2020 Survey of Juvenile Salmonids in Caithness rivers

Caithness District Salmon Fishery Board

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The Smerrary survey site on the mainstem of the River Thurso, showing the positioning of 2 x 15m stop-nets.

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1. Introduction

The evolving Covid epidemic put the 2020 electric-fishing survey in doubt. However, following risk assessment just before work started it was decided to go ahead and the survey was carried out safely and as planned. In all 17 sites were surveyed (Table 1).

Table 1. Survey site details

River Catchment	Site name	Ordnance Survey Coordinates	Status	Channel Area (m^2)	Date of Survey
Forss	Cnoc glas	ND 03391 51810	Previous	193	5/9
	Torran	ND 03773 52090	New	106	5/9
	Shurrery	ND 03915 57811	Key	89.8	29/8
	Lythmore	ND 04629 66338	Previous	184	29/8
Thurso	Rumsdale	NC 96748 40791	Key	182	30/8
	L Beg	ND 08680 46327	New	108	30/8
	Smerrary	ND 12250 48237	Previous	156	31/8
	Rangag	ND 16869 43375	New	82.2	2/9
	Tacher	ND 17008 46917	Previous	131	2/9
	Inshag	ND 14591 48765	Previous	111	12/9
	Poll Chreagain	ND 13092 51434	New	102	12/9
Wick	Acharole1	ND 23210 51752	Previous	134	24/9
	Clow	ND 23246 52307	Key	160	1/9
Dunbeath	Culvid	ND 12537 32407	Key	215	4/9
Berriedale	Gobernuisgach	NC 98416 31240	Key	166	3/9
Langwell	Wag	ND 01604 25974	Key	212	3/9
	Aultibea	ND 04807 23354	Previous	241	4/9

The six key sites that are surveyed every year were examined again. A new site at Torran on the River Forss was added to obtain more extensive information on the upper river above Loch Shurrery. The upper part of the Little River was explored for the first time by surveying a new site at Rangag. Since water levels were unusually low in Thurso River the opportunity was taken to survey a new site on the main river at the run-in to Loch Beag and also to electric-fish the site at Smerrary which has been examined in some previous years. The results of fishing the key sites at Clow on Wick River and at Wag on Langwell Water were checked by surveying previous sites at Acharole1 and at Aultibea, respectively.

Finally, when it became obvious that the Thurso catchment was saturated or nearly saturated with fry the opportunity was taken to survey Inshag, a previous site, and a new site at Poll Chreagain. The intention of these additions was to set up a research sequence to be examined in due course by Liam Godwin of the Environmental Research Institute. Along with the Board, the FCRT part-funds Liam's studies and the survey work at Inshag and Poll Chreagain was funded by the Trust.

There are three background points to note regarding the 2020 report.

A systematic clerical error regarding the Gobernuisgach site on Berriedale Water was identified and corrected. The site is 18.4m in length and it has an average channel width of 9.0m. The site's channel area is therefore 166m^2 as shown in Table 1 and not 131m^2 as indicated in previous reports. The

error does not materially affect the conclusions drawn in previous years but all the site's values for density and biomass density have been corrected in this report.

In previous reports, a colour-coded system was used to examine the densities of fry or parr observed on the first-pass of electric fishing, comparing them with equivalent benchmark data compiled some time ago for the northern rivers by Godfrey (see previous reports). This procedure has been omitted for 2020 because now, after eight years of survey work, the Board can use its own data to set more telling benchmark values for fish numbers and biomass.

In most years, very few trout are captured in the Board's survey sites. Trout parr, including some larger adults, are encountered only infrequently and their occurrence is sporadic. Trout fry are captured only rarely. Substantial populations of trout have sometimes been encountered in very small streams on the periphery of catchments - during the NEPS surveys in 2018 and 2019, for example, or in the course of contract work for windfarm developers. Generally, however, only trivial numbers of trout occur in the Board's survey sites and trout have usually been excluded from previous assessments. In 2020, most of the Board's sites again contained few or no trout. However, unexpectedly large numbers of trout were present at some sites and because of this the status of trout in all the survey sites has been examined in greater detail for 2020 than in previous reports.

2. Methods

All the survey methods were identical to those used previously and as detailed in previous reports.

In brief, a bankside generator was used to power a control box linked to the electrodes. Smoothed DC was used with voltage (180-200V) adjusted according to circumstances. Stop-nets were deployed. Three-pass fishing followed by Zippin correction for efficiency of capture was used throughout. Capture was by an appropriate combination of hand- and banner-nets, according to the depth of the water and the rate of flow. The ages of salmon parr were determined by scale-reading and the age of some large salmon fry was confirmed in the same way.

Electric-fishing sites on the mainstem of the Thurso poses special problems and the cover picture shows how these are overcome. Stop-nets are required in all situations to prevent fish escaping from the survey area during the course of work. On smaller streams twin stop-nets are deployed to span the full width of the stream, defining the top and the bottom of the survey area. In the case of main river sites, however, it is impossible to control nets set like this even when the river flow is relatively low. The problem is exacerbated on productive rivers like the Thurso because the lower stop net tends to quickly block with weed and algae displaced in the course of the work and the usual outcome is that the nets are ripped from their fixings part-way through the survey.

To overcome this, the Board's team joins two 15m nets, fixes one end of the resulting 30m net to the river bank at the upstream end of the survey site and the middle of the net to a stake located in mid-river, leaving the free end of the net to find its own line down the mid-river flow. This set-up defines two of the site boundaries and the stream bank defines a third. Only the lower boundary remains open. Since survey work always progresses upstream from the lower boundary any fish moving ahead of the electrode are prevented from leaving the site by the stop-net arrangement above them or to their side. The cover picture shows all the features of this arrangement. Potentially, two 15m nets can be made to enclose a maximum stream area, top and side, of 225m^2. In practice, however, the enclosed area is always less than this and the actual area is measured precisely once survey work is complete. These are the values that are given in Table 1.

3. Results

4.1 Salmon

Table 2 shows the total numbers of salmon observed at each survey site after the three passes of electric-fishing. Estimates of the true number of fry or parr present were generated by Zippin correction for capture efficiency based on the rate of decline in the observed numbers of fish on each of the three passes. The resulting estimates of the true numbers of fish present were divided by the channel area of the site to provide estimates of the numerical density of each age-class as shown in the last three columns of the table.

Table 2. Numbers of juvenile salmon captured at each survey site and true numerical density by age class.

Salmon										
Site	Area (m^2)	Observed number			True number			**True numerical density (n/m^2)**		
		0+	1+	2+	0+	1+	2+	0+	1+	2+
Cnoc glas	193	20	16	2	21	17	2	**0.11**	**0.09**	**0.01**
Torran	106	14	6	5	14	6	5	**0.13**	**0.06**	**0.05**
Shurrery	89.8	12	10	2	13	10	2	**0.14**	**0.11**	**0.02**
Lythmore	184	75	2	2	76	2	2	**0.41**	**0.01**	**0.01**
Rumsdale	182	238	34	6	254	35	6	**1.40**	**0.19**	**0.03**
L Beg	108	39	3	3	40	3	3	**0.37**	**0.03**	**0.03**
Smerrary	156	552	52	0	583	52	0	**3.74**	**0.33**	**0**
Rangag	82.2	252	8	4	264	8	4	**3.21**	**0.10**	**0.05**
Tacher	131	346	28	2	384	29	2	**2.93**	**0.21**	**0.02**
Inshag	111	163	15	0	176	15	0	**3.05**	**0.14**	**0**
Poll Chreagain	102	224	18	1	233	18	1	**2.31**	**0.18**	**0.01**
Acharole1	134	148	25	2	149	25	2	**1.11**	**0.19**	**0.01**
Clow	160	80	67	2	81	70	2	**0.51**	**0.44**	**0.01**
Culvid	215	165	6	13	172	6	13	**0.80**	**0.03**	**0.06**
Gobernuisgach	166	28	24	4	31	26	4	**0.19**	**0.16**	**0.02**
Wag	212	9	15	5	9	15	5	**0.04**	**0.07**	**0.02**
Aultibea	241	62	36	12	68	39	13	**0.26**	**0.16**	**0.05**

Table 3 shows the average length of fish by age-class for each site. The average body weight of individual fish was estimated from their length using Shackley's formula (see previous reports) and used to derive average values for body weight for each age-class. These values were combined with the numerical density values specified in Table 2 to derive estimates of biomass density for each age-class. These values were summed to derive the total value for each site as shown in the final column of Table 3.

Table 3. Average length of juvenile salmon at each survey site, estimated average weight and biomass density, all by age-class. The total biomass density for all fish at each is indicated in the final column.

Salmon										
Site	Average length (mm)			Estimated average weight (g)			**True biomass density (g/m^2)**			
	0+	1+	2+	0+	1+	2+	0+	1+	2+	**Total**
Cnoc glas	69.8	119	129	3.50	20.3	25.8	0.38	1.68	0.27	**2.33**
Torran	69.1	112	127	3.44	16.2	25.3	0.45	0.92	1.19	**2.56**
Shurrery	73.1	114	141	4.05	17.5	35.1	0.59	1.95	0.78	**3.32**
Lythmore	78.3	127	141	5.23	24.8	35.1	2.16	0.27	0.38	**2.81**
Rumsdale	59.6	98.6	117	2.08	10.9	19.1	2.90	2.04	0.63	**5.57**
L Beg	69.9	118	140	3.54	19.8	34.0	1.31	0.55	0.94	**2.81**
Smerrary	57.7	107	n/a	1.94	14.3	n/a	7.25	4.77	0	**12.0**
Rangag	44.4	104	139	0.81	13.1	34.2	2.60	1.27	1.66	**5.54**
Tacher	48.0	99.5	127	1.05	11.6	24.5	3.08	2.48	0.37	**5.93**
Inshag	55.4	111	n/a	1.65	16.3	n/a	2.62	2.20	0	**4.82**
Poll Chreagain	55.8	102	125	1.69	12.3	23.5	3.86	2.17	0.23	**6.26**
Acharole1	61.2	97.0	119	2.29	10.4	19.8	2.55	1.94	0.30	**4.78**
Clow	64.6	98.4	126	2.70	10.9	23.9	1.37	4.56	0.30	**6.23**
Culvid	59.5	93.3	120	2.14	9.70	21.0	1.71	0.27	1.27	**3.25**
Gobernuisgach	61.6	102	129	2.32	12.2	26.0	0.43	1.76	0.63	**2.82**
Wag	68.9	112	131	3.32	16.8	28.0	0.14	1.19	0.66	**1.99**
Aultibea	67.8	102	122	3.18	12.1	21.8	0.90	1.81	1.18	**3.88**

Table 3 shows that the average body length of salmon fry and salmon parr varied substantially between sites.

Figure 1 shows the values for the average body length of fry for each of the six key Caithness sites and for all survey years, 2013 – 2020. It can be seen from Figure 1 that the fry had grown well in 2020 and were larger than usual at most sites. Notably, fry at the Shurrery site on the River Forss were very large relative to all previous survey years. The average length of Shurrery fry was 73.2 mm in 2020; the previous largest value was 60.8mm in 2013. Due to the nature of the relationship between length and weight, the differences in body length correspond to relatively larger differences in body weight. Shurrery fry, for example, were on average about twice as heavy (4.0g) in 2020 than the maximum value (2.2g) in previous years.

