CDSFB

Juvenile Salmonids in the Rivers of Caithness:

2017 Electric-fishing Survey.

A.F. Youngson

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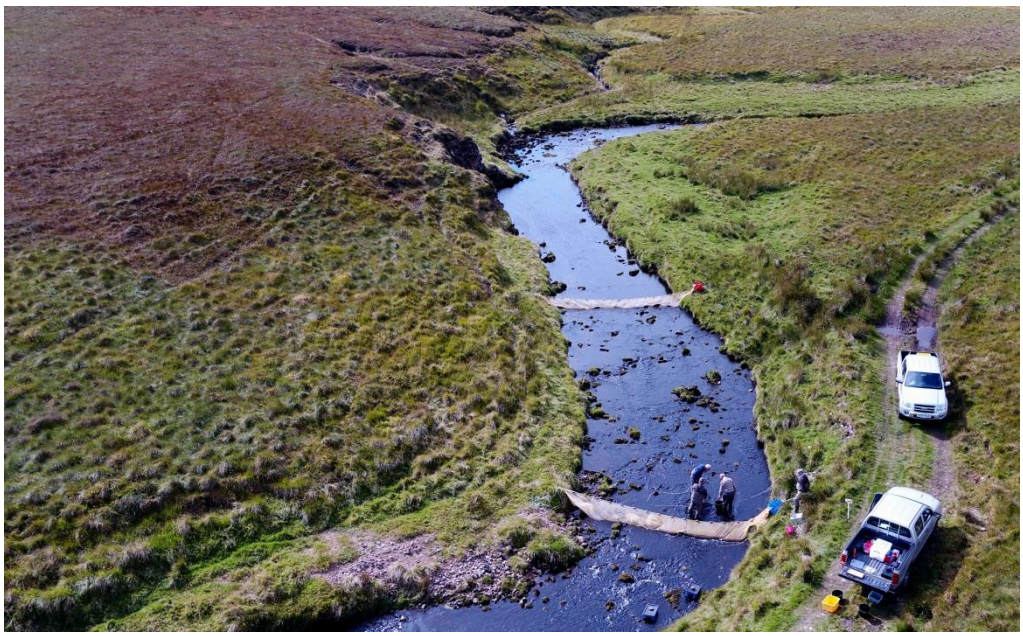


Rumsdale, River Thurso. Photo: Jamie McCarthy.

Contents

1. Introduction.

The Board's strategy for 2017 was to concentrate on Thurso River while maintaining basic surveillance of the other main rivers in Caithness. Survey work on the Wester River was suspended following the FCRT's detailed survey of the catchment in 2016.

New sites on the Achlachan and Braehour Burns were electric-fished in order to increase coverage of the lower part of the Thurso catchment. Both are relatively small streams but the lower catchment lacks the large tributary streams that are generally preferred for survey work. In the past, this difficulty has been overcome by fishing a main-river site at Hoy. But in years of relatively higher river flow, the Hoy site (like all potential main river sites) is not accessible. Indeed, due to high water the Hoy site could not be fished as planned for 2017. A third new site was surveyed at Altnabreac on Thurso bringing the Sleach Water which drains much of Strathmore Forest under surveillance for the first time.

The location, size and physical habitat characteristics of each of the three new sites were documented and the Index of Electric-fishing Sites posted on the Board's website was updated accordingly.

Elsewhere, electric-fishing was repeated for sites examined in previous years on the Rivers Forss, Wick, Dunbeath and Berriedale/ Langwell. In the latter case, the high-altitude Gobernuisgach and Wag sites were selected for survey because of the additional interest in following the repercussions of the very low levels of fry recruitment observed there in 2015 and attempting to untangle the sequence of events that followed.

The aims of this report are (1) to permanently document all the data that were obtained in 2017 and (2) to assess the condition of the Caithness rivers in 2017 relative to previous years using the data series compiled from 2013 onwards. In addition, (3) the choice of a final set of new survey sites is considered with a view to completing a framework of sites for Caithness within the next couple of years.

2. Results.

In total, 12 sites were electric-fished in the Board's usual, standard time-window in early September, as per Table 1. Due to continuous high water after 8th September, the thirteenth site (The Clow on Wick River) could not be surveyed before 14th October.

River	Site name	O.S.	Alt (m)	Date	Standard area (m^2)
Forss	Cnoc glas	ND 030 515	110	3 Sept	192.7
	Shurrery	ND 039 578	89	3 Sept	89.8
Thurso	Rumsdale	NC 988 408	159	5 Sept	181.6
	Dalganachan	ND 005 389	147	4 Sept	148.9
	Altnabreac	ND 005 454	142	4 Sept	90.8
	Tacher	ND 171 469	80	2 Sept	130.5
	Inshag	ND 146 488	68	2 Sept	110.9
	Braehour	ND 102 532	61	6 Sept	139.8
	Achlachan	ND 134 528	53	6 Sept	146.3
Wick	The Clow	ND 233 524	35	14 Oct	160.0
Dunbeath	Culvid	ND 123 325	97	7 Sept	215.4
Berriedale	Gobernuisgach	NC 984 312	250	5 Sept	131.1
Langwell	Wag	ND 016 260	188	7 Sept	212.0

Table 1. Electric-fishing survey sites (2017).

River	Site name	Observed density of trout ($n.m^{-2}$)		
		Fry	Parr	Other species
Forss	Cnoc glas	0.31	0.02	Eel
	Shurrery	0.02	0	-
Thurso	Rumsdale	0.03	0.04	Eel
	Dalganachan	0.01	0.01	Eel
	Altnabreac	0.65	0.04	Eel
	Tacher	0	0.04	Eel, stickleback
	Inshag	0	0.02	Eel
	Braehour	0.25	0.09	Eel
	Achlachan	0.73	0.05	-
Wick	The Clow	0.02	0.01	Eel
Dunbeath	Culvid	0	0	Eel
Berriedale	Gobernuisgach	0.05	0.07	-
Langwell	Wag	0	0.04	Eel

Table 2. Presence of trout and non-salmonid species.

Table 2 shows the densities of trout fry and trout parr observed at each site and also indicates the presence of non-salmonid species. Eels and trout fry and/ or trout parr were present at most sites. It can be seen that, as for previous years, trout fry and trout parr were generally a minor feature of the established Caithness sites. However, substantial densities of trout fry were present at Cnoc glas on

the Forss (as has been noted in some previous years) and at each of the three new sites that were surveyed on Thurso. This is consistent with the general pattern observed in previous years in which trout were found to contribute substantially to the salmonid populations in some of the smaller streams near the periphery of the river networks. The principal aims of the Board's surveys are to describe the distribution of young salmon and to pin-point places where the numbers are limited by levels of spawning or by habitat quality. But it is also necessary to consider that, in the smaller streams when substantial numbers of trout are present, the densities of salmon fry and salmon parr are probably lower than would otherwise be the case because of competition between the two species.

Table 3 shows the primary survey data – the number of salmon fry and salmon parr captured on each pass of 3-pass electric-fishing for each of the sites.

River	Site name	Fry			Parr		
		1st pass	2nd pass	3rd pass	1st pass	2nd pass	3rd pass
Forss	Cnoc glas	140	46	15	27	2	1
	Shurrery	194	49	8	51	7	1
Thurso	Rumsdale	191	76	18	35	12	3
	Dalganachan	219	68	32	43	8	3
	Altnabreac	95	20	12	1	5	0
	Tacher	266	129	37	43	14	7
	Inshag	65	23	8	28	6	2
	Braehour	174	69	23	24	6	2
	Achlachan	219	80	19	8	1	1
Wick	The Clow	260	79	29	72	24	4
Dunbeath	Culvid	169	73	14	50	20	5
Berriedale	Gobernuisgach	44	14	7	20	6	3
Langwell	Wag	102	53	18	49	12	4

Table 3. Numbers of salmon fry and parr captured at each site for each pass of 3-pass electric-fishing.

Table 4 updates similar presentations in previous Board reports. Following Godfrey (2005), each site is categorised according to the density of salmon fry (left panel) or salmon parr (right panel) detected on the first pass of 3-pass fishing. Categorisation is according to Godfrey's threshold values for northern rivers (as specified in the lower panel of the table). The categories are colour-coded and they range from red (very poor) through orange (poor), yellow (average), green (good), light blue (very good) to dark blue (excellent).

River	Site	Salmon									
		Fry					Parr				
		2013	2014	2015	2016	2017	2013	2014	2015	2016	2017
Forss	Cnoc-glas										
	Shurrery										
	Lythmore										
Thurso	Rumsdale										
	Dalganachan										
	Altnabreac										
	Dalnagleton										
	The Fanks										
	Smerrary										
	Tacher										
	Inshag										
	Dalemore										
	Braehour										
	Achlachan										
	Hoy										
Wester	Barrock Mill										
Wick	Acharole										
	The Clow										
	Sheriff's										
	Bilbster										
Dunbeath	Achnaclyth										
	Culvid										
Berriedale	Gobernuisgach										
	Corrichoich										
	Braemore										
	Strathcoull										
Langwell	Wag										
	Aultibea										
	Coille Braigh										

	Critical percentile values for density (n.m^{-2}) 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

Table 4. Classification of sites based on critical quintile values for observed density (n.m^{-2}) of salmon fry and parr (based on first pass only of three-pass fishing as per Godfrey [2005] for northern rivers).

Table 4 shows that fry densities were "very good" or "excellent" for all the sites that were surveyed in 2017. Parr densities were generally "good" to "excellent" with the exceptions only of two of the new sites - Altnabreac and Achlachan. Consistent differences are evident in the classification of sites

and the classification of some sites varies greatly among years. But in order to investigate the causes of these variations and, in particular, to pinpoint possible problems, it is necessary to consider matters in greater detail, as follows.

Table 5 shows the 3-pass data for fry and for 1+ and 2+ parr. No older parr were captured. Indeed, even 2+ parr were infrequent showing that most fish had left fresh water at around two years of age. The densities of residual 2+ parr were greatest at Shurrery (0.09/ m^2) and The Clow (0.06/ m^2).

