2018 Survey of Juvenile Salmonids in the Caithness rivers.

Caithness District Salmon Fishery Board

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Langwell Water, September 2018

Contents

1. Introduction.

The Board's electric-fishing survey for 2018 was more extensive than for previous years because of the introduction of the National Electrofishing Programme for Scotland[1] managed by Marine Scotland Science (MSS).

The MSS programme aims to obtain high quality information on juvenile salmonid populations in rivers throughout Scotland. The programme was conceived as an adjunct to the MSS River Grading exercise which has so far been based only on rod catch data for adult fish. The aim of the River Grading exercise is to identify rivers that are not fully populated with fish and, where necessary, to introduce fishery restrictions in order to ensure that enough of the returning adult fish go on to spawn.

However, as the Board has argued, the number of adult fish that are caught is not likely to accurately reflect the numbers that are actually present and some of the gradings for Caithness rivers in 2018 appeared flawed. The National Electrofishing Programme may help to resolve these issues because it aims to improve or replace assessments based on catch data with assessments based on direct measures of the status of juvenile populations. From the Board's point of view, the Programme is therefore worthy of support. MSS relies on local Fishery Boards to acquire the field data for the national programme and the Board was asked to electric-fish a set of 30 sites in the Caithness rivers.

The 30 sites were chosen by MSS to be fully representative of the river catchments by making site selection somewhat random. Although all the MSS sites for Caithness are potentially interesting, some of them are of only marginal interest in the context of the Board's own on-going programme. For example, some of the sites are on small streams on the periphery of catchments beyond the main areas where salmon consistently spawn. Others are in deep pool-like habitat that is not much favoured by young fish. Equally, however, some of the sites appeared to be a good fit with the Board's programme. It was therefore decided to integrate the MSS and Board programmes, obtaining all the information required by MSS and, when it was advantageous, upgrading MSS sites scheduled for single-pass fishing to 3-pass fishing to make sure that the resulting data met the Board's needs.

More specifically, the basic MSS programme comprised a mixture of 1-pass and 3-pass sites. The Board has used only 3-pass electric-fishing methods in the past because the rate of decline in the number of fish captured on successive passes can be used to measure the survey team's efficiency and to check on data quality. Single-pass fishing cannot provide this assurance. Its sole advantage is in being less time-consuming although the marginal gains tend to be modest given that, for both 1-pass and 3-pass methods, the same amount of time must be invested in reaching the survey location and setting up the equipment.

The second component of the Board's programme focussed closely on the Forss and Dunbeath rivers. Late in 2017, both rivers had been allocated provisional River Gradings for the 2018 fishing season that were unexpectedly low. Despite representations by the Board, the final gradings for 2018 remained unchanged. It was therefore decided to obtain electric-fishing data for a greater number of sites on both the Forss and Dunbeath rivers to support any representations that might be

[1] https://www2.gov.scot/Topics/marine/Salmon-Trout-Coarse/Freshwater/Monitoring/ElectrofishingProgramme

required regarding the 2019 river gradings[2]. All the established Board sites on both rivers were examined and in each case four new sites were added.

The third component of the 2018 survey was to maintain continuity in the Board's ongoing programme by electric-fishing the set of six key sites that has been surveyed every year since the current survey series started in 2013.

The aims of the Board's 2018 electric-fishing survey were therefore (1) to obtain the data required by MSS, (2) to integrate the MSS and Board programmes to maximise the benefit to the Board, (3) to acquire more extensive data than previously for the Rivers Forss and Dunbeath and (4) to maintain continuity by re-examining the Board's set of key sites. In all, 44 sites were electric-fished and 27 of them were examined using 3-pass fishing.

2. Procedures

All the methods used were the same as those detailed in previous reports. A bankside generator and control box were preferentially used for electric-fishing but portable backpack equipment was used for the more remote of the MSS sites where access was problematic.

Because of the large number of scheduled sites, fieldwork was started earlier than in previous years (in mid-July). However, all the Board's sites and those of the MSS sites adopted by the Board were fished in late August and early September. This has been the standard period for the Board's fieldwork since the current series of surveys started in 2013.

2018 was notable for its prolonged and severe drought and the survey period was dominated by low water conditions and high water temperatures. Fieldwork was abandoned on some occasions due to high temperatures and on other occasions scale-sampling was suspended to avoid causing harm to fish. At the Board meeting in late August, it was decided to terminate scale sampling for general welfare reasons because adult fish in some rivers were showing signs of infection by *Saprolegnia.* The age of the parr (1+ or 2+) is not known without scale-reading and, for affected sites, this has prevented reporting on the progress of specific cohorts in consecutive years.

