporarily baulked from entering their rivers when low-water conditions prevail, they later do so in reduced numbers when rainfall restores river flow (the fate of the missing adult fish remains to be explained). If this is the situation, then the link between parr numbers and subsequent spawner numbers is being broken in the adult phase of the life-cycle at the pre-spawner stage. Such a scenario would explain all the points made in 2 and 3, above.
6. In the 2021 Survey Report, it was also suggested that low survival of fish between the fry stage in 2020 and the parr stage in 2021 was caused by poor water quality associated with the drought conditions that prevailed over the summer. As a general rule, the yield of 1+ parr from the previous year's crop of fry is expected to be around 30% (as explained in the 2021 Survey Report). But in 2021, the yield of parr at both Clow and at Acharole1 was only around 5%. In 2022, matching sets of density data for fry and 1+ parr were available for two survey sites. Yield was higher than expected at Sheriffs but again low at Acharole1 (at 7%).
7. Equivalent values for the preliminary survey sites at Achairn and Newton were 15% and 10%, respectively.
8. It should be noted that when fry densities are low to start with it is difficult to provide accurate or meaningful estimates for the yield of 1+ parr. In addition, the low observed yields of parr can only be linked to impaired water quality by inference because no direct measures of water quality are available for the sites in question.
9. In future, therefore, WAA has proposed that steps are taken to obtain direct measures of water quality data for Wick River if, and when, summer drought conditions recur.

In summary, in 2022 the status of juvenile salmon in the Wick survey sites was notably patchy. On the Strath Burn, the Sheriffs site and, by implication, the Scoriclet site showed improvements on

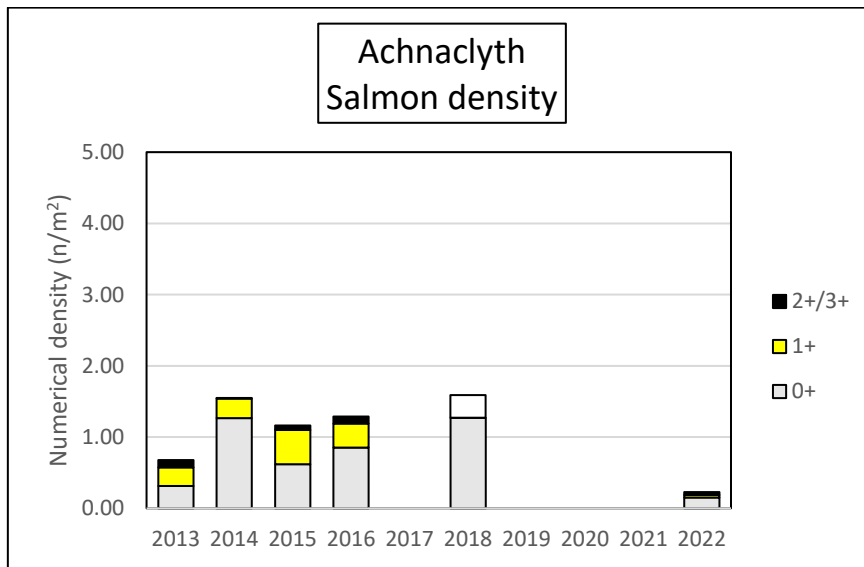
² Kirkpatrick Baird, F., Stubbs Partridge, J. & Spray, D. 2021. Anticipating and mitigating projected climate-driven increases in extreme drought in Scotland, 2021-2040. *NatureScot Research Report No. 1228*.

2021. Parr densities were moderate and, while the fry densities were still very much lower than in former years, they may still be sufficient to produce another moderate crop of parr in 2023. This can be tested at survey in September, 2023. On the Scouthal Burn, parr densities at Clow and Acharole¹ were poor and fry densities were not sufficient to produce adequate crops of parr in 2023. The position on the main river at Bilbster was similar to that on the Scouthal Burn.

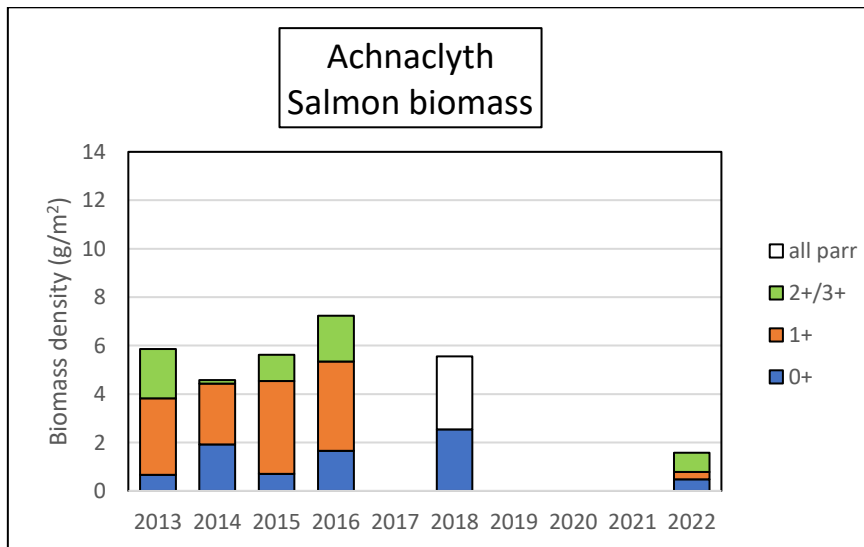
6. Dunbeath

Like most of the other rivers in Caithness, Dunbeath River has been profoundly affected by low summer water levels over the recent run of drought years. And in 2021, as previously, it was reported that few fish were on the redds at spawning time. Two sites were surveyed in 2022 – the standard key site at Culvid which is visited every year and the site at Achnaclyth, about 3.5km upstream of Culvid, which was last visited in 2018.

