2021 Survey of Juvenile Salmonids in Caithness Rivers

Caithness District Salmon Fishery Board

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January, 2022

Survey Site NEPS21 0461. Salmon are absent from the Quoynee Burn which links Loch Watten and Loch Scarmclate in the upper catchment of Wick River.

1. Introduction

The National Electrofishing Programme for Scotland (NEPS) is organised, run and reported on by Marine Scotland Science (MSS). NEPS was suspended in 2020 due to the Covid epidemic but reintroduced in 2021. CDSFB is responsible for carrying out the NEPS fieldwork in the Caithness rivers and passes the resulting data to MSS for collation and analysis.

The main aim of the NEPS programme is to provide regional assessments of the status of salmon fry and salmon parr throughout Scotland. MSS has reported on previous NEPS programmes for 2018 and 2019 at https://data.marine.gov.scot/dataset/national-electrofishing-programme-scotland-neps-2019. In 2021, the Caithness electric-fishing team surveyed 30 NEPS sites in addition to the 18 sites surveyed for the Board's own programme.

The aim of the Board's programme differs from that of the NEPS programme. The Board's programme is designed to provide surveillance of juvenile salmon stocks in each of the six Caithness rivers, to build up a picture of how the various stocks are constrained and to use this information to provide advice to fishery managers.

It has become clear over the years that each of the Caithness rivers functions rather differently and that juvenile populations fluctuate within rivers and vary between the rivers in divergent ways. It is therefore intrinsically problematic to find a way to monitor all the rivers effectively while staying within the limits of the resources available.

Since 2013, the Board's approach to this problem has been to examine a set of key sites every year to provide continuity and to choose additional sites strategically to provide greater understanding or to probe emergent issues. In recent years, extra pressures such as drought and disease have affected some of the Caithness rivers and this is adding to the problems the Board faces in trying to keep abreast of all the developments in its area.

As described above, NEPS is a national programme and the way in which NEPS data is gathered is not designed to address the river-specific questions that are of particular interest to the Board. However, the NEPS programme does potentially provide some local information and, with MSS' agreement, the NEPS21 data has been used in this year's Board report to supplement the Board's coverage where possible.

For the Board's own survey, the electric-fishing team surveyed an additional 18 sites. These included the six key sites that are fished each year. Otherwise, particular emphasis was placed on –

1. The Forss where the juvenile population has been in steep decline, probably since 2018 and certainly since 2019.

2. The Thurso in the vicinity of the proposed Tormsdale Windfarm in order to generate a longer run of more robust data for what may turn out to be the pre-development phase of the proposed windfarm.

3. The Wick River where the key site at Clow on the Scouthal Burn and the alternative site just upstream at Acharole1, were found to be deficient in fry and parr when the survey was

carried out. It was decided therefore to extend work to include the site at Sheriffs on the Strath Burn for which some information is available for previous years.

4. The Langwell where fry recruitment had been poor in 2020.

2021 was again a drought year. Summer droughts have been a recurrent feature of the Caithness rivers since 2018. The particular characteristics of each drought have differed but in 2021, many months of near-zero summer rainfall throughout Caithness resulted in extreme reductions in water levels by the time of survey. For example, the photograph below (Figure 1) shows the abnormal condition of the Board's key site at Clow on Wick River.

Figure 1. The Scouthal Burn at Clow on Wick River on 1st September, 2021.

Salmon in the six Caithness rivers have been impacted by the recent sequence of drought years in different ways and to different extents and, as a result, each river is now on a more-or-less unique trajectory. As a result, this year's report is necessarily longer and more detailed than previously and therefore a more taxing read. In order to get round this problem, summary sections are included for each river and these can used to consider the most important findings of the 2021 survey without dwelling on the data that underlies them.

2. Methods

As for previous years, all the Board sites were surveyed by 3-pass electric-fishing, with Zippin correction for variation in capture efficiency, to provide fully quantitative data. A bank-based generator and control box was used.

Survey of the NEPS sites was carried out using portable backpack equipment to comply with the requirements of the NEPS programme for standardisation throughout - and bearing in mind that many of the NEPS sites were accessible only by foot or by ATV thereby precluding the use of heavy or cumbersome equipment.

Fry and parr were distinguished based on the length/ frequency diagram for the site in question. For the Board sites, 1+ parr were distinguished from 2+ parr by scale-reading. For the NEPS sites, parr were not classified since the scale-samples obtained during survey were sent directly to MSS.

As for previous years, all values for fish density and biomass density were expressed in terms of the channel area of the site, rather than wetted area, in order to avoid the potential distorting effect caused by any stream shrinkage due to drought.

Note, however, that the official NEPS programme standardises on using wetted area to express density. For some sites, therefore, the density values that MSS will present in the NEPS21 report will differ from those given in the present Board report. The official NEPS values will be greater than the Board's values for sites where drought and low water level caused the wetted area of the survey site to be appreciably less than the normal channel area.

The NEPS survey uses a mixed strategy to balance the requirements for precision and coverage. Only a subset of 12 of the 30 NEPS sites was surveyed by 3-pass electric-fishing: the remaining sites were surveyed, as specified by MSS, using only a single pass. The potential extra coverage provided by all 30 of the NEPS sites was realised for the Board by comparing fry or parr values derived from single-pass NEPS sites with data from the first pass, only, for those sites (Board and NEPS) that were surveyed by 3-pass fishing.

3. Results

3.1. Semi-quantitative Data from 1-Pass Electric-fishing

Table 1 (see Appendix 7.1) shows site details for the 30 NEPS sites. Table 2 (Appendix 7.2) shows values for the observed density of fry and parr for the NEPS sites on single-pass fishing, or on the equivalent first pass of 3-pass fishing.

MSS chooses the locations of NEPS sites somewhat randomly from those parts of the river network where it is deemed possible to carry out electric-fishing (ie. wide river reaches are excluded) and where salmon might be expected to be present. In practice, the second criterion is set wide enough to include sites that do not support salmon at all, usually because the sites are located near the periphery of catchments or sometimes because the habitat is unsuitable. Only two salmon fry and no salmon parr were detected at NEPS21 0474 in the further reaches of the Rumsdale Burn in the Thurso catchment: no salmon fry or parr were detected in another seven of the NEPS sites. All eight sites in question are listed below.

- NEPS21 0474 at Rumsdale, Thurso – a small, peripheral stream.
- NEPS21 0455 at Gerston, Thurso - a channelised, peripheral stream.
- NEPS21 0478 above Altnabreac, Thurso - a low gradient, peatland canal.
- NEPS21 0480 at Braehour, Thurso - a peripheral, peatland stream.
- NEPS21 0490 above Dalnawillan, Thurso - a peripheral, peatland stream.
- NEPS31 0473 at Lynegar, Wick - a very small, peripheral stream.
- NEPS21 0461 at Quoynee, Wick - a channelised, peripheral stream (see cover photograph).
- NEPS21 0463 at Thrumster, Wick – a channelised, peripheral stream.

The absence (or near absence) of salmon in all these locations was as expected based on the streams' locations and characteristics. The eight sites in question have therefore been excluded from further consideration since they are not informative in the particular context of this report.

Table 3 (Appendix 7.3) shows site details for all 18 of the Board sites.

As always, the Board sites were surveyed by 3-pass electric-fishing in order to generate fully quantitative data. However, the values for the fry and parr densities observed on the first pass, only, are shown in Table 4 (see Appendix 7.4) in order to match the equivalent data available for the NEPS sites (as per Table 2).

The two sets of 1-pass values - NEPS and Board - were combined to provide a broad oversight of the condition of young salmon in Caithness District.

In order to display these data, fry or parr densities were colour-coded according to Godfrey's scheme as depicted in Table 5. This procedure is unchanged from similar presentations contained in previous reports to CDSFB – low values, coloured-coded red, range through orange, yellow, green and light blue to the highest values of all which are coded dark blue.

Table 5. Classification scheme for salmon fry and salmon parr densities observed on 1-pass electric-fishing (after Godfrey, 2005).

	Critical percentile values for density (n/m2) and colour-codings					
	< 20th	**20th – 40th**	**40th – 60th**	**60th – 80th**	**80th - 100th**	**> 100th**
Fry	0.05	0.13	0.28	0.33	0.67	> 0.67
Parr	0.04	0.07	0.13	0.19	0.28	> 0.28

3.1.1 Salmon fry

Figure 2 shows mapped values for fry (spawned in 2020).

The most notable features of Figure 2 are as follows -

1. The River Forss shows a cluster of modest or poor fry values.

2. The River Thurso shows mostly high fry values.

3. The Wick River shows unexpectedly poor fry values in the catchment area upstream of Watten.

4. The Dunbeath, Berriedale and Langwell Rivers show fry values that match those that are expected based on past years.

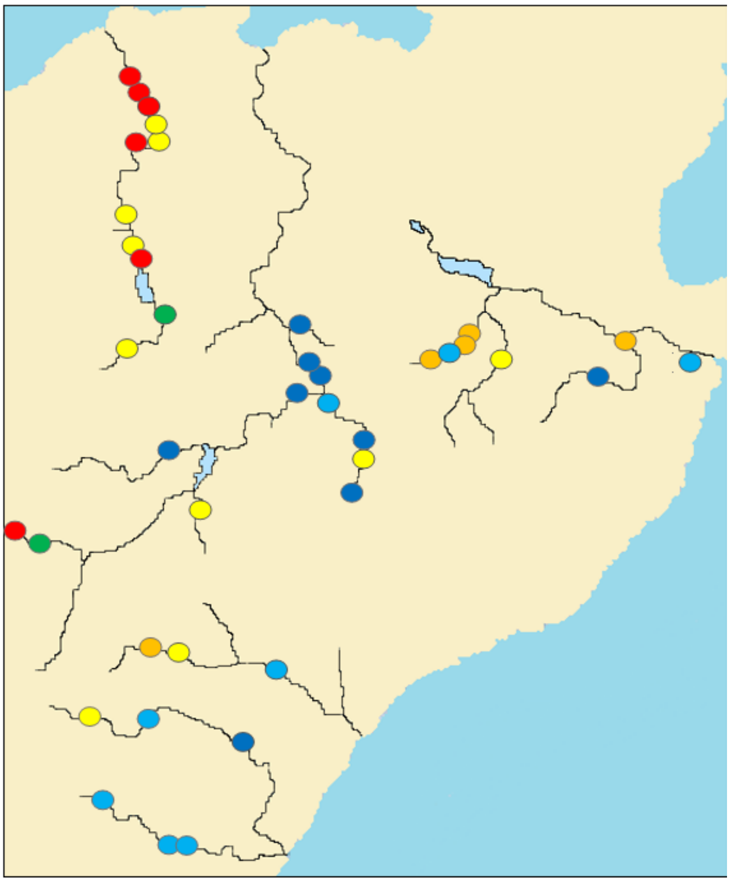


Figure 2. The distribution of values for the density of salmon fry observed on 1-pass fishing. The data are for the combined Board and NEPS sites (40 in total). The colour-codings are as per Table 5.

3.1.2 Salmon parr

Figure 3 shows equivalent data for parr. Parr in Caithness rivers are mostly two-years-old and, therefore, the majority of the parr in 2021 were spawned in 2019, becoming fry in 2020.

Figure 3 shows that -

1. The lower part of the Forss shows a cluster of low values. This is as expected based on the fry densities reported in the 2020 Board survey. Parr values above Broubster Leans, however. appear to be more favourable - although still lower than expected based on the values reported for the years before 2019.

2. Parr values in Thurso River are generally high and all are in line with expectation based on location and habitat type.

3. Parr values in the Wick River are unexpectedly low in the normally productive area in upper catchment above Watten.

4. Parr values for Dunbeath and Berriedale are generally good and in line with expectation for habitat and location.

5. The Langwell River shows only low parr values but this is as expected following on from the low fry values reported in 2020.

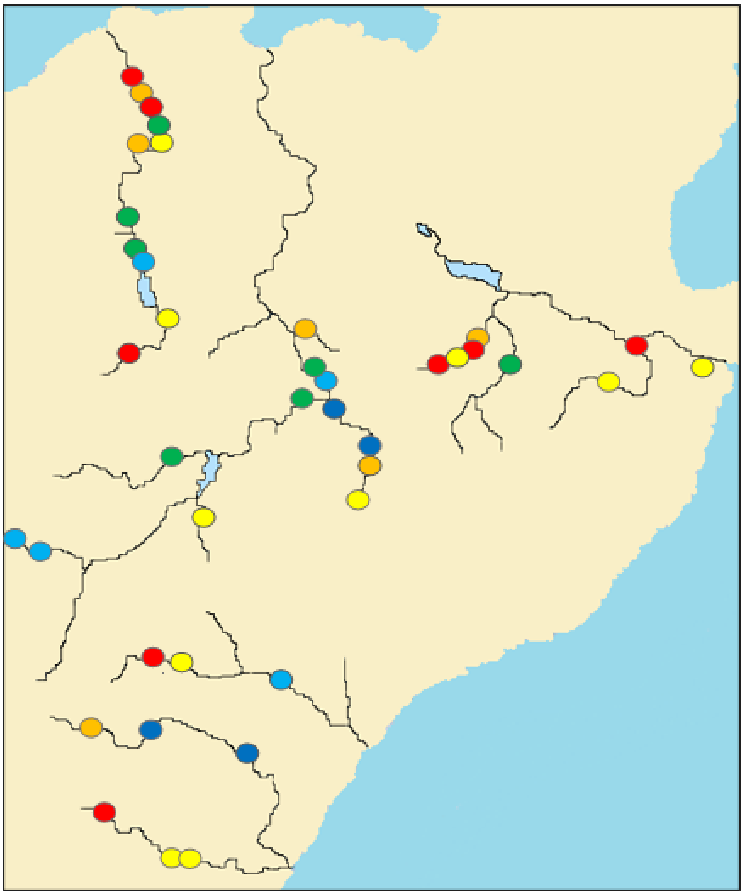


Figure 3. The distribution of values for the density of salmon parr observed on 1-pass fishing. The data are for the combined Board and NEPS sites (40 in total). The colour-codings are as per Table 5.

3.1.3 Summary of Semi-quantitative Data

The patterns illustrated in Figures 2 and 3 are generally as expected based on previous Board surveys, coupled with surveillance of the rivers in the period leading up to spawning in 2020.

However, the 1-pass data appear to pinpoint one new issue of concern and an issue of potential importance that has not previously been noted.

- Firstly, the area of the Wick catchment to the south of Watten is one of the main drivers of the Wick fishery. In 2021, the observed (1-pass) levels of both fry and parr in the cluster of five sites on the Scouthal and Strath Burns were much less than the values expected based on survey data for previous years.

- Secondly, low recruitment in the Forss has been a recurring problem since 2019. Based on the unusually large number of 1-pass sites surveyed on the Forss in 2021, the observed values for parr, in particular, in the upper river (above the potential refuge for spawners afforded by Broubster Leans) may be greater than those in the lower river. This raises the possibility that the upper river has been partially protected from the extreme declines in recruitment noted further downstream.

  This situation might result if some adult fish gain access to the upper part of the river in the earlier part of the season while the river level is still high and before the Falls of Forss begins to impede their upstream movement. If this is so, the case would be reinforced for easing the barriers at (1) the Falls of Forss to give fish access to the Leans of Broubster in a greater range of flow conditions and (2) Shurrery dam to give fish unconstrained access to the large area of catchment beyond Loch Shurrery.

3.2. Fully Quantitative Data

Table 6 shows numerical and biomass density values by age-class for each of the 18 Board sites. The values are based on 3-pass fishing with Zippin correction and are therefore fully quantitative.

Table 6. Numerical and biomass density values for the 18 CDSFB sites electric-fished in 2021.

Catchment	**Location**	**Numerical density (n/m^2)**			**Biomass density (g/m^2)**			
		0+	**1+**	**2+**	**0+**	**1+**	**2+**	**Total**
Forss	Cnoc-glas	0.30	0.02	0.01	0.71	0.30	0.10	1.11
	Shurrery	0.04	0.26	0.02	0.18	4.28	0.79	5.24
	Lythmore	0.06	0.04	zero	0.46	0.94	zero	1.40
Thurso	Rumsdale	0.71	0.26	0.02	1.66	2.80	0.30	4.76
	Rangag	3.10	0.10	zero	0.71	zero	2.32	3.03
	Tacher	1.24	0.52	0.02	0.98	3.67	0.32	4.97
	Inshag	1.09	0.40	0.01	1.48	4.33	0.18	5.99
	Pipe Bridge	1.28	0.24	0.05	1.82	2.03	0.90	4.74
	Tulach More	1.94	0.34	0.01	2.43	2.94	0.26	5.63
	Poll Chreagain	1.77	0.39	0.01	2.13	3.85	0.17	6.15
Wick	Acharole1	0.56	0.06	zero	1.60	0.94	zero	2.54
	Clow	0.09	0.03	zero	0.35	0.39	zero	0.74
	Sheriffs	0.22	0.14	0.01	0.37	1.37	0.21	1.95
Dunbeath	Culvid	0.32	0.36	zero	0.39	3.39	zero	3.78
Berriedale	Gobernuisgach	0.23	0.03	0.04	0.37	0.30	0.68	1.34
	Braemore	1.33	0.63	0.03	2.05	4.76	0.61	7.42
Langwell	Wag	0.74	0.06	zero	2.13	0.95	zero	3.08
	Aultibea	0.95	0.10	0.01	1.62	1.16	0.27	3.04

Table 7 shows the average body length of fry (0+) and 1+ parr. The equivalent values for 2+ fish are not shown because their numbers were generally too low to support meaningful comparisons

Table 7. The average body length of fry (0+) and 1+ parr at the 18 CDSFB sites electric-fished in 2021.