River	Site name	Observed Density ($n.m^{-2}$) and year of hatch			
		0+ fry (2017)	1+ parr (2016)	2+ parr (2015)	All parr
Forss	Cnoc glas	1.04	0.12	0.03	0.16
	Shurrery	2.80	0.59	0.09	0.68
Thurso	Rumsdale	1.57	0.27	0.01	0.28
	Dalganachan	2.14	0.35	0.01	0.36
	Altnabreac	1.40	0.06	0.01	0.07
	Tacher	3.31	0.47	0.02	0.49
	Inshag	0.87	0.31	0.02	0.33
	Braehour	1.90	0.21	0.01	0.23
	Achlachan	2.17	0.06	0.01	0.07
Wick	The Clow	2.30	0.57	0.06	0.63
Dunbeath	Culvid	1.19	0.33	0.01	0.35
Berriedale	Gobernuisgach	0.50	0.20	0.02	0.22
Langwell	Wag	0.82	0.30	+	0.31

Table 5. Observed density of salmon fry and parr from 3-pass fishing.

The observed numbers of fish were Zippin-corrected in order to estimate the true density values (ie. allowing for fish that evaded capture) and these values are shown in Table 6.

It can be seen that the values in Tables 5 and 6 are little different. This is because the efficiency of the electric-fishing procedure, as estimated from the rate of decline in the number of fry or parr captured on each of the 3 successive electric-fishing passes, was generally very high. This was attributable to the stream flows being relatively high in 2017 relative to previous years; the high flows tended to aid the efficient capture of fish.

For 2017, the median density of salmon fry in the 13 sites that were surveyed was 1.64/m^2; the corresponding value for 1+ parr was 0.32/m^2.

River	Site name	Estimated true density (n.m^{-2})		
		Fry	1+ parr	2+ parr
Forss	Cnoc glas	1.08	0.12	0.03
	Shurrery	2.83	0.59	0.09
Thurso	Rumsdale	1.64	0.28	0.01
	Dalganachan	2.24	0.36	0.01
	Altnabreac	1.44	0.06	0.01
	Tacher	3.55	0.50	0.02
	Inshag	0.90	0.32	0.02
	Braehour	2.01	0.21	0.01
	Achlachan	2.23	0.06	0.01
Wick	The Clow	2.38	0.58	0.06
Dunbeath	Culvid	1.24	0.36	0.01
Berriedale	Gobernuisgach	0.52	0.21	0.02
Langwell	Wag	0.90	0.31	0.01

Table 6. Estimated true density of salmon fry and parr.

The average values for the length of each age group are shown in Table 7. In cases where the number of fish belonging to any group was sufficiently large the Standard Deviation is indicated to provide a measure of the spread of individual values (as a rule of thumb, roughly 70% of the individual values lie within one standard deviation of the mean value).

River	Site name	Mean body length (mm)		
		Fry	1+ parr	2+ parr
Forss	Cnoc glas	62.9 (5.40)	106.6 (6.81)	121.6
	Shurrery	59.8 (5.11)	96.7 (7.17)	119.6
Thurso	Rumsdale	56.1 (5.26)	99.1 (8.87)	125.0
	Dalganachan	50.7 (5.17)	90.8 (9.87)	125.0
	Altnabreac	59.0 (5.63)	108.8	147.0
	Tacher	47.6 (4.93)	89.3 (9.12)	118.3
	Inshag	52.1 (4.81)	91.5 (11.0)	121.0
	Braehour	53.8 (5.81)	103.6 (9.26)	126.5
	Achlachan	49.4 (6.06)	107.7 (12.4)	121.0
Wick	The Clow	55.0 (6.84)	95.8 (7.11)	118.2
Dunbeath	Culvid	52.4 (4.95)	91.1 (10.4)	118.0
Berriedale	Gobernuisgach	52.9 (4.55)	97.3 (7.23)	120.3
Langwell	Wag	61.6 (4.24)	109.0 (7.03)	121.0

Table 7. Mean body lengths of fry, 1+ parr and 2+ parr. Where appropriate the Standard Deviation is indicated in parentheses.

Fry were smallest at Tacher (mean = 47.6 mm) and largest at Cnoc-glas (62.9 mm); 1+ parr were largest at Wag (109.0 mm) and smallest at Tacher (89.3 mm).

In Figures 1 and 2 the annual series of body length measurements are updated for fry and 1+ parr, respectively, for the set of sites surveyed in 2017.

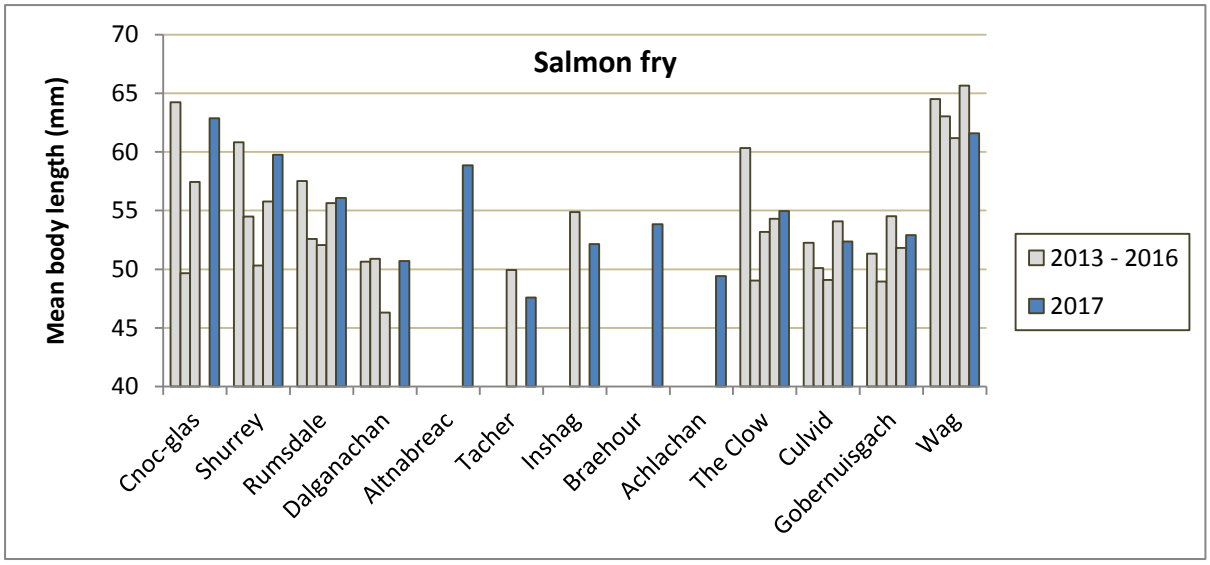


Figure 1. Average body length of fry by site, 2013–2017.

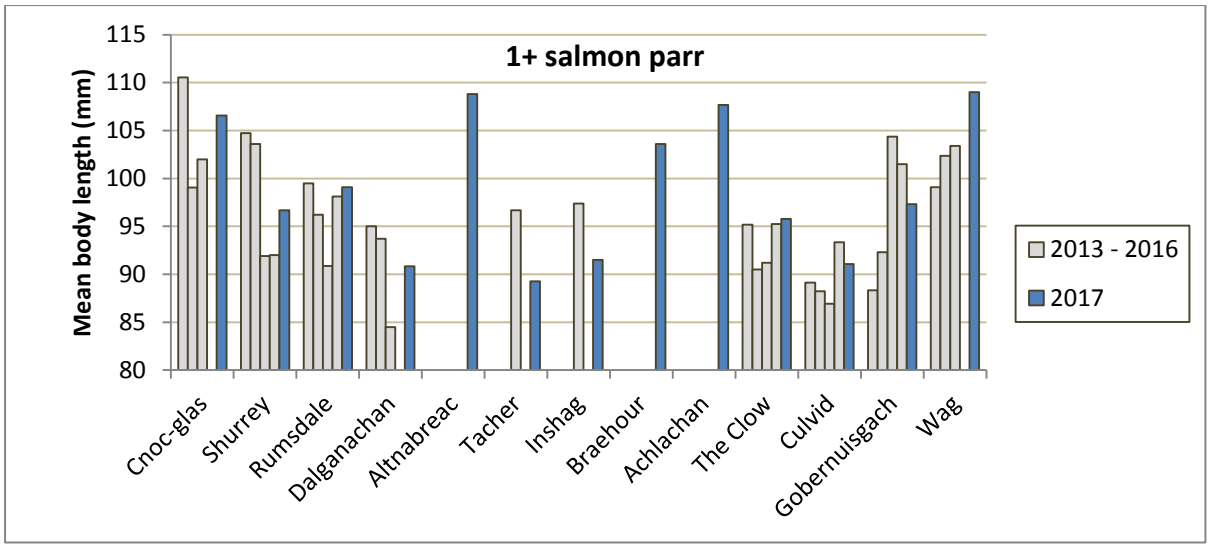


Figure 2. Average body length of 1+ parr by site, 2013–2017.

As in previous years, the body weight of individuals was calculated from body length using Shackley's formula (see previous reports) in order to estimate values for biomass density. The values for body weight are shown in Table 8 – matching the length data shown in Table 7.

River	Site name	Estimated mean body weight (g)		
		Fry	1+ parr	2+ parr
Forss	Cnoc glas	2.50 (0.60)	14.1 (2.87)	21.5
	Shurrery	2.11 (0.57)	10.3 (2.34)	20.5
Thurso	Rumsdale	1.72 (0.51)	11.2 (3.16)	23.5
	Dalganachan	1.24 (0.41)	8.7 (3.14)	23.5
	Altnabreac	2.02 (0.61)	15.0	40.2
	Tacher	1.01 (0.32)	8.0 (2.69)	19.7
	Inshag	1.35 (0.40)	8.9 (3.61)	21.1
	Braehour	1.52 (0.51)	13.0 (3.60)	24.5
	Achlachan	1.16 (0.46)	15.0 (5.65)	21.1
Wick	The Clow	1.65 (0.67)	10.4 (3.42)	19.7
Dunbeath	Culvid	1.38 (0.42)	8.7 (3.33)	19.6
Berriedale	Gobernuisgach	1.41 (0.38)	10.5 (2.63)	20.8
Langwell	Wag	2.31 (0.51)	15.2 (3.18)	21.1

Table 8. Estimated mean body weights of fry, 1+ parr and 2+ parr. Where appropriate the Standard Deviation is indicated.