6.1 Achnaclyth

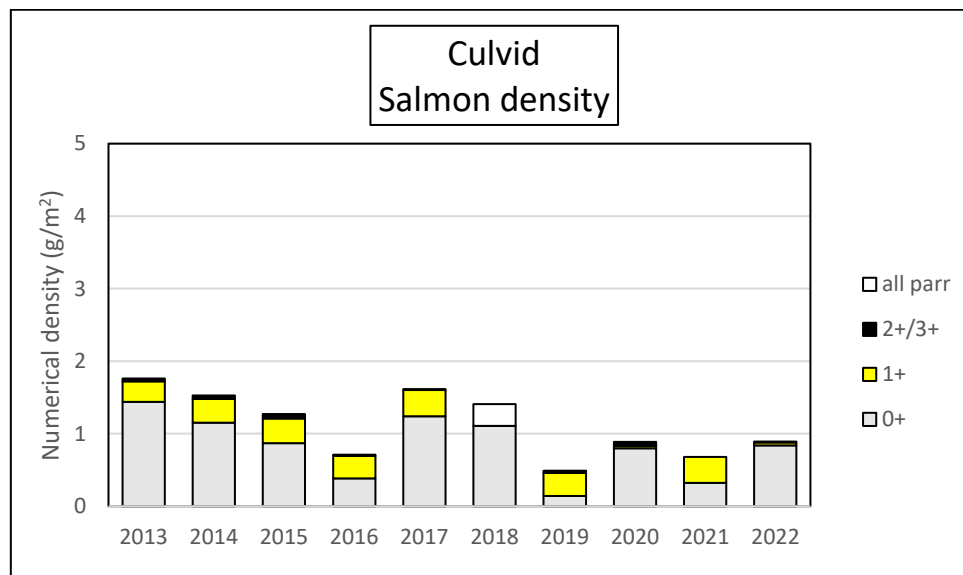


Densities of both fry ($0.15/m^2$) and 1+ parr ($0.04/m^2$) were much lower than in former years. Older parr were present at $0.04/m^2$. The values were also considerably lower than the NEPS benchmark values for Achnaclyth which are $0.55/m^2$ for fry and $0.15/m^2$ for parr.



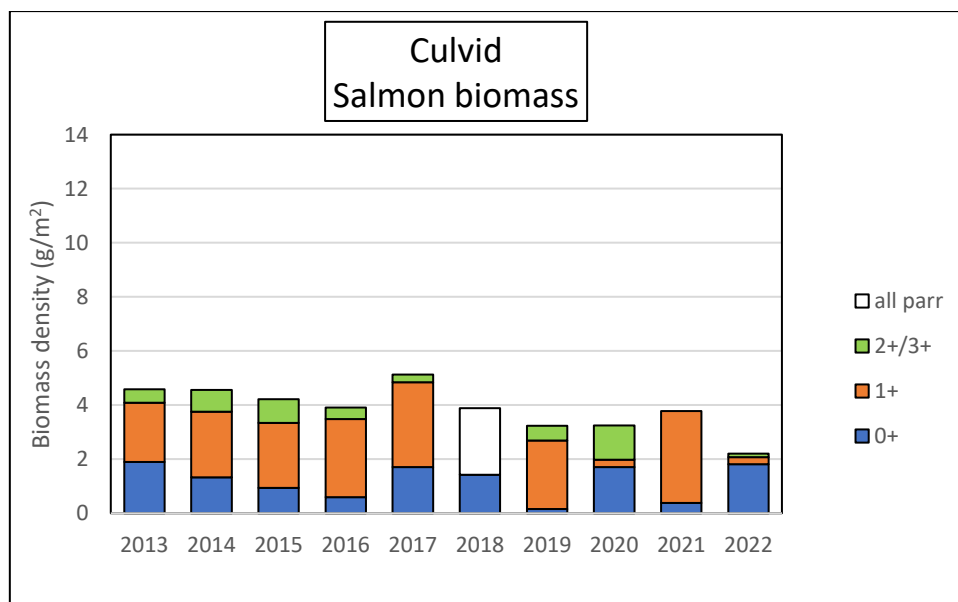
The few fry present were large for the site (average body length 68.4mm, equivalent to 3.3g). The average length of the few 1+ parr was unremarkably at 87.6mm (equivalent to 7.6g). The total biomass density was $1.58g/m^2$, well down on values in previous years.