Catchment	Location	Average length (mm)	
		0+	1+
Forss	Cnoc-glas	62.1	106
	Shurrery	72.8	112
	Lythmore	78.3	121
Thurso	Rumsdale	61.8	97.5
	Rangag	43.4	86.1
	Tacher	44.1	85.2
	Inshag	52.1	98.2
	Pipe Bridge	52.8	90.6
	Tulach More	50.6	91.2
	Poll Chreagain	50.4	94.7
Wick	Acharole1	65.4	110
	Clow	71.2	110
	Sheriffs	55.0	94.1
Dunbeath	Culvid	50.3	93.9
Berriedale	Gobernuisgach	54.9	95.4
	Braemore	54.5	87.8
Langwell	Wag	65.8	113
	Aultibea	55.9	99.3

Figure 4 shows the average body length of fry at each of the six key Board sites that are surveyed every year for all the years since 2013; values for 2021 are marked in orange. Figure 5 shows the equivalent data for 1+ parr. Some data points for 2018 are missing for Figure 5 because scale-sampling for age determination was suspended part-way through the annual survey due to the high water temperatures that year.

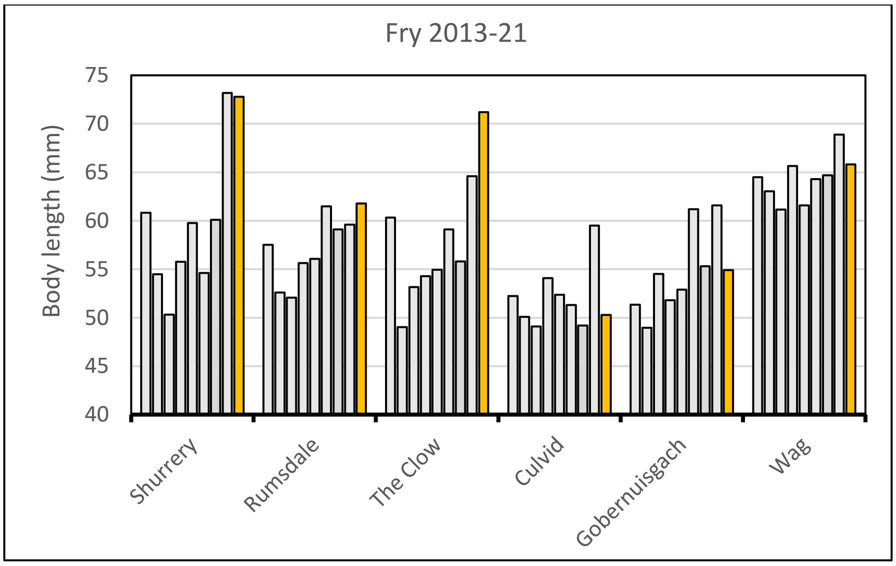


Figure 4. Average body length of fry each year (2013-21) at each of the six key sites The values for 2021 are shown in orange.

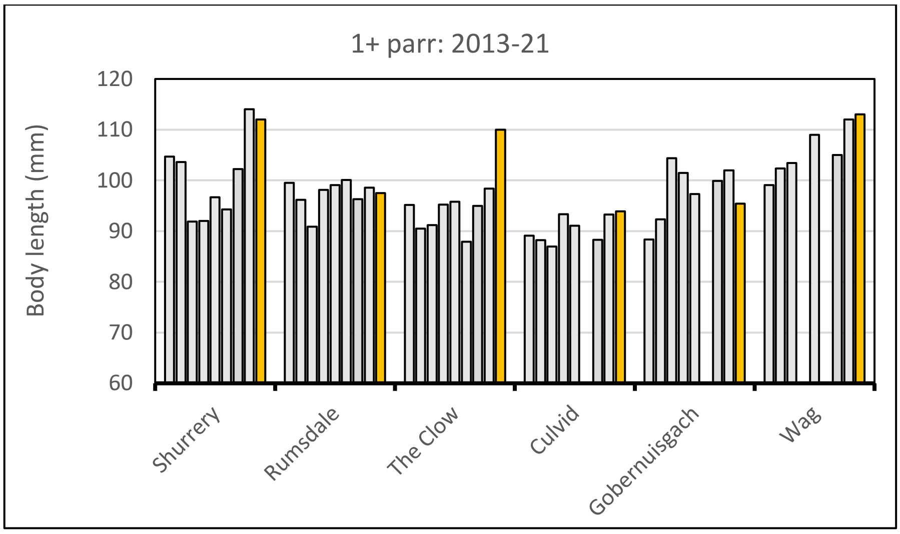


Figure 5. Average body length of 1+ parr each year (20139-21) at each of the six key sites. The values for 2021 are shown in orange.

Table 8 (Appendix 7.5) shows fry and parr densities at each of the 12 NEPS sites that were surveyed by quantitative 3-pass fishing. When appropriate, these values are used in the assessments in Section 4, below, to support the data obtained from the Board's own survey sites.

The wide range of dates over which the NEPS sites were fished means that fish experienced different periods for growth before their survey date. Since this prevents meaningful comparisons of average length-at-age or, therefore, of biomass density, these values are not shown.

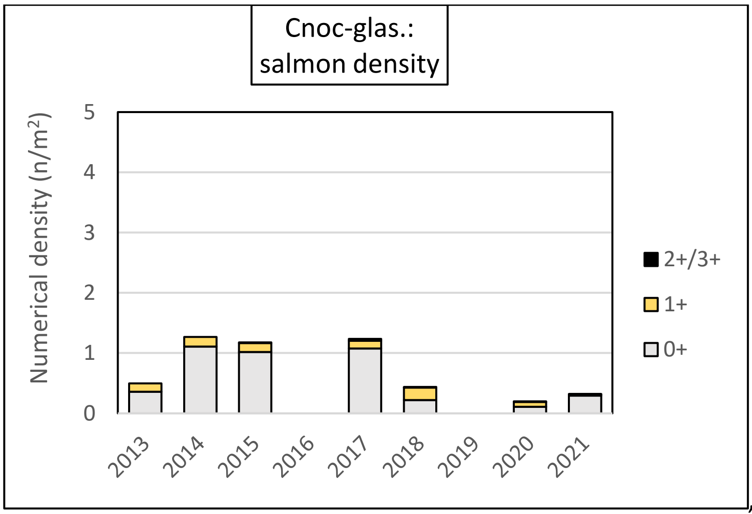
Table 9 (see Appendix 7.6) shows numerical density for trout fry and trout parr and the biomass density of trout fry. Biomass data for trout parr are omitted from the table because trout parr were infrequent at all sites. Trout fry were absent or infrequent at most of the survey sites but have become a novel feature of the sites on the Forss that have shown low recruitment of young salmon in recent years.

4. Site Assessments Based on Fully Quantitative Data

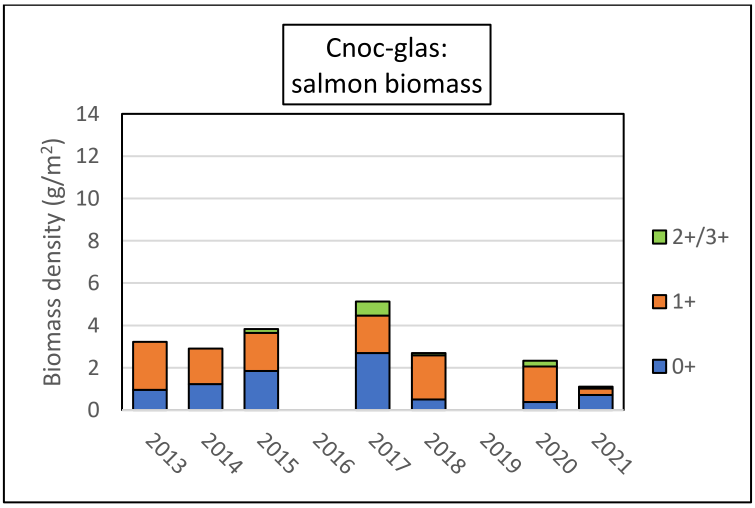
In the graphs below showing numerical density values and biomass density values for each site, the range of the axes has been held constant in order to facilitate visual comparison of the data for different sites.

4.1. Forss Water

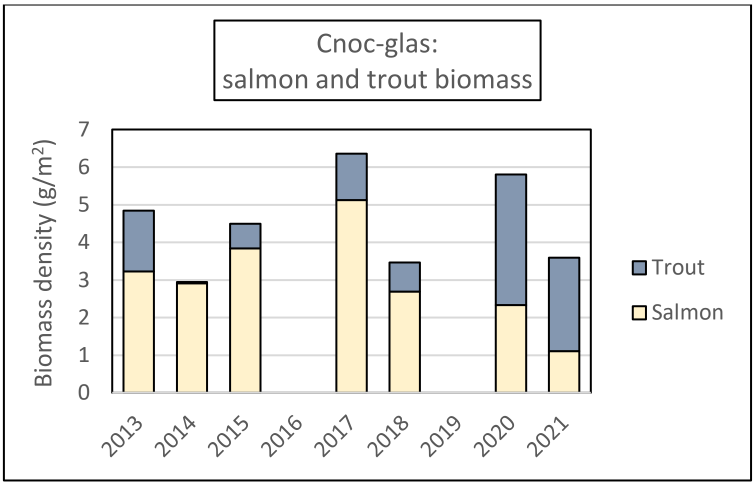
4.1.1 Cnoc-glas



In 2021, the density of salmon fry (0.30/m^2) extended a sequence of poor recruitment years relative to the earlier part of the data series. The density of 1+ parr (0.02/m^2) was the lowest observed in any year following on from the very poor crop of fry (0.11/m^2) in 2020.



Despite the relatively large size of both the fry (av. 62 mm) and the 1+ parr (av. 106 mm) the total biomass density of salmon (1.1 g/m^2) was the lowest value recorded to date.

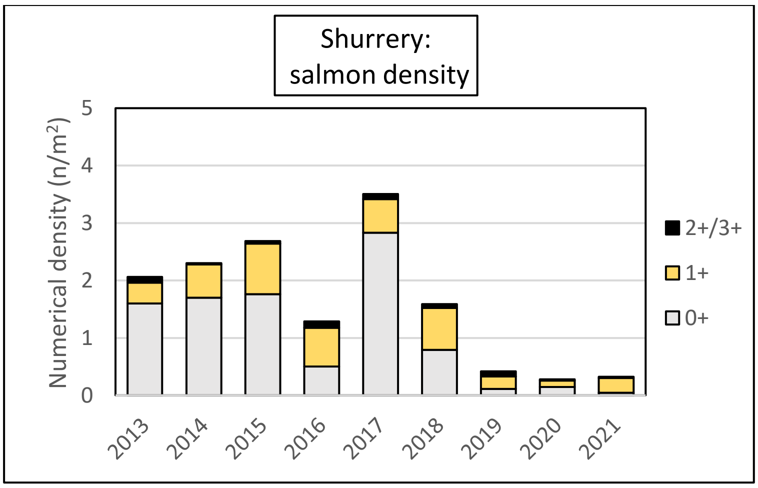


Trout have been a fairly consistent feature of the Cnoc-glas site throughout the survey series - perhaps because the site lies towards the periphery of the river's catchment. However, as noted in the Board's 2020 report, there are preliminary signs that trout populations in the Forss, generally, may have increased since the decline of salmon set in.

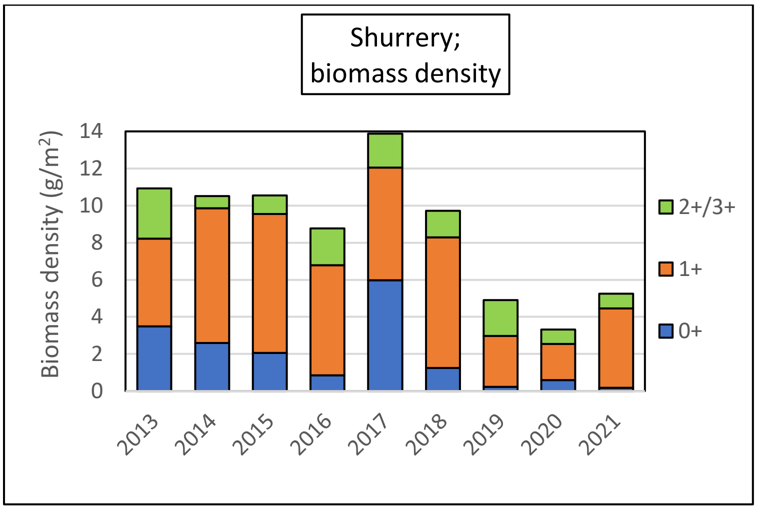
In line with this, in 2021 the biomass density of trout fry at Cnoc-glas was rather greater than in most previous years at 2.5 g/m^2. Overall, the combined biomass density of salmon fry, salmon parr and trout fry (3.6 g/m^2) was not far short of the long-term average value of about 4.5 g/m^2. But for the second year in succession the trout fry contributed more than the combined contribution made by salmon fry and parr. It can also be seen that the combined values for salmon and trout vary less across years than the separate values for either species suggesting an element of competition between the species

These observations lend support to the possibility that the fortunes of salmon and trout are to some extent reciprocal. It may be that, with declining numbers of young salmon, trout at Cnoc-glas are opportunistically using an increasing part of the stream resources (space and food) that are jointly available for both species.

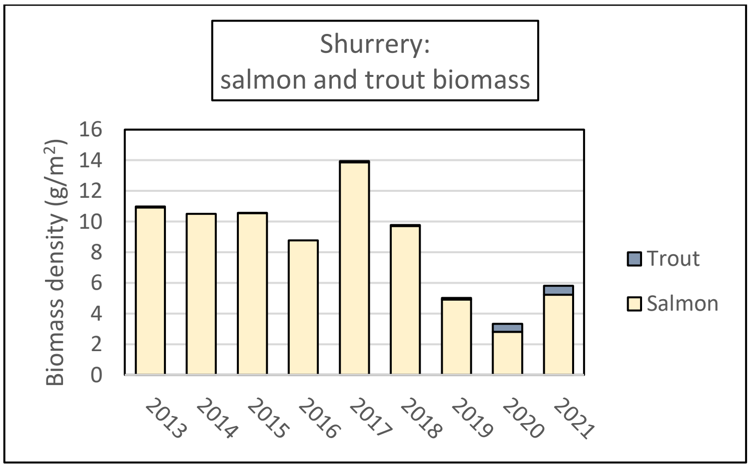
4.1.2 Shurrery



At Shurrery, the salmon density values for 2021 continue a poor sequence that extends back to 2019. The density of salmon fry was the lowest yet recorded at 0.04/m^2. The density of 1+ parr was also very low at 0.26/m^2 - much less than in most former years.

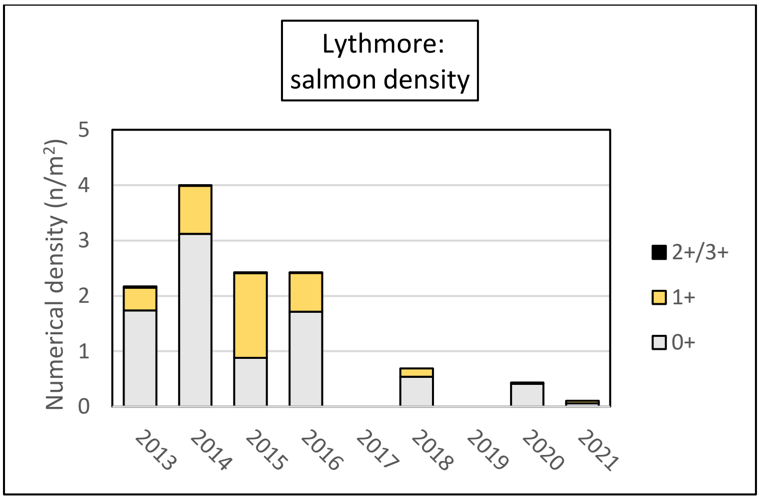


The total biomass density of salmon (5.2 g/m^2) was about 50% of the value consistently achieved in the years before 2019. The 2021 value was buoyed by the fishes' large size-at-age and particularly by the contribution of the 1+ fish which were again unusually large (av. 112mm).