Because of the drought conditions in 2018, some of the survey sites were reduced in width where the stream had withdrawn from its edges as water levels fell. Entrenched sites tend not to be affected in the same way. It is important to emphasise that, in what follows, the density of fish at every site is expressed in terms of the site's "normal" channel-full width. This has been the case for all the Board's past surveys because standardising in this way makes it possible to rigorously compare the productivity of different sites and to compare sites between years.

3. Results

Table 1 (see Appendix) shows the details of each electric-fishing site. The sites are grouped by river and given a trivial name to aid reference. For new sites, the OS grid reference for the lower limit of the site and the site's length are given; existing Board sites are documented in previous reports. The

[2] This matter was subsequently resolved when MSS allocated Grade 1 status for the Rivers Forss and Dunbeath for the 2019 season.

availability of scales is indicated and the number of electric-fishing passes that were carried out is specified for each site.

3.1. 1-pass Electric- fishing

Table 2 (Appendix) shows densities of fish - salmon and trout and fry and parr - observed for the 17 sites fished by 1-pass and for the 27 sites that were fished by 3-pass fishing. In the latter case, the data refer only to the first pass of 3-pass fishing so that all 44 sites can be compared on the same basis. Fry and parr were distinguished based on the distribution of body lengths at each site.

The cells on Table 2 are colour-coded (adopting the approach used in previous Board reports) according to the criteria proposed by Godfrey (2005)[3] for categorising salmon fry and salmon parr densities as observed in 1-pass fishing in the northern rivers. The critical values and the colour-codes used are shown in Table 3.

Table 3. Critical values for salmon and fry densities in northern rivers (Godfrey, 2006)

	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

So, for example, applying Godfrey's criteria it is expected that fewer than 0.05 salmon fry per m^2 (colour-coded red) will be observed in about 20% of all sites examined: the top 20% of sites (colour-coded light blue) are expected to contain between 0.34 and 0.67 salmon fry per m^2. Past surveys have shown it necessary to include an additional category for sites that contain more than 0.67 fry per m^2 (colour-coded dark blue). The same principles are applied to salmon parr using the values specified in Table 3, including an additional category for sites containing densities of parr greater than $0.28/m^2$.

3.1.1. Densities of salmon

It can be seen from Table 2 that salmon fry and salmon parr were present at average, or better, densities (coded yellow, green or blue) at most sites. Salmon fry were sparse or absent (coded red or orange) at seven sites. Salmon parr were sparse or absent at seven sites including all three sites on the Watten arm of Wick River from which salmon fry were also absent. Salmon, both fry and parr, were also essentially absent from the Gaineimh site (Thurso catchment) which was found not to be suited to supporting salmonids - being deep, sluggish and with a bottom formed of deep peat.

No equivalent of Godfrey's classification scheme is available for trout. However, the values shown in Table 2 indicate that trout were essentially absent from all but six of the 44 sites examined.

Figures 1 and 2 map the salmon data contained in Table 2 to show spatial variation in fry and parr densities, respectively. The colour-codes are the same as those used in Table 2.