6.2 Culvid



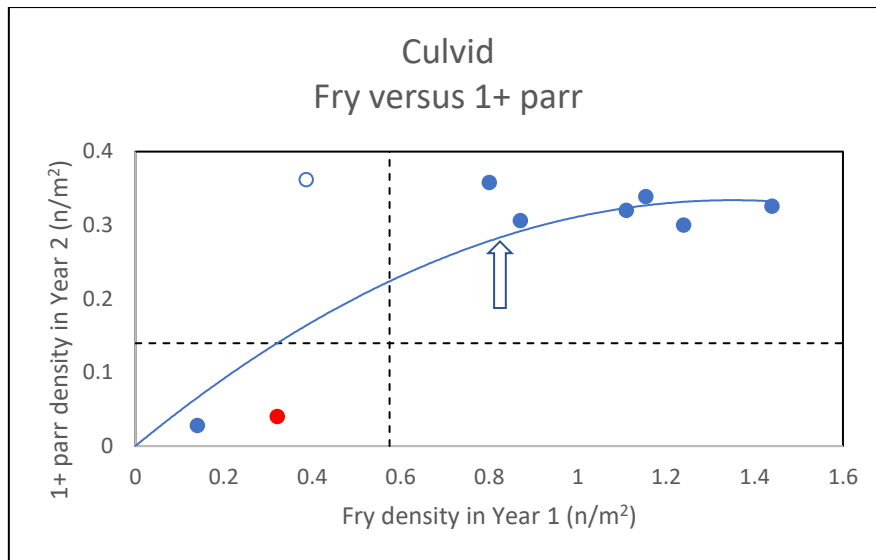
The density of fry in 2022 was 0.84/m² which is about the site average for previous years. The density of 1+ parr was low (0.04/m²) despite the moderate density of fry present in 2021. As usual, few older parr were present.

The density of fry in 2021 was 0.32/m² and the yield of 1+ parr in 2022 was therefore only 13% (see below).



The fry were larger than usual for Culvid at an average value of 59.9mm, greater than the equivalent value in any previous year.

Driven by the large contribution from the fry but lacking a substantial contribution from the parr, the total biomass density was 2.20g/m², the lowest value in the time series.



The figure above plots the density of fry at Culvid in each of the years 2013-2021 against the density of 1+ parr in the following year (2014-2022) – a total of nine points representing nine pairs of years.

The broken vertical line marks the NEPS benchmark value for fry at Culvid ($0.57/m^2$). It can be seen that six of the nine points lie to the right of the broken vertical line, meaning that fry density exceeded the NEPS benchmark in six of the nine years between 2013 and 2021.

The broken horizontal line shows the NEPS benchmark value for Culvid parr ($0.14/m^2$). Seven of the nine points lie above the horizontal line showing that parr density exceeded the NEPS benchmark value in those years.

The open blue circle represents fry in 2016 versus 1+ parr in 2017 and, since the point is clearly anomalous, it has not been included in the data used to derive the blue line which, otherwise, represents the best overall relationship between all the other values for fry density in Year 1 and the density of 1+ parr in Year 2.

Among these points, the red point represents fry in 2021 versus the 1+ parr density observed in the present 2022 survey. It can be seen that the red point falls far short of the blue line. Based on the blue line, the fry density observed in 2021 ($0.32/m^2$) would have been expected to yield 1+ parr at about $0.15/m^2$ in 2022. However, the observed density of 1+ parr in 2022 was $0.04/m^2$, about 27% of the value predicted from the blue line. It should be noted, however, that this value is inherently imprecise because most of the points observed over the years lie far to the right, in the upper part of the distribution of values for the Culvid site. The exact position of the blue line around the point that is of particular interest is therefore uncertain.

It can be seen from the figure that, in general, a fry density of about $0.8/m^2$ is sufficient to ensure maximum production of 1+ parr at a value of around $0.3/m^2$ and that beyond this point greater densities of fry do not result in greater densities of parr. On this basis, the density of fry observed in 2022 ($0.84/m^2$) should be sufficient to saturate, or nearly saturate, the Culvid site with 1+ parr in 2023, as is indicated by the arrow. The accuracy of this projection can be checked at survey in 2023.

6.3 Conclusions

The condition of the two sites surveyed in Culvid was markedly different.

The key site at Culvid was well-stocked with fry although parr density was low following on, partly, from the modest crop of fry recorded in 2021. In addition, however, the yield of 1+ parr from the fry

of 2021 was anomalously low, suggesting poor survival of fish at some point between the survey dates in 2021 and 2022. The density of fry recorded in 2022 was large enough to indicate that, all else being equal, the production of parr at Culvid will be restored to normal levels in 2023.