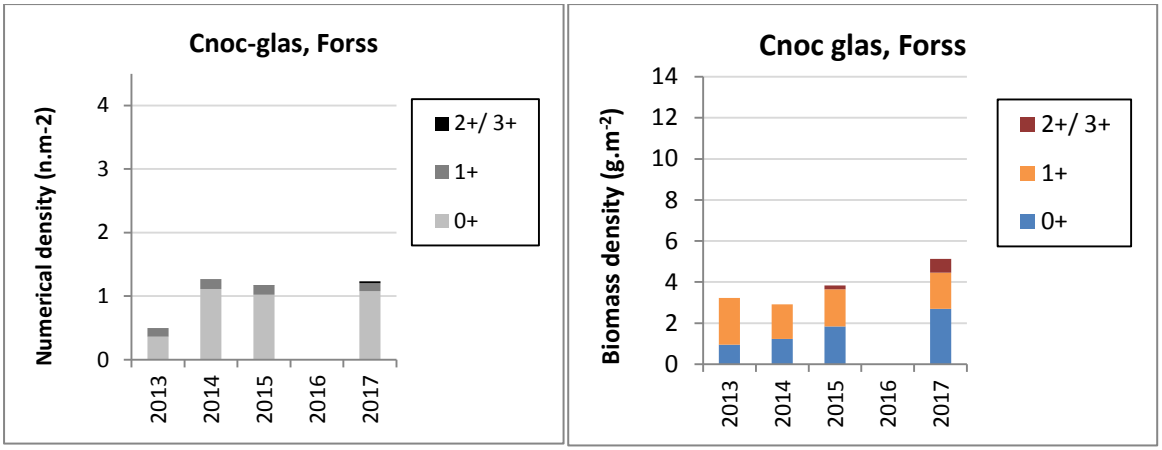
From a biological point of view, the weights of fish are a better measure of their condition than their lengths because they directly show the extent to which individuals have been able to assimilate stream resources (ie. food) within the constraints imposed by the qualities of the site (levels of food availability) and by the presence of other fish (levels of competition).

The mean body weights of fry and parr varied substantially among sites. On average, the smallest fry (at Tacher; mean = 1.01 g) were only about 40% of the weight of the heaviest (at Cnoc glas; mean = 2.5 g) and, on average, the smallest 1+ parr (at Tacher; mean = 8.0 g) were only 50% of the weight of the heaviest (at Wag; mean = 15.2 g).

Following on from survey reports for previous years, the body weight estimates shown in Table 8 were used to generate the estimates of biomass density used in the site assessments for 2017, as below.

3. Site Assessments.

As in previous reports, the assessments for each survey site are centred on two summary panels. The left-hand panel shows the numerical densities (ie. number of fish per square meter for each age-class) presented in the form of a stacked column. The panel on the right shows the equivalent presentation for biomass density (ie. the weight of fish per square metre).



At Cnoc glas, salmon fry were again present in excess of 1.0/m^2. The fry had grown well for the site (see Figure 1) and their biomass density (2.7g/m^2) was the greatest in the time series. The density of 1+ fish (0.12/m^2) was about average for the site. Like the fry, the 1+ fish had grown well (see Figure 2) and their biomass density was in line with values noted in previous years. Driven by good growth for all age-classes, the total biomass density was the greatest so far observed at around 5g/m^2.

Over the sequence of annual surveys, densities of salmon fry at Cnoc glas have consistently been less than for the other Forss sites - Shurrery and Lythmore. However, Cnoc glas differs from the other sites because non-trivial densities of trout fry are often (but not always) present. The numerical densities values for trout fry and salmon fry are shown below for all survey years.

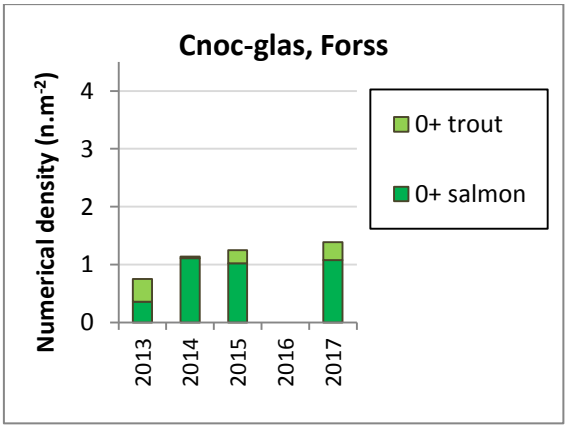
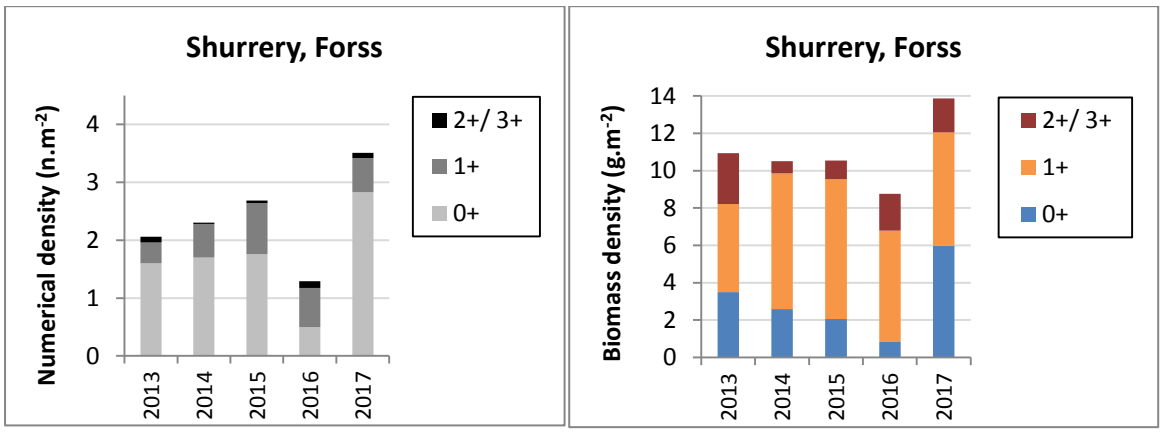


Figure 3. Numerical densities values for trout fry and salmon fry at Cnoc glas (2013-2017). The site was not fished in 2016

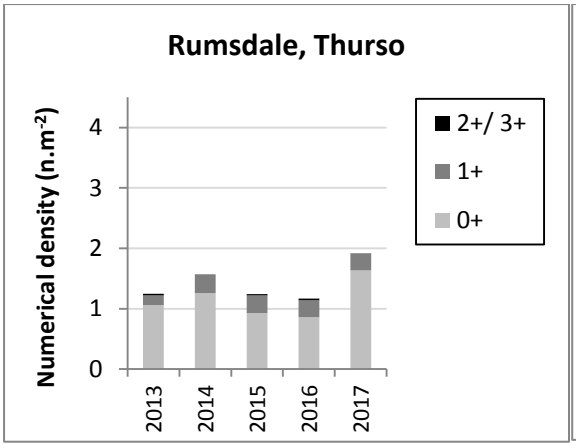
In 2017, the density of trout fry was 0.31/m^2 and the combined density of trout and salmon fry was 1.4/m^2. This latter value was the highest annual value recorded at the Cnoc glas site. No trout parr were detected in 2017. Indeed, across all years, trout parr were present only in 2013 and then only at low density (0.03/m^2).

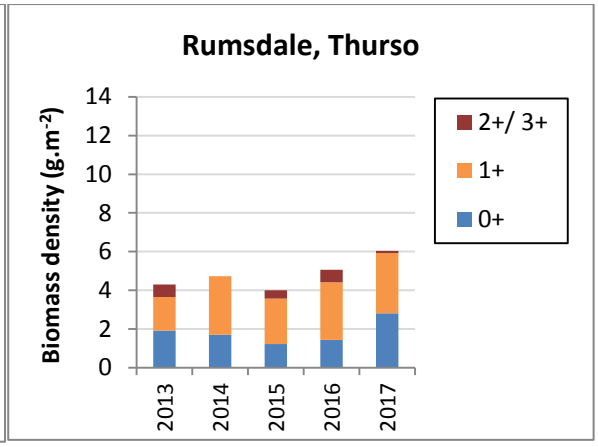
The presence of the trout potentially complicates assessment of the Cnoc glas salmon population. However, the densities of trout fry are moderate and those of trout parr are low. At the levels so far observed the trout can probably be regarded as just another one of the many factors that affect the quality of the stream habitat available to salmon. However, even directly accounting for trout, the combined salmonid population at Cnoc glas consistently underperforms the salmon populations at Shurrery and Lythmore. Once again, the 2017 data strengthen the view that this is not due to any restriction on the input of fry to Cnoc glas. It is much more likely that habitat quality, particularly for parr, is inferior to that at both Shurrery and Lythmore.



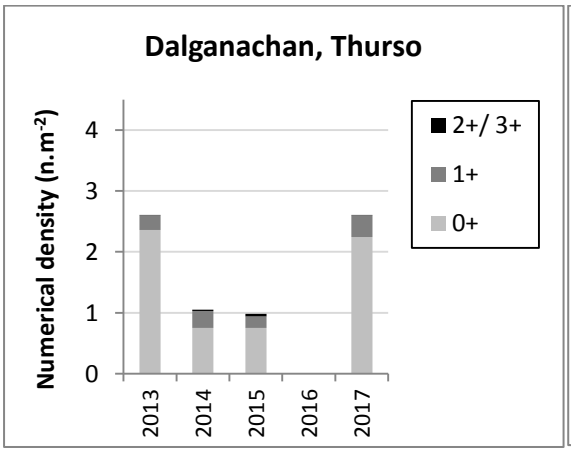
The numerical density of salmon fry at Shurrery was extremely high (2.8/m^2) and greater than previously observed at the site. The density of 1+ parr in 2017 was also extremely high (0.59/m^2) despite the relatively low density of 0+ fish in 2016. Indeed, the density of 1+ fish in 2017 was greater than the density of 0+ fish in 2016 showing that there had been net inwards movement in the intervening period. As a result of this, the biomass density of 1+ fish (6.1g/m^2) was roughly as expected for the site.