[3] J.D. Godfrey (2005). https://www2.gov.scot/Resource/Doc/295194/0096508.pdf

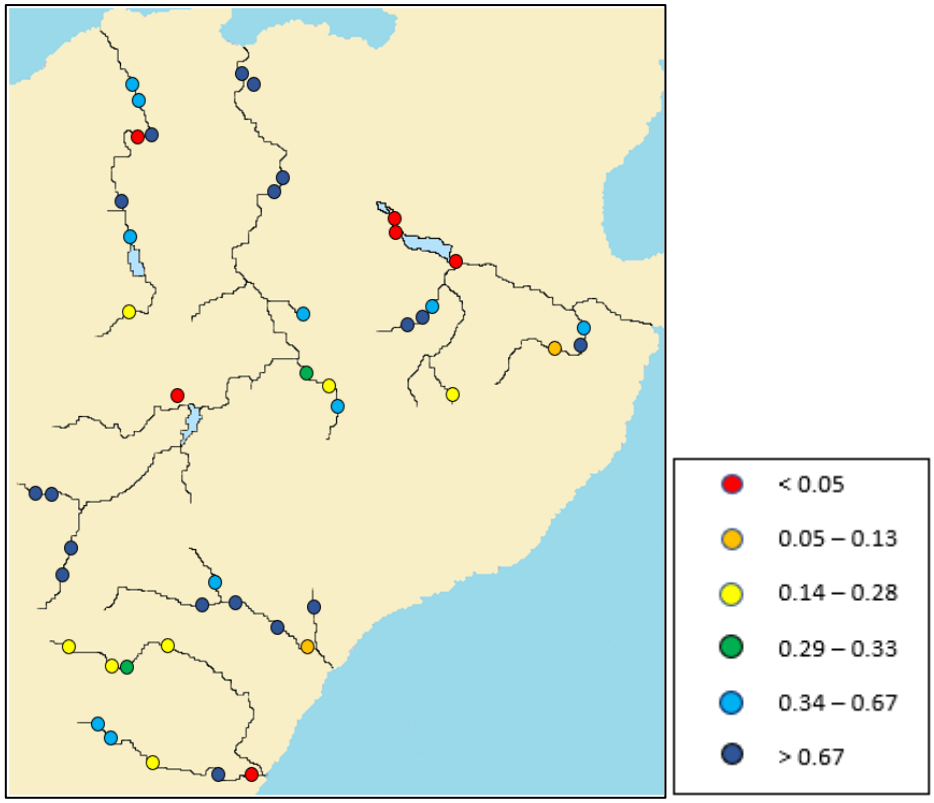


Figure 1. Densities of salmon fry (n/m^2) observed for 1-pass electric-fishing.

High fry densities were observed throughout each of the Caithness catchments suggesting that spawning by adult fish in 2017 had been widespread and, in some places, intense.

Salmon fry were absent or sparse (coded red or orange) -

1. At Forsie on the River Forss. This site is a torrent at normal flows and it lies below an extensive reach of exposed bedrock unsuited to spawning.

2. At the group of three sites on the Watten arm of the Wick catchment. Local knowledge indicates that adult salmon do not use this part of the catchment.
3. At Achairn on the Haster Burn near Wick. The site is uniformly deep and slow-flowing and not suited to supporting salmon fry.

4. At Gaineimh, on the Uidh Ruadh Burn, a sluggish tributary of the Sleach Water, near Loch More, that is unsuited to salmon.

5. At Ballachly and at Langwell House on the lowermost reaches of the Dunbeath and Langwell Rivers, respectively.

Otherwise, high values for fry density were represented in all six river catchments. Considering all 44 sites, the median value for fry density on 1-pass fishing was 0.49/m^2. The Forss and Dunbeath rivers were a specific focus of the 2018 survey and average densities of fry were high in both at 0.66 and 0.77/m^2, respectively.