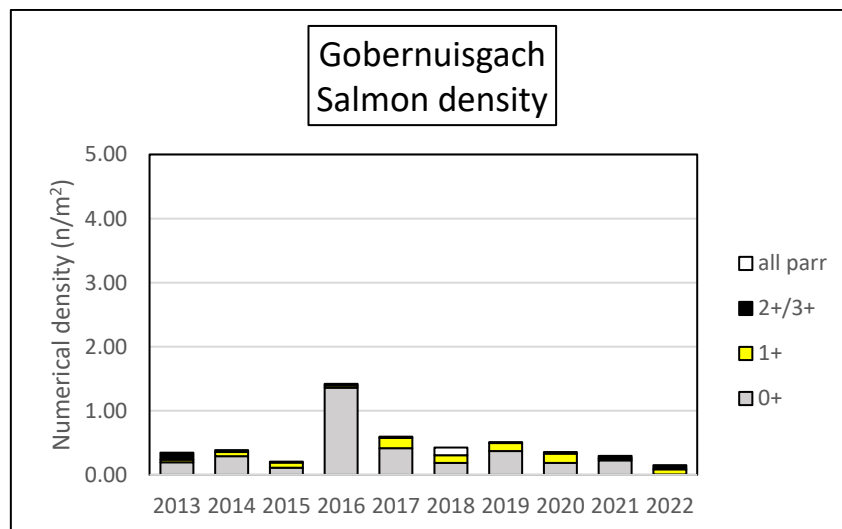
Both fry and 1+ parr were poorly represented at Achnaclyth relative to previous survey years. In the case of the 1+ parr this may have resulted from the poor spawning year in 2020 (matching the low fry density at the Culvid site in 2021). However, it is not clear why fry density at Achnaclyth in 2022 fell so far short of the value observed at Culvid. This mis-match should be checked at survey in 2023.

7. Berriedale/ Langwell

Two sites were surveyed on each of the Berriedale and Langwell arms of the catchment.

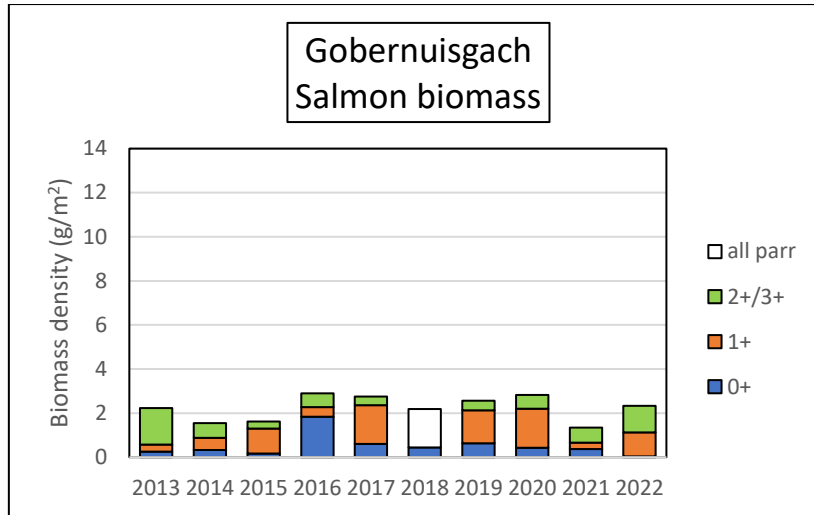
7.1 Gobernuisgach

Gobernuisgach is the uppermost site on the Berriedale arm of the dual Berriedale/ Langwell river.

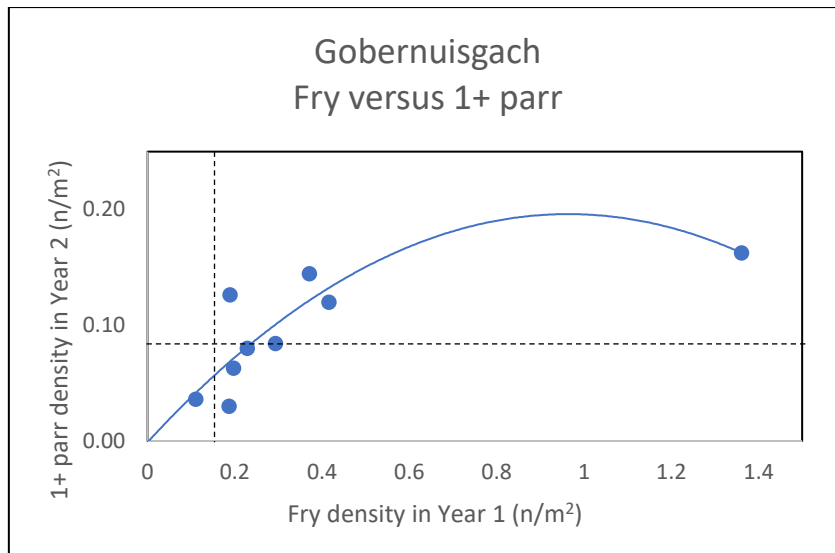


Only two fry were captured at the key Gobernuisgach site, giving a notional density of 0.01/m². This was the lowest value in the time series. The NEPS benchmark value for fry at Gobernuisgach is 0.16/m².

1+ parr and 2+ parr were present at 0.08/m² and 0.06/m², respectively, roughly as expected for the site based on previous years. The NEPS benchmark value for parr (all ages) at Gobernuisgach is 0.07/m².