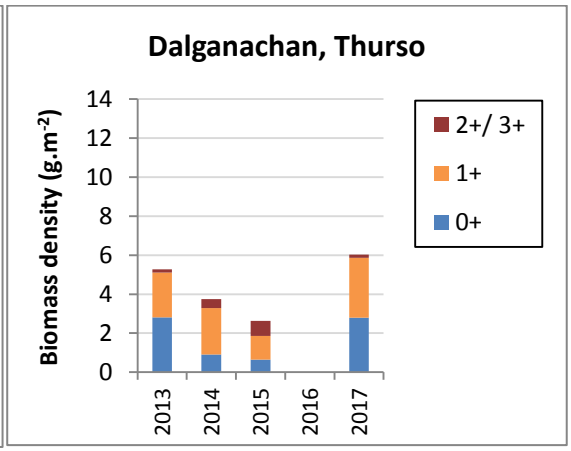
The growth of the 1+ fish had been about average for the site. However, the growth of the fry had been relatively high and, coupled with their high density, resulted in the highest biomass density of fry so far observed at Shurrery (6.0 g/m^2). The total biomass density (around 14g/ m^2) was also the highest value yet observed for Shurrery or, indeed, for any of the other Caithness sites since the start of the survey series in 2013.



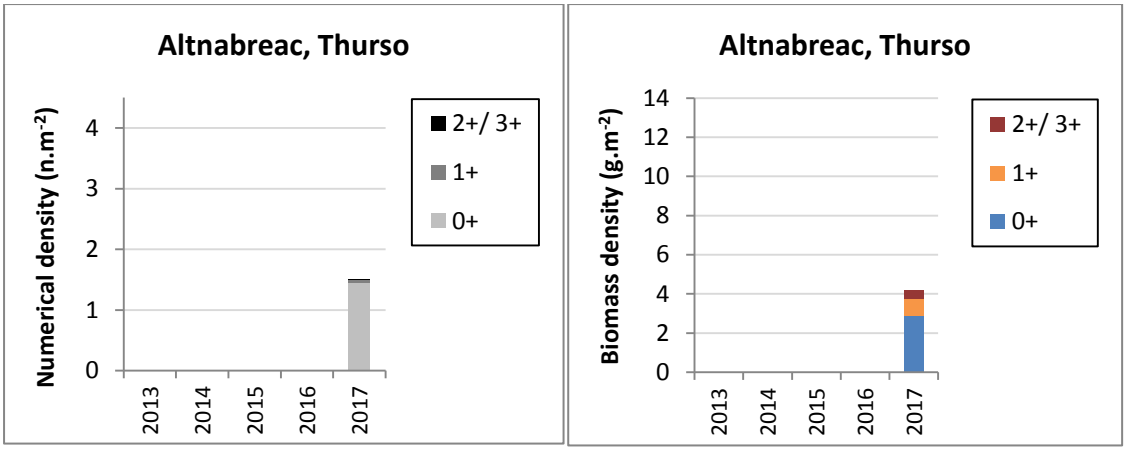


The numerical density of 1+ fish at Rumsdale (0.28/m^2) was roughly as expected based on past years. However, the density of fry (1.6/m^2) was the highest level yet recorded at the site. The fry had also grown well by the standards of the site. Driven by the contribution of the fry, the overall biomass density was around 6 g/m^2, the greatest value yet observed for Rumsdale.





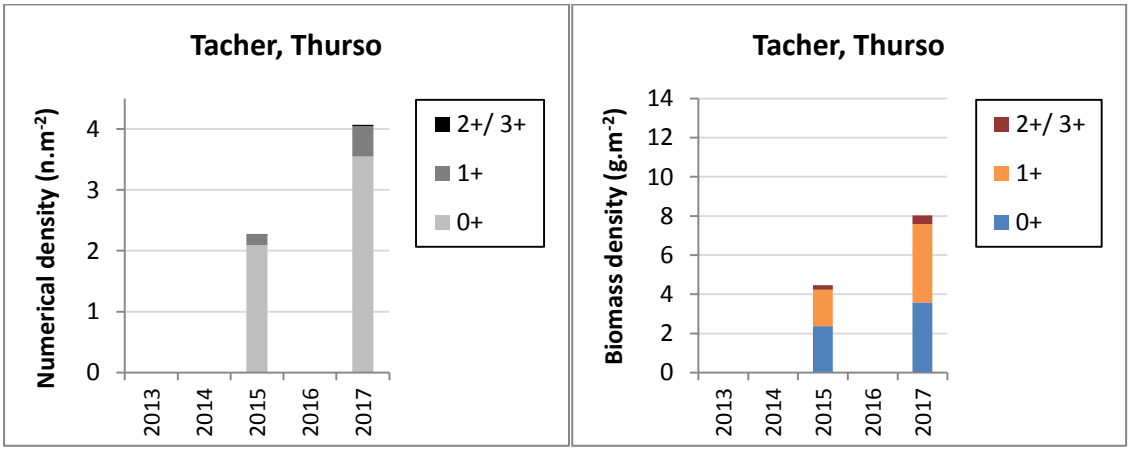
Fry densities at Dalganachan (2.2/m^2) were much greater than values in recent years but similar to the values of 2013. The density of 1+ fish (0.36/m^2) was greater than in previous years. The fry had grown well for the site and their biomass density was similar to the value achieved in 2013. The growth of the 1+ parr had been unremarkable. However, due to their greater numerical density, the biomass density of 1+ parr was greater than in 2013. As a result, total biomass density at Dalganachan was greater in 2017 than in any previous year at around 6g/m^2.



The Altnabreac site on the Sleach Water has not been surveyed previously. The Sleach Water drains much of Strathmore Forest before entering the north-western edge of Loch More. The stream drops only 25m in the 11km between the western edge of the forest and the loch. It is therefore meandering and sluggish for most of its length and not obviously prime rearing habitat for salmon. Despite this, the numerical density of salmon fry was high (1.4/m^2) although few salmon parr (0.06/m^2) were present.

Trout fry (0.55/m^2) were a prominent feature of the Altnabreac site but, like salmon parr, trout parr were present only at low density (0.08/m^2). The total density of trout and salmon fry was (2.0/m^2).

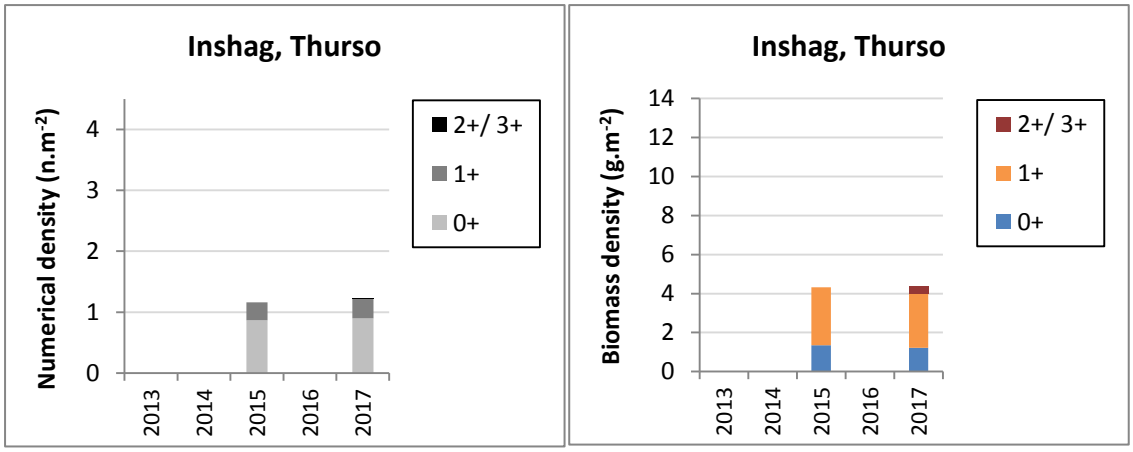
Both the salmon fry and the few salmon parr that were present had grown relatively well by comparison with fish of similar ages at the other survey sites. The total biomass density of juvenile salmon at Altnabreac was around 4g/m^2 – lower than the levels regularly achieved at many other Caithness sites.



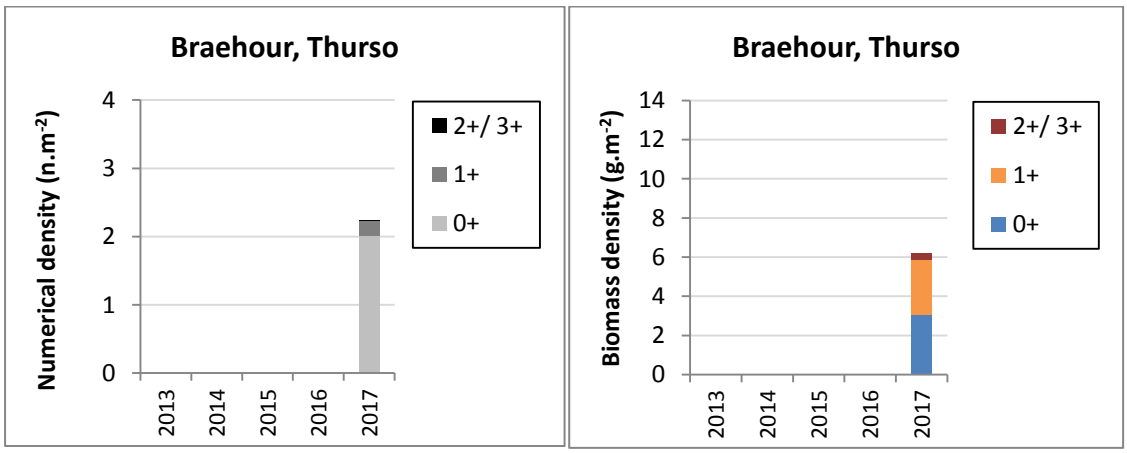
The Tacher site on the Little River was surveyed only once previously – in 2015. In 2017, the density of fry was even greater than the 2015 value and exceptionally high (3.6/m^2) by any standard. The density of 1+ parr (0.50/m^2) was also exceptionally high and much greater than in 2015.