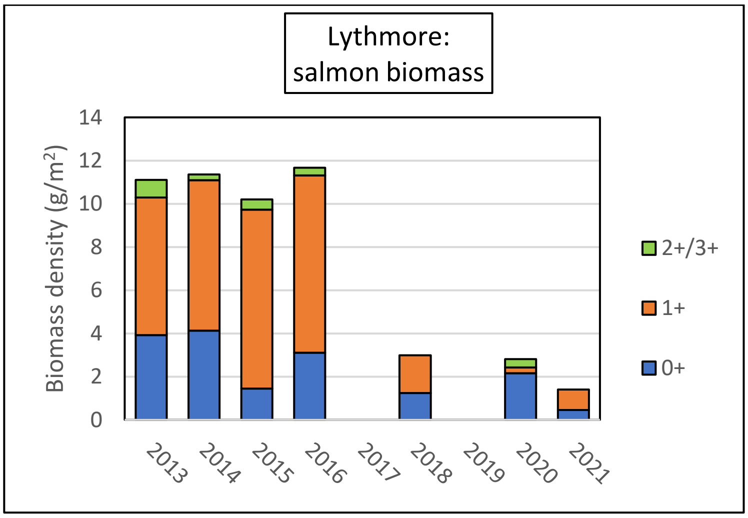


Trout fry were a very minor feature at the Shurrery site before 2020. In 2021, trout fry once again contributed more substantially to the combined biomass of salmon and trout. As for Cnoc-glas this suggests that trout are becoming a more prominent feature at Shurrery. However, the biomass contribution of trout fry was still minor (0.58 g/m^2) and the combined biomass density of both species still fell well short of equivalent values noted in the early part of the data series.

4.1.3 Lythmore

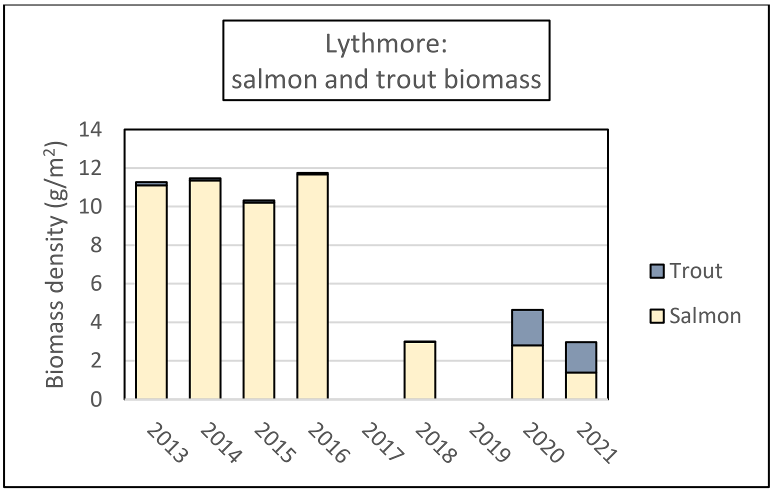


Salmon fry and salmon parr were again very scarce at Lythmore. In 2021, the density of fry (0.06/m^2) was the lowest yet recorded there and the density of 1+ parr was only 0.04/m^2. No older parr were present.



The size-at-age of both the fry and the parr was very large due to lack of competition among the few fish present. The average length of fry was 78 mm and the average length of 1+ parr was 121mm. These were the greatest values encountered anywhere in Caithness in 2021.

Despite the fishes' large size, the total biomass density of fry and parr was only 1.40g/m^2, the lowest value yet recorded and a small fraction of what the site has proved capable of producing in the past.



In 2021, trout fry were again a prominent feature of Lythmore. For the first time, trout fry (0.20/m^2) outnumbered salmon fry (0.06/m^2). The total biomass density of trout and salmon was about 3g/m^2 - of which trout contributed 1.6g/m^2 – falling well short of the site's proven capacity to support salmonids.

As for Cnoc-glas and Shurrery, the status of trout at Lythmore has changed. Trout can now be considered the dominant species at Lythmore – as judged from both numerical density and the biomass density values.

4.1.4 Summary Status of Forss

The 2021 survey has shown a picture of continuing decline for Forss salmon. None of the 2021 survey's findings are surprising given events since 2018 – as discussed in the 2020 Report – and, in particular, the continuing (and unresolved) problem of disease and mortality in summer among potential spawners lying in the lower river.

The low fry densities observed in the Forss in 2021 are in line with the mortalities noted among potential spawners in 2020. The low densities of parr observed in 2021 are in line with the low densities of fry present in the 2020 survey. This sequence of poor recruitment years will probably continue into 2022 given the scarcity of adult fish in 2021 and the additional effects of continuing disease.

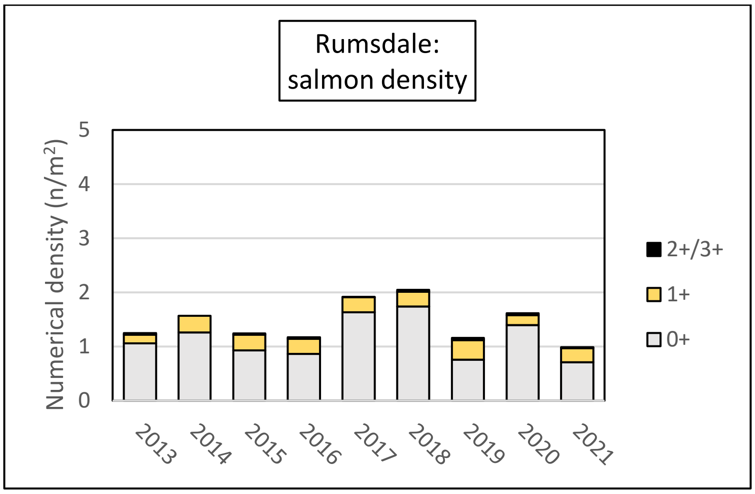
As regards the fishery in 2022, the ongoing ramifications of the accident at Shurrery Dam in 2018 will reduce the number of 2SW fish returning to the river in 2022 and the low density of parr in 2020 (smolts in 2021) will be reflected in low returns of 1SW fish (grilse).

The range of options for promoting recovery of the river remains the same as that discussed in the 2020 Report.

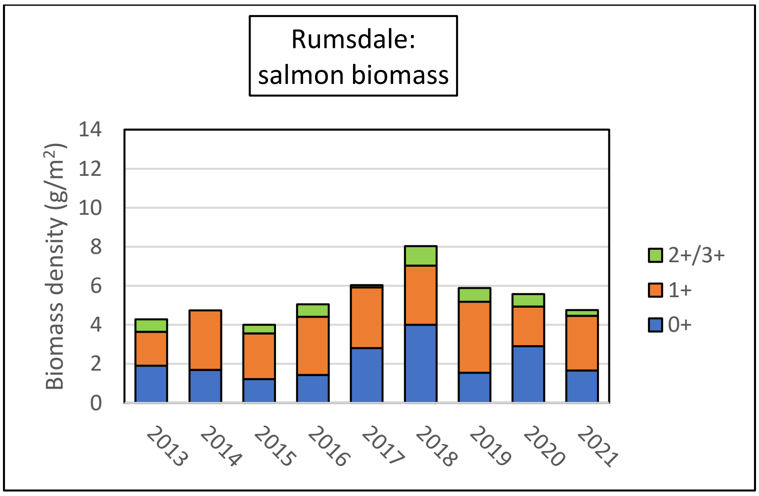
Ultimately, full recovery of the fishery will be dependent on a new sequence of good or adequate spawning years by whatever means this comes about.

4.2 River Thurso

4.2.1 Rumsdale



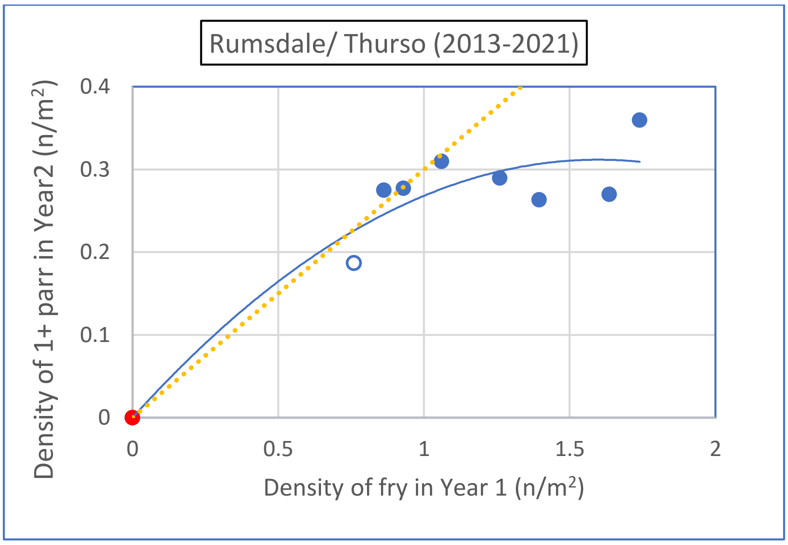
The densities of both fry (0.71/m^2) and 1+ parr (0.26/m^2) at Rumsdale were unremarkable and about average for the site.



The biomass densities of all the age-classes at Rumsdale were in line with expectation. The total biomass density was about average at 4.8 g/m^2.

Since a continuous run of data covering nine survey years is now available. it is possible to be more explicit than previously about the long-term status of the Rumsdale salmon population.

The diagram below plots the numerical density of fry at Rumsdale for each year between 2013 and 2020 versus the density of 1+ parr that were present the following year (in 2014-2021). Eight between-year comparisons can be made from the 9-year run of data and the comparisons are represented by the eight blue points in the diagram. The theoretical point where the absence of fry in any year would be expected to result in the absence of 1+ parr the following year is shown by the red point.



The blue line shows the overall relationship for all nine points. The line takes the expected "hockey-stick" form. In particular, increases in fry density (ie, along the horizontal axis) tend to result in increases in 1+ parr density up to a level at which the site is saturated and no more parr can be accommodated.

It can be seen that it takes about 0.8 fry per m^2 to fill the Rumsdale site with 1+ parr and that the ceiling level for parr is about 0.3 parr per m^2. The extent of the difference between the matched fry and parr densities also shows that many of the fry disappear in the year between one survey and the next.

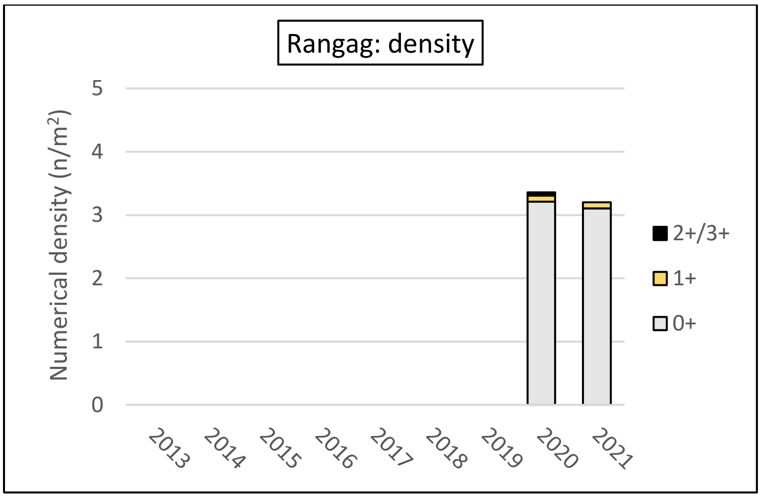
Survival rate between the fry and 1+ parr stages over all the years of record can be calculated for the six key Caithness sites; the average survival rate is about 30% (see Appendix 7.7). The broken orange line on the figure shows the 1+ parr densities that would be expected for any given fry density if survival rate had matched the average 30% value.

It can be seen that the blue and orange lines are coincident up to a level of about 1 fry per m^2 indicating that survival rate is average over this part of the range. However, the blue line falls short of the orange line when the fry density is greater than $1/m^2$. This means that more fry than expected are going missing in years when their density exceeds the value required to saturate the site with parr. The fate of the extra missing fry is not known but they must either (a) die at greater rates than the average or (b) move out of the Rumsdale site to find unoccupied space elsewhere in the stream.

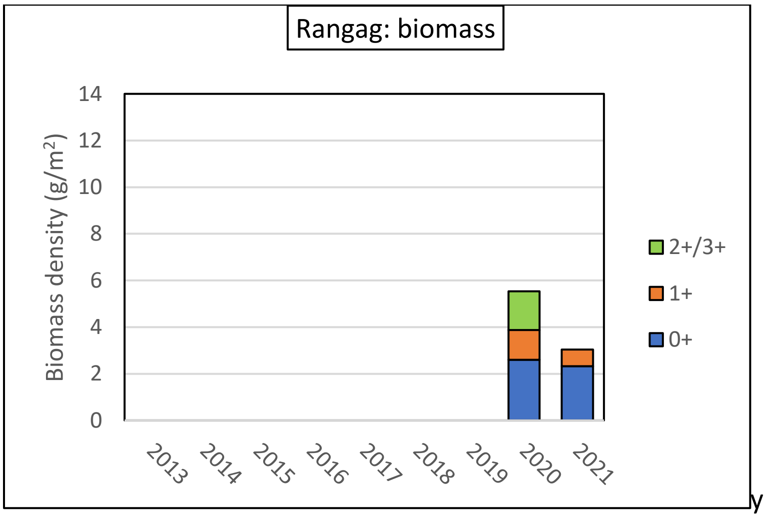
The blue circle in the diagram represents the fry in 2019 versus the 1+ parr in 2020. It can be seen that the fry density was not sufficient to saturate the site with parr. Otherwise, it can be seen that, in seven of the eight possible comparisons, the density of fry at Rumsdale was sufficient to saturate the site with parr.

In other words, with a single exception, Rumsdale has been filled to capacity with young salmon every year since the survey series began in 2013.

4.2.2. Rangag



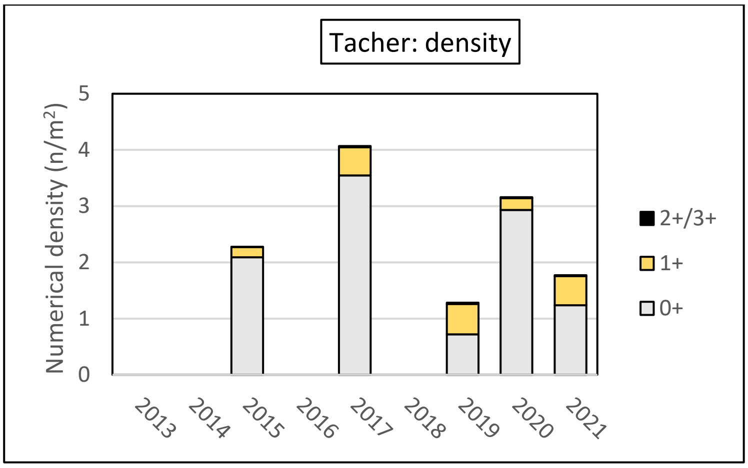
The site at Rangag on the Little River has been surveyed twice. Fry density in 2021 was very high (3.1/m^2) and similar to the value for 2020. The stream substrate at Rangag is composed of relatively fine material and the site itself holds only low densities of parr. It is likely, therefore, that the Rangag sites exports young fish to alternative locations elsewhere in the upper part of the Little River that are more suited to supporting older, larger parr.



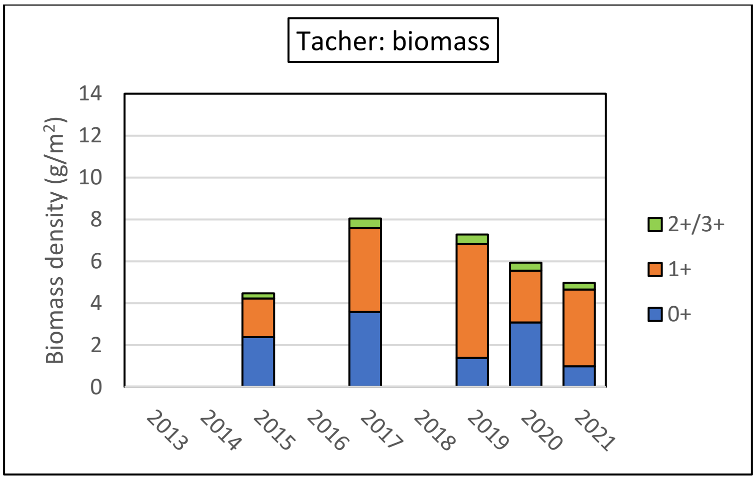
y

In 2021, the total biomass density at Rangag was dominated by the contribution made by large numbers of very small fry (av. 43mm). The total biomass density (3.0 g/m^2) was lower than in 2020 but this was mostly because a few large 2+ parr that were present in 2020 whereas none was encountered in 2021.