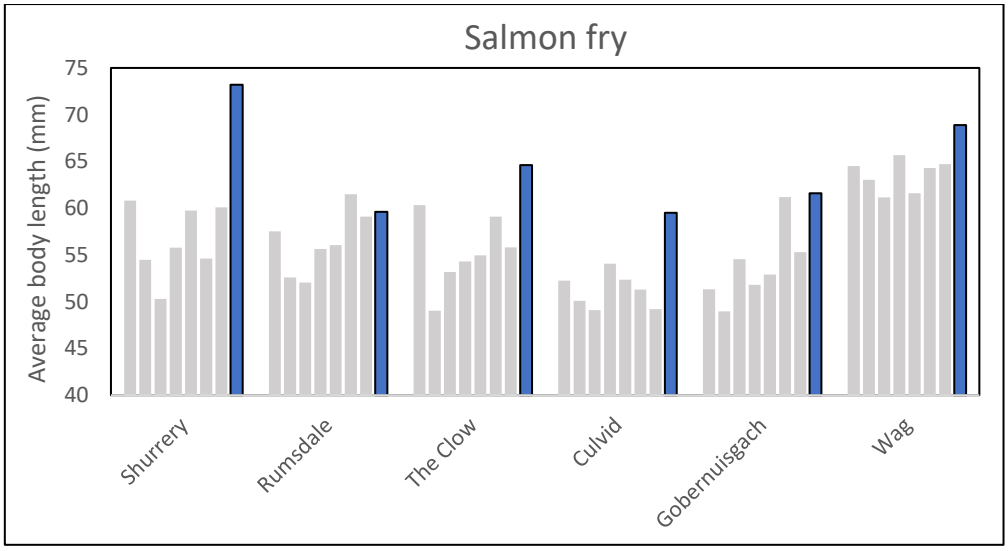


Figure 1. Average body length of salmon fry at each of the six key sites for the years 2013-2020. The values for 2020 are indicated in blue.

Figure 2 shows the equivalent values for 1+ parr. There are missing values for the Culvid, Gobernuisgach and Wag sites for 2018 because scale samples were not obtained due to the extremely high water temperatures that prevailed during the survey that year.

In 2020, the body length of the 1+ parr was greater than or equal to previous values at all six sites but, as for the fry, the average length of 1+ parr at Shurrery was much greater than in previous years. In 2020, the average length of 1+ parr at Shurrery was 114m while the previous greatest value was again for 2013 at 105mm. This difference in length corresponds to a weight difference of around 30%.

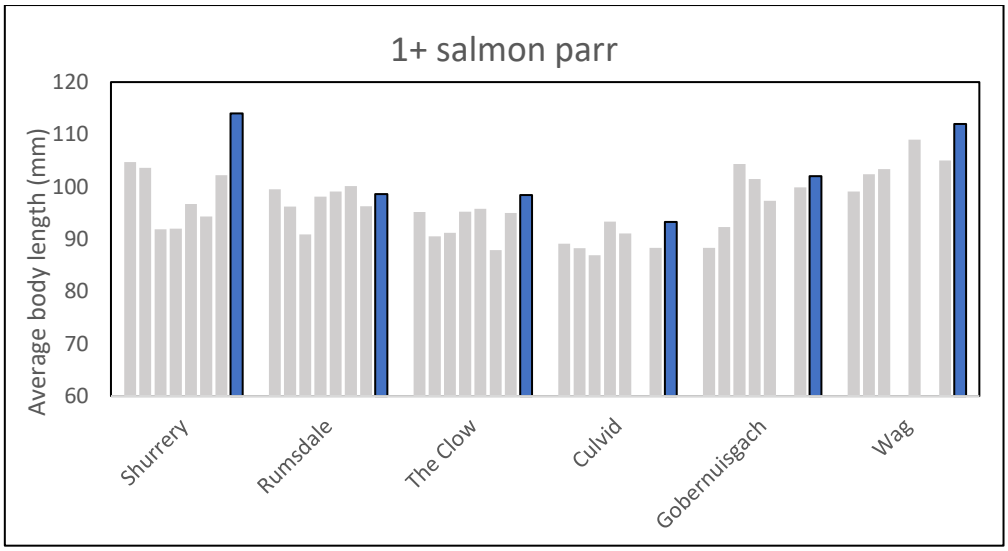


Figure 2. Average body length of 1+ salmon parr at each of the six key sites for years 2013-2020. The values for 2020 are indicated in blue.

4.2 Trout

As noted above, trout have registered only infrequently in previous Board surveys but in 2020 numbers were notably greater than before at all four sites on the River Forss.

The numbers of trout fry and trout parr encountered at all 17 survey sites are shown in Table 4. Three groups are shown – fry, parr equal to or less than 140mm in length and parr greater than 140mm in length. Scale reading was not carried out for the trout but, based on the length distributions, the 140mm cut-off separates 1+ trout from older fish.

Table 4 shows the observed numbers of trout fry and trout parr. It can be seen that trout fry were absent or infrequent at most sites as has been the case in previous years. 1+ Parr and older parr were absent or few in number at all the sites. At most sites, therefore, juvenile trout made only a trivial contribution to stream production.

However, fry were more abundant than expected at five sites including the four sites on the River Forss – Cnoc-glas, Torran, Shurrery and Lythmore – and also the Rumsdale site in the Thurso catchment. The density of fry was substantial at some of these sites, ranging up to 0.79/m^2.

Table 4. The observed number of trout fry, small parr and large parr on 3-pass fishing. Density values are indicated for sites where non-trivial populations (> 0.10/m^2) of trout were present.

Trout							
Observed number				True number		True numerical density (n/m^2)	
Site	Fry	Parr < 140mm	Parr > 140mm	Fry	Parr	Fry	Parr
Cnoc-glas	128	0	0	133	0	**0.69**	**0**
Torran	60	1	1	62	2	**0.58**	**0.02**
Shurrery	9	0	0	9	0	**0.10**	**0**
Lythmore	44	0	0	45	0	**0.24**	**0**
Rumsdale	134	1	2	144	3	**0.79**	**0.02**
L Beg	0	0	4	n/a			
Smerrary	0	0	1	n/a			
Rangag	6	1	1	n/a			
Tacher	0	3	1	n/a			
Inshag	0	3	0	n/a			
Poll Chreagain	0	1	1	n/a			
Acharole1	0	0	0	n/a			
Clow	0	0	0	n/a			
Culvid	0	1	1	n/a			
Gobernuisgach	0	2	4	n/a			
Wag	1	1	1	n/a			
Aultibea	5	0	4	n/a			

Table 5 shows the average lengths of trout fry and, for the five sites where fry were present in non-trivial numbers, estimates are shown for average body weight and biomass density.

Table 5. Average body length, estimated average body weight and biomass density of trout fry at the five survey sites where non-trivial densities (> 0.10/m^2) of trout fry were present.

Trout fry			
Site	Average body length (mm)	Average body weight (g)	True biomass density (g/m^2)
Cnoc glas	77.6	5.04	**3.48**
Torran	69.1	3.44	**2.00**
Shurrery	78.8	5.27	**0.53**
Lythmore	87.4	7.52	**1.80**
Rumsdale	57.6	1.91	**1.51**

4. Interpretation of site data

The background to the 2020 survey was set at spawning time in 2018. Spawning was observed to be generally, and unexpectedly, poor that year - perhaps due in some way with the prolonged drought over the spring and summer. The eggs that were spawned in 2018 hatched in 2019 and the Board's survey in September that year showed that, on average, fry densities were present at about 50% of the expected values. This finding was confirmed by the Marine Scotland Science NEPS survey in the same year which found that fry densities in the Caithness rivers were much lower than they had been in 2018 - the only other NEPS survey year. As a matter of note, sites in the Forss appeared to be particularly hard hit. The four Forss sites that were surveyed both in 2018 and 2019 (Shurrery, Broubster, Westfield and Lythmore1) showed a year-on-year drop in fry densities of between 60% and 90%. Given the shortage of fry in 2019, it was expected that the densities of 1+ parr in 2020 would be lower than usual.

However, spawning reportedly returned to normal levels in 2019 and the fry recruiting in 2020 were expected to do unusually well given the low level of competition from the small year-class of 1+ parr running ahead of them. So, a large year-class of fry was expected for 2020.

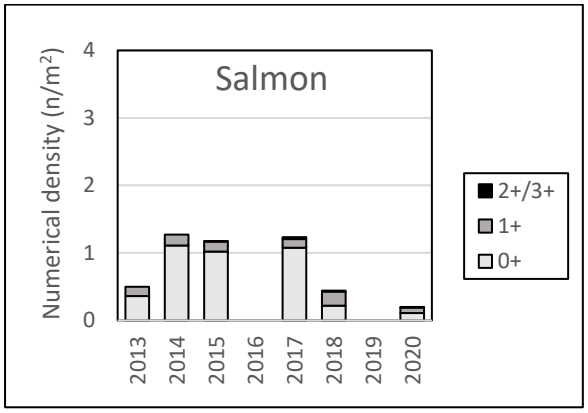
On the Forss, the background in recent years has been rather different from the other Caithness rivers probably due to a documented series of mishaps and the additional effects of Red Skin Disease (RSD); RSD appears to have taken a heavier toll on potential spawners in Forss than in other rivers. Spawning is not monitored in Forss but it was hoped that, as for the other rivers, a stronger than usual year-class of fry in 2020 might help return the river towards its normal condition.

The following section aims to interpret the 2020 survey data in these contexts.

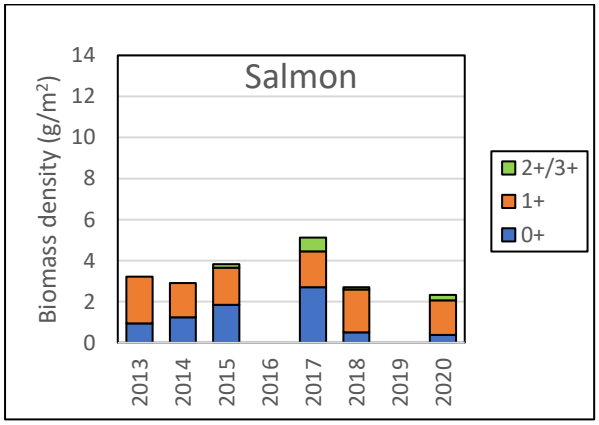
5.1 River Forss

5.1.1 Cnoc-glas

Salmon

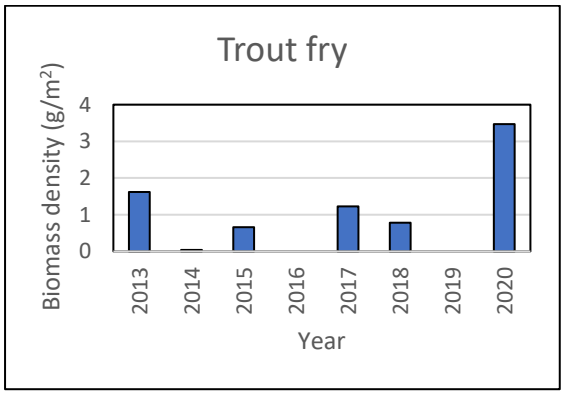


The Cnoc-glas site was not surveyed in 2016 or in 2019. At the last survey in 2018 the density of fry was 0.22/m^2 the lowest value observed to that date - indicating a weak spawning year in 2017. In 2020, the density of fry was even lower at 0.11/m^2 – suggesting another weak spawning year in 2019. The density of 1+ parr was also very low at 0.08/m^2 - the lowest value in any of the six survey years and about 50% of the expected value. Although the density of fry in 2019 is unknown, the low density of 1+ parr in 2020 suggests another weak spawning in 2018. The last three spawnings (2017-19) have probably therefore all been inadequate. In 2020, older parr were few as is usual for the site.