The average size of both fry and parr was less than the equivalent value in 2015. Indeed, both the fry and the parr at Tacher had shown the least growth among all the set of sites surveyed in 2017.

Despite the poor growth of individual fish and because of their high densities, the biomass densities of both fry and parr were greater in 2017 than in 2015. The overall value for 2017 was around 8g/m^2.



The Inshag site on the Little River, near its confluence with the main river, was surveyed only once before – in 2015. The numerical and biomass density values were very similar in both years; fry and 1+ parr densities were around 1.0 and 0.3/m^2, respectively, and total biomass density was around 4g/m^2.



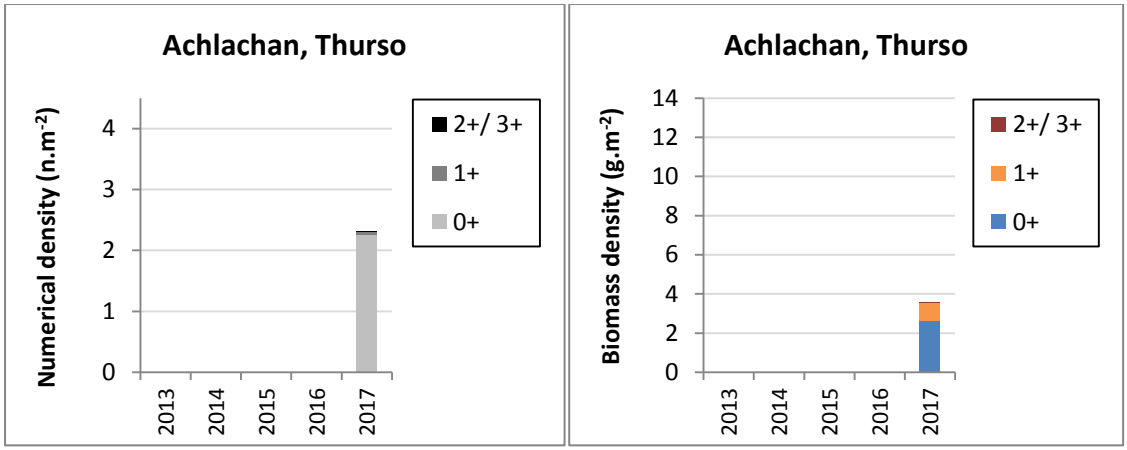
The Braehour Burn drains the forest of the same name and flows northwards to join the main river Thurso just downstream of Westerdale. The stream is relatively small but it is one of the few streams draining into the lower part of the main river (although the confluence is still about 18km above head of tide). A new site on the burn, just to the west of the Westerdale and Scotscalder road, was

surveyed for the first time in 2017 in order to increase coverage of the lower part of the Thurso catchment.

Salmon fry were present at very high density (2.0/m^2); 1+ parr were present at a modest density of 0.21/m^2.

Although salmon were predominant at Braehour, substantial numbers of trout were also present. At 0.25/m^2, the density of trout fry was much less than the (very high) density of salmon fry; the density of trout parr was modest (0.09/m^2) but still high relative to most other Caithness sites. The combined density of salmon and trout fry was 2.3/m^2; the combined density of salmon and trout parr was 0.30/m^2.

The combined biomass density of salmon fry and salmon parr was around 6g/m^2. So, even ignoring the contribution of the trout, this value puts the Braehour Burn among the more intrinsically productive streams in Caithness.

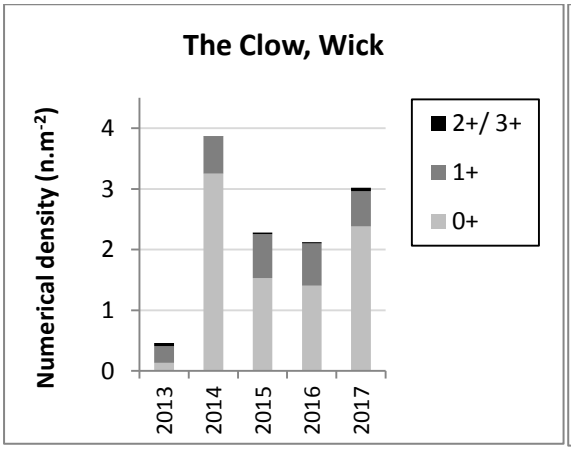


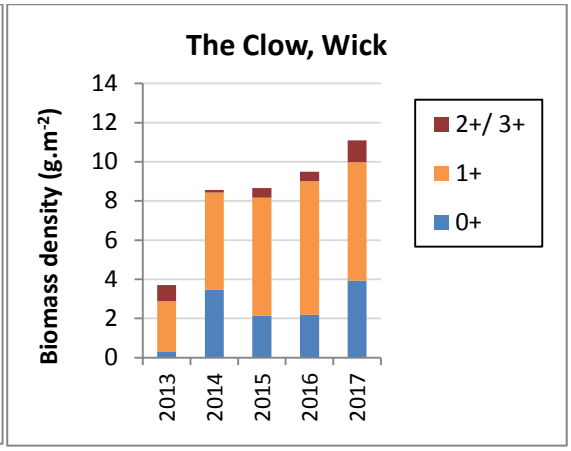
The Achlachan Burn drains open moorland and forest around Achlachan and Dale Mosses near Westerdale. The stream joins the main river on its right bank about 1.5 km above the confluence of the river with the Braehour Burn. Like the Braehour Burn, the Achlachan Burn is one of the few streams draining into the lower main river but, again, it is probably rather small to be a truly reliable index site. The stream is about 2m wide at the survey site, just to the east of the public road between Westerdale and Halkirk.

As for the Braehour Burn, salmon fry densities at Achlachan were very high (2.3/m^2) although salmon parr were relatively few (0.07/m^2). The parr had grown better than the average for the other Caithness sites surveyed in 2017 but the fry were relatively small. The combined biomass density of salmon fry and parr was about 3.5g/m^2.

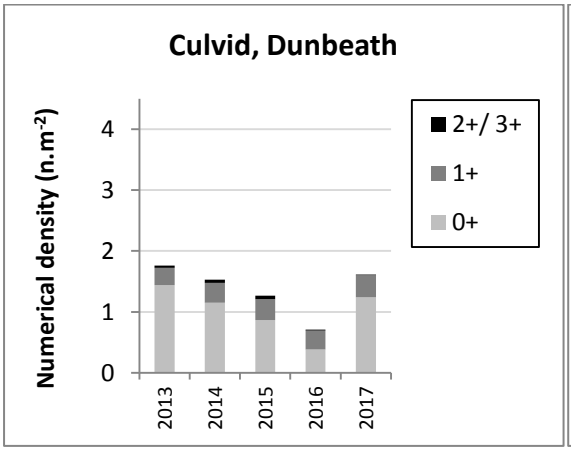
Like Braehour, the Achlachan site contained substantial numbers of trout. The density of trout fry was 0.73/m^2 (the greatest value encountered in 2017) making the combined density of trout and salmon fry 3.0/m^2. Trout parr were relatively few (0.05/m^2) and the combined density of both salmon and trout parr was still only 0.12/m^2. The preponderance of fry probably reflects the nature

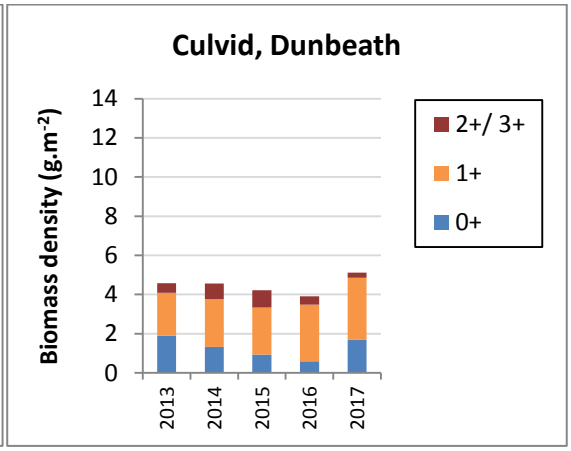
of the stream and, in particular, a lack of the physical complexity that would afford shelter for larger fish.



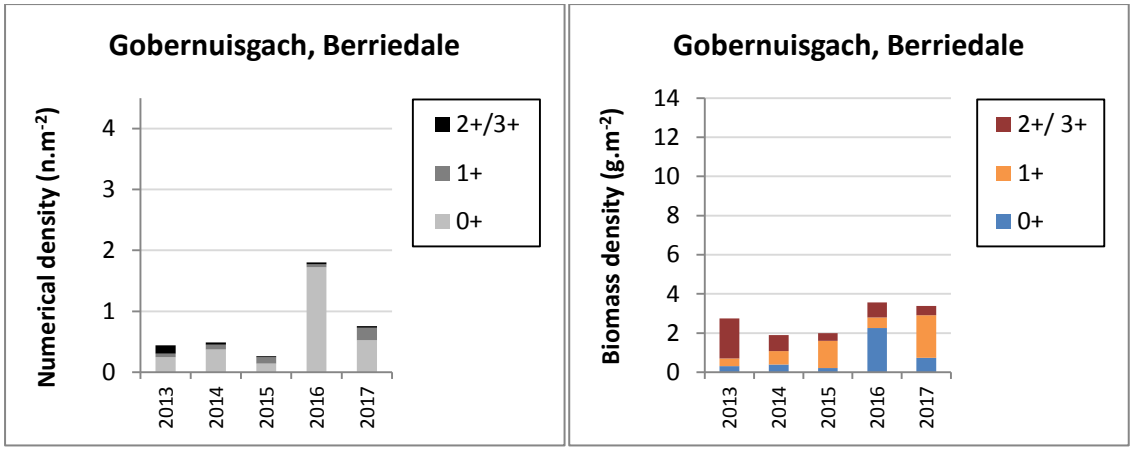


The Clow site has been surveyed annually since 2013. In 2017, the density of fry (2.4/m^2) and the density of 1+ parr (0.58/m2) were roughly as has come to be expected for the site (excepting the anomalous year in 2013). Both groups of fish had grown well by the standards of the site and the combined biomass density was the greatest in the series at around 11g/m^2.