4.2.3 Tacher

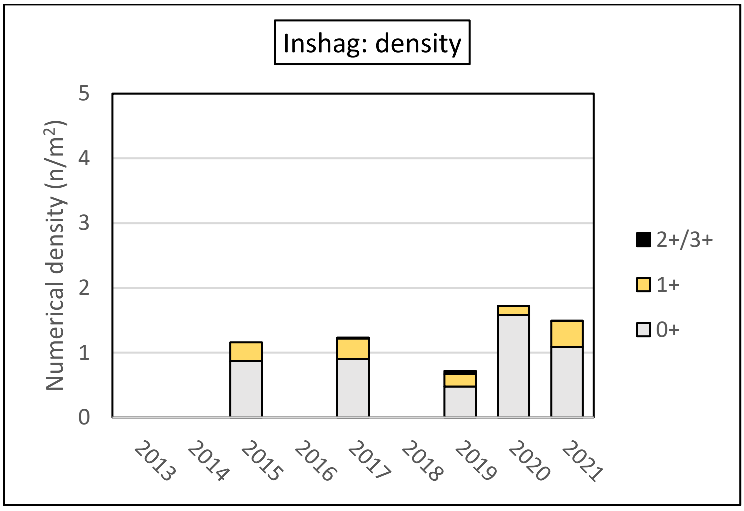


At Tacher, the density of fry was lower than in some former years but still high at 1.24/m^2. The density of 1+ parr was greater than is usual at 0.52/m^2.

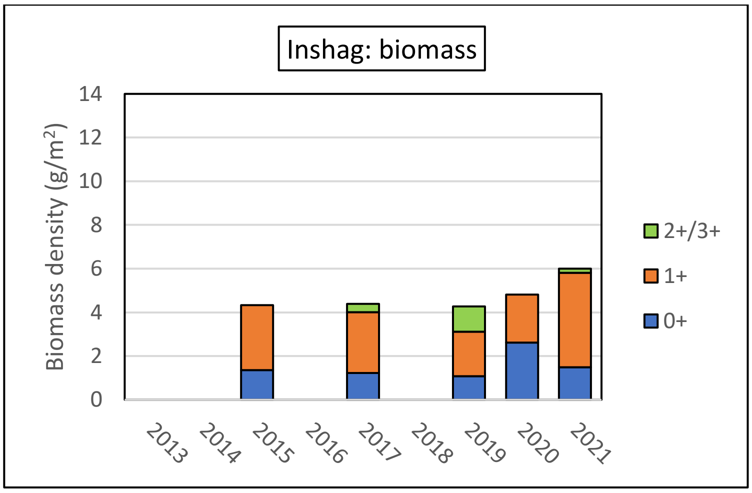


The total biomass density at Tacher was 5.0 g/m^2 about average for the site.

4.2.4 Inshag



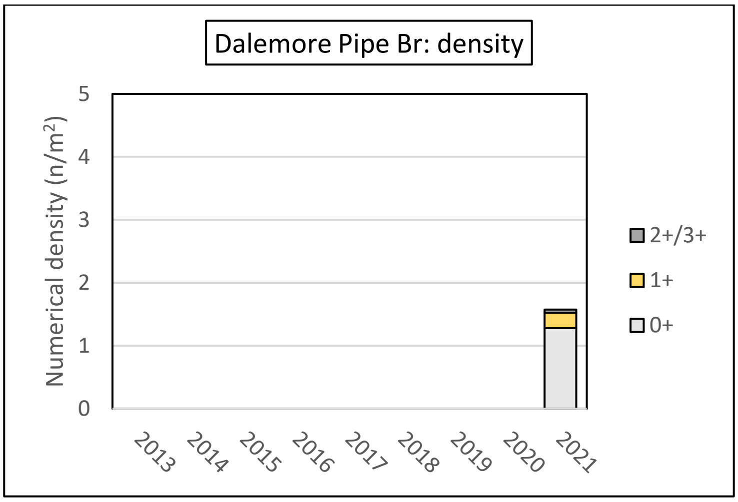
Fry density at Inshag (1.09/m^2) was about average for the site. The density of 1+ parr (0.40/m^2) was greater than usual, following on from the high fry density that had been present in 2020.



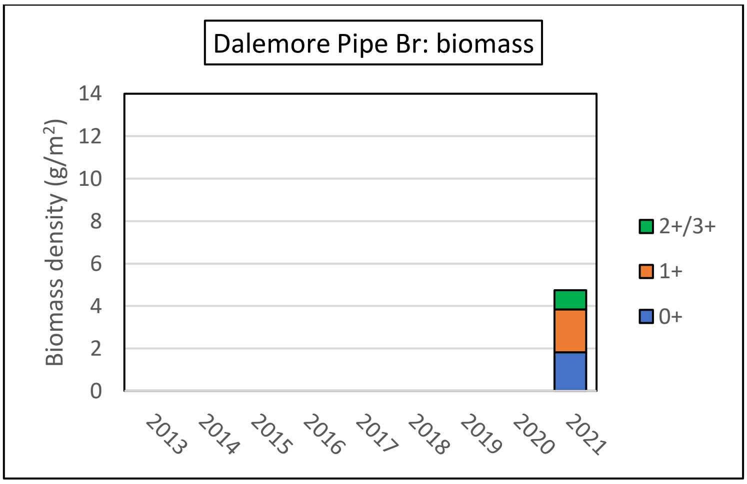
Buoyed by a large contribution from the 1+ parr, total biomass density was the greatest value encountered so far at Inshag at 6.0 g/m^2.

4.2.5 Dalemore Pipe Bridge

This new site is on the main river and it was fished for the first time in 2021 taking advantage of the very low water.

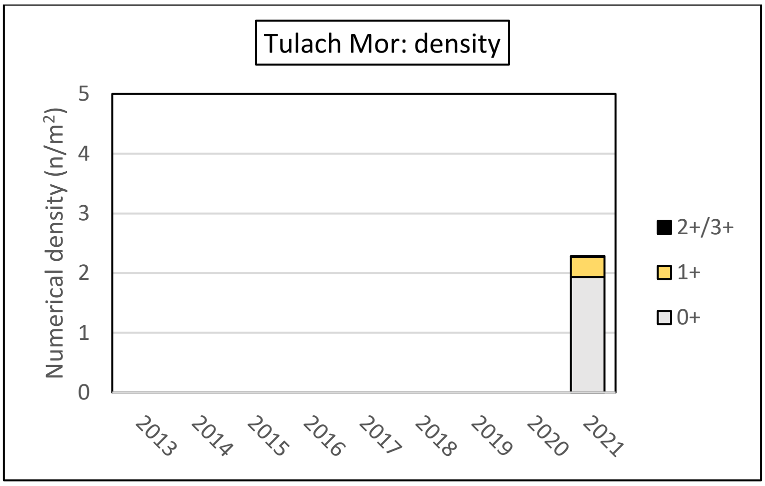


The density of fry was relatively high at $1.3/m^2$. The density of 1+ parr was $0.24/m^2$. Older parr were few in number.

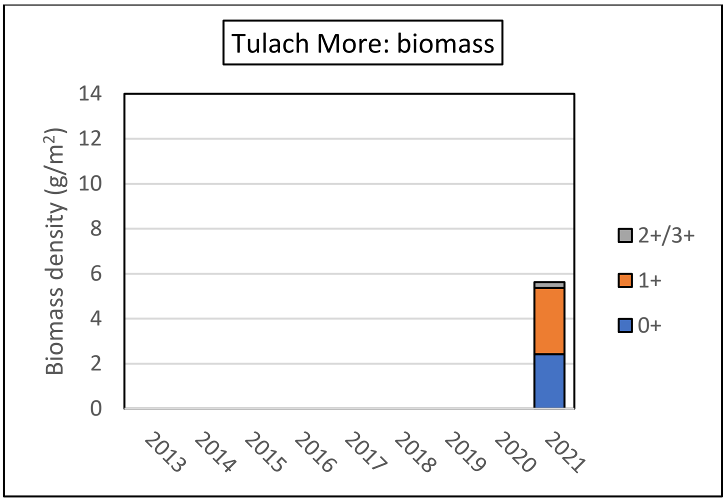


The total biomass density at the Pipe Bridge site was 4.7 g/m^2 – lower than for the comparable sites at Tulach Mor and Poll Chreagain (see below).

4.2.6 Tulach Mor

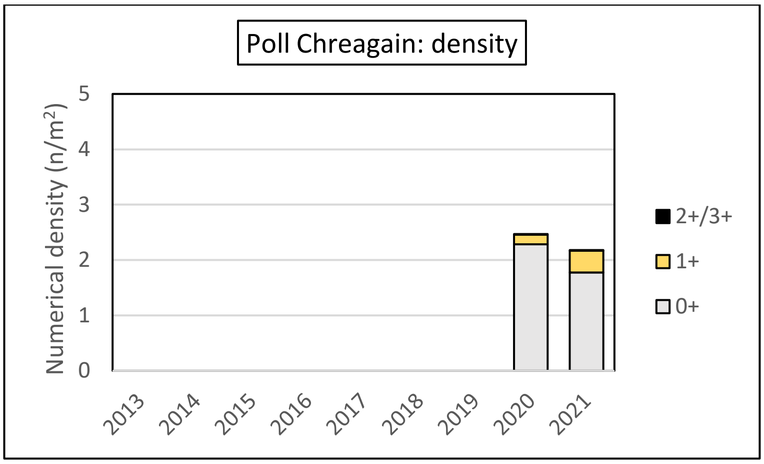


Tulach Mor was also surveyed for the first time in 2021. Fry density was high at 1.9/m^2. The density of 1+ parr was 0.34/m^2.

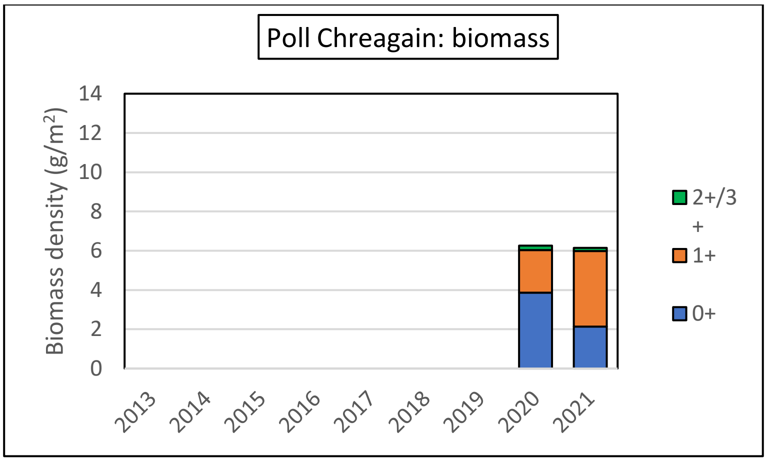


Total biomass density at Tulach Mor was 5.6g/m^2.

4.2.7 Poll Chreagain



Poll Chreagain was surveyed previously in 2020. The results for 2021 were rather similar. The density of fry was slightly lower at 1.8/m^2 but still very high by general standards. The density of 1+ parr was also relatively high at 0.39/m^2. Older parr were few in number.



The total biomass density at Poll Chreagain was 6.2 g/m^2 and almost identical to the equivalent value in 2020.

4.2.8 Summary Status of Thurso

Rumsdale is the Board's key site on the River Thurso with a continuous set of data covering all the years back to 2013. Using this data it has been shown in Section 4.2.1 that a fry density of about 0.8/m^2 is sufficient to saturate the site with 1+ parr the following year and that the actual fry value usually exceeds this threshold and it often does so by a large margin. Indeed, the Rumsdale site has been saturated with young fish almost every year since the survey began in 2013. The exception is for 2019 when fry recruitment was lower than usual following a poor spawning year in 2018 after the extreme summer drought

In 2021, fry density at Rumsdale fell slightly short of the critical value for only the second time. Paradoxically, the oscillating and reciprocating patterns of fry and parr biomass density since 2019 suggest that this seeming shortfall may have more to do with the continuing ramifications of the poor spawning in 2018 than with events at spawning in 2020. This will become clearer when the next survey is carried out and the 1+ parr densities for 2022 are known.

Otherwise, using the critical fry value derived from the Rumsdale data as a general guideline for sites elsewhere in the Thurso, it can be seen that in 2020 all six of the additional Board survey sites easily exceed the 0.8/m^2 target for fry density. Additionally, two of the three NEPS sites that were surveyed by 3-pass fishing also easily exceeded the 0.8/m^2 target. The exception was the site at Shinval on the Little River - a site of poor physical habitat quality for salmon (Figure 6).

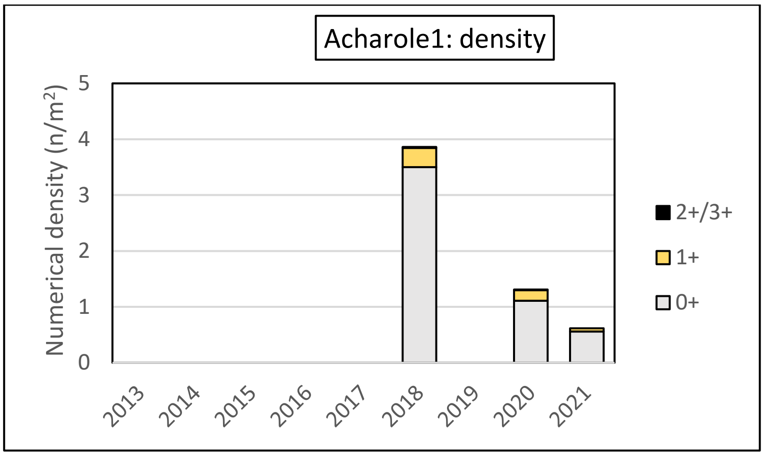
In summary, therefore, all the available data indicate that, once again, the Thurso River was saturated, or nearly saturated, with young fish in 2021. Furthermore, since spawning in 2021 was noted to be good the expectation must be that the status of juvenile salmon in the Thurso will again be favourable in 2022.

Figure 6. NEPS21 0457 at Shinval on the Little River

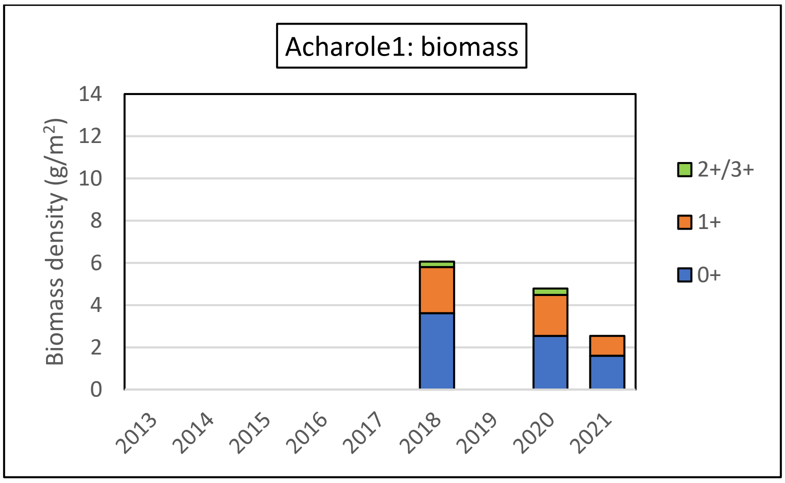
4.3 Wick River

4.3.1 Acharole1

The site at Acharole1 lies 700m upstream of the Board's key site at Clow. Acharole1 was adopted as a potential replacement for Clow in 2020 when it became clear the performance of the Clow site was sometimes anomalous. In particular, the recruitment of fry to Clow is delayed in some years, possibly due to the reluctance of fry to cross the bedrock shelves above the site in dry summers when the water is low. Acharole1 is not affected in this way. The Acharole1 and Clow sites have been surveyed in parallel since 2020 with a view to making the necessary change-over in due course.

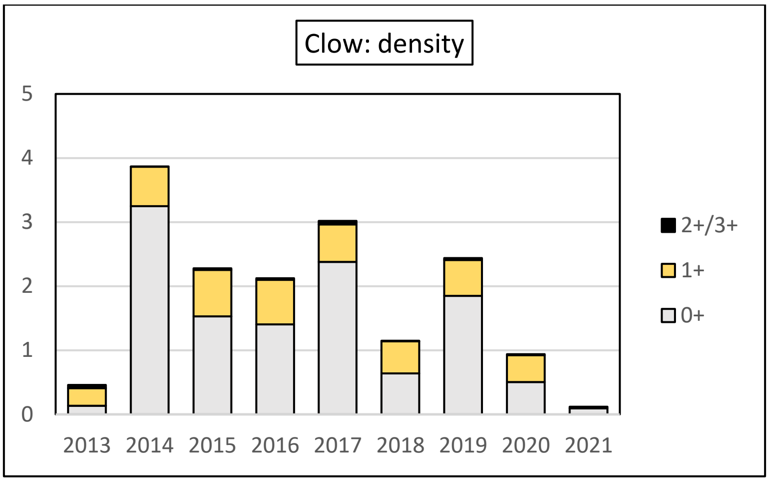


In 2021, the densities of both the fry at 0.56/m^2 and the one-year-old parr (ie. 1+ parr) – at 0.06/m^2 were lower at Acharole1 than in previous years. Older parr were absent.