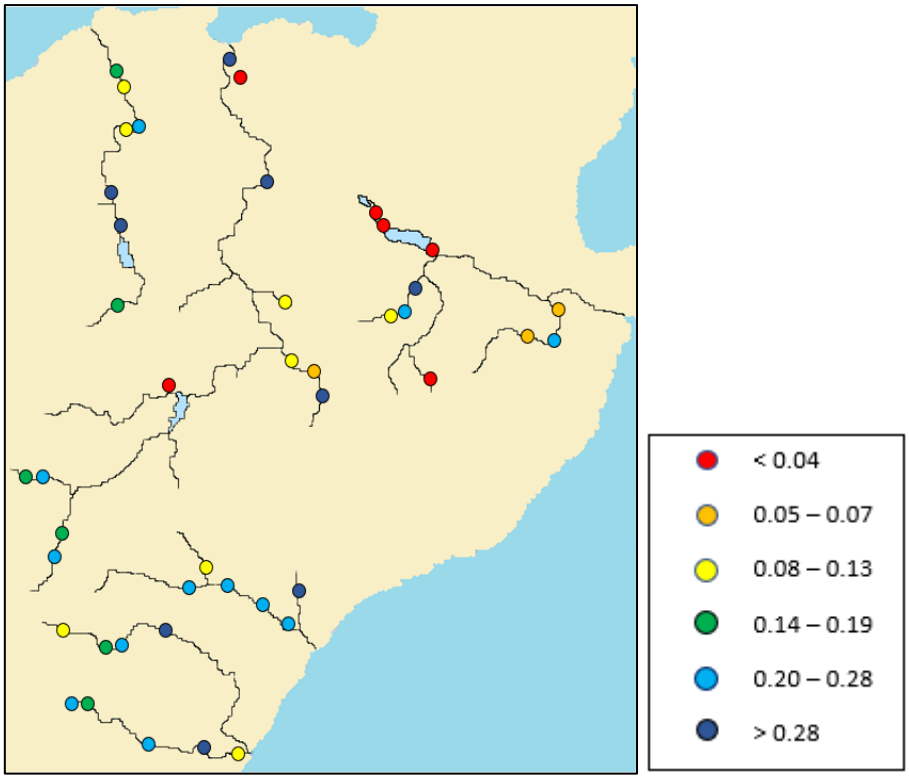


Figure 2. Densities of salmon parr (n/m^2) observed for 1-pass electric-fishing.

Figure 2 shows that the pattern of representation of salmon parr generally paralleled the pattern shown by fry. Like fry, parr were absent or sparse (coded red or orange) in the Watten arm of Wick river and at Gaineimh on Thurso.

Salmon parr were also absent or sparse:

1. In the Carsgoe Burn near Thurso and in the uppermost reaches of the Camster Burn on Wick River. The few parr at Camster were 2+ rather than 1+ years of age, suggesting that adult fish may not spawn there every year resulting in the sporadic representation of particular year-classes; the Carsgoe Burn may be affected in the same way.
2. At Tacher 2 on the Little River. The site is not obviously suited to salmonids although salmon fry were present in reasonable numbers.

3. At Haster, on the Achairn Burn near Wick. This was one of the few survey sites that failed to meet expectations. The site had not been surveyed before but physical habitat quality appears to be high. Indeed, fry were present at high density at Haster and parr were present

at high density at the Puldagon site nearby. There is no obvious explanation for the mismatch and the site ought to be checked again in a future survey-year.

Considering all 44 sites, the median value for parr density on 1-pass fishing was 0.18/m^2.

The Forss and Dunbeath were a particular focus of the 2018 survey and the average value for parr density for the rivers was 0.24 and 0.25/m^2, respectively.

3.1.2. Densities of trout

Godfrey's criteria are strictly valid only for young salmon. In what follows, however, Godfrey's criteria have been applied to trout densities in order to visualise the results and make them easily comparable with those of the salmon. The same colour-codings have been used to denote categories of abundance. The results are shown in Figures 3 and 4 for trout fry and trout parr, respectively.