Culvid has also been surveyed annually for the last five years. In 2017, the density of fry (1.2/m^2) was greater than in 2015 and 2016 but generally as expected for the site; the density of 1+ parr (0.36/m^2) was also as expected. Both groups of fish had shown good growth and the combined biomass density of all fry and parr was the highest in the series at around 5g/m^2.



Previous surveys have shown that sites on the dual Berriedale/ Langwell system tend to be less productive than those on the more northern rivers of Caithness. This is probably because the Berriedale and, especially, the Langwell catchments lie beyond the southern limit of the sandstones that cover most of the rest of Caithness. Rivers running over the Caithness sandstones tend to be hydrochemically benign and this affects many aspects of the aquatic environment in positive ways. The igneous and metamorphic bedrocks of much of the Berriedale/Langwell system are likely to be less conducive to the production of salmon and other species.

A glance at the summary panels above shows that the dynamics of the Gobernuisgach population have also been unusually complex. In the earlier years, densities of both fry and 1+ parr were rather low. But in 2015, in common with some of the other survey sites on Berriedale/ Langwell, Gobernuisgach suffered an extremely low fry year. In 2016, therefore, 1+ parr were very sparse (0.05/m^2) but, perhaps because of this, the density of fry (1.7/m^2) was the greatest yet observed.

Following on from this, 2017 was characterised by the greatest density of 1+ parr observed at the site (0.21/m^2). The density of fry (0.53/m^2) had returned towards the more usual values of previous years. Both the fry and the 1+ parr had grown relatively well and the combined biomass density of fry and parr was about 3.5g/m^2.

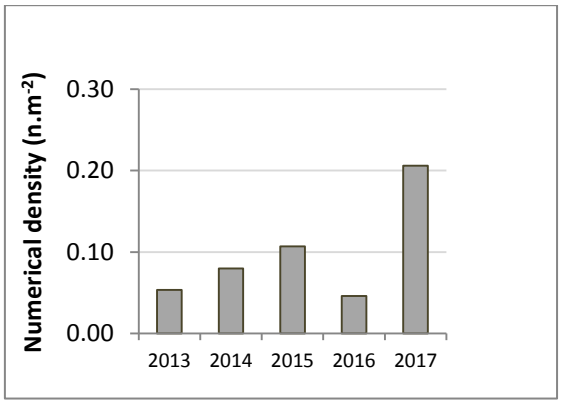
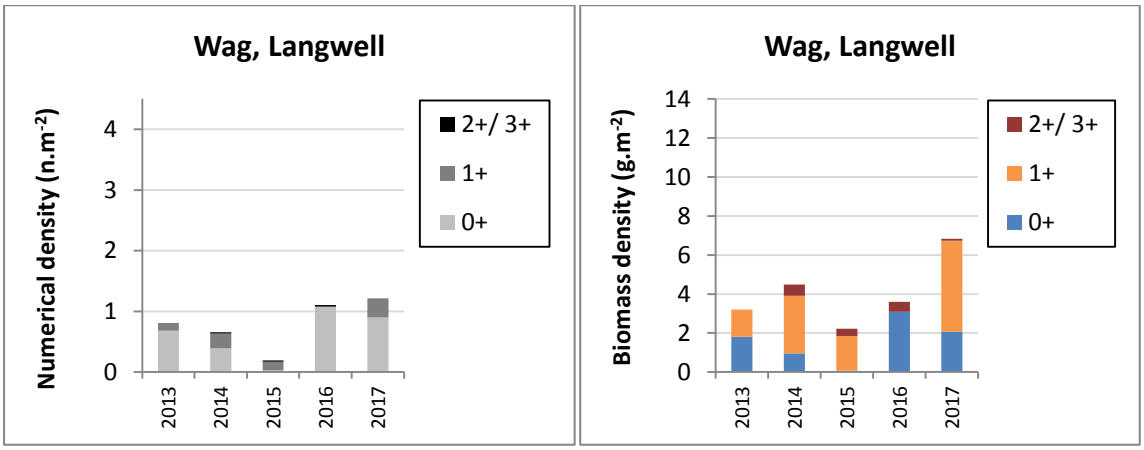


Figure 4. Numerical density of 1+ salmon parr at Gobernuisgach (2013-2017).

Figure 4 shows the densities of 1+ fish at Gobernuisgach. It can be seen that the loss of production of 1+ parr in 2016 was compensated (and perhaps over-compensated) by the unusually high numbers of 1+ fish in 2017. Thus the average density of 1+ parr for 2013, 2014 and 2015 was 0.08/m^2 but the average density for 2016 and 2017, the two years directly or indirectly affected by the poor fry class of 2015, was 0.13/m^2.

As per previous Board reports, these swings back and forth hint at complex interactions between site quality, fry supply, fry uptake, and the mortality, mobility and growth of competing individuals. The Board's data are insufficient to formally test these possibilities. Even so, from a management perspective, it is necessary to be aware that mechanisms like these operate, in order to explore the full range of insights offered by the survey data.



Wag and Gobernuisgach are part of the same dual Berriedale/ Langwell catchment. Wag is the uppermost of the Board's Langwell sites. Wag has been electric-fished every year since 2013 and, like Gobernuisgach, it suffered a very poor fry year in 2015. This offers the opportunity to compare the pattern of recovery at Wag with the pattern of recovery observed at Gobernuisgach.

In 2013 and 2014, fry density at Wag was 0.68 and 0.39/m^2, respectively. As for Gobernuisgach, recruitment of fry was heavily constrained in 2015 and, in fact, no fry were detected at all. As a result, no 1+ parr were detected in 2016 but, as for Gobernuisgach, fry density reached the greatest value yet noted (1.1/m^2).

As a result of this large year-class of fry, the density of 1+ parr in 2017 was also higher than before at 0.31/m^2. Fry uptake in 2017 was also good (0.90/m^2). Both the fry and the parr had grown well and the total biomass density reached the highest level yet achieved at Wag at around 7g/m^2.

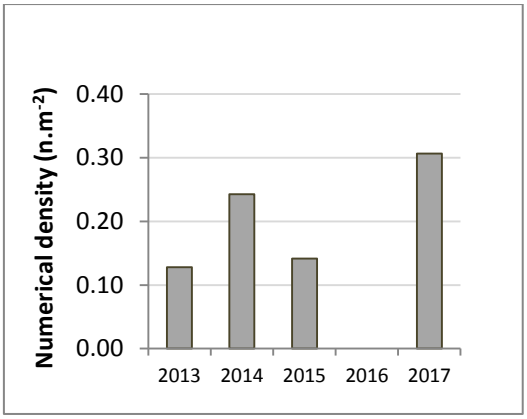


Figure 5. Numerical density of 1+ salmon parr at Wag (2013-2017); no 1+ parr were detected in 2016.

As for Gobernuisgach, the pattern of production of 1+ parr suggested that compensatory mechanisms were in play. Thus, as described above, in 2017 the largest crop of 1+ fish yet noted at Wag followed on from 2016 when no 1+ fish were detected (Figure 5). The average value for 1+ density for 2016 and 2017 (the two years following on from the zero fry-year of 2015) was 0.15/m^2. The average value for the preceding three years had been only slightly higher at 0.17/m^2. Compensatory mechanisms may therefore have maintained the average annual production of 1+ fish (ie. pre-smolts) despite variations in the annual supply of fry.

There is another interesting feature of the Wag site. Figures 1 and 2 show that fish of both the main age-classes, and especially the fry, grow consistently well at Wag and they consistently out-perform fish in other locations throughout Caithness. Both age-classes are also the most uniform in size at Wag (ie. the Standard Deviation is lowest relative to the mean value for both fry and 1+ parr). There is no obvious characteristic of the site that might explain these unusual features.

However, it is possible that the annual supply of fry to the Wag site is consistently inadequate and that all those fish that do recruit are able to thrive as a result of consistently low levels of competition. Such a situation might arise early on in life due to lack of spawning gravel, due to inadequate numbers of spawners, or due to high mortality rates among eggs or early fry. These possibilities merit further investigation, especially because juvenile salmon in the Berriedale/ Langwell system appear to be intrinsically more fragile than populations elsewhere in Caithness.

4. Condition of Caithness Sites in 2017.

1. Thirteen sites were surveyed in 2017. Densities of salmon fry varied from 3.6/m^2 (at Tacher on the Thurso) to 0.52/m^2 (Gobernuisgach, Berriedale). The median value over all the sites was 1.6/m^2.

2. For 1+ parr, densities ranged from 0.59/m^2 (Shurrery on the Forss) to 0.06/m^2 at (Altnabreac and Achlachan both on Thurso); the median value for all sites was 0.32/m^2.

3. Considering single sites, uptake of salmon fry was high (> 1/m^2) in the three sites surveyed for the first time. For all the other sites, fry density was either in line with or greater than expectation based on site values in previous years. Likewise, the density of 1+ salmon parr was average or, in most cases, better than the average value for the site.

4. Where comparison was possible, the mean body length of both fry and 1+ parr at any given site was average or better than the average for that site.

5. At eight of the 10 sites that had been surveyed previously, total biomass density was greater than in previous years; levels were about average for the other two sites.