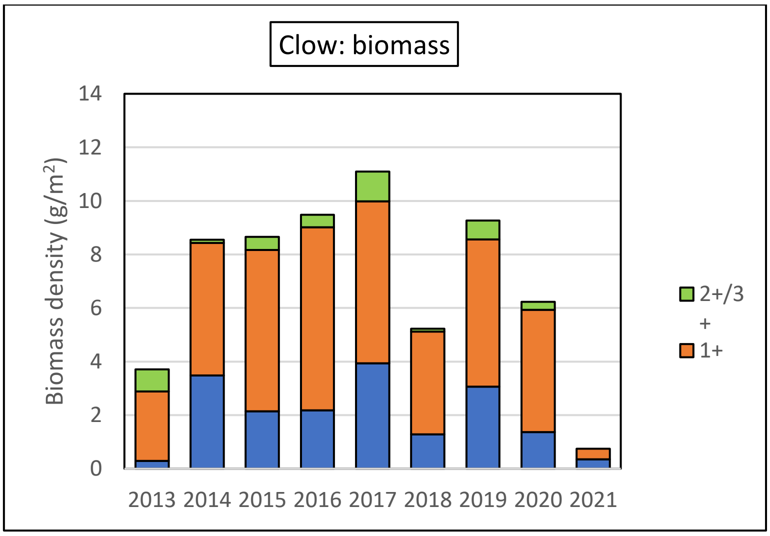


Because of their low densities and corresponding low levels of competition, both the fry (av. = 65mm) and 1+ parr (av. = 110mm) were very large. Despite this, and driven by the low numerical density of fish, the total biomass density was only 2.54 g/m^2 and the lowest value encountered to date.

4.3.2 Clow



In 2021, fry density at Clow was only 0.09/m ^{2}, the lowest value recorded to date. The density of 1+ parr was only 0.03/m^2 - also the lowest value recorded so far. No older parr were present.



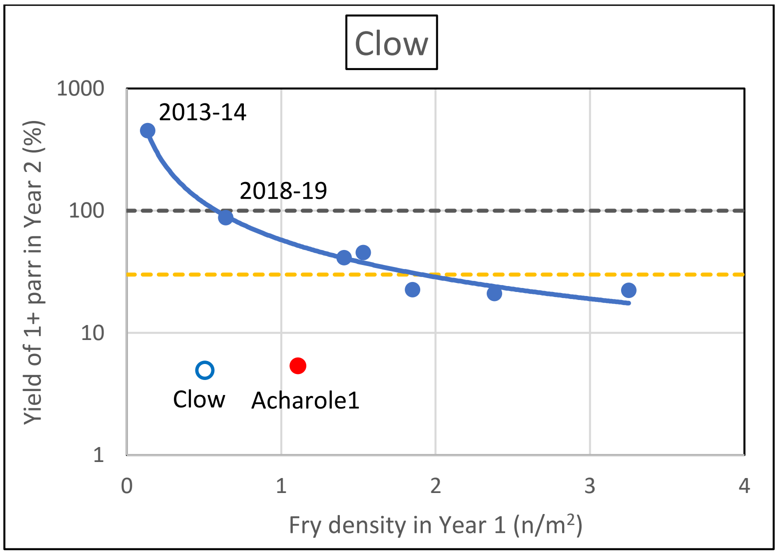
Both the fry (av. 71mm) and the 1+ parr (av. 110mm) were much larger than previously due to low levels of competition. Even so, the total biomass value was only 0.7 g/m^2, by far the lowest value recorded to date.

In past years, low fry densities at Clow were associated with the drought summers of 2013, 2018 and 2020. (2019 was also a drought year but the drought broke and stream flow was restored in late summer before the Board's electric-fishing survey took place). 2021 was another drought year. So, at first sight, the low density of fry in 2021 might once again be attributed to the effect of low water impeding fry recruitment from areas higher in the stream. If so, the shortfall in fry recruitment may already have resolved itself – as has happened before - with the advent of the autumn rains. Yet, this may not be the case given the relatively poor status of fry at Achrole1 just upstream of Clow. The true position will become clear when the 2022 survey is carried out and the density of 1+ parr becomes known.

Even if the fry shortfall at Clow proves to be temporary, another major issue related to the low numbers of 1+ parr still remains to be explained.

As above, Clow appears to be an unusual site in that drought conditions noticeably hamper the timely recruitment of the fry which go on to become the 1+ parr of the next year. This was most clearly evident in 2013-14 when a fry density of only 0.14/m^2 generated 1+ parr at 0.61/m^2. Since parr numbers were greater than fry numbers the Clow site was obviously in net receipt of fry (or post-fry) over the period that elapsed between the 2013 and 2014 surveys. The situation was similar, but not so extreme, in 2018-19 when a fry density of 0.64/m^2 generated a 1+ parr density of 0.56/m^2.

This pattern was <u>not</u> repeated in 2020-21. Instead, a relatively low (but still substantial) fry density (0.51/m^2) in 2020 was associated with only a tiny crop of 1+ parr (0.03/m^2) in 2021. This anomaly can be examined more closely based on the 9-year run of data that is now available for the Clow site.



The diagram above shows the density of fry in any year (Year 1) for the period 2013-2019, along the horizontal axis. The vertical axis shows the corresponding values for 1+ parr the next year (Year 2), for the matching 2014-2020 sequence.

The parr data are expressed not as density but as “yield” which is the density of 1+ parr in Year 2 divided by the density of fry in Year 1 and multiplied by 100 to give a percentage value. The concept of yield is used to avoid any suggestion that the 1+ parr captured in Year 2 are necessarily the same individuals as those captured as fry in Year 1. Note, also, that the vertical axis on the diagram is compressed (logarithmic) to accommodate the wide range of yield values.

The seven between-year comparisons from 2013 onwards are represented by the blue dots; the equivalent comparison for 2020-21 is represented by the blue circle.

The blue line represents the overall relationship between the seven blue points. The orange broken line represents the average rate of survival from fry to 1+ parr (calculated for the Board’s six key sites over the period 2013-2021) which, as discussed previously, has a value of about 30%.

It can be seen from the diagram that –

1. The blue line represents the distribution of the blue points very precisely.

2. For fry density values above about 1.5/m^2, the blue line is approximately coincident with the broken orange line. This means that the yield of 1+ parr is roughly in line with the expected survival rate from the fry stage to the parr stage. This, in turn, means that net migration into, or out of, Clow between the fry and 1+ parr stages was insubstantial.

3. There is a suggestion from the blue line, however, that the yield tends to be lower than the expected 30% value at the higher values for fry density – if so, this must be due to net out-migration and/ or to higher-than-average mortality rates under these conditions.

3. The yield for two of the points (2013-14 and 2018-19), when fry density was lowest, are near to or above 100% - suggesting higher than average survival and/or net in-migration. Indeed, net inwards migration to the Clow site must have occurred in 2013-14 when the yield exceeded 100%.

Further –

4. The blue circle marked Clow 2020-21 is highly anomalous. The yield of 1+ parr for Clow in 2021 was less than 5% - much less than the 30% value anticipated from the average fry-to-parr survival rate for Caithness (the orange line) and even further short of the value predicted by the blue line. This must mean that fry-to-parr survival rate was (a) much less than average between the 2020 and 2021 surveys and/or (b) that out-migration grossly exceeded in-migration.

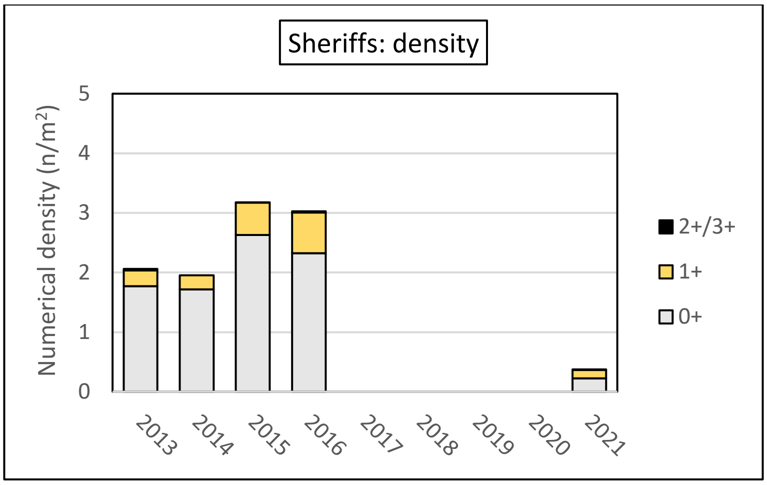
5. The equivalent point for Acharole1 is shown by the red point. As for Clow, the yield of 1+ parr at Acharole1 in 2021 was just 5%.

Additional local information is available for NEPS21 0465 which is about 400m downstream of the Board's site at Clow and for NEPS21 0477 near Shielton farm about 3.5km above Acharole1. Data exist only for 2021 and so it is not possible to calculate yield in either case. However, the density values were very low at NEPS21 0465 (0.14/m^2 for fry and 0.05/m^2 for parr) and also at NEPS21 0477 (0.15/m^2 for fry and 0.02/m^2 for parr). In both cases, the sites' poor status was fully consistent with the depleted populations of young salmon present at Acharole1 and Clow.

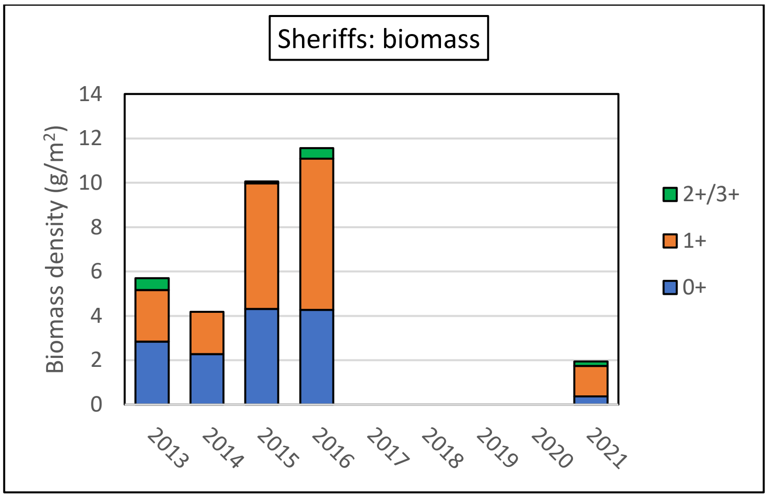
In summary, therefore, between the surveys of October, 2020 and September, 2021 potential 1+ parr either (a) died in unexpectedly large numbers in the vicinity of the Clow and Acharole1 survey sites or (b) left the vicinity of Clow and Acharole1 in unusually large numbers to take up vacant habitat elsewhere.

4.3.3 Sheriffs

The sites at Acharole1 and the Clow lie on the Scouthal Burn, the westernmost of the two main arms of the Wick River above the village of Watten. Because of the poor status of these formerly productive sites, an additional site on the eastern arm of the upper river, the Strath Burn, was surveyed at Sheriffs. Some information for this site is available for previous years.



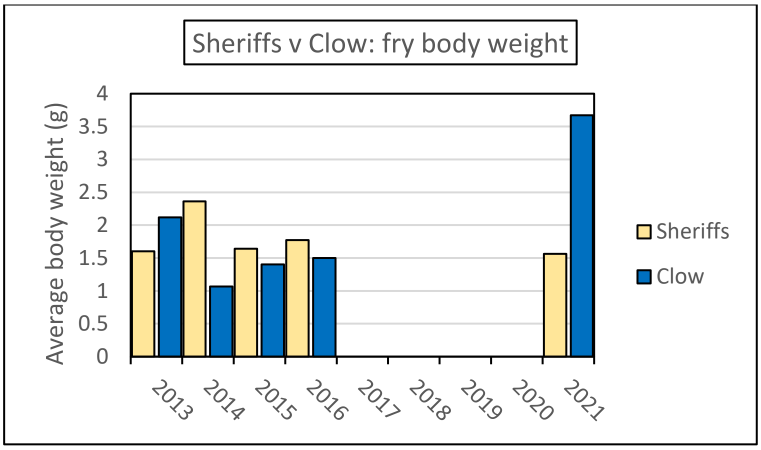
In 2021, the density of fry (0.22/m^2) at Sheriffs was very much lower than previously. The density of 1+ parr (0.14/m^2) was also lower than in any previous year.



Given the low numerical density of fry and parr, it is not surprising that the total biomass density (2g/m^2) was also lower than in previous years.

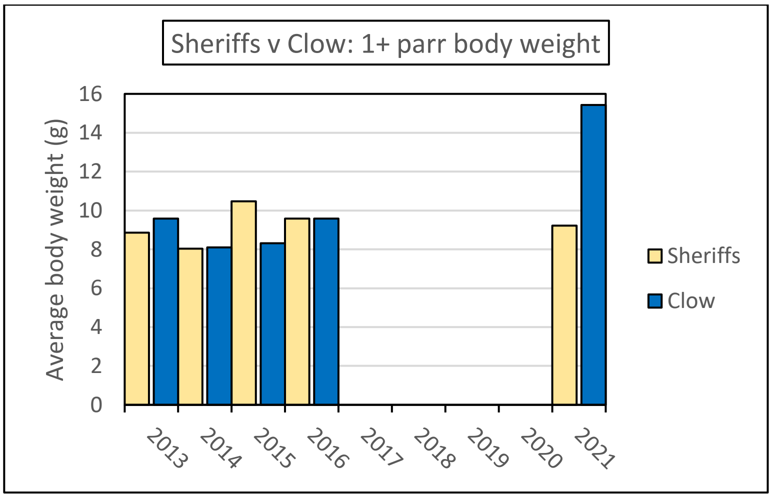
As a general rule, individual fish respond to reduced numerical density, and consequently reduced competition, by increasing their growth rate and becoming larger than would otherwise be the case. Typically, this growth response causes biomass density to be greater than would otherwise be expected. This general rule applied, for example, at Clow and Acharole1 in 2021 - as described above. Similar responses have been noted on a number of occasions elsewhere in the Caithness rivers when similar circumstances have applied. At Sheriffs, however, despite unusually low fish density and reduced levels of competition, the body lengths of both fry (av. 55 mm) and 1+ parr (av. 94 mm) were indistinguishable from the corresponding values for previous years when fish densities had always been much greater.

The diagrams below demonstrate this point by comparing the sizes of fry or 1+ parr at the Sheriffs and Clow sites across years. The values are for estimates of average body weight derived from fish length. Body weight is used to best characterise changes in the fishes' ability to acquire and store energy (ie. body weight) from the food resources available to them locally.



Between 2013 and 2016 when fish densities were consistently high, the average weight of fry at Clow (shown in blue) was around 1.5g at the time of survey in September. However, in 2021, when fish densities were much reduced, the few fry present were able to take advantage of reduced competition to double their average body weight to about 3.5g.

At Sheriffs (shown in yellow) the same general rule did not apply. Although the numbers of fish that were present was very low in 2021, the average weight of fry (1.5g) was not distinguishable from the equivalent values for 2013-2016 when fish densities were much higher.



The patterns evident among the fry were repeated among the 1+ parr. At Clow (shown in blue) average body weight under low levels of competition in 2021 was about 15g - almost double the values achieved in 2013-2016 when competition was more intense.

At Sheriffs (shown in yellow), the body weight of 1+ parr was around 9g in 2021 and indistinguishable from the equivalent values achieved in 2013-2016 under higher levels of competition.

The patterns of density and growth shown by the fry and the 1+ parr at Sheriffs were essentially the same. In both cases, low density (and low competition) in 2021 was not associated with increased growth. Similar patterns were not noted elsewhere in 2021 or in previous annual surveys. The patterns at Sheriffs were therefore anomalous.

The simplest explanation for the anomalously small size of the fry and parr at Sheriffs is that –

1. In the lead up to the survey the densities of fish at Sheriffs were rather greater than those measured on the survey date (11th September).

2. The capacity of the Sheriffs site to support salmon biomass became critically reduced shortly before the survey date - perhaps due to the increasingly severe effects of the drought.

3. At the time of survey, the body size of the few fish remaining at Sheriffs reflected prior rather than current levels of competition and growth.