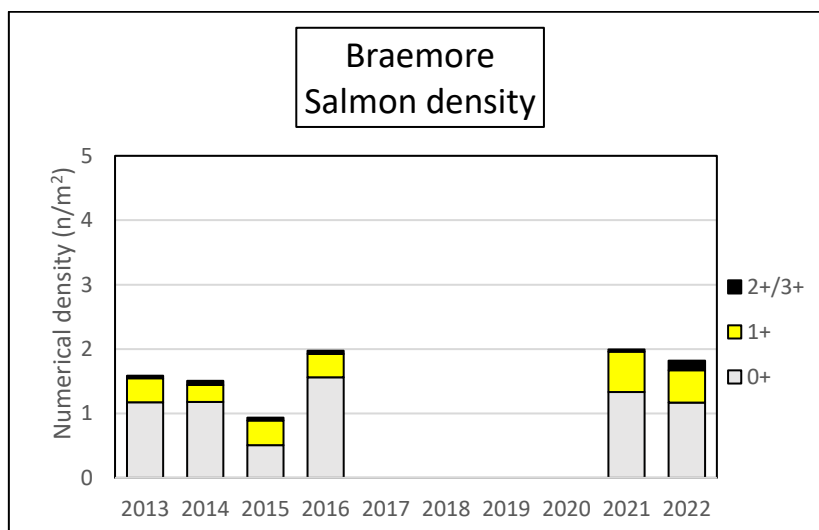
Due almost solely to the contribution from the parr, the total biomass density was 2.3/m², about average for the site.



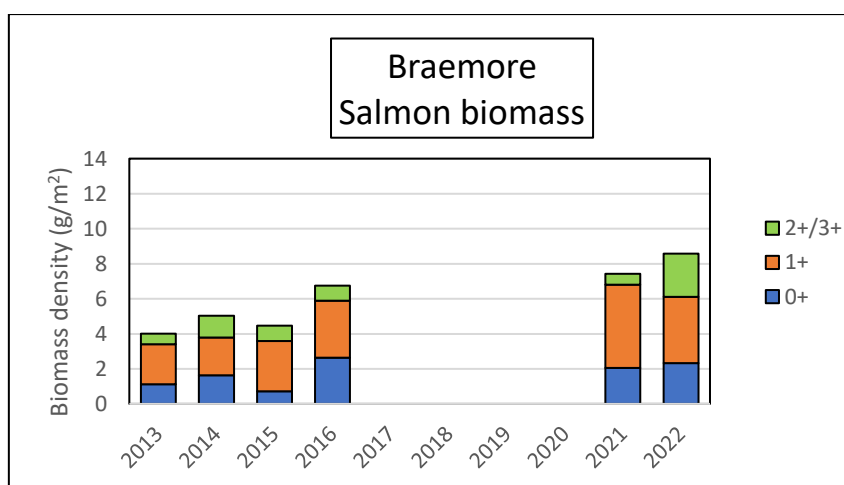
The relationship between fry density and the density of 1+ parr in the following year has been updated to include data for fry in 2021 and the 1+ parr in 2022. A total of nine inter-year comparisons is now available for the period covering 2013-2022. The blue line represents the best relationship between all the points. The broken lines represent the NEPS benchmark values for fry and parr at Gobernuisgach. As has been pointed out in a previous report, it can be seen that fry density was demonstrably high enough to saturate the site with 1+ parr on only one occasion (fry in 2016 generating the 1+ parr of 2017).

Compared with the NEPS benchmark value, however, fry density was less than the benchmark for only one of the nine years shown and two of the ten years for which data is currently available (ie including 2022). The 1+ parr exceeded the NEPS benchmark for parr in five years and were less than the benchmark on four. However, the NEPS benchmark is for parr of all ages and 2+ parr are relatively more frequent at Gobernuisgach than elsewhere in Caithness. Considering parr of all ages, densities at Gobernuisgach exceeded the benchmark value in nine of the ten years for which data is available, excepting only 2016.

7.2 Braemore



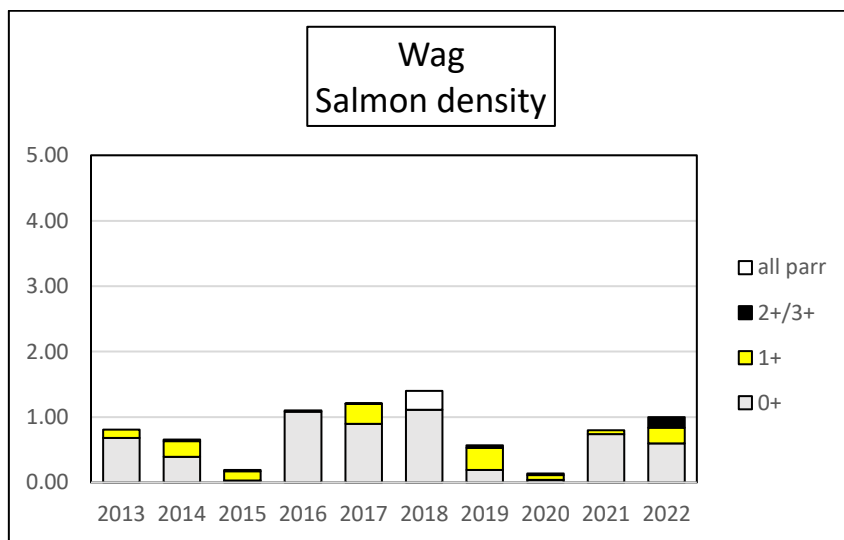
Fry were abundant at $1.2/m^2$ and $0.05/m^2$, respectively, at the Braemore site, in the middle reaches of Berriedale and about 11.5km downstream from Governuigach. The density of 2+ parr was unusually high at $0.15/m^2$. The observed values easily exceeded the site's NEPS benchmark values of $0.52/m^2$ for fry and $0.15/m^2$ for parr.