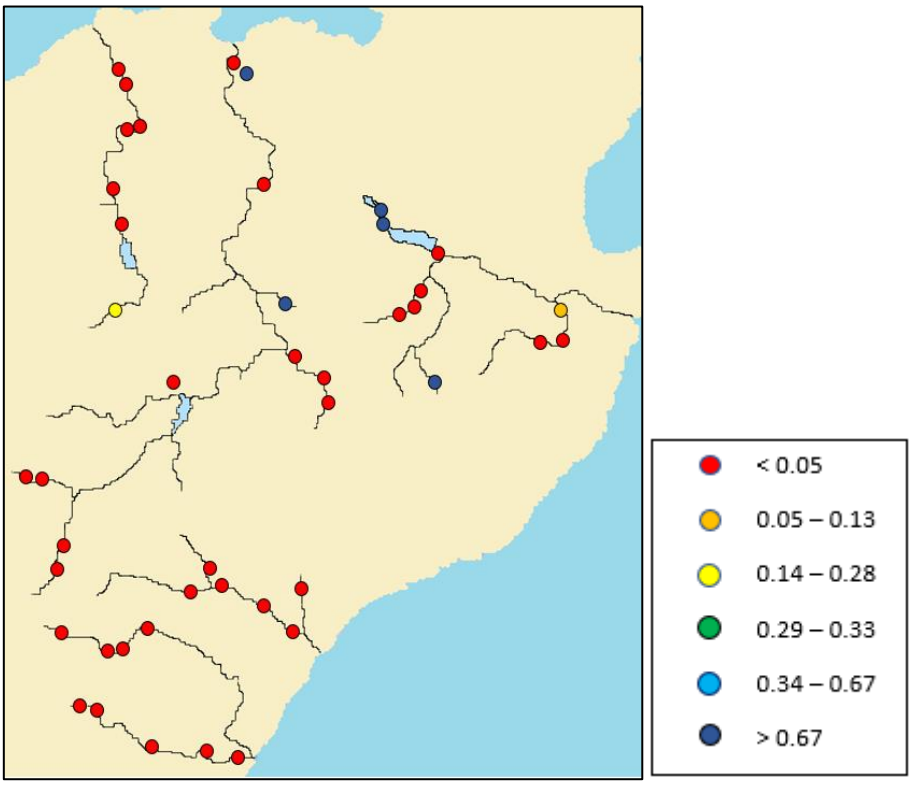


Figure 3. *Densities of trout fry (n/m^2) observed for 1-pass electric-fishing.*

Figure 3 shows that trout fry were absent or sparse in most of the survey sites. Most of the exceptions were for sites on the smallest streams examined (viz. Carsgoe, Achlachan and Camster and the twin sites on the Bower Burn above Loch Watten). Trout fry were also present at Haster in the Wick catchment and at Cnoc-glas on Forss, just below Loch Caluim.

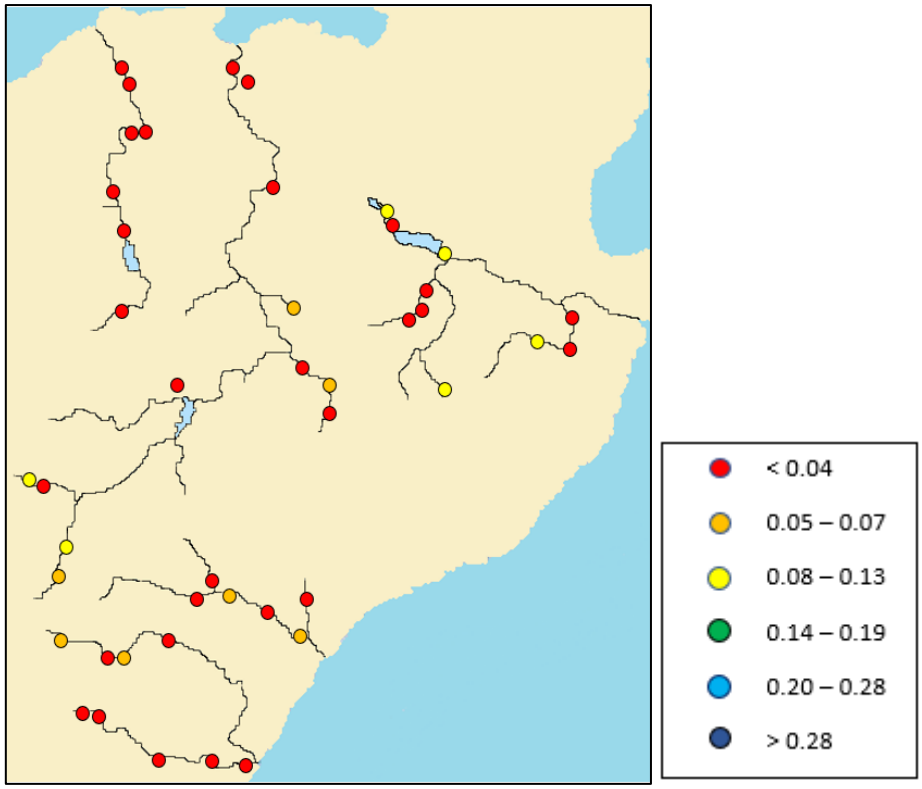


Figure 4. *Densities of trout parr (n/m^2) observed for 1-pass electric-fishing.*

Figure 4 shows that trout parr were more widely represented than fry although parr were still absent or sparse at most sites.

3.1.3. Biomass densities of salmon fry and parr

Table 4 (see Appendix) shows summary data for the body lengths of salmon fry and parr at each of the 44 survey sites. The average value is given for fry because they can be readily distinguished from parr based on differences in body length. However, the median value is given for parr because the ages of individuals for many sites are not known in the absence of scale-reading and they are likely to be a variable mixture of 1+ and 2+ fish.

The fry were largest at Ballachly (mean = 68.3mm) on the lower Dunbeath River and smallest at Camster (mean = 40.2mm). Parr were also largest at Ballachly (median = 112mm) and smallest at Tacher 1 (median = 80mm) in the Thurso catchment.

The body length of individuals was used to estimate body weight and weights were used derive the total biomass density of fry and parr observed for each site. These values are shown in Table 5 (see Appendix).

Figure 5 maps the total biomass values for 1-pass fishing using the colour-coded categories indicated.