4. The missing parr had either (a) died or (b) moved out of the Sheriffs site.

Considering all three sites above Watten village - The depleted populations at Sheriffs, Clow and Acharole1 in 2021 may be linked by the toll taken by the developing drought. Perhaps, the varying status (ie. body size) of the individuals comprising the residual populations of fry and 1+ parr at the time of survey reflects differences in the critical dates when the separate stream sites lost the capacity to support their original, higher densities of fish.

As regards the fate of the fish that were demonstrably missing from Acharole1 and Clow and probably also missing from Sheriffs –

1. The fish may have died on-site when the stream could no longer support them.

2. They may have moved away to take up vacant habitat elsewhere in the stream. However, there is no reason to expect that significant amounts of vacant habitat were available in the near-vicinity since all of the Wick catchment was affected by the drought conditions in much the same way.

3. On balance, therefore, it is likely that the missing fish died when their original locations in the stream could no longer support them.

4.3.4 Summary Status of Wick River

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 $2/m^2$, parr densities greater than $0.5/m^2$ have been common and biomass densities often exceeded the $8\text{-}10g/m^2$ 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.

Various factors may have contributed to the shortfalls but it seems likely that the over-riding one was the severe summer drought. The most likely explanation for what was observed is that, ultimately, juvenile salmon were decimated by the effects of low flow and declining water quality. Such an effect has not been evident in previous drought years - on Wick River or elsewhere - but the effects of the 2021 drought on Wick River, in particular, appear to have been unrelenting, extreme and prolonged. It is hoped to pursue this point further when the discharge data from the Tarroull gauging station are made available by SEPA.

Elsewhere in the Wick catchment, sites at Haster (NEPS21 0484) and Achairn (NEPS 0468) on the Haster Burn and a site on the Newton Burn (NEPS 0479) were surveyed as part of the NEPS project. The site at Haster comprises poor habitat for young salmon and the survey results reflected this but the fish populations at Achairn and Newton contained good or satisfactory densities of both fry and parr.

The Newton results were particularly encouraging because judging by informal surveys by WAA in previous years the distribution of young salmon was at best sporadic. The Newton survey of 2021 was followed up by means of an informal survey of an area further upstream at Humster where fry and parr were again shown to be present in reasonable numbers. It should be noted, however, that these populations may not have persisted through the drought because after the surveys were carried out the outlet of Loch Hempriggs which feeds the Newton Burn was cut off by the falling level of the loch. The persistence of the populations that were present at survey in 2021 can be checked by repeat survey in 2022.

In previous years it has been shown repeatedly that productive rivers like the Wick are robust to the effects of a single poor spawning year. Turn-over of young fish is very rapid because of their fast growth rate and almost all the smolts leave the river at two years-of-age. In essence, therefore Wick River supports only two year-classes of juveniles - fry and 1+ parr.

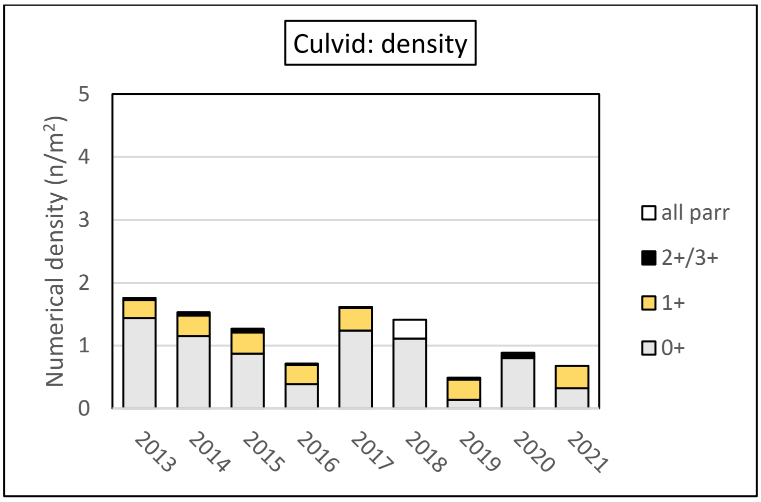
If an adequate or good spawning year follows a poor recruitment year, the space left unoccupied the previous year is filled with an abundance of fry because of the lack of competition from the small year-class of parr running ahead of the new year-class of fry. This reciprocation tends to blunt the effects of a single year of poor fry year spreading the effects over a longer period of time. However, reciprocation cannot compensate for two poor recruitment years in succession. Two consecutive years of poor fry recruitment will result in unutilised or under-utilised habitat, low biomass density and faltering production of juvenile fish.

In 2021, fry recruitment was shown to have been inadequate in the productive upper catchment of Wick River and, in addition, the 1+ parr year-class had been compromised. This scenario already constitutes a couplet of poor recruitment years irrespective of their cause(s). It is therefore imperative for the long-term interests of the river and the fishery that a strong year-class of fry should recruit in 2022.

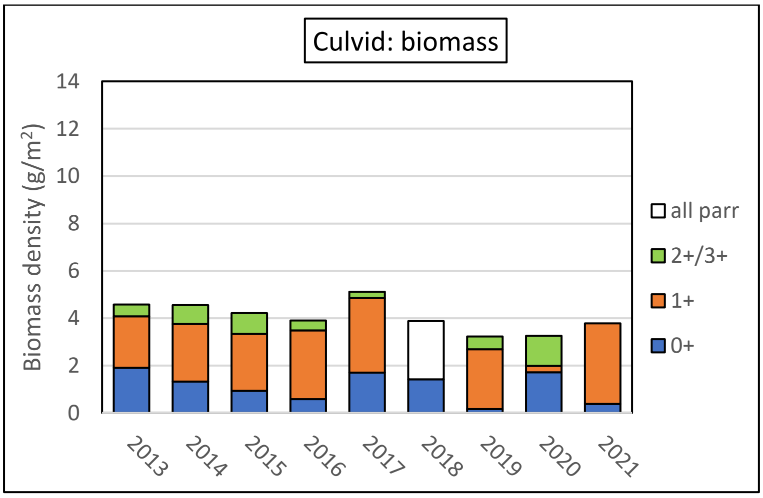
Unfortunately, observation of the river at spawning time in 2021 suggested a dearth of spawning fish – probably also related to the effect of the drought. The actual outcome of the 2021 spawning will become known when the 2022 survey is carried out. However, a sequence of poor smolt-years is already in train for Wick River for 2022 and 2023, and this will have knock-on effects on the fishery (and on spawning) from 2023 onwards. It will be essential to try to break this pattern in 2022 before it sets in and poor fisheries become the norm.

4.4 Dunbeath Water

4.4.1 Culvid



In 2021, fry density was relatively low at 0.32/m^2 and probably insufficient to ensure a full crop of 1+ parr in 2022. However, the density of 1+ parr had been restored to long-term average values in 2021 following on from the poor parr crop of 2020 caused, in turn, by the poor spawning year in 2018 - the notable drought year.



Total biomass density in 2021 was in line with expectation at around 4g/m^2. The events that followed the poor spawning year in 2018 continued to propagate through to 2021 as seen in the reciprocating contributions of the fry and the 1+ parr to the total biomass values in 2019, 2020 and 2021.

4.4.2 Summary status of Dunbeath Water

In 2021, the status of the Culvid site was generally as anticipated. The density of fry was rather low and probably insufficient to ensure a full crop of 1+ parr in 2022.

Surveillance of Dunbeath Water at spawning time in 2021 indicated a dearth of potential spawners due - once again - to the drought conditions that prevailed throughout the summer. The exact outcome of the 2021 spawning will become known when the site is surveyed again in 2022.

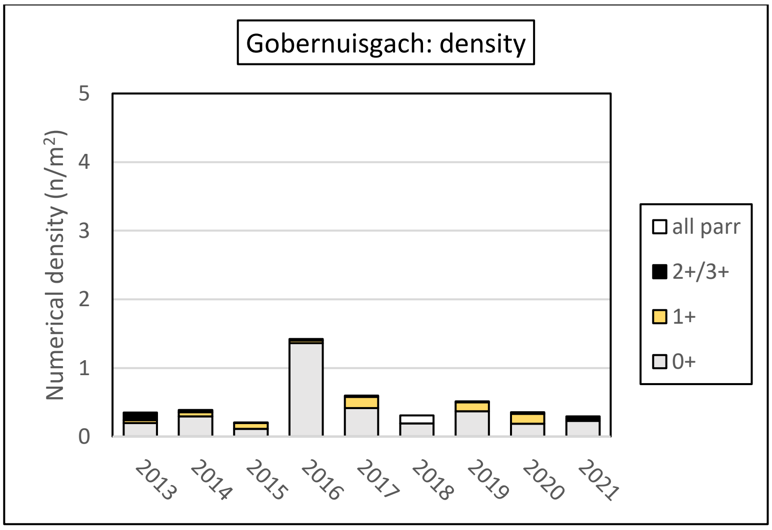
Even now, however, it seems likely that the pattern of the events that started with the poor spawning in 2018 and was still evident in 2021 will start to be replicated again from 2022 onwards.

If this is so, a weak year class of fry in 2022 will be followed by another weak crop of 1+ parr in 2023. But, if spawning in 2022 is sufficient, a bumper year class of fry will result in 2023 due to the low levels of competition from the small number of parr travelling ahead of them.

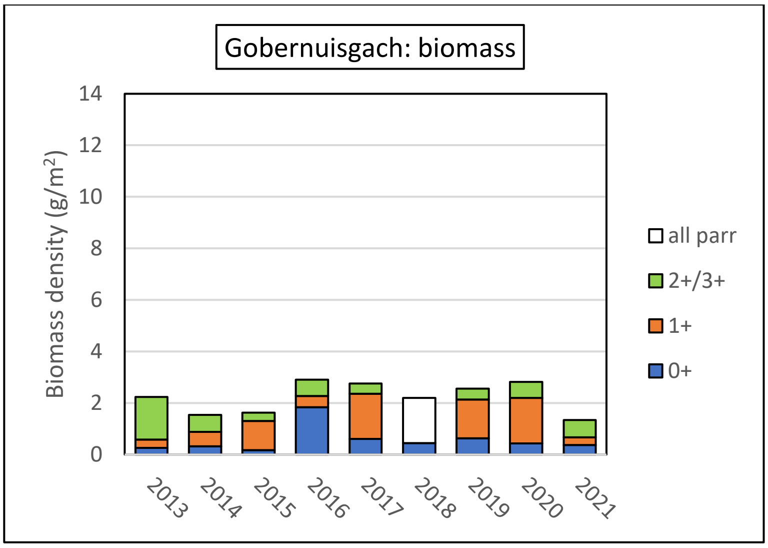
It will be particularly important, therefore, to try to ensure that the 2022 spawning is sufficient to fully replenish the river with eggs.

4.5 Berriedale/ Langwell

4.5.1 Gobernuisgach

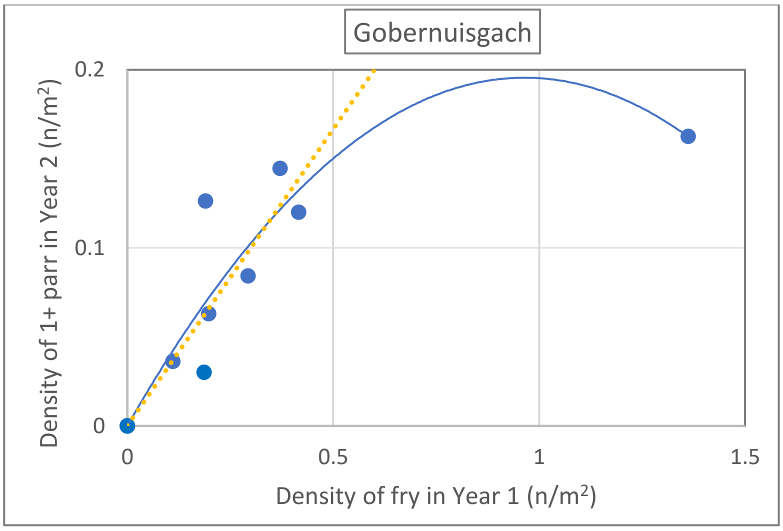


In 2021, fry density at Gobernuisgach was about average for the site at 0.23/m^2. Densities of 1+ parr (0.03/m^2) were among the lowest so far encountered. Older parr were also sparse at 0.04/m^2. It had been hoped that the shortage of fry in 2020 coupled with low levels of competition from a very poor crop of 1+ parr in 2021 would lead to a resurgence in the number of fry but this was not evident.



The body lengths of the fry were about average. The parr were also unremarkable in size although there were too few to generate anything better than an indicative average value. Driven mainly by the low density of 1+ parr, the total biomass density at Gobernuisgach was the lowest observed to date at 1.34g/m^2.

Consideration is being given to relocating the Board's key site on Berriedale River to a site lower in the catchment. The density of fish at Gobernuisgach has always been relatively low and the site may be too peripheral to best capture variation in the river's general status. After nine years of data gathering it is worth taking stock of what is now known about Gobernuisgach by considering the data set as a whole.



The diagram above shows the density of fry each year (Year 1) from 2013 to 2020 plotted against the density of 1+ parr the following year (Year 2) over the matching sequence of data from 2014 to 2021.

A nine-year sequence of data yields eight pair-wise comparisons and these are marked by blue points. The ninth blue point is for the theoretical condition where zero fry in Year 1 are expected to result in zero 1+ parr in Year 2. The blue line represents the overall relationship between fry density in Year 1 and 1+ parr density in Year 2 for all nine points. The orange line represents the relationship to be expected for the average survival rate between the fry and 1+ parr stages for Caithness which is about 30%.

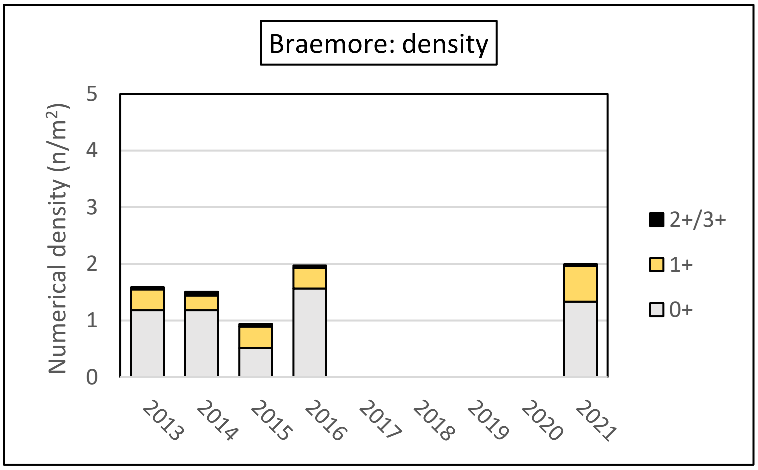
There is no evidence that the site has been saturated with fry in any year other than 2016 when, in the wake of the poor fry year of 2015, an unusually large crop of fry (1.4/m^2) became established. The following year (2017) the density of 1+ parr fry was the greatest of the values observed at 0.16/m^2 which is probably about the upper limit of the capacity of the Gobernuisgach site. This ceiling value is relatively low among all the other sites in Caithness but, at 250m elevation, the upper Berriedale is a high-altitude mountain stream.

Otherwise, it can be seen that fry densities were always less than 0.4/m^2 and none of these values was evidently sufficient to saturate the site with 1+ parr. The distribution of all these points tended to match the orange line quite closely suggesting that survival rates from fry to 1+ parr tended to match the 30% average rate of survival for Caithness as a whole.

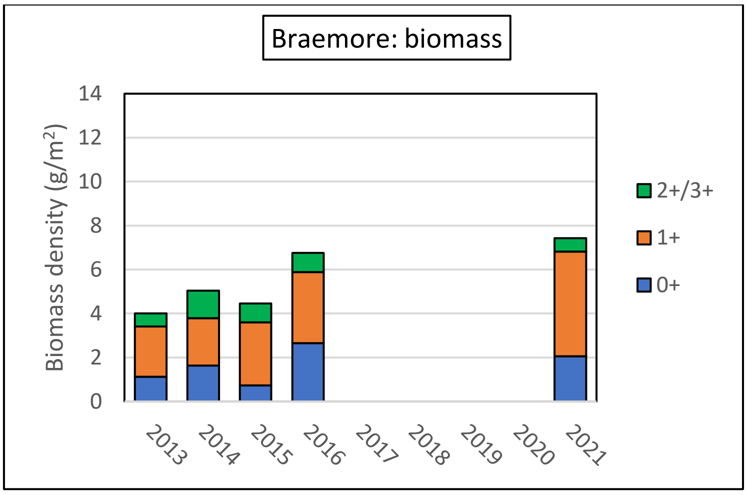
It may now be that the flow of new information from Gobernuisgach is slowing and that the Board will be able to learn more by transferring effort to an alternative key site lower in the Berriedale catchment.