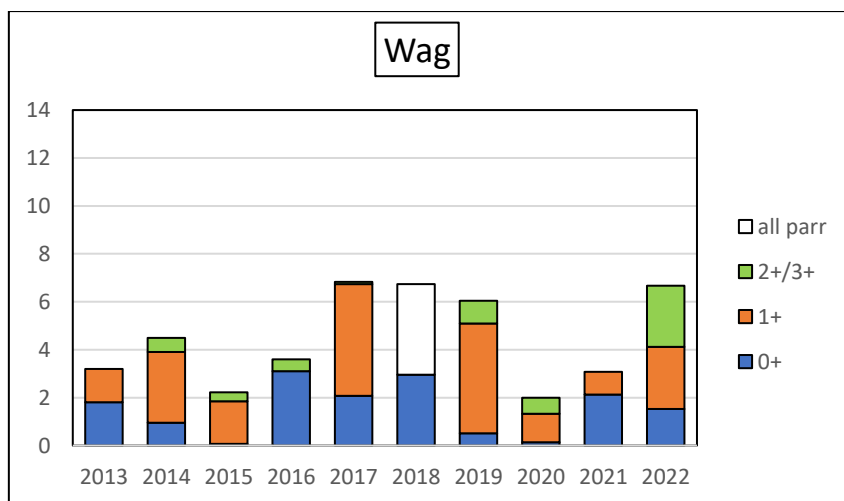
Buoyed by the large contribution of older, larger parr, the total biomass density at Braemore was the greatest in the time series at $8.6g/m^2$.

7.3 Wag

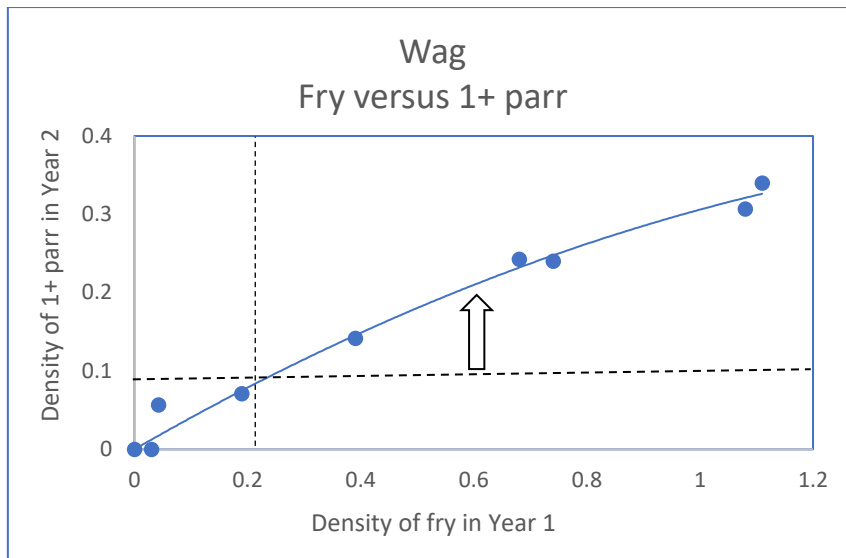
Wag is the uppermost survey site on the Langwell arm of the joint Berriedale/Langwell catchment.



Fry were present at $0.60/m^2$ and 1+ parr at $0.24/m^2$, roughly as expected based on previous years. Older parr were present in unexpectedly high numbers ($0.16/m^2$). The NEPS benchmark values for fry and parr are $0.22/m^2$ and $0.09/m^2$, respectively and both the benchmark values were easily exceeded.



The total biomass density was $6.67g/m^2$, among the highest values so far observed. The high value was due to the unusually large contribution made by the (larger) 2+ parr; the biomass contributions of fry and 1+ parr were approximately as expected based on previous years.

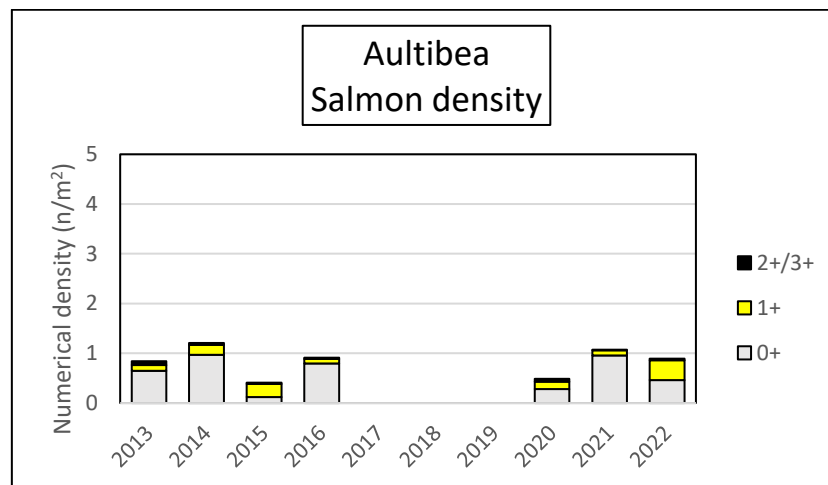


The fry density versus 1+ parr density diagram shows paired comparisons of fry density with the resultant density of 1+ parr the following year. The diagram has been updated to include fry density in 2021 versus 1+ parr density in 2022. Nine comparisons as represented by the blue points are now available from the ten-year data set (2013-2022) accumulated so far. The blue line represents the best overall relationship between all the points. The broken vertical line represents the NEPS benchmark for fry; the broken horizontal line represents the NEPS benchmark value for parr.