In the past Cnoc-glas has proved capable of supporting salmon biomass densities of ca. 5g/ m^2. In 2020 the total biomass density of salmon (2.32g/ m^2) was lower than values in previous years because of the low numerical densities of both fry and parr. However, both the fry (av = 69.8mm) and the 1+ parr (av = 119mm) were larger than usual - probably because growth was favoured by the low density of fish and correspondingly low levels of competition for space and food. As a consequence, the shortfall in salmon numbers was not fully reflected in the biomass values.

Trout



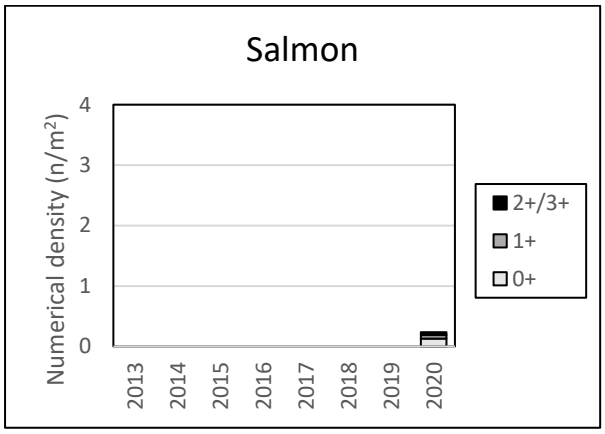
Cnoc-glas is unusual among the Board's survey sites in that trout fry have been a substantial feature in some years. Indeed, in past surveys trout fry have contributed up to 1.6g/m^2 (in 2013) to the site's total biomass density. In 2020, the numerical density and the biomass density of trout fry was much greater than in any previous year at 3.5g/m^2. The total biomass of all salmonids (salmon and trout fry and salmon parr) was 5.80g/m^2 - similar to the highest equivalent value attained previously (6.36g/m^2 in 2017). This suggests that the environmental quality of the site has not been impaired in any way and that the recent changes in the numbers of fish present, their sizes and the species' mix is due to changes in patterns of recruitment.

5.1.2 Torran

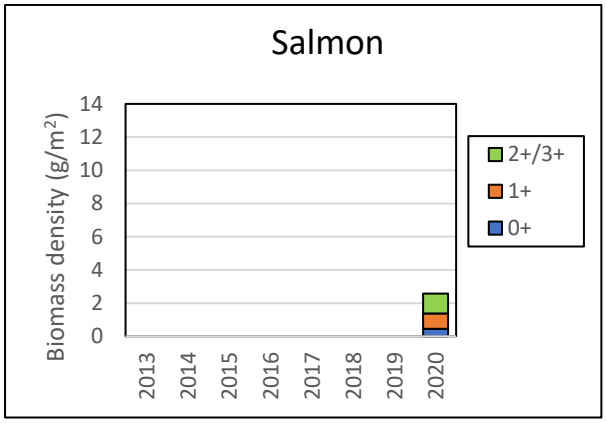
A new survey site was established at Torran, 700m downstream of the Cnoc-glas site, with the aim of checking whether the Cnoc-glas survey data are typical of that stretch of the river. As can be seen from the photograph, the general conformation of the Torran site suggests that it is likely to be good habitat for young salmonids.

Torran on the River Forss.

Salmon

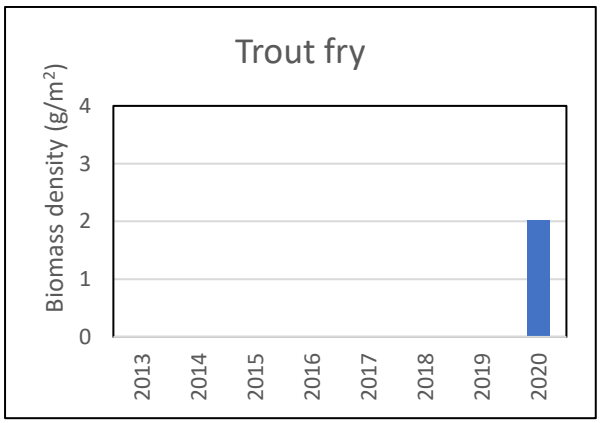


The densities of fry (0.13/m^2) and 1+ parr (0.06/m^2) were very low at Torran but similar to those encountered at Cnoc-glas. Both fry (av = 69.1mm) and 1+ parr (av = 112mm) were large relative to values encountered elsewhere in Caithness but, again, similar to the values observed at Cnoc-glas. The values obtained for the new site at Torran suggest that the long-established site at Cnoc-glas accurately reflects recent changes in the character of the salmon population in this part of the Forss catchment.



Despite the low densities of fish and buoyed by their large size, the total biomass density of salmon at Torran was 3.03g/m^2. This value is modest by Caithness standards and slightly greater than the corresponding value for Cnoc-glas.

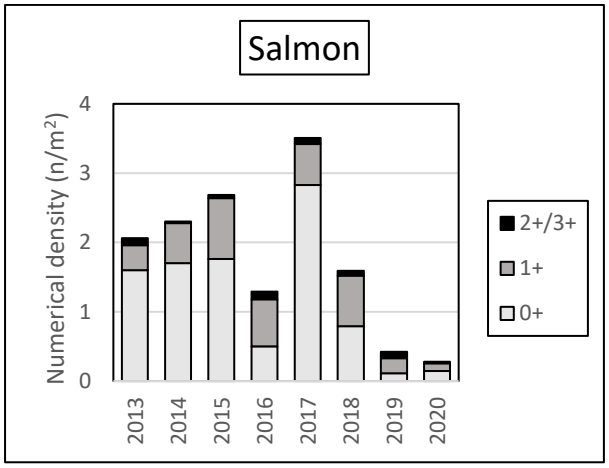
Trout



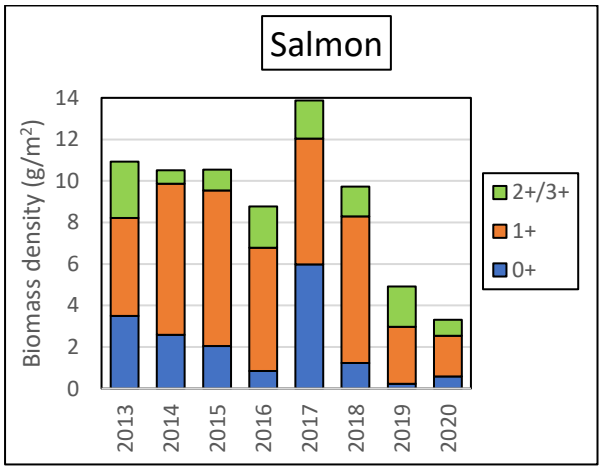
As for Cnoc-glas, trout fry were abundant at Torran. The biomass density of trout fry was 2.01g/m^2. The biomass density of all salmonids (salmon and trout fry and salmon parr) was therefore 5.06g/m^2. This compares closely with the equivalent value of 5.80g/m^2 for Cnoc-glas, again indicating that the sites are rather similar and that longer-term developments in this part of the river have been accurately captured at Cnoc-glas.

5.1.3 Shurrery

Salmon

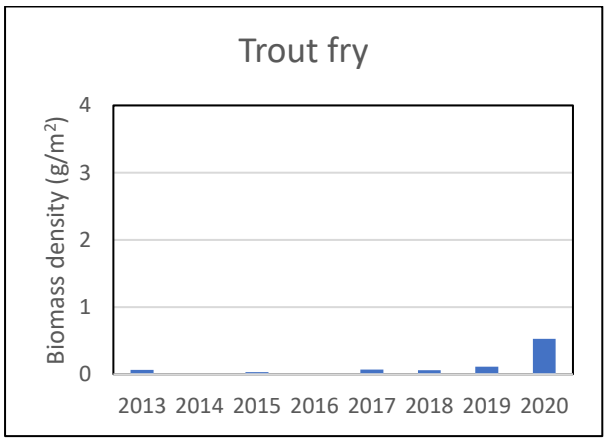


As expected given the dearth of fry at Shurrery in 2019, the density of 1+ parr in 2020 was very low (0.11/m^2). It was expected that fry recruitment would be particularly strong in 2020, because so few older fish were present. However, fry density was only 0.14/m^2, similar to the low density observed in 2019 and much less than in previous years. As for Cnoc-glas, this points to a failure at spawning in 2019 following on from a similar failure in 2018.



The total biomass density of salmon at Shurrery was 3.32g/m^2 – lower than in any previous year. The low numerical densities of fry and parr were not fully reflected in their biomass contributions because the average lengths of both the fry (av = 73.2mm) and the 1+ parr (av = 114mm) were much larger than in any previous year.

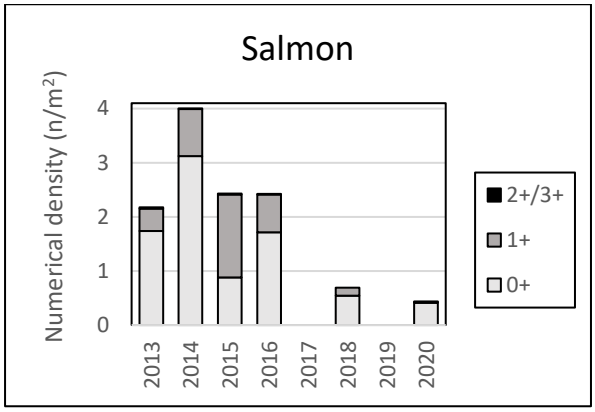
Trout



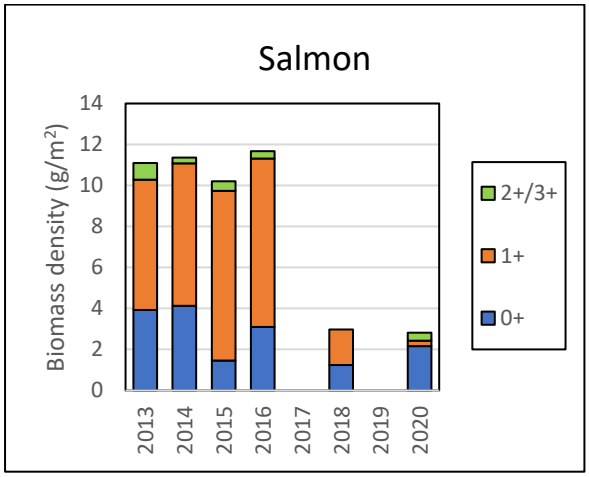
As for Cnoc-glas and Torran, trout fry were a more prominent feature of the Shurrery site than in previous years - although to a lesser extent than for the other Forss sites. The biomass density of trout fry in 2020 was 0.53g/m^2 and the total biomass density of salmon and trout was therefore 3.85 g/m^2. This value falls far short of the potential productive capacity of the site since equivalent values of around 10g/m^2 were consistently achieved in previous years.