6. In summary, the high densities of fry, the good growth of both fry and parr and the high levels of total biomass production indicate that the overall status of juvenile salmon in the Caithness rivers in 2017 was again good and probably even better than in previous years.

7. The exceptional nature of the 2017 assessment may be attributable to a year-effect associated with atypical patterns of rainfall and higher than average river flows.

5. Atypical river discharge in 2017 and exceptional fish performance.

There are two SEPA gauging stations in Caithness - at Halkirk on Thurso and at Tarroul on Wick River. At some times, water levels at the Halkirk Gauging Station are affected by regulation of the sluices at Lochmore. Tarroul was therefore chosen from the gauged sites in Caithness to examine summer patterns of river flow.

Based on the gauging data, SEPA provides a value for the average discharge rate at Tarroul for each day. Over the summer period, discharge values at Tarroul are usually less than 3.0 m^3/s although higher values are associated with freshets or spates running up to, and occasionally exceeding, 10 m^3/s.

In Figure 6 the frequency with which particular discharge values occurred over the 0 to 10 m^3/s range is shown for each of the survey years, 2013-2017. The values are for the 123 days over the period 1st May to 31st August. This period is chosen to cover the time that elapses between the fry's emergence onto the streambed and the commencement of the Board's survey which is fixed for the first week of September. The months of May to August therefore cover the period in which the variation in the growth and survival of fry, in particular, as assessed by the Board's surveys, is actually engendered.

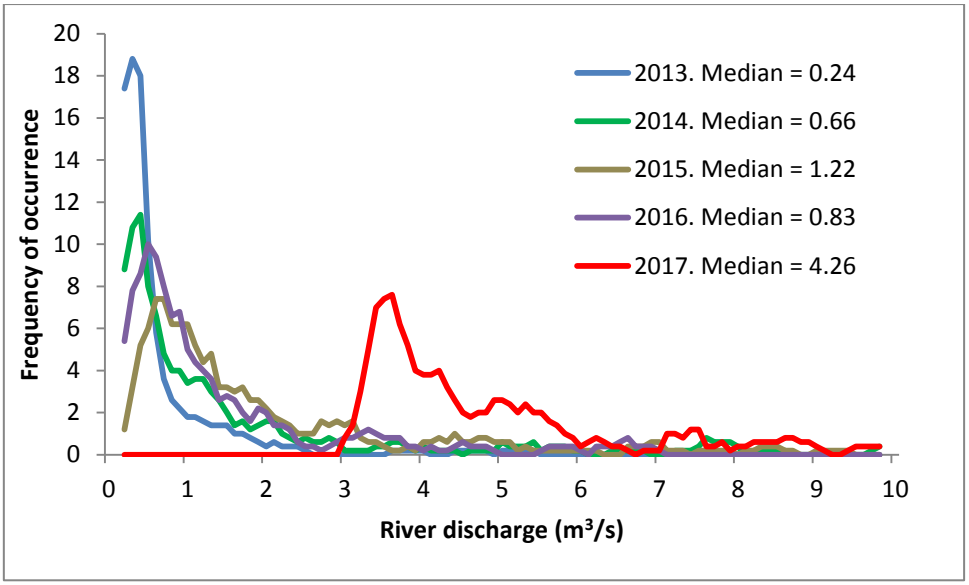


Figure 6. Frequency distribution of mean daily discharge values at Tarroul Gauging Station on Wick River for period 1st May to 31st August and for the years 2013 – 2017. The distributions are smoothed as 5-point running means. Data from SEPA.

Figure 6 shows that the pattern of river discharge values for the summer of 2017 contrasted starkly with the lower values characteristic of all previous survey years. Assuming that the pattern of river flows at Tarroul was typical of the Caithness rivers in general, it is therefore possible that the unusually high performance of young fish noted for 2017 was attributable to the prevalence of atypically high river flows throughout Caithness District. Flow affects many aspects of the river environment and there are therefore a number of factors that might link flow and performance. Perhaps the simplest possibility is that the relatively high flows of 2017 prevented the shrinkage of survey sites that is caused by de-watering of the stream margins during low summer flows. Shrinkage would be expected to raise levels of competition among fish and reduce their performance but high flows would be expected to remove or lessen this constraint.

In any case, it must be recognised that if patterns of river flow do affect fish performance, then the high levels of performance evident in 2017 may not be attainable in coming years unless flows are similarly favourable.

6. Site habitat quality (2013 to 2017).

In the past, it has proved impossible to produce a robust measure of the quality of stream habitat by directly measuring the wide range of physical and chemical factors that combine to determine the capacity of any stream site to support fish. One of the Board's original objectives was to discover a reliable measure of the habitat quality of particular sites based on the fish data obtained in the electric-fishing surveys. As discussed in previous reports, the total biomass density of young salmon at particular sites varies less from year to year than any other measure of performance. A maximum capacity to support biomass therefore appears to be an intrinsic characteristic of any particular site that is related to its habitat quality. Measuring maximum biomass capacity may therefore be a route

towards assessing the habitat quality of particular sites and making allowance for this when comparing the performance of fish across a range of different sites.

However, any site will not reach its potential maximum capacity if recruitment of young fish is limiting. It is therefore helpful to be able to measure the biomass capacity of sites when fry abundance is high. It is also helpful to measure biomass density at the same site over a series of years in order to exclude anomalously low values.

The Board has now obtained electric-fishing data for a total of 29 sites gathered over five survey years (2013-17). In each of these years the density of fry in the Caithness rivers has been high by comparison with similar measurements made elsewhere. Table 9 shows the median fry density for each year over all the sites surveyed that year and the maximum value measured at any of the sites. In Table 4 the preponderance of blue or dark blue cells in the left-hand panel also shows that many individual sites reached or exceeded the maximum value for fry density as proposed by Godfrey for the northern rivers.

	Numerical density of salmon fry (n/m^2)	
	Median	**Maximum**
2013	0.68	3.27
2014	1.17	3.25
2015	0.87	4.53
2016	0.86	2.32
2017	1.64	3.31

Table 9. Annual summary values for fry density.

So, during the period of the surveys, fry have evidently been very abundant in Caithness. This, in turn, suggests that spawning has been good and that juvenile production has not been consistently or generally limited by any shortage of fry. Moreover, although a few sites have been surveyed only once or twice, most of the sites have been surveyed more often. Under these circumstances, the maximum value for total biomass density that was observed at each site can be treated as an interim measure of that site's intrinsic capacity to support fish (ie. habitat quality). The resulting classification is provisional because greater biomass values may be detected in future surveys - especially for the few sites that have not been surveyed repeatedly to date.

Bearing all this in mind, Figure 7 shows the values for the maximum biomass density detected at each site in any of the survey years so far. To date, the median value for all sites is 6.0 g/m^2. In Figure 7, values greater than the median value have been colour-coded green (6.0 – 7.9 g/m^2) or blue (> 8.0 g/m^2). Values less than the median have been colour-coded yellow (4.0 – 5.9 g/m^2), orange (2.0 – 3.9 g/m^2) or red (< 2.0 g/m^2).

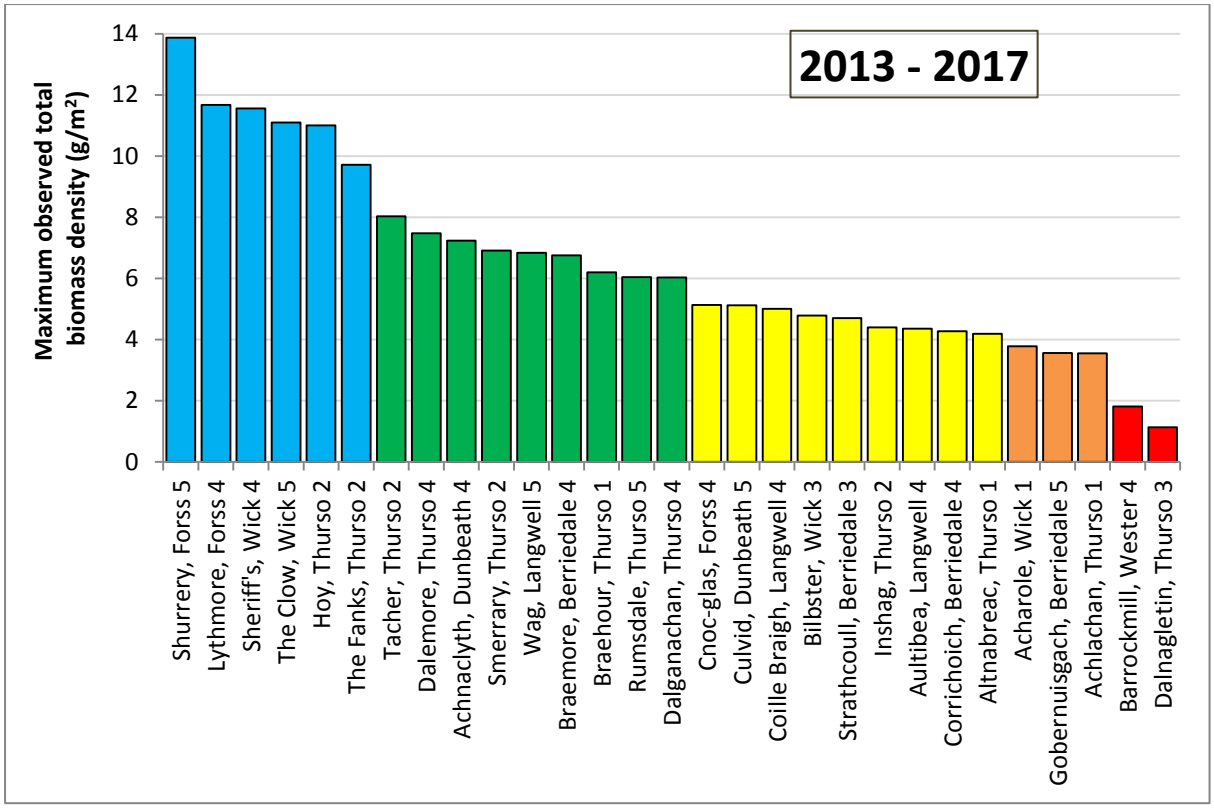


Figure 7. All Caithness survey sites ranked according to the maximum biomass density of salmon (based on Zippin-corrected, 3-pass data) observed in any survey year. The number associated with each site identity specifies the number of occasions between 2013 and 2017 on which that site was surveyed.