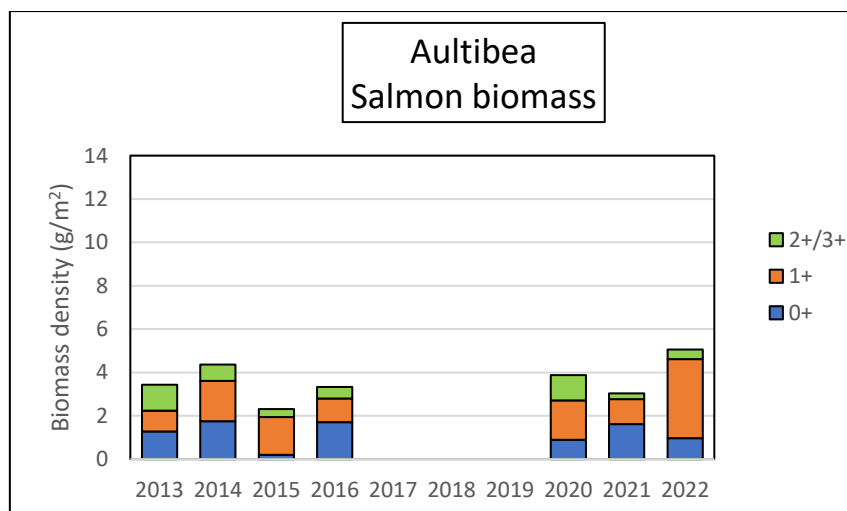
It can be seen that the blue line shows little evidence of levelling off at higher fry values. This suggests that in every year fry values have been insufficient to saturate the site with 1+ parr and that the real capacity of the Wag site to support 1+ parr is greater than the maximum value so far observed.

On the other hand, fry density exceeded the NEPS benchmark in five of the nine years as depicted on the diagram. Fry density also exceeded the NEPS benchmark in 2022 and although the resulting density of 1+ parr will not be known until the 2023 survey is carried, the value predicted from the blue line for 1+ parr density is around 0.20/m², as depicted by the arrow. This value easily exceeds the NEPS benchmark value for parr, as did five of the nine values observed in previous years.

7.4 Aultibea



Fry density at Aultibea was $0.46/m^2$, about average for the site. Following on from the large crop of fry observed in 2021, the density of 1+ parr was $0.40/m^2$, the largest value in the time series. The fry value was an approximate match for the NEPS benchmark value for fry of $0.52/m^2$. The density of 1+ parr greatly exceeded the NEPS benchmark for all parr of $0.15/m^2$.



The total biomass density was $5.06g/m^2$, the largest value so far observed. This was mainly due to the large contribution made by the 1+ parr.

7.5 Conclusions

The survey results for the four sites surveyed on Berriedale/ Langwell in 2022 showed an overall improvement on recent years in terms of stability and balance, following consecutive years in 2021 and 2022 when fry densities were reasonable. The only significant anomaly was at the high-altitude site at Governuigach where, although parr were relatively abundant, fry were essentially absent. This shortfall remains unexplained (but note the parallel with Achnaclyth on Dunbeath River). Any consequences of the lack of fry at Governuigach can be established at survey in 2023.

8. Acknowledgements.

Thanks are due to Jamie McCarthy, Simon Harrison and Jamie Coughlin for taking part in the survey fieldwork.

9. Appendices

Appendix 1. Survey site locations in 2022



1. Shurrex
2. Lythmore
3. Bumsdale
4. Rangag
5. Tacher
6. Inshag
7. Tulach Mor
8. Poll Chreagain
9. Acharole/ Achaole1
10. Clow
11. Scorricet
12. Sheriffs/ Sheriffs1
13. Bilbster
14. Achairn
15. Newton
16. Achnaclyth
17. Culvid
18. Gobernuisgach
19. Braemore
20. Wag
21. Aultibea

Appendix 2. Sampling dates in 2022 and fixed characteristics of the survey sites

Site	Date	OS Coordinates	Length (m)	Area (m ²)
Shurrey	29/8	ND 03915 57811	13.4	90
Lythmore	29/8	ND 04629 66338	24.0	184
Rumsdale	27/8	ND 14265 49007	22.7	182
Rangag	28/8	ND 16869 43375	38.4	82
Tacher	28/8	ND 17008 46917	33.3	131
Inshag	27/8	ND 14591 48765	23.3	111
Tulach Mor	14/8	ND 14792 49392	13.3	172 #
Poll Chreagain	14/8	ND 13091 51436	20.4	122 #
Acharole	8/7	ND 23102 51430	25.6	133
Acharole1	31/8	ND 23210 51752	29.0	134
Clow	31/8	ND 23246 52307	28.0	160
Scoriclet	30/8	ND 24729 50248	25.4	149
Sheriffs	30/8	ND 24583 52234	22.1	170
Sheriffs1	9/7	ND 25401 52400	16.0	136
Bilbster	4/9	ND 28068 53748	26.0	387
Achairn	8/7	ND 30048 50016	23.4	120
Newton	10/7	ND 35247 50343	51.0	92
Achnaclyth	3/9	ND 10495 33647	12.3	129
Culvid	3/9	ND 12537 32407	16.7	215
Gobernuisgach	1/9	NC 98416 31240	18.4	166
Braemore	1/9	ND 07294 30413	13.8	156
Wag	2/9	ND 01604 25974	23.3	212
Aultibea	2/9	ND 04807 23354	16.0	241

For mainstem river sites, site area varies depending on river conditions and is measured at survey each year.