5.1.4 Lythmore

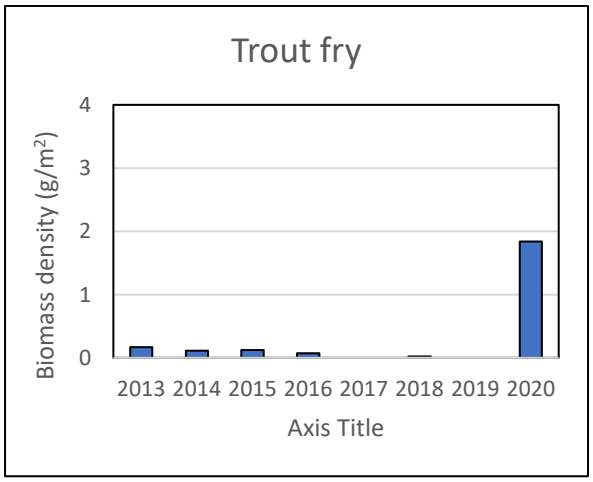
Salmon



Lythmore was not surveyed in 2017 or in 2019. Recent developments there have evidently been catastrophic. Only four parr were identified in 2020 whereas, for example, more than 100 parr were captured in 2015. Despite the dearth of parr, the recruitment of fry had also been poor at 0.41/m^2 - the lowest value on record.



Despite the large size of the fry (av = 78.3mm) and also of the few parr that were present, the total biomass density of salmon at Lythmore was only 2.81g/m^2. In previous years, the site has regularly supported 10 or 12 g/m^2.



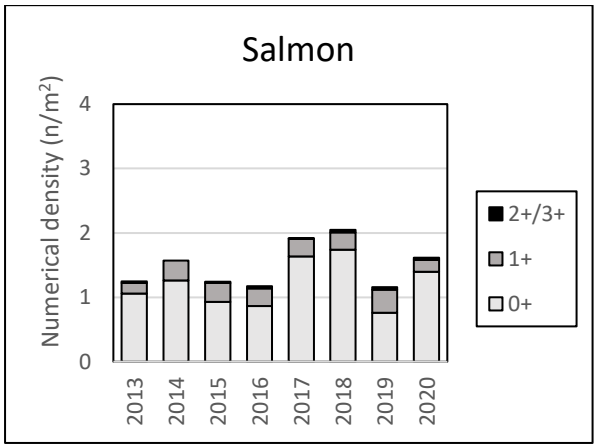
As for the other Forss sites, trout fry were present in non-trivial numbers at Lythmore for the first time. The biomass density of trout fry was 1.84g/m^2. The total biomass density of trout fry, salmon fry and salmon parr was therefore 4.65g/m^2 – still less than 50% of the proven potential productive capacity of the site.

5.2 River Thurso

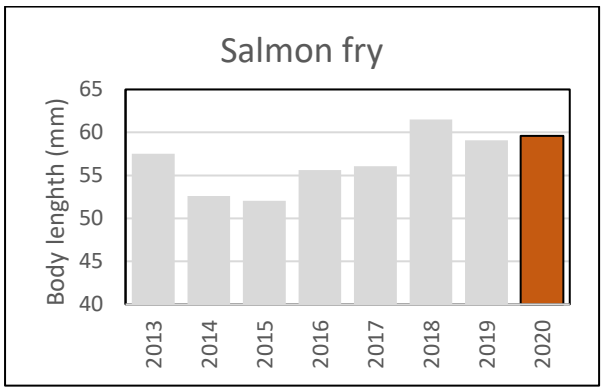
5.2.1 Rumsdale

In 2020, all four sites on the River Forss supported unexpectedly large year-classes of trout fry and unusually low densities of young salmon as disclosed in the previous section of this report. It is possible that the advent of substantial populations of trout in the Forss sites resulted from their opportunistic uptake of stream habitat vacated by the declining salmon populations. The uppermost site on the River Thurso at Rumsdale was the only other site among the 13 non-Forss survey sites to show a similarly unusual pattern of trout recruitment. The survey data for Rumsdale are therefore considered below in some detail to find out whether the Rumsdale site paralleled the Forss sites in any other respects.

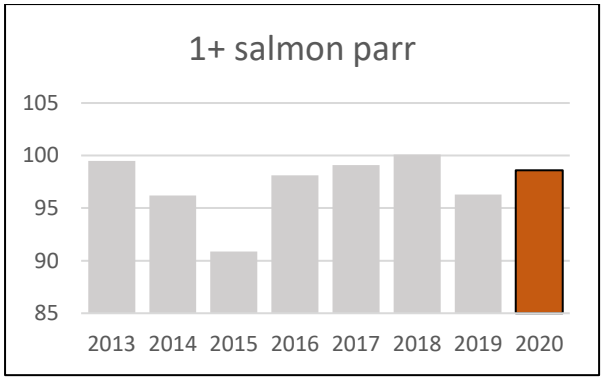
Salmon



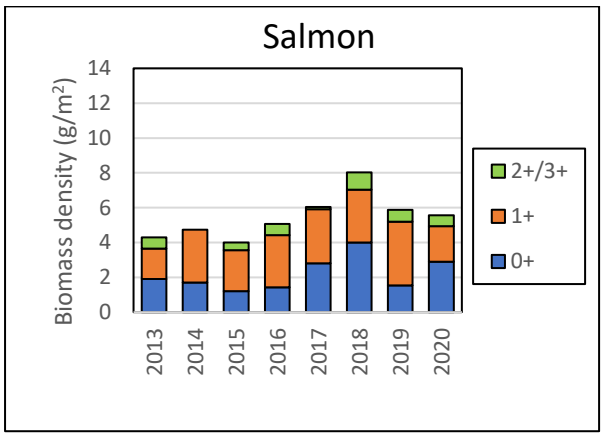
As expected, following the poor spawning in Caithness in 2018, the density of 1+ salmon at Rumsdale (0.19/ m^2) was lower than usual in 2020 although only slightly so. Fry density was among the highest levels recorded to date at 1.4/m^2. Older parr were infrequent as is usually the case.



The average body length of the salmon fry (59.6mm) was only slightly better than the average value for Rumsdale in previous years. The Rumsdale value was much lower than the equivalent values at any of the Forss sites, suggesting that competition among individuals had been more intense at Rumsdale than in the Forss.

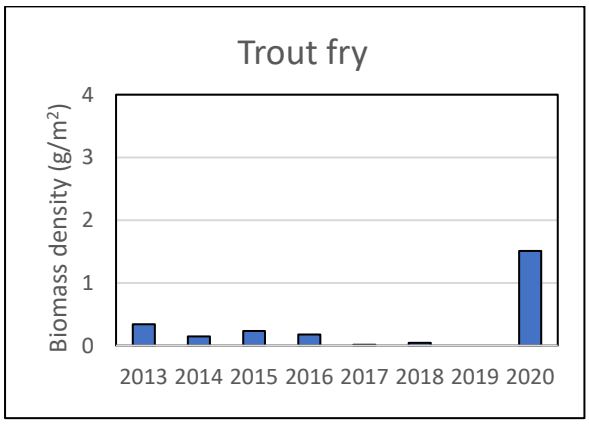


Similarly, in 2020 the length of 1+ parr at Rumsdale (av = 98.6mm) was close to the average value for the site. Rumsdale parr were much smaller than at any of the Forss sites again suggesting more intense competition at Rumsdale, at levels that were near-normal for the Rumsdale site.



In 2020 the total biomass density of salmon at Rumsdale (5.57 g/m^2) was unremarkable and only slightly greater than the average value for the site.

Trout

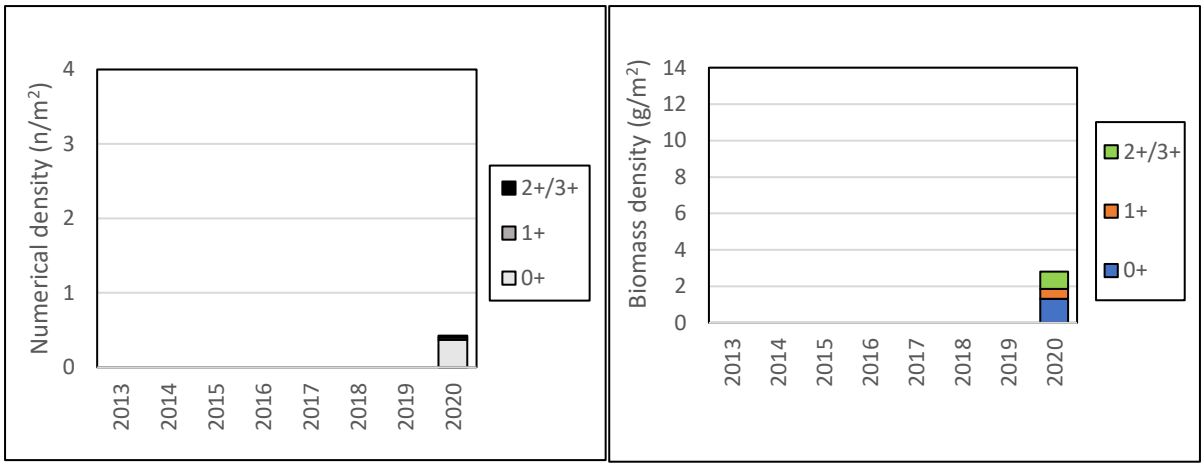


Trout fry have been present at the Rumdale site in most previous years but only as a minor feature. In 2020, however, the population of trout fry was 1.51g/m^2 making the total biomass density of trout fry, salmon fry and salmon parr 7.08g/m^2. This is the highest value of its type for any year except 2018 when the equivalent value was 8.07 g/m^2.

In summary, therefore, in the cases of all four sites on the River Forss the success of the trout fry in 2020 was associated with the contraction of salmon population below the sites' proven capacity to support salmon numbers and salmon biomass. However, this was not obviously the case at Rumsdale, the only other site in Caithness where trout fry were a prominent feature of the overall fish population. At Rumsdale, trout fry had prospered in 2020 alongside a salmon population that was similar to previous years in body size, abundance and structure.

Rumsdale and the four Forss sites should be surveyed again in 2021 to discover whether the influx of trout fry in 2020 to all the Forss sites was a one-off occurrence or whether and under what conditions the effect may persist.