With this in mind, the survey site at Braemore (about 11km downstream of Gobernuisgach) was revisited in 2021 with a view to building up a two- or three-year set of overlapping data in which both sites are surveyed.

4.5.2 Braemore

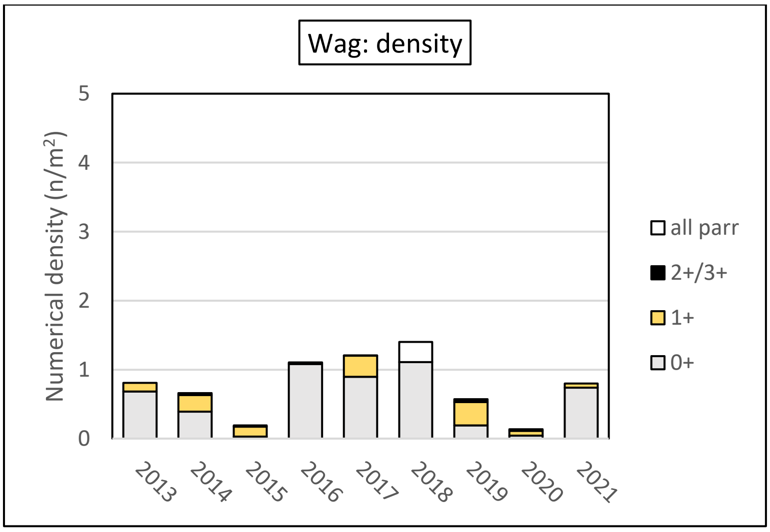


In 2021, fry density at Braemore (1.3/m^2) was about the same as in previous years. The density of 1+ parr was 0.63/m^2 and greater than any of the equivalent values for 2013 -16. Older parr were sparse.

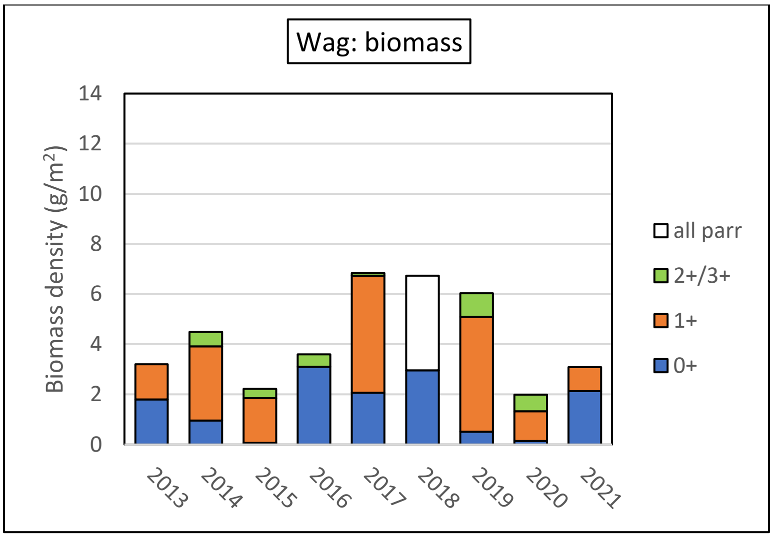


The total biomass density was 7.4g/m^2, the greatest value encountered to date, with a well-balanced contribution from all the individual year-classes.

4.5.3 Wag

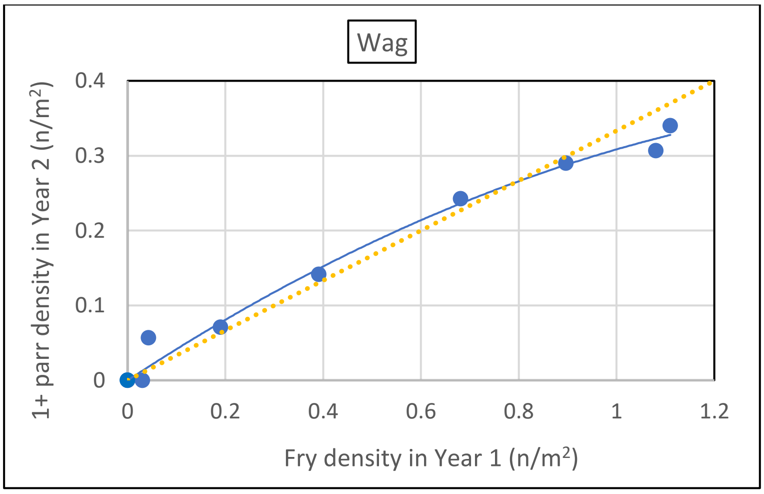


Fry densities at Wag on Langwell Water rebounded in 2021 (0.74/m^2) following the poor crop of fry in 2020 and consequently weak competition from the small year-class of 1+ parr (0.06/m^2) that was present in 2021. This particular pattern is similar to a previous sequence played out in 2015-16 under similar conditions. Older parr were absent.



Because of their low density the 1+ parr made the smallest contribution to total biomass density since the similarly anomalous year in 2016. Total biomass density was 3.1g/m^2 – about average for the site.

As for Gobernuisgach on Berriedale, consideration is being given to relocating from the key site at Wag which is located towards the periphery of the Langwell catchment to another location further downstream. Again, therefore, it is instructive to consider what has been discovered about the Wag site after nine years of survey.



The diagram above shows the density of fry in Year 1 plotted against the density of 1+ parr in Year 2 for all the nine years from 2013 to 2021. Eight pairwise comparisons are possible from a continuous nine-year sequence of data. The additional ninth point is for the theoretical condition in which zero fry in Year 1 are expected to generate zero 1+ parr in Year 2.

All nine points are marked in blue and the blue line is derived from the points to best represent the overall relationship between fry density and the resulting density of 1+ parr. The broken orange line represents the relationship expected from a survival rate from fry to 1+ parr of 30% – the average survival rate for all the key sites in Caithness over all the years since 2013.

It can be seen that the blue and orange lines are essential coincident with, perhaps, some indication of divergence between the lines at fry densities in excess of 1/m^2. It is possible that this divergence represents a ceiling on the site's capacity to support 1+ parr at around $0.3/m^2$. Although the evidence for this is not compelling it is unrealistic to expect that the true ceiling value is much above the $0.3/m^2$ figure. This value would, for example, place the Wag site and the Rumsdale site on Thurso River (see Section 4.2.1, above) in the same general category. However, while the Rumsdale site was saturated with fry and therefore 1+ parr in most of the years since survey work began, fry density at Wag failed to reach saturation level in most years.

There is no indication of substantial net in-migration or out-migration between the fry and parr stages at Wag. In particular, compared with the comparable site at Gobernuisgach on Berriedale Water (see Section 4.5.1) there is little evidence of in-migration or out-migration between the fry and 1+ parr stages and, equally, little evidence that the average Caithness survival rate of 30% does not apply uniformly among years. The status of the Wag site probably therefore closely reflects the status of the wider area of stream the same year and in the same general vicinity.

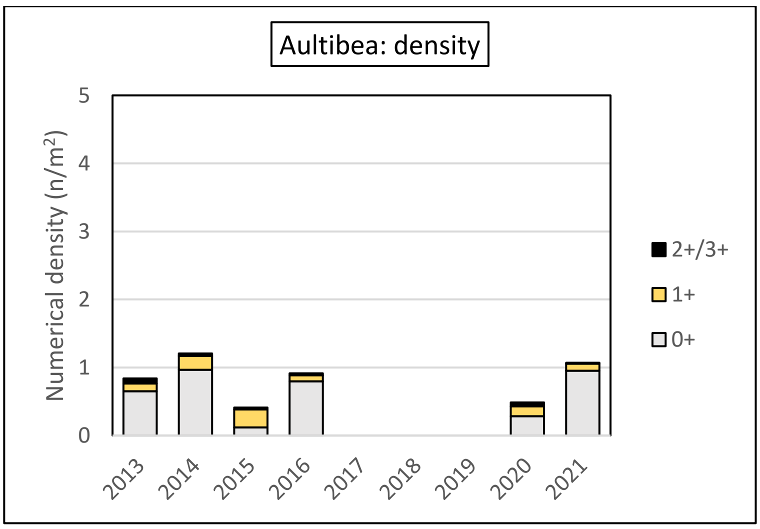
Unusually for Caithness, Wag was deficient, or very deficient, in fry for most of the years in the data sequence and this was also the case for the analogous site at Gobernuisgach high in the Berriedale catchment.

Indeed, Wag and Gobernuisgach are the two highest elevation sites in the Caithness set at 190m and 250m, respectively, although these elevations are not extreme for salmon streams when considered in the wider Scottish context. There are no impediments to access by adult spawners to either site. Both sites are located on substantial streams (8 or 9m in width) and in both cases long reaches of viable salmon habitat lie upstream. Individual fry and parr grow relatively well at both sites (Figures 4 and 5, above) and especially at Wag suggesting that habitat quality is not limiting on individual performance or on overall juvenile production.

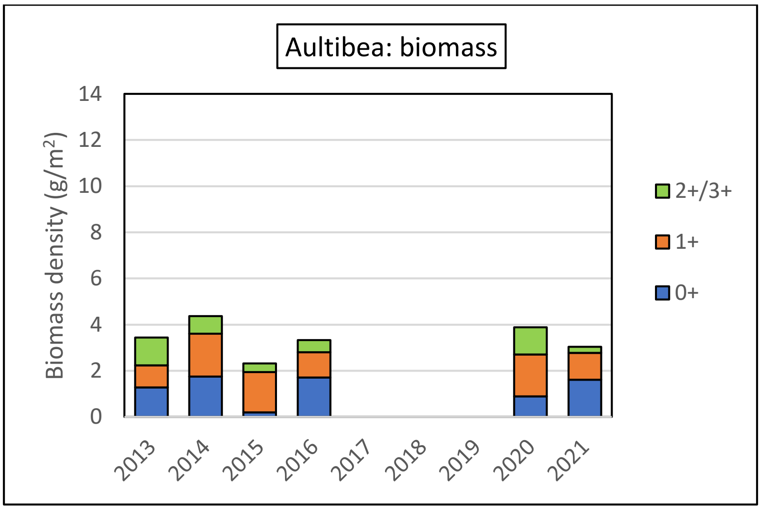
Presumably, therefore, recruitment at Wag (and at Gobernuisgach) must be constrained by egg deposition or by egg-to-fry mortality rates. If so, the Board's juvenile monitoring programme cannot resolve these issues.

Therefore, having thoroughly characterised the key site at Wag, the Board's interests would probably be best served by moving its future focus to the site at Aultibea about 5km downstream.

4.5.4 Aultibea



In 2021, fry density at Aultibea (0.95/m^2) recovered following the poor crop of fry in 2020 (0.28/m^2) repeating the pattern previously evident in 2015-16. As expected, the density of 1+ parr in 2021 was relatively low (0.10/m^2) as a result of the same poor fry year.



Total biomass density at Aultibea in 2021 was about average for the site at 3.0g/m^2. This value was less in 2021 than in 2020 partly because of the small number of older, larger parr that were present but also because although fry were more numerous in 2021 they were also much smaller. The mean length of fry in 2020 was 68mm (equivalent to 3.2g) but only 56mm (equivalent to 1.7g) in 2021.

4.6.3 Summary status of Berriedale/ Langwell

In 2021, the status of fry at the Board's key site at Gobernuisgach on Berriedale Water was roughly as expected based on past years but the status of parr was relatively poor.

Further downstream at the Braemore site fish densities were much greater than at Gobernuisgach. Indeed, the overall status of the Braemore site was better in 2021 than in any previous year – with a good density of fry, an excellent density of parr and a high total biomass density.

Additionally, a single NEPS site was surveyed at Corrichoich, (NEPS21 0470) about midway between Gobernuisgach and Braemore. The site was fished by single-pass only giving 1-pass densities of 0.46/m^2 for fry and 0.36/m^2 for parr, rather similar to the equivalent values at Braemore (0.41 and 0,45/m^2 respectively) and very different from the equivalent values at Gobernuisgach (0.13 and 0.05/m^2, respectively).

Langwell Water was in good condition in 2021, and much more robust than in 2020, due to the recovery of fry densities to better-than-average values at both Wag and Aultibea. In addition, the NEPS21 0486 site about 300m upstream from the Board's site at Aultibea was surveyed by 3-pass fishing. Fry density was 0.73/m^2 and the density of 1+ parr was 0.16/m^2, values which are very similar to those at the Board's site. The improvement in fry density in 2021 ought to ensure that a good crop of 1+ parr will follow in 2022 to follow on from the rather weak parr crop that was present in 2021.

However, surveillance of Berriedale/ Langwell over the summer of 2021 showed substantial mortality among potential spawners in the lower river due to disease. Once again, it is very likely that this was due to the continuous low water caused by the summer drought and the close confinement of large numbers of fish crowded into the lower river and unable to make progress upstream. As a result of the losses, it is likely that spawning in 2021 will have been sub-optimal. The extent of any shortfall will become evident at the time of the 2022 survey.

If spawning was indeed insufficient, and given relatively sound status of Berriedale/ Langwell in 2021, it should be noted that a good spawning in autumn, 2022 will quickly restore the river's juvenile population to its usual condition. Indeed, a similar scenario can be seen to have played out previously when poor fry recruitment in 2015 at Gobernuisgach, Braemore, Wag and Aultibea was succeeded by an unusually large crop of fry in 2016.

Therefore, although the available options for additional management of Berriedale/ Langwell are very limited, every effort should be made to try to ensure that a good spawning does take place in 2022.

5. Conclusions

Salmon populations in all the Caithness rivers have been affected to different extents and in various ways by the series of summer droughts that has occurred since 2018. Significantly, only the Thurso River – the largest river in Caithness - has remained unscathed although it too has been affected at times.

All the Caithness rivers are spate rivers – that is, they show relatively low levels of baseflow and a characteristically direct and transitory response to rainfall. Spate rivers belong to a spectrum of types. The range of types depends partly on catchment size - the larger catchments extend further into the interior of Caithness where rainfall is higher - and partly on the volume of baseflow derived from groundwater held back in fractured bedrock, soils and peatlands. Baseflow drives river flow when rainfall is lacking but eventually falls away as groundwater reserves become depleted.

The dams at Loch More and at Shurrery partially protect the lower reaches of the Thurso and the Forss, respectively, from the effects of low baseflow by storing rainfall when run-off is high and discharging the stored water slowly over a longer period of time. However, there are no dams on the Wick, Dunbeath, Berriedale or Langwell and consequently these rivers are fully exposed to all the highs and lows of their natural hydrological regimes.

When groundwater becomes depleted, it takes a surprisingly long time (many months) for full recharge to occur once normal patterns of rainfall return. For example, the prolonged summer drought of 2018 was the partial cause of the low river levels associated with the early summer drought in 2019. Groundwater had still not been fully replenished by this time - despite the winter rains – and baseflow was still low. Because of this, the rivers fell away very rapidly when another period of low rainfall set in from springtime onwards.

Drought and low river flow causes problems for adult fish and for juvenile populations, too.

1. Adult fish that reach river mouths but are baulked from moving further by low water sometimes fail to enter their rivers in the expected numbers when rainfall and high river flows do eventually arrive. The fate of the missing fish is unknown but it must include either (a) high rates of mortality during the fishes' extended wait in coastal waters (predation is a candidate cause) or (b) eventual re-

location to run and spawn unnoticed in other rivers. The Dunbeath River showed very clear examples of this phenomenon in 2018 and 2021. Adult spawners were notably very scarce following the prolonged drought in these years although potential spawners had earlier been present at the river mouth.

2. Disease and mortality have occurred among potential spawners constrained in the lower reaches of some drought-affected rivers. For example, since 2019 the Forss has been beset in every year by high rates of mortality among adult fish in the lower river associated with dense infections of *Saprolegnia* fungus. As a result, a sequence of three poor spawning years has impacted heavily on the juvenile salmon population.

Berriedale/Langwell was similarly affected by disease in 2021 and the resulting loss of potential spawners will probably have a knock-on effect on the density of fry in 2022.

Despite extensive investigations by the Fish Health Inspectorate and others, the cause of the disease is still not known. It has not been possibly to pinpoint a viral or bacterial agent. It is possible, therefore, that the fish losses are directly attributable to *Saprolegnia* – which is always present in fresh water - propagated among stressed fish crowded together in low flows of unusually warm water of deteriorating quality.

3. The electric fishing surveys show that losses of potential spawners due the direct or indirect effects of drought have had knock-on effects on juvenile populations, most directly evident as shortages of fry.

This was the case for Dunbeath River in 2018-19, for example, when the residual run of adults was small as a consequence of the prolonged period of low river flow in 2018 and the density of fry in 2019 was exceptionally low. This pattern will probably be repeated in 2021-22.

In the River Forss, on-going mortality among adults due to disease has resulted in a step-change in juvenile populations from very high to very low values. This state of affairs will probably continue into 2022.