Appendix 3. Primary data for salmon in 2022

Site	Fry				Parr				
	Pass 1	Pass 2	Pass 3	Av. Length mm (SD)	Pass 1	Pass 2	Pass 3	Av. Length 1+ mm (SD)	Av. Length 2+ mm (SD)
Shurrery	1	0	0	75.0 (n/a)	17	4	1	127 (7.0)	152 (n/a)
Lythmore	0	1	0	78.0 (n/a)	8	1	0	144 (7.5)	
Rumsdale	118	43	13	65.0 (4.46)	25	8	0	98.0 (5.48)	118 (n/a)
Rangag	123	26	3	50.6 (8.14)	8	1	1	97.6 (4.92)	115 (n/a)
Tacher	122	23	11	58.4 (7.08)	40	5	2	95.6 (8.86)	
Inshag	43	17	11	63.3 (4.51)	17	5	2	101 (8.1)	115 (n/a)
Tulach Mor	247	104	39	55.0 (5.32)	25	14	3	94.3 (5.25)	117 (8.3)
Poll Chreagain	73	22	6	63.5 (4.26)	16	1	1	96.7 (8.43)	
Acharole	6	3	0	(NB July)	8	4	2	n/a	(NB July)
Acharole1	15	1	1	74.4 (3.58)	4	1	0	120 (9.7)	
Clow	5	0	0	77.6 (n/a)	5	3	0	126 (3.77)	
Scorricket	79	17	6	59.9 (5.53)	37	5	0	95.1 (8.78)	122 (n/a)
Sheriffs	85	27	7	64.3 (5.75)	26	6	3	97.3 (9.75)	118 (2.8)
Sheriffs1	276	80	22	(NB July)	25	3	2	n/a	(NB July)
Bilbster	1	0	0	83 (n/a)	11	4	9	108 (3.3)	122 (6.2)
Achairn	13	4	2	(NB July)	16	3	1	n/a	(NB July)
Newton	0	0	0	(NB July)	5	0	1	n/a	(NB July)
Achnaclyth	18	1	0	68.4 (5.87)	9	1	0	87.6 (n/a)	120 (n/a)
Culvid	109	49	13	59.9 (5.95)	7	6	0	85.8 (14.3)	127 (n/a)
Gobernuisgach	1	1	0	65 (n/a)	20	2	2	104 (5.0)	119 (6.2)
Braemore	95	53	17	58.7 (4.47)	67	27	4	88.1 (6.65)	111 (4.8)
Wag	81	31	10	63.3 (4.12)	73	8	3	98.9 (4.80)	111 (3.9)
Aultibea	102	9	1	59.2 (6.31)	64	27	7	93.4 (6.89)	114 (2.4)

Average values for body length are shown. Values in brackets are for Standard Deviation of length measurements. Where fish numbers are too low, a value for Standard Deviation is not presented as designated by n/a.

NB July. For preliminary survey of Wick River, no values for body length are presented due to non-standard survey dates.

Appendix 4. Primary data for trout in 2022

Site	Fry				Parr		
	Pass 1	Pass 2	Pass 3	Average mm (SD)	Pass 1	Pass 2	Pass 3
Shurrery	2	2	0	80.8 (n/a)	1	0	0
Lythmore	30	10	3	90.5 (8.19)	4	3	0
Rumsdale	19	10	3	62.9 (5.42)	4	2	0
Rangag	18	5	2	59.3 (8.83)	4	0	0
Tacher	0	0	0		13	1	0
Inshag	0	0	0		3	2	1
Tulach Mor	0	0	0		0	0	0
Poll Chreagain	0	0	0		0	0	0
Acharole	6	4	1	(NB July)	3	2	0
Acharole1	4	1	0	78.6 (n/a)	0	1	0
Clow	2	0	0	88.0 (n/a)	0	1	0
Scorricket	7	0	0	66.7 (12.1)	0	0	0
Sheriffs	0	0	0		1	0	0
Sheriffs1	0	0	0	(NB July)	3	0	0
Bilbster	3	1	0	82.8 (n/a)	0	0	0
Achairn	8	0	0	(NB July)	2	0	0
Newton	0	0	0	(NB July)	3	0	0
Achnaclyth	1	0	1	68.4 (n/a)	2	0	0
Culvid	0	0	0		4	0	0
Gobernuisgach	0	0	0		8	5	1
Braemore	0	0	0		2	0	0
Wag	4	2	0	68.3 (3.90)	5	1	0
Aultibea	1	0	0	54.0 (n/a)	4	7	0

Summary data for the body length of trout parr are not presented because they tended to be present only in low numbers and because their ages were not determined by scale reading.