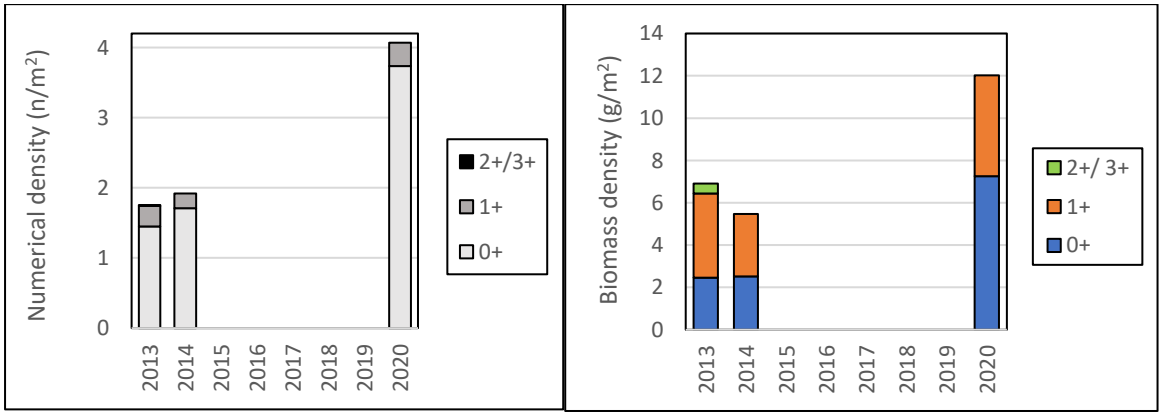
5.2.2 Loch Beg



A new site was examined 500m below the dam at Loch More on the western arm of the main river where it splits around the small island about 30m above L. Beg. The density of fry was modest (0.37/m^2) and parr were scarce. Habitat quality is sub-optimal due to fine sediment deposition in the more protected western side of the island. Recruitment in the vicinity is probably also limited by the dearth of spawning habitat in the stretch of river below the dam. Exploratory investigation suggested that parr were present at higher density in the eastern arm of the river but, even in low water conditions, the flow here is too great to allow accurate survey work.

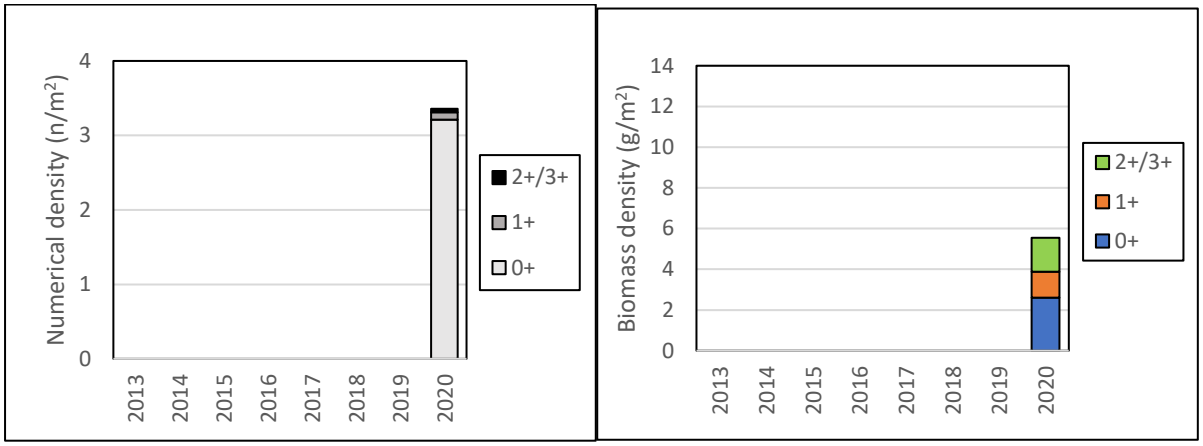
The average length of the fry at the Loch Beg site (69.9mm) was the highest value encountered among the Thurso sites and the few parr present were also larger than their counterparts elsewhere – confirming that lack of recruitment and low levels of competition were probably in play. Despite the large size of the fish, the total biomass density was only 2.81 g/m^2 which is low for sites in Thurso River.

5.2.3 Smerrary



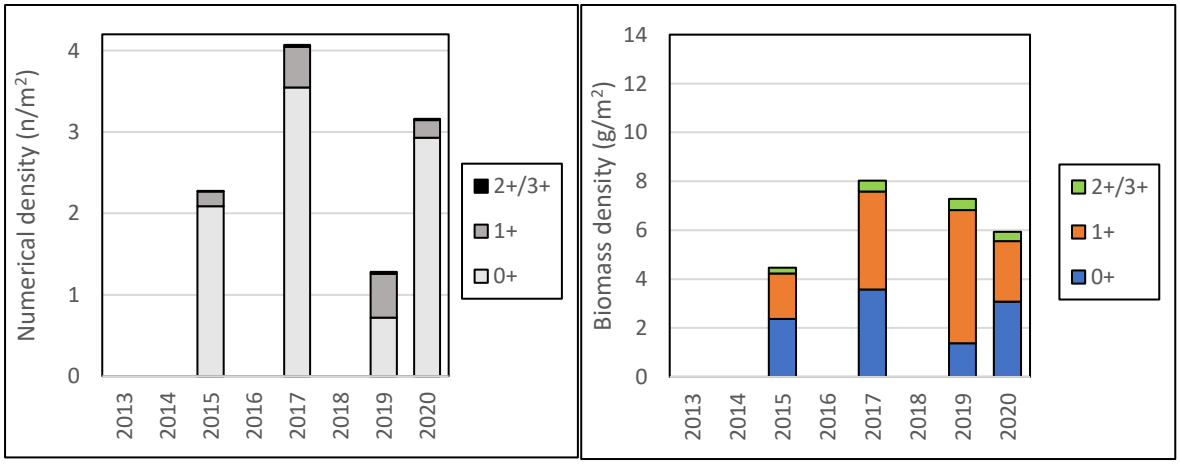
The site at Smerrary has not been surveyed since 2014 when the nearby site at The Fanks was preferred because it is more consistently accessible over a wider range of water conditions. In 2020, fry density was much higher than previously at 3.74/m^2. The density of parr was about the same as in 2013 and 2014. Both the fry (av = 57.7mm) and the 1+ parr (av =107mm) were relatively small but, driven by the large numbers of fry, the total biomass density was 12.0 g/m^2 – the highest value observed among all the 2020 survey sites.

5.2.4 Rangag



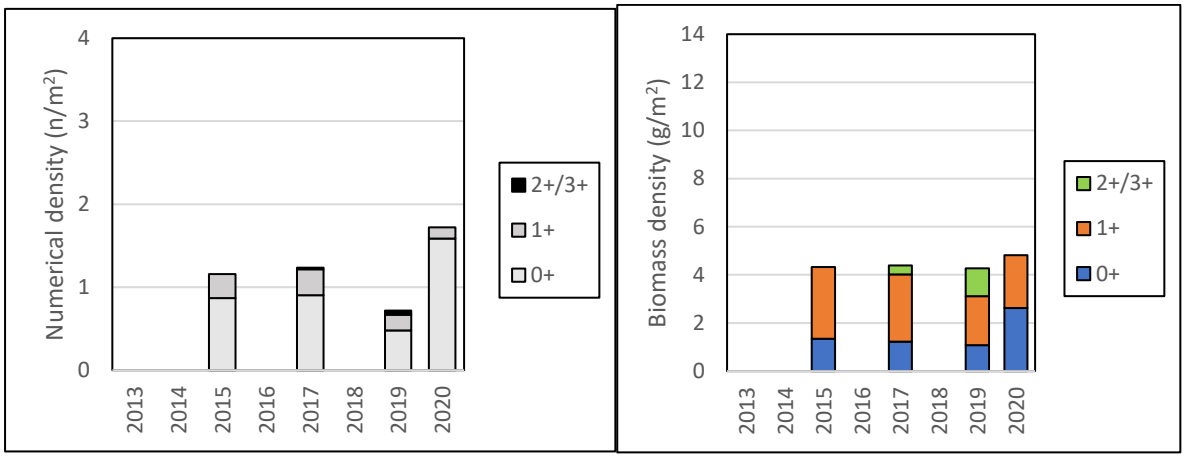
A new site at Rangag on the Little River was established. The site lies about 2km below the outlet of Loch Rangag and 5km above the existing site at Tacher. Salmon fry were exceptionally abundant (3.2/m^2), 1+ parr were present in modest numbers (0.10/ m^2) and a few older parr (0.05/m2) were also present. The fry were tiny (av = 44.4mm) and the smallest encountered in the 2020 survey. The 1+ parr were also small (av = 104mm) by Caithness standards. The total biomass density (5.54g/m^2) included roughly equivalent contributions from all three age-classes despite the superabundance of fry and because of their very small size.

5.2.5 Tacher



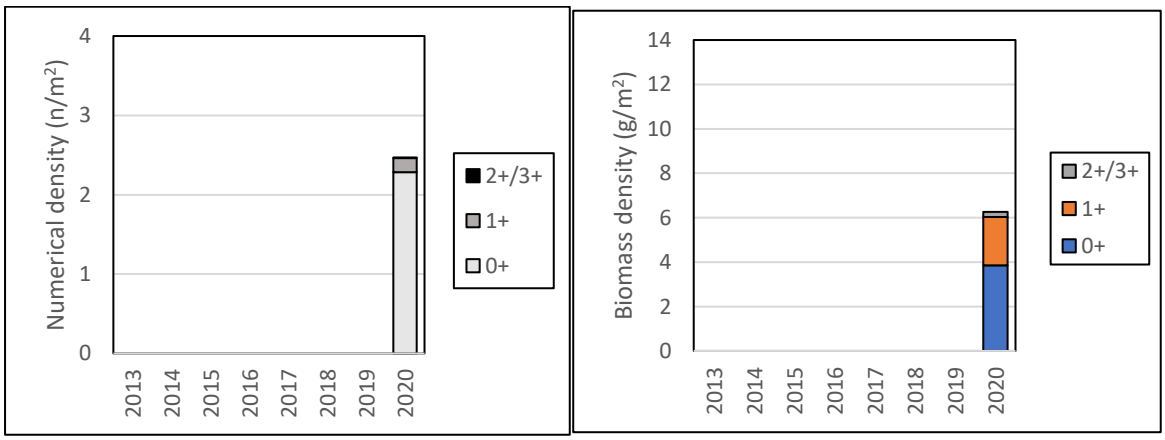
The Tacher site is on the Little River. The density of salmon fry was relatively low in 2019 (0.72/m^2) and consequently the density of 1+ parr in 2020 was relatively modest. As for Rangag, salmon fry were very abundant in 2020 (2.93/m^2). Both the fry (av 48.0mm) and the 1+ parr (av 99.5mm) were relatively small. Given the small size of the fry and the modest density of the parr, the total biomass was about average for the site at 5.93g/m^2.

5.2.6 Inshag



As for Tacher about 4km upstream, 1+ parr at Inshag were relatively few (0.14/m^2) in 2020 while fry numbers were the highest so far recorded at 1.59/m^2. The fry were small (av = 55.4mm). Driven by the large number of fry, the total biomass density (4.82g/m^2) was about average for the site.