4. Drought conditions have direct effects on the juveniles themselves.

In some cases, the effects may be unexpectedly positive. For example, the juvenile population at Rumsdale on the upper River Thurso was at its highest recorded level in 2018 towards the end of the drought that year. In the months before the survey was carried out, stream temperature at Rumsdale had regularly exceeded 20^{o}C and, on occasion, 25^{o}C – values that are far outside the range preferred by salmon.

Ultimately, however, high temperatures and low river flow will prove harmful for salmon. This was evident from the inadvertent experiment carried out at Shurrery Dam during the 2018 drought. The dam provides compensation flow to the river but when this was interrupted the Board's survey data show that a large proportion of the juvenile salmon in the lower river died.

In 2021, as described above, the Board's electric-fishing surveys in the upper part of the Wick River catchment identified what is probably the first case of outright mortality to be detected among juvenile salmon that is attributable to the direct effects of drought.

It is evident from the Board's electric-fishing surveys and from surveillance of the fisheries that many of the Caithness rivers have been adversely affected in a range of different ways by the series of droughts that started in 2018 and that by 2021 the continuing good status of juvenile populations in the smaller rivers was in question. The effects of problems that are already in train will extend into 2022. From a management point of view, none of the problems described above can be directly addressed.

The electric-fishing data have shown repeatedly that the effects of a single poor spawning year on juvenile recruitment can be absorbed because of compensation among year-classes. In essence, when a poor fry-year is followed by a good fry-year, young fish recruit particularly strongly because they are subject to only weak competition from the low density of fish running a year ahead of them. The effects of the original shortfall are therefore partially mitigated and, by the time the adults return either as grilse (1SW) or 2SW salmon, any residual shortfall in juvenile production has been spread over two years.

However, compensation is an effective buffer for only a single year. Most smolts leave the Caithness rivers do so as two-year-olds. So, if two poor year-classes follow one another in succession stream habitat vacated by smolts will not be fully occupied, the losses to average annual smolt production will become more tangible and the resulting deficits will become more noticeable at the adult stage.

Surveillance of the rivers suggested that spawning in 2021 will have been sub-optimal in Forss, Wick, Dunbeath and Berriedale/ Langwell for various reasons that are all attributable to drought. Thurso River is not affected in this way.

In 2021, juvenile populations in Dunbeath and Berriedale/ Langwell were sufficient to absorb the effects of poor spawning in 2021 but – as described above - only if a good spawning follows in 2022.

The 2021 survey data suggest that Wick River supported two weak year-classes (fry and 1+ parr) in 2021. If this is the case, a good spawning in 2022 will not compensate fully for losses of juvenile production that are already in train but it will stop the development of an unfavourable trend.

Forss has experienced a succession of poor years for juvenile production and a good spawning in 2022 will be essential to kick-start the river's recovery.

Therefore, the most pressing priority for all the Caithness rivers with the exception of Thurso River is the same - to try to ensure that spawning populations are good or excellent in autumn 2022 even if this means sacrificing the short-term interests of the fisheries.

6. Acknowledgements

Thanks are due to Jamie McCarthy, Ben Falconer, Neil Groat, John Mackay, Gordon Warren and Jamie Coughlin who all took part in the Board's survey programme at various times.

7. Appendices

7.1 Table 1

Table 1. Site details for each of the 30 NEP21 sites.

NEPS21 Code	Date	Catchment	Location	Passes	OS start position	Channel area (m2) surveyed
0471	1 Aug	Forss	Broubster	1	ND 03603 59319	127
0483	7 Aug	Forss	Lythmore	3	ND 04551 66719	144
0451	7 Aug	Forss	Lythmore	1	ND 04424 67223	137
0459	8 Aug	Forss	Westfield	3	ND 05694 63942	140
0475	8 Aug	Forss	Lythmore	3	ND 05183 65124	130
0485	19 Aug	Forss	Shurrery	1	ND 03950 58388	145
0453	31 Aug	Forss	Torran	3	ND 05595 53049	137
0491	11 Sep	Forss	Forsie	1	ND 04654 63521	220
0455	7 Jul	Thurso	Gerston	1	ND 11436 59562	100
0464	8 Jul	Thurso	Achlachan	3	ND 13166 52836	130
0462	10 Jul	Thurso	Rumsdale	1	NC 96330 39882	116
0474	10 Jul	Thurso	Rumsdale	1	NC 95480 41060	85
0478	10 Jul	Thurso	Altnabreac	1	NC 99756 45044	128
0480	11 Jul	Thurso	Braehour	1	ND 07593 51474	56
0457	18 Jul	Thurso	Shinval	3	ND 16955 45256	137
0460	28 Jul	Thurso	Backlass	1	ND 07389 43202	149
0476	31 Jul	Thurso	Ganeimh	3	ND 03957 44483	137
0490	9 Sep	Thurso	Dalnawillan	1	ND 04654 63521	89
0473	12 Jul	Wick	Lynegar	1	ND 22407 58520	44
0479	13 Jul	Wick	Newton	1	ND 35247 50343	92
0461	15 Jul	Wick	Quoynee	1	ND 21021 58678	181
0463	23 Jul	Wick	Thrumster	1	ND 33110 49955	61
0468	25 Jul	Wick	Achairn	3	ND 30048 50016	119
0484	11 Aug	Wick	Haster	1	ND 32420 51909	102
0477	12 Aug	Wick	Shielton	3	ND 20843 50810	165
0465	16 Aug	Wick	Clow	3	ND 23437 52584	156
0456	17 Jul	Dunbeath	Pollroy	1	ND 05512 34179	119
0454	17 Jul	Dunbeath	Pollroy	3	ND 07042 33406	113
0470	5 Sep	Berriedale	Corrichoich	1	ND 03897 30208	117
0486	2 Sep	Langwell	Aultibea	3	ND 04612 23558	159

7.2 Table 2

Table 2. Fry and parr densities at each of the 30 NEPS sites. The values are those observed for one-pass fishing.

NEPS21 Code	Catchment	Location	Passes	1-pass fry density	1-pass parr density
0471	Forss	Broubster	1	0.25	0.23
0483	Forss	Lythmore	3	0.01	0.04
0451	Forss	Lythmore	1	0.01	0.03
0459	Forss	Westfield	3	0.20	0.12
0475	Forss	Lythmore	3	0.17	0.18
0485	Forss	Shurrery	1	0.19	0.15
0453	Forss	Torran	3	0.36	0.07
0491	Forss	Forsie	1	0.02	0.06
0455	Thurso	Gerston	1	zero	zero
0464	Thurso	Achlachan	3	1.54	0.05
0462	Thurso	Rumsdale	1	zero	0.23
0474	Thurso	Rumsdale	1	0.02	zero
0478	Thurso	Altnabreac	1	zero	zero
0480	Thurso	Braehour	1	zero	zero
0457	Thurso	Shinval	3	0.26	0.05
0460	Thurso	Backlass	1	0.27	0.07
0476	Thurso	Ganeimh	3	1.48	0.16
0490	Thurso	Dalnawillan	1	zero	zero
0473	Wick	Lynegar	1	zero	zero
0479	Wick	Newton	1	0.52	0.12
0461	Wick	Quoynee	1	zero	zero
0463	Wick	Thrumster	1	zero	zero
0468	Wick	Achairn	3	0.83	0.11
0484	Wick	Haster	1	0.10	zero
0477	Wick	Shielton	3	0.10	0.02
0465	Wick	Clow	3	0.12	0.05
0456	Dunbeath	Pollroy	1	0.08	0.03
0454	Dunbeath	Pollroy	3	0.25	0.12
0470	Berriedale	Corrichoich	1	0.46	0.36
0486	Langwell	Aultibea	3	0.63	0.07

7.3 Table 3

Table 3. *Table 1. Site details for each of the 18 Board sites.*

Catchment	**Location**	**Date**	**OS Coordinates**	**Channel area (m^2)**
Forss	Cnoc-glas	31 Aug	ND 03391 51810	193
	Shurrery	30 Aug	ND 03915 57811	90
	Lythmore	30 Aug	ND 04629 66338	184
Thurso	Rumsdale	28 Aug	ND 14265 49007	182
	Pipe Bridge	21 Aug	ND 14265 49007	173
	Rangag	29 Aug	ND 16869 43375	82
	Tacher	29 Aug	ND 17008 46917	131
	Inshag	28 Aug	ND 14591 48765	111
	Tulach Mor	21 Aug	ND 14792 49392	172
	Poll Chreagain	27 Aug	ND 13084 51445	134
Wick	Acharole1	1 Sep	ND 23210 51752	134
	Clow	1 Sep	ND 23246 52307	160
	Sheriffs	11 Sep	ND 24583 52234	170
Dunbeath	Culvid	2 Sep	ND 12537 32407	215
Berriedale	Gobernuisgach	2 Sep	NC 98416 31240	166
	Braemore	3 Sep	ND 07294 30413	156
Langwell	Wag	4 Sep	ND 01604 25974	212
	Aultibea	4 Sep	ND 04807 23354	241

7.4 Table 4

Table 4. Table 1. Fry and parr densities observed at each of the Board Sites on the first pass, only, of 3-pass fishing.

Catchment	Location	1-pass fry density	1-pass parr density
Forss	Cnoc-glas	0.17	0.03
	Shurrery	0.04	0.24
	Lythmore	0.03	0.03
Thurso	Rumsdale	0.48	0.22
	Pipe Bridge	0.72	0.16
	Rangag	2.12	0.10
	Tacher	0.79	0.37
	Inshag	0.64	0.32
	Tulach Mor	1.20	0.19
	Poll Chreagain	1.06	0.17
Wick	Acharole1	0.43	0.10
	Clow	0.08	0.03
	Sheriffs	0.18	0.14
Dunbeath	Culvid	0.13	0.23
Berriedale	Gobernuisgach	0.13	0.05
	Braemore	0.41	0.45
Langwell	Wag	0.42	0.03
	Aultibea	0.59	0.09

7.5 Table 8

Table 8. Fry and parr densities at each of the 12 NEPS sites that were surveyed by quantitative 3-pass fishing.

NEPS21 Code	Catchment	Location	Passes	3-pass fry density (with Zippin correction)	3-pass parr density (with Zippin correction)
0483	Forss	Lythmore	3	0.03	0.07
0459	Forss	Westfield	3	0.35	0.26
0475	Forss	Lythmore	3	0.30	0.24
0453	Forss	Torran	3	0.69	0.07
0464	Thurso	Achlachan	3	2.22	0.06
0457	Thurso	Shinval	3	0.41	0.08
0476	Thurso	Ganeimh	3	2.12	0.23
0468	Wick	Achairn	3	1.39	0.14
0477	Wick	Shielton	3	0.15	0.02
0465	Wick	Clow	3	0.14	0.05
0454	Dunbeath	Pollroy	3	0.36	0.20
0486	Langwell	Aultibea	3	0.73	0.16

7.6 Table 9

Table 9. Numerical and biomass densities for trout.

		Numerical density (n/m^2)	Biomass density (g/m^2)	Numerical density (n/m^2)
Catchment	**Location**	**Fry**	**Fry**	**Parr**
Forss	Cnoc-glas	0.67	2.48	0.03
	Shurrery	0.13	0.58	zero
	Lythmore	0.20	1.57	0.02
Thurso	Rumsdale	0.12	0.43	0.05
	Pipe Bridge	zero	zero	zero
	Rangag	0.32	0.41	zero
	Tacher	0.02	0.03	0.06
	Inshag	zero	zero	0.05
	Tulach More	zero	zero	zero
	Poll Chreagain	zero	zero	0.02
Wick	Acharole1	zero	zero	zero
	Clow	zero	zero	zero
	Sheriffs	zero	zero	zero
Dunbeath	Culvid	zero	zero	zero
Berriedale	Gobernuisgach	zero	zero	zero
	Braemore	zero	zero	zero
Langwell	Wag	zero	zero	zero
	Aultibea	0.01	0.03	0.03

7.7 Annual survival rate between fry and 1+ parr stages in Caithness rivers

In this year's report it has proved useful to have a measure of the proportion of fry that survive over the 12 months between electric-fishing surveys to reach the 1+ parr stage. Survival rate probably varies among locations and among years. However, an average measure can be used as a yard-stick to compare density values measured in the field with the values that might be expected and to identify cases that deviate markedly from expectation. Then, from a management point of view, anomalous cases can be given greater scrutiny in attempting to identify causes.

Cunjac and Therrien (1998)[i] have calculated inter-stage survival rates for Atlantic salmon in Catamaran Brook, part of the Miramichi catchment in eastern Canada. Annual values for survival rate from the fry to the 1+ parr stage were calculated for a sequence of six years. Most of the values were in the range 14% to 35% and the average value across all years was 33%.

The Caithness data were checked, as below, to determine whether they are consistent with the values reported for Canada.

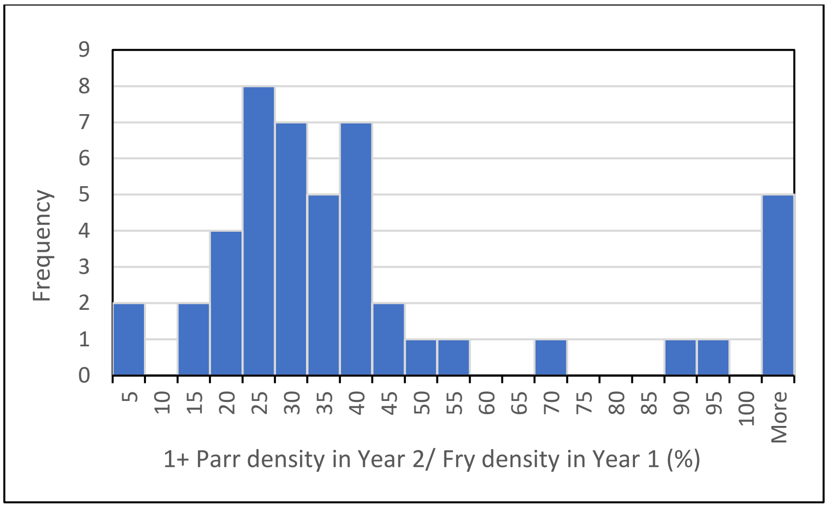
Six key sites in Caithness have been surveyed in exactly the same way every year since 2013. As of 2021, therefore, the densities of fry and 1+ parr are known for nine consecutive years at each site. Eight between-year comparisons of fry and 1+ parr densitities can be derived from a nine year sequence of data. A total of 48 between-year comparisons are therefore possible based on the data available.

In most cases, the densities of 1+ parr at any site are found to be rather lower than the densities of fry the previous year and this is partly due to on-going mortality – from disease, predation, parasitic infection, starvation etc - over the 12 months that elapse between the annual surveys.

Additionally, however, fry can leave any of the key sites to take up residence elsewhere before the 1+ parr stage and there is no way of distinguishing losses due to movement out of the site from losses due to mortality. Equally, fry can move into the key sites from other locations over the same period and any inwards movement will obscure the full extent of losses due to ongoing mortality. Indeed, inwards and outwards movement can occur simultaneously. So, accounting for the effects of fish movement necessitates considering net changes.

Net gains or losses of fish that move to or from any one site must be equally matched by reciprocal losses or gains in other locations. This means that over all locations, the average rate of net inwards and/ or outwards movement ought to be zero.

The figure below shows the frequency distribution of the ratios between 1+ parr density in Year 2 and the density of fry in Year 1 expressed as a percentage value. Six key sites over 9 years potentially generate 48 values but only 47 are plotted; the value for the Shurrery key site in 2018-19 has been omitted since it was affected by mortalities directly resulting from the closure of Shurrery Dam.



The distribution of values shows a symmetrical central block. There are a small number of low outlying values and a larger number of high outliers - some of which exceed 100% (confirming positive rates of net inwards movement).

Assuming that losses due to movement between the fry and 1+ parr stages reciprocate among sites, then the average value for the ratio over all sites ought to approximate the condition where net movement is zero. In this particular case, the value of the ratio between parr and fry densities must identify the average rate of survival between the fry and 1+ parr stages over all the sites and all the years examined.

Returning to the graph, above, the median value for the data set – which is the central value in the set with an equal number of greater values (net inwards movement) above and lesser ones (net outwards movement) below – is found to be 31%.

In other words, based on the assumptions listed, the average survival rate from fry to 1+ parr for the years and sites examined was deduced to be around 31%. This is reassuring close to the 33% average value calculated by Cunjac and Therrien for Catamaran Brook.

Therefore, in the present report, a fry-to-parr survival rate of 30% has been chosen as a general yardstick for guidance in the interpretation of site data for the Caithness rivers.

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[i] R.A. Cunjac and J. Therrien (1998). Inter-stage survival of wild juvenile Atlantic salmon, *Salmo salar* L. Fisheries Management and Ecology 5: 209-223).