It can be seen from Figure 7 that most sites have proved capable of supporting a biomass density of between 4 and 8 g/m^2 (green or yellow). Five sites (orange or red) have proved capable of supporting a value less than 4 g/m^2 but, for various reasons, none of these cases is surprising (as discussed in individual site assessments in this and previous reports). There are six outstanding sites of high quality (in blue) that are capable of supporting a total biomass density greater than 8 g/m^2.

In Figure 8, the same values are shown mapped onto the Caithness river network. Seven additional values are shown for the River Wester in the north-east sector. These values were obtained in the course of the Flow Country Rivers Trust's detailed survey of the Wester catchment in 2016. As Figure 8 shows, biomasses of juvenile salmon are relatively low in the River Wester due to extensive and radical modification of the stream network associated with land drainage works.

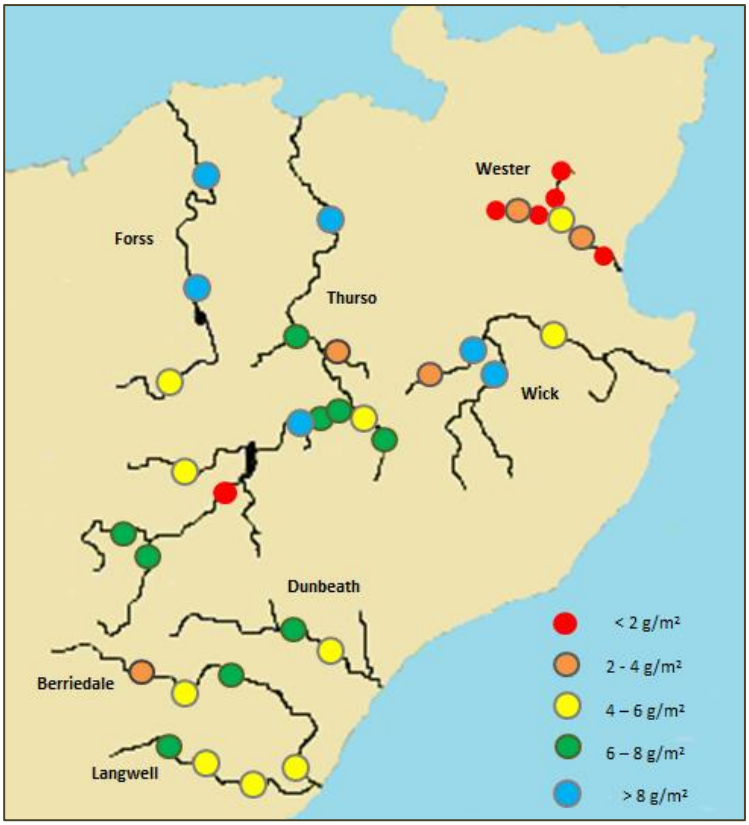


Figure 8. Biomass density of juvenile salmon.
Maximum observed value 2013-17 (Zippin-corrected, 3-pass data).

Excepting Wester, weak patterns are evident in the distribution of biomass and, by inference, habitat classifications in the other six Caithness rivers. All the highest category sites (blue) are located in the Forss, Thurso or Wick catchments in the northern part of the survey area. For these same rivers, 64% of all 19 sites are classified as being better than the overall median value for Caithness. For the Dunbeath, Berriedale and Langwell rivers only 33% of nine sites exceed the median value. This is probably to be expected given the generally less favourable characteristics of the southern Caithness rivers. Even so, it is worth noting that, excepting Wester, all the Caithness rivers contain at least one site in the highest green or blue categories for biomass density.

Figure 8 also points up gaps in the Board's current coverage of the Caithness rivers that could be filled in future surveys. This point is considered more fully, below.

7. Considerations for 2018.

1. No incipient problem was identified at any of the sites examined in 2017 and therefore none of these sites needs to be prioritised for inclusion in the 2018 electric-fishing programme.

2. The Board's monitoring of the aftermath of the low fry year of 2015 on Berriedale/ Langwell drew to a close with the 2017 survey of the Gobernuisgach and Wag sites. The year-class in question was spawned in 2014, reaching the fry stage in 2015 and the 1+ stage in 2016.

In 2016, all seven Berriedale/ Langwell sites were surveyed and based on the densities of 1+ fish, all of the Langwell catchment and the upper part of the Berriedale catchment had been most affected by the original lack of fry (see 2016 report). In spring 2017, a correspondingly weak cohort of two-year-old smolts will have left these affected areas. As a result, uncharacteristically weak classes of grilse and 2SW fish are expected to return in 2018 and 2019, respectively.

This weakness may not be evident on the Berriedale River because only the upper reaches appear to have been affected by the original shortfall in fry. However, all the Langwell sites were affected and the Langwell fisheries of 2018 (grilse) and 2019 (2SW fish) are therefore likely to be weaker than usual. Knowing this, the appropriate management measures can be put in place before the affected fisheries take place.

The 2017 survey suggests that there may be an upside to this. The grilse fishery on Langwell in 2019 and the 2SW fishery in 2020 may prove to be better than would otherwise be the case. As described above, the low densities of 1+ parr in 2016 appear to have favoured high levels of fry recruitment in 2016 and, therefore, unusually high densities of 1+ parr in 2017 (as per Figures 4 and 5, above). As a result, the Langwell smolt run of 2018 is expected to be larger than usual and the resulting spawning stocks (and the fisheries) will benefit from this in 2019 and 2020.

A cautionary note should be attached to all forecasts of this type. It must be remembered that while the size of the smolt run sets an upper limit on the number of adult fish that can return, the marine mortality rate determines the proportion of fish that actually do so. The marine mortality rate is always high and it varies unpredictably from year to year. This means that variation in the size of the smolt run is not always fully, or even faithfully, reflected in variation in the size of the ensuing adult run – far less the catch.

3. The Board's annual surveys have gone some way to (a) identifying the 2015 fry problem in Berriedale/ Langwell, (b) defining its spatial extent, (c) working out the complex sequence of compensations that followed and (d) forecasting the possible consequences for the fishery. However, the cause of the problem remains unknown. The 2015 event may have been a one-off or similar events may recur sporadically throughout the Caithness rivers without so far being detected. In this case the underlying cause would be regarded as just another factor that generates variation between years and between sites.

But perhaps, instead, low fry recruitment is a consistent feature of parts of the Berriedale/ Langwell system that the Board's survey methods can identify only when recruitment is most constrained and the effects are most evident. As discussed above, the consistently good growth of fry at the Wag site on Langwell suggests that it is an unusual site and hints that consistent shortfalls in fry recruitment are implicated. If this is the case, it would undoubtedly be instructive to discover more about the underlying cause(s).

8. Choice of new sites to complete spatial framework of survey coverage.

Figure 9 repeats Figure 8 but with the addition of the proposed locations and identities of 12 new sites that could be targeted to complete a framework for the Caithness rivers. The new sites are chosen to give uniform spatial coverage and also to address questions raised by the distribution of biomass categories as shown in the figure. So, for example, there is an unexplained discontinuity between the lower and upper parts of the Forss that could be examined by adopting a new site at Torran. For the Wick River, there is a discontinuity that could be resolved by adopting sites at Watten and Ingimster. Gobernuisgach on the uppermost part of Berriedale River is only poorly productive and comparison with Glutt and Pollroy in the adjacent catchments might help explain this. All these new sites could be electric fished by 2019 if the Board's annual programme is continued at its present level.

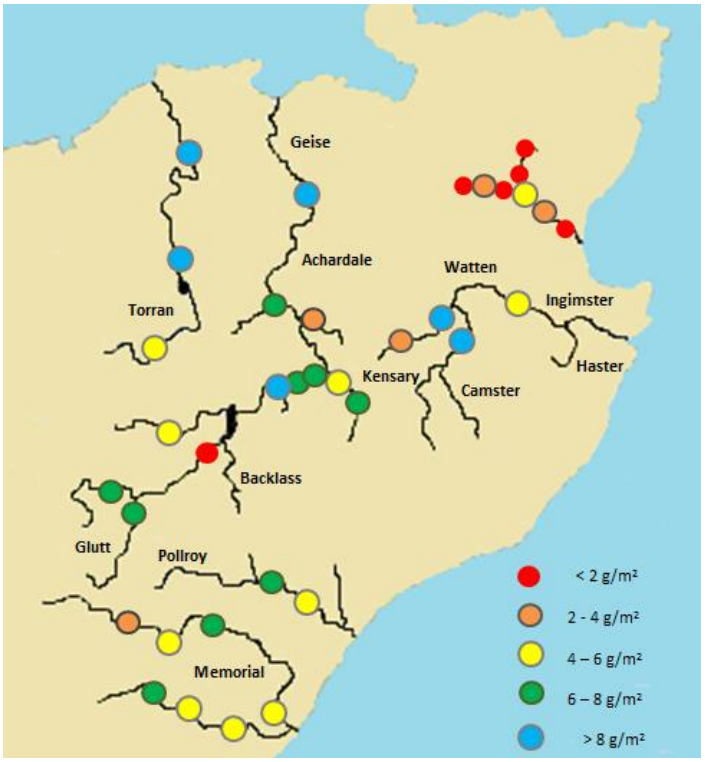


Figure 9. New locations proposed to complete the framework of sites for the Caithness rivers.

9. Acknowledgements.

Thanks to Jamie McCarthy, Neil Groat, George Doull Jnr, Cammie Chapman, Pat Quinn and John Mackay who all participated in the survey at various times. Thanks also to Shaun Stanworth of SEPA's Dingwall Office for providing updated, 2017 discharge data for Tarroul Gauging Station.