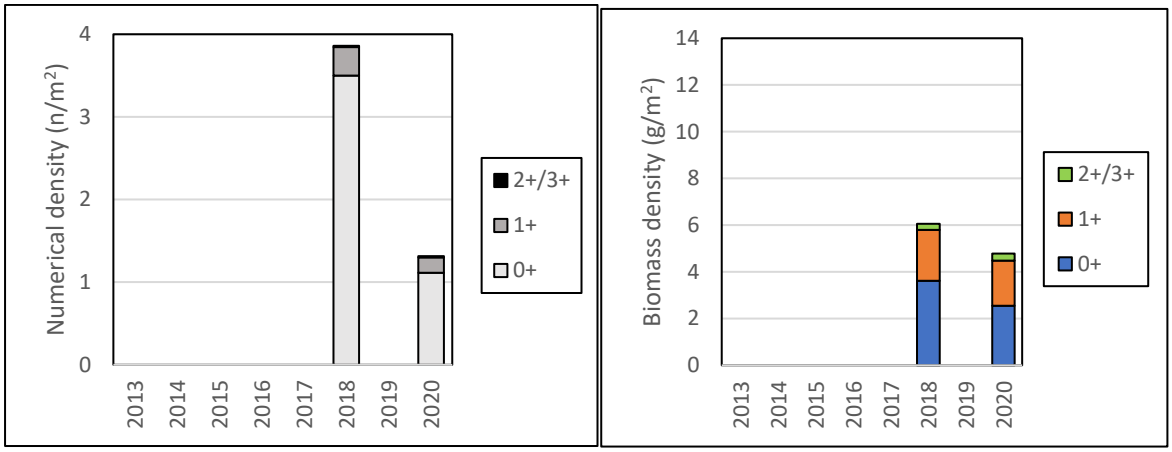
5.2.7 Poll Chreagain



A new site was established at Poll Chreagain on the main river near Westerdale. Fry were very numerous (2.28/m^2) and small in size (av = 55.8mm). The density (0.18/m^2) and the size (av = 102mm) of the 1+ parr were both modest. Total biomass density was 6.26 g/m^2.

5.3 Wick River

5.3.1 Acharole1



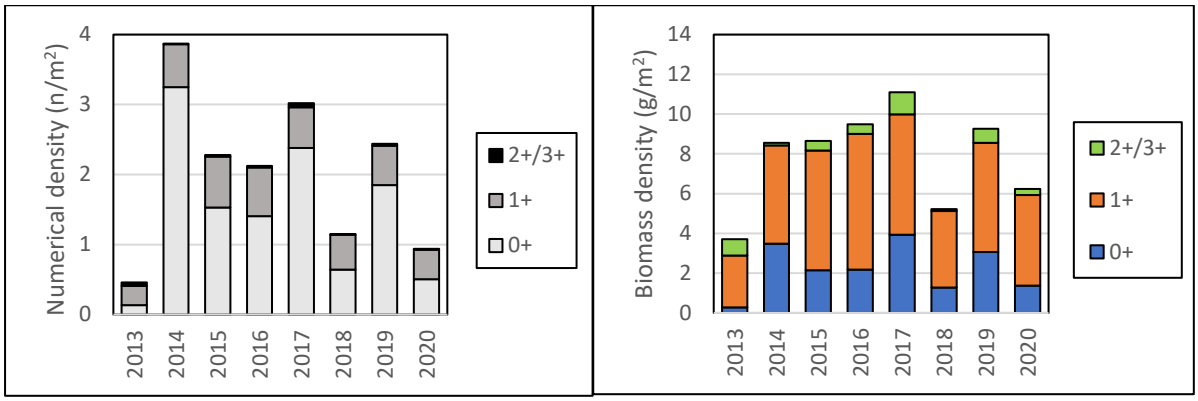
Achararole1 lies about 600m upstream of The Clow, which being one of the Board's key sites, is surveyed every year. Acharole1 was surveyed in 2020 to check whether The Clow site fully merits its special, key status.

Acharole1 was surveyed on one previous occasion, in 2018, when fry density was shown to be very high (3.50/m^2) and much greater than at The Clow in the same year (0.64/m^2).

In 2020, fry density at Acharole1 was much less than in 2018 but still relatively high at 1.12/m^2. The density of 1+ parr (0.19/m^2) was substantially less than it had been in 2018 (0.35/m^2) although it had been anticipated that this might be the case following on from the poor spawning year in 2018.

In 2018, the fish had been very numerous and therefore very small due to intense competition and the average lengths of fry and 1+ parr were only 48mm and 83mm, respectively. The corresponding values for 2020 were much larger at 61mm and 97mm. Total biomass density was more similar in 2018 and 2020 than might otherwise be expected as a result of the trade-offs between fish number and fish size. The value for 2018 was around 6g/m2 while the 2020 value was 4.78g/m^2.

5.3.2 The Clow



The Clow site on Wick River is surveyed every year. In 2020, the densities of both fry (0.51/m^2) and 1+ parr (0.42/m^2) were relatively low for the site. The density of fry was notably lower at The Clow than at the neighbouring site at Acharole1, as had also been the case in 2018 when fry density at Acharole1 was 3.5/m^2 but only 0.64/m^2 at The Clow. The Clow site has proved capable of supporting high densities of fry in previous years (max = 3.25/m^2 in 2014). The exceptions occurred in 2013, 2018 and 2020 which were all years of summer drought characterised by prolonged periods of low stream flow. An apparent association with drought is also evident in the low values for total biomass density in 2013, 2018 and 2020 driven in each case by the reduced contribution made by relatively small numbers of fry. In 2020, the total biomass density at The Clow was 6.23g/m^2, higher than in 2013 and 2018 but lower than in any non-drought year.

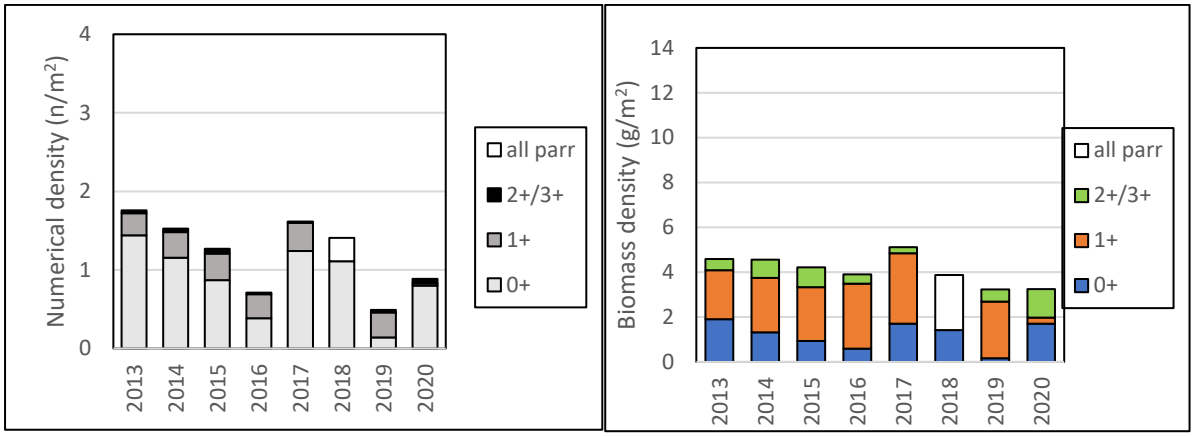
In summary, therefore, the Clow site is unusual because the structure of the fish population at survey time rather clearly depends on hydrological conditions over the summer. This is the time when fry disperse downstream away from their hatching locations to take up vacant stream space. Spawning habitat is available near Acharole1 but the 600m reach of stream below Acharole1 and above The Clow mainly comprises continuous sequences of exposed bedrock shelves. The simplest explanation for what has been observed at The Clow and for the difference between the structures of the fish populations at The Clow and at Acharole1 is that in those years when extreme low flows prevail over the summer the downstream dispersal of fry over the exposed bedrock is impeded.

It follows from this that the value to the Board of the Clow site as a key monitoring location is now in doubt. In future, survey effort might be better directed to the Acharole1 site or the Sherriff's site on the Strath Burn for which some prior information also exists.

For the record, the only other survey site in Caithness where recruitment of fry may be affected by upstream bedrock shelves is at Forsie on the River Forse. The Forsie site was fished only once previously, during the drought year of 2018, and fry were found to be atypically sparse.

5.4 Dunbeath Water

5.4.1 Culvid

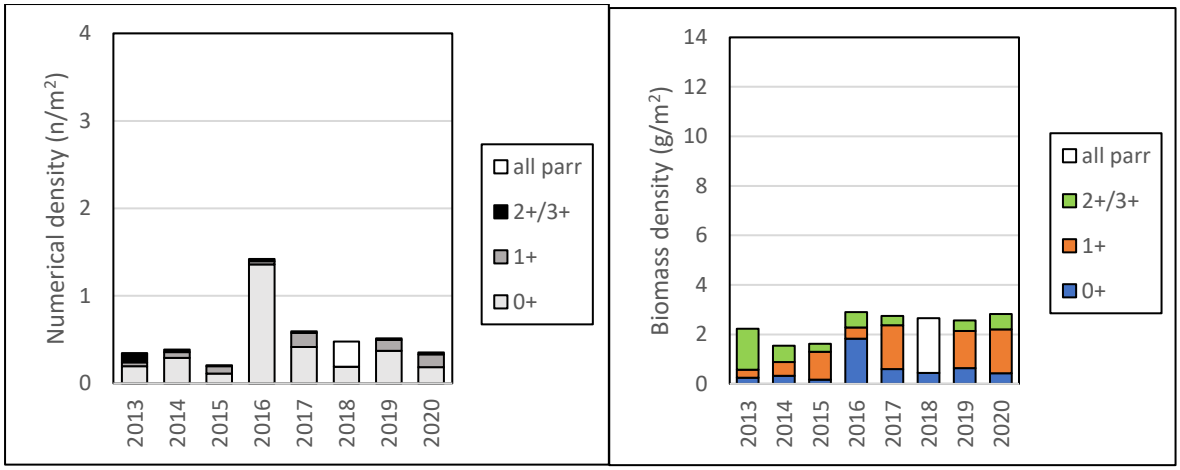


Culvid is surveyed every year. In 2018, scales were not obtained due to high water temperature and therefore, as indicated, the parr were not classified by age.

Spawning was observed to be poor in 2018 and in 2019 the density of fry at Culvid was the lowest recorded (0.14/m^2). Consequently, the density of 1+ parr in 2020 (0.03/m^2) was also the lowest recorded. A few older parr were present as is usually the case. As expected, the setback in fry recruitment in 2019 has proved temporary and a strong year class of fry (0.80/m^2) was established in 2020. In the absence of competition from the year-class above them, the fry were much larger than in all previous years and they contributed strongly to the total biomass value of 3.25g/m^2. The few (but large) 2+ parr also made a substantial contribution. Overall, however, the biomass value was slightly less than in previous years because of the atypically small contribution made by the few 1+ parr that were present.

5.5 Berriedale Water

Gobernuigach



All the Gobernuisgach density and biomass density values have now been corrected for a previous clerical error that systematically understated the site's area.

Parr were not classified by age in 2018, as indicated, since scale samples were not obtained in that year's survey.

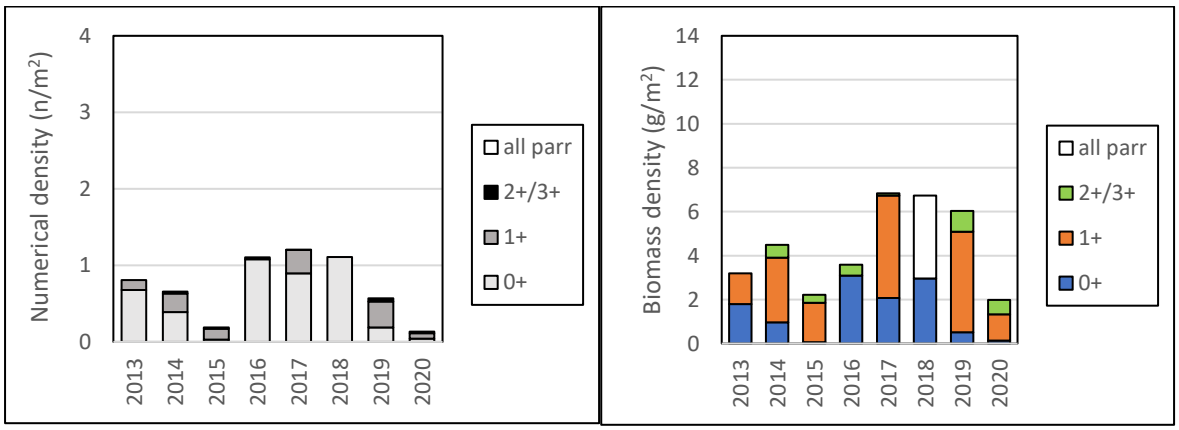
The situation at Gobernuisgach presents an overall picture of low-level production but relative, long-term stability that has continued into 2020. Fry density (0.19/m^2), 1+ parr density (0.14/m^2) and total biomass density (2.82g/m^2) were all unremarkable. The values are generally lower than at sites in the other Caithness rivers but this reflects the site's altitude, the lack of agricultural or forestry input and the unforgiving nature of much of the bedrock geology in the western part of the Berriedale catchment.

The only marked discontinuity in the site data for Gobernuisgach occurred after 2015 when fry recruitment had been relatively low. In 2016, 1+ parr densities were also consequently very low (0.04/m^2) and, as a likely result of reduced competition, the recruitment of fry in 2016 was anomalously high (1.36/m^2) as is clearly evident from the left-hand panel, above.

This pattern was replicated at the Wag site in Langwell Water, as discussed below.

5.6 Langwell Water

5.6.1 Wag

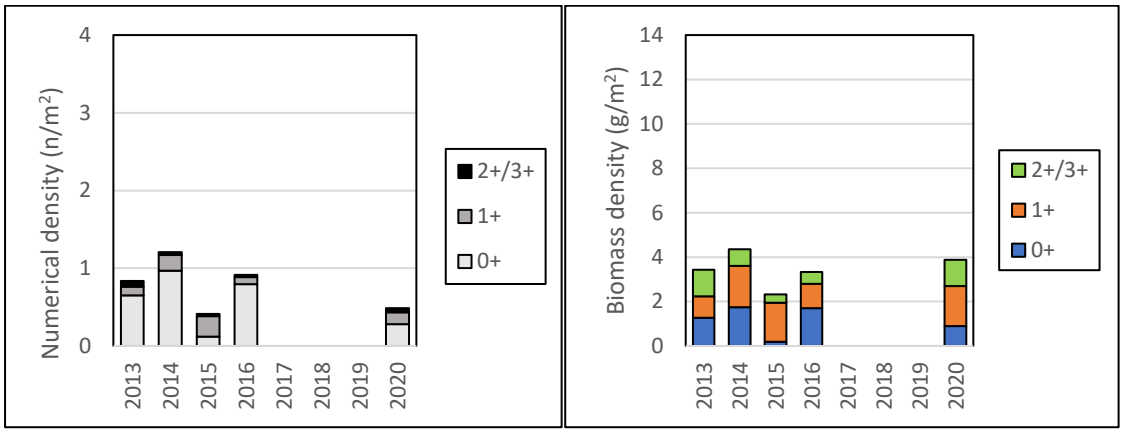


In 2020, fry recruitment failed at Wag (0.04/m^2), 1+ parr were also few in number (0.07/m2) and, as usual, older parr were very sparse. The total biomass density (1.99g/m^2) was the lowest value yet observed. There is no obvious explanation for Wag's poor showing.

However, the picture at Wag in 2020 is strikingly similar to the situation there in 2015 - and also to the situation at Gobernuisgach (see above) and Aultibea (see below) that same year - suggesting that poor fry recruitment at Wag in 2015 was part of a more general failure in the wider Berriedale/ Langwell. The gap between the events of 2015 and 2020 is five years – equivalent to the life-span of a 2SW spawner. It is possible therefore that the poor fry crops at Wag in 2015 and in 2020 are directly linked.

This will become clearer when fry density is known for the coming year (2021). The poor crop of fry in 2015 was followed by a much larger one in 2016 and the resulting 2SW salmon will have spawned in 2020. So, if linkage between generations is clearly in play at Wag then a good crop of fry is expected for 2021.

5.6.2 Aultibea



The Aultibea site was surveyed in order to check the results obtained at Wag. Aultibea is the nearest alternative site to Wag but about 4.5km downstream. The site was last surveyed in 2016.

Fish were more abundant at Aultibea than at Wag. The density of fry (0.26/m^2) was only moderate relative to previous years and greater only than the value in 2015. The density of 1+ parr (0.16/m^2) and the total biomass density (3.88g/m^2) were roughly as expected.

Overall, therefore, spawning in the Langwell was probably poor in 2019 although the effect on fry densities in 2020 was more marked at Wag than at Aultibea. More generally Wag, Gobernuisgach and Aultibea all showed some evidence for possible linkage of fry densities across a span of five years.

5. Conclusions

6.1 The Forss

Formerly, the survey sites at Shurrery and Lythmore on the lower Forss were among the most productive in Caithness both in terms of the number of fish they held and the biomass densities that they supported. More recently, this has not been the case and since 2018 the river's population of juvenile salmon has shown a rapid and severe decline and this has continued into 2020. It is not likely that there is a single cause for the problem and the interplay of various possible factors hampers interpretation. However, trying to understand what has happened is important since this will help to assess prospects for recovery and also inform attempts to manage the river back to good health.

6.1.1 Shurrery Dam

In 2019, a likely impact of operations at Shurrery Dam on fish survival downstream was identified from the survey data. This was discussed in the 2019 report and is updated here.

In 2019, parr were surprising sparse given that good levels of fry had been present the previous year. Parr were scarce in all six of the main river sites that were surveyed; they covered the length of river between Shurrery and Lythmore1. For four sites that were surveyed both in 2018 and in 2019 (Shurrery, Broubster, Westfield and Lythmore1) parr densities in 2019 ranged between 10% and 40% of the equivalent value for 2018. This shortfall is plausibly linked to the accidental de-watering of the lower river when the release of water passing through Shurrery Dam was cut off for a period of days in late August (just after the Board's survey had been completed). At the time, the river's flow was already very low due to the 2018 summer drought.

In the case of the Board's key survey site at Shurrery, the numbers of fry and parr are known for every year since the current survey sequence started in 2013. Fry density in any year can therefore be compared with 1+ parr density the following year to find out how well the fish have survived over the intervening period. Since the Board now (ie. in 2020) has eight years' worth of data, seven year-on-year comparisons are possible (ie. fry density in 2013 to 2019 versus 1+ parr density in 2014 to 2020) as shown in Figure 3.

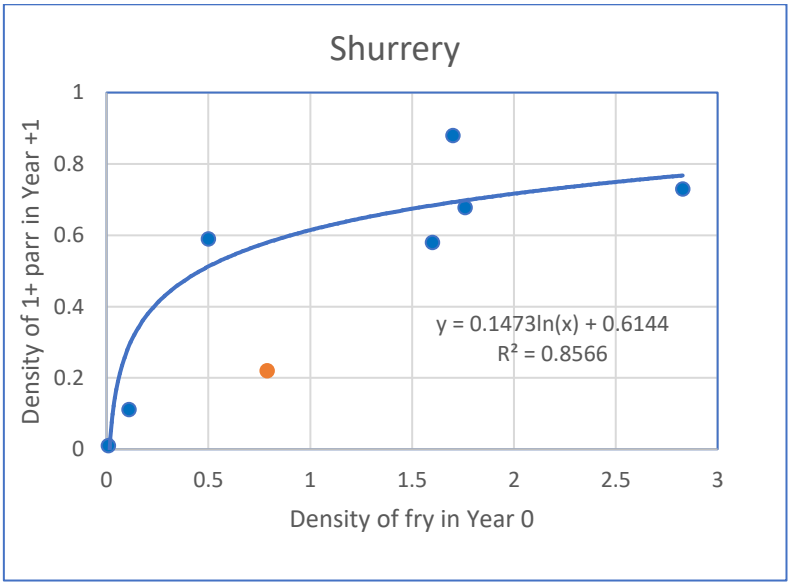


Figure 3. Relationship between the density of fry and the density of 1+ parr the following year. The comparison between the fry of 2018 and the 1+ parr of 2019 is shown in orange.

The relationship depicted by the blue line in Figure 3 is based on the blue points. Six of the points depict comparisons between age-classes and the seventh blue point is located at the origin of the blue line at the extreme left - where zero fry in Year 0 is expected to correspond to zero 1+ parr in Year +1.

The line's curve shows that the survival rate from fry to 1+ parr varies and that it tends to be greater when fry density is lower. In years when fry densities are higher the survival rate to 1+ parr falls off as the parr reach densities at, or near to, the plateau value represented by the right-hand part of the blue curve.

The plateau value for parr density at the Shurrery site is set at around 0.6 - 0.8/m^2 by the limits of the amount of stream space that is available to the fish. In most years fry densities have been sufficient to produce 1+ parr densities in the 0.6 - 0.8/m^2 range.

The orange point in Figure 3 shows fry density in 2018 (just before the accident at the dam occurred) versus 1+ parr density a year later. The orange point can be compared with the blue line and this shows that based on the density of fry the previous year, 1+ parr values in 2019 fell well short of the value predicted by the blue line.

This indicates that, following the dam closure, the mortality rate between the fry and 1+ stages was abnormally high. The size of the shortfall indicates that 1+ parr density in 2019 was only around 40% of the expected value based on the density of fry present in 2018. This value supersedes the previous estimate of around 30% based on the data available to 2019. The estimated shortfall in parr at Shurrery is substantial and it broadly aligns with the unexpectedly low parr densities observed at survey sites elsewhere in Forss in 2019.

If this interpretation is correct it means that parr numbers in 2019 and, therefore, smolt numbers in 2020 will have been reduced by about 60%. It then follows that grilse numbers in 2021 and 2SW numbers in 2022 should be expected to be reduced to the same extent.

Furthermore, if fry were killed by the dam's closure just after the 2018 survey date, then parr probably suffered the same fate. The Board's survey data cannot be used to test this possibility because the survivors of the incident will have left the river as smolts long before the 2019 survey took place. If parr were also killed in 2018, then smolt numbers in 2019, grilse numbers in 2020 and 2SW numbers in 2021 will be proportionately affected.

In summary, although the dam closure was a one-off event affecting only the lower river it may have had extended ramifications for the fishery (and for spawner numbers) extending from 2020 to 2022. Any effect will peak in the coming year (2021) when the numbers of both the grilse and the 2SW salmon produced from the area of river below the dam should be expected to fall to about 40% of the numbers that would otherwise have returned.

6.1.2 Fry recruitment in the Forss.

There are 10 sites on Forss that were surveyed once or more between 2013 and 2020. For clarity the sites are identified on the map in Figure 3 and in Table 6 where the sites are ordered from the top of the catchment.

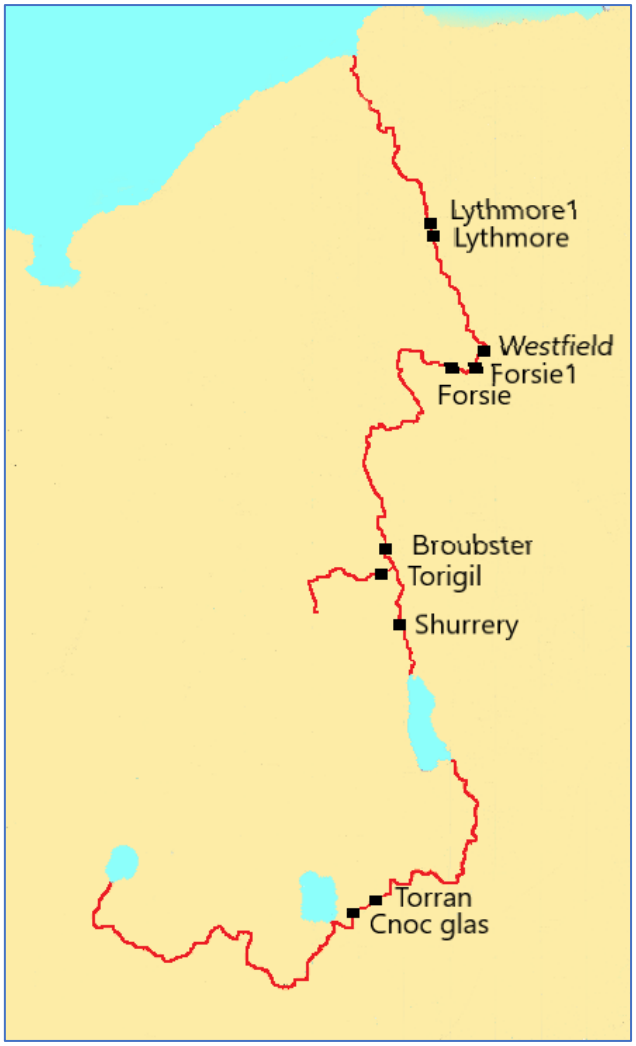


Figure 3. Map of River Forss showing the positions of all 10 sites for which electric-fishing survey data are available from the Board's annual surveys or from the Marine Scotland NEPS surveys.

Table 6. Description of the sites on the Forss that have been surveyed to date.

Site name	Notes
Cnoc-glas	600m downstream of L. Caluim. Above the Cnoc-glas site the river runs westwards for 10km to its main source in L. Tuim Glais.
Torran	700m below Cnoc-glas; ca. 5.5km above L. Shurrery.
Shurrery	1km below L. Shurrery and Shurrery Dam.
Torigil	Western tributary stream 600m above Broubster Village; the tributary site is 300m beyond the main river.
Broubster	600m above the road bridge at Broubster.
Forsie	On cataract immediately above bridge to West Forsie farm.
Forsie1	Below Knockglass farm and 700m below the Forsie site.
Westfield	300m downstream of the site at Forsie1.
Lythmore	250m below the road bridge at Lythmore; 3km below the Westfield site,
Lythmore1	350m below the Lythmore site.

All the available data for fry densities in the Forss sites has been re-examined to try to cast more light on where problems in recruitment may have occurred and when they arose. So far, the changes to fry recruitment are entirely separate from any effect the dam closure at Shurrery may have since, as discussed above, the first possible impact of the closure fell at spawning time in 2020 and fry recruitment cannot therefore be affected before hatching time in 2021.

In order to consider and compare fry densities at all the sites, it has been necessary to revert to a modified version of Godfrey's (2006) classification as per Table 7. The values are for 1-pass electric-fishing or for the first pass only of 3-pass fishing. The values have been colour-coded as indicated; red is the lowest category and dark blue is the highest.

Table 7. Godfrey's five criteria for classification (red through to light blue) of fry density. Two additional, higher categories have been included to better describe all the values observed for Forss sites.

Categories for salmon fry density (n/m^2) with colour-codings.						
0-0.05	0.06-0.13	0.14-0.28	0.29-0.33	0.34-0.67	0.68–1.00	> 1.00

Table 8. 1-Pass fry density by colour code for all years and sites for which data is available.

	2013	2014	2015	2016	2017	2018	2019	2020
Cnoc-glas							Low	
Torran							Low	
Shurrery								
Torigil								
Broubster								
Forsie								
Forsie1								
Westfield								
Lythmore					Low		Low	
Lythmore1								

For four cells for which measurements of fry density are lacking, tentative assessments of fry density are possible based on the density of 1+ parr observed in the following year's survey. For each of the four cases fry density was inferred to be "low", as indicated.

Judged qualitatively, the main features of Table 8 are that 1-pass fry densities –

- tended to be excellent (> 0.7/m^2) over the period 2013 to 2017
- were probably in decline in 2018
- tended to be poor (<0.28/m2) in 2019, and especially in 2020.

Fry values in 2020 were probably affected by the outbreak of Red Skin Disease (RSD) in 2019 and consequent mortality among potential spawners.

Fry values in 2019 were probably affected by the poor spawning year in 2018 following the summer drought. However, fry values in Forss were depressed more severely than in the other Caithness

rivers although the drought conditions were general, suggesting that an additional factor may have been in play in Forss.

Indeed, even in 2018 fry levels were lower than expected in the three main Forss sites and fry levels were probably low at Lythmore in 2017. There is no obvious explanation for these shortfalls.

6.1.3 Options for recovery of Forss

The Caithness rivers usually respond to a single poor spawning year by over-producing fry the following year when spawner numbers have returned to normal. The effects of any loss of smolts due to a single poor fry-year and any gain due to compensatory over-production the next year become smoothed out by the adult stage because both the losses and the gains are split between years – between the grilse and the 2SW salmon. In most cases, therefore, the effects of a single poor spawning year on the fishery may be imperceptible by the time that the affected fish return as adults. This is not the case if poor spawning years occur in couplets or longer sequences because compensatory over-production of fry is not possible.

In 2020 the hoped-for resurgence in fry densities did not occur in Forss. This means that fry recruitment in the Forss has been inadequate for the last two and possibly the last three years as indicated by Table 8. The resulting shortfalls in parr and smolt production will adversely affect the number of adults (ie. potential spawners) that return to Forss in coming years. The shortfall in fry in 2019 will affect grilse numbers in 2022 and 2SW salmon numbers in 2023; the 2020 shortfall in fry will affect 2023 and 2024 in the same way. These shortfalls will be in addition to the shortfalls expected to result from the dam closure at Shurrery; these are predicted to fall in 2020-2022, as described above.

Furthermore, given the prevalence of RSD in 2020 and the consequent mortalities observed among potential spawners it is not reasonable to expect good fry recruitment in 2021 (this must be checked at the time of the 2021 annual Board survey). If fry recruitment is poor in 2021, then spawner numbers can be expected to continue to be depressed through to 2024 (grilse) and 2025 (2SW salmon).

In fact, even this is likely to a best-case scenario describing only the events that are already in train. Even if the problems afflicting Forss at present are identified and removed, the sequence of poor returns already in the pipeline through to 2025 will probably result in a further sequence of inadequate spawning years.

In order to break this chain of events a good spawning year or, better, a sequence of good, or even moderate, spawning years is urgently required. Looking again at Figure 3, for example, fry density at Shurrery needs to be at least 0.5/m^2 to generate full year-classes of parr and smolts; in 2020, fry density was only 0.14/m^2 and, in 2019, 0.11/m^2.

Consistently wet years with high river levels in summer and matching low water temperatures allow fish to spread out more quickly, to distribute more widely, to hold station in more conducive conditions and all these factors are ultimately favourable for spawning. Since 2018, however, the effects of drought have meant that spring and summer river levels on Forss have been lower than normal for longer periods than usual and water temperatures have often been unusually high. Some of the problems afflicting Forss salmon will probably be lessened or removed if more favourable water conditions prevail in the coming year. Obviously, however, there can be no assurance that this

will be the case in 2021 or in any other year and, therefore, the possibility of management intervention should be considered.

A wide range of different options is available to the river's managers to help promote the recovery of Forss and they ought to be explored, in consultation with SEPA, Scottish Water and Marine Scotland as appropriate.

1. Suspend all angling for two years (with subsequent review) to eliminate angler-induced mortality and angler-induced stress in potential spawners.
2. Use only single, barbless hooks in small sizes and knotless landing nets, coupled with mandatory catch-and release following training/ instruction on appropriate methods of release in order to minimise angler-induced mortality.
3. Suspend angling over periods when the maximum daily water temperature (as measured at 1700hr) exceeds 17°C (63°F) in order to eliminate the disturbance of fish in warm water and to lower associated stress and mortality.
4. Explore ways to ease the passage of fish at Forss Falls, especially during times of low flow, in order to reduce stress among fish held up in the lower river.
5. Reconsider the improvements made to the river mouth which have eased passage of fish into the lower river at times of low flow while, perhaps, leading to crowding and stress when the river is low.
6. Review the effects of land-use and farming in the lower part of the Forss catchment (downstream from Achalone) in order to prevent any recurrence of pollution events such as those documented by SEPA in recent years.
7. Review arrangements for fish passage at Shurrery Dam in order to ensure the fish have free and timely access to the upper river.
8. Review arrangements for compensation discharge at Shurrery Dam to ensure the best use is made of what water is available, especially during periods of low rainfall.
9. Continue to press Marine Scotland Science for resolution of the RSD problem with a view to eliminating or reducing mortality resulting from the disease.

6.2 Condition of rivers other than Forss

Aside from the River Forss, there are no obvious or pressing problems in the Caithness rivers. The key Board survey site at Clow on Wick River performed as expected. There was a strong resurgence in fry density at Culvid on Dunbeath Water following its poor showing in 2019. Gobernuisgach on Berriedale Water was in its expected condition. Fry densities at Wag on Langwell Water were low and while those at Aultibea further downstream were better they were still also low, perhaps as a legacy effect of the last poor fry year in 2015. If this is the case, then recovery will follow in 2021 and checking this should be a priority for in the 2021 Board survey. Finally, although fry density was unremarkable at the new survey site above Loch Beg on Thurso all the other sites were heavily populated with fry. The average fry density over all seven Thurso sites was 2.4/m^2 (ranging to 3.7/m^2) suggesting that the river was saturated, or nearly saturated, with fry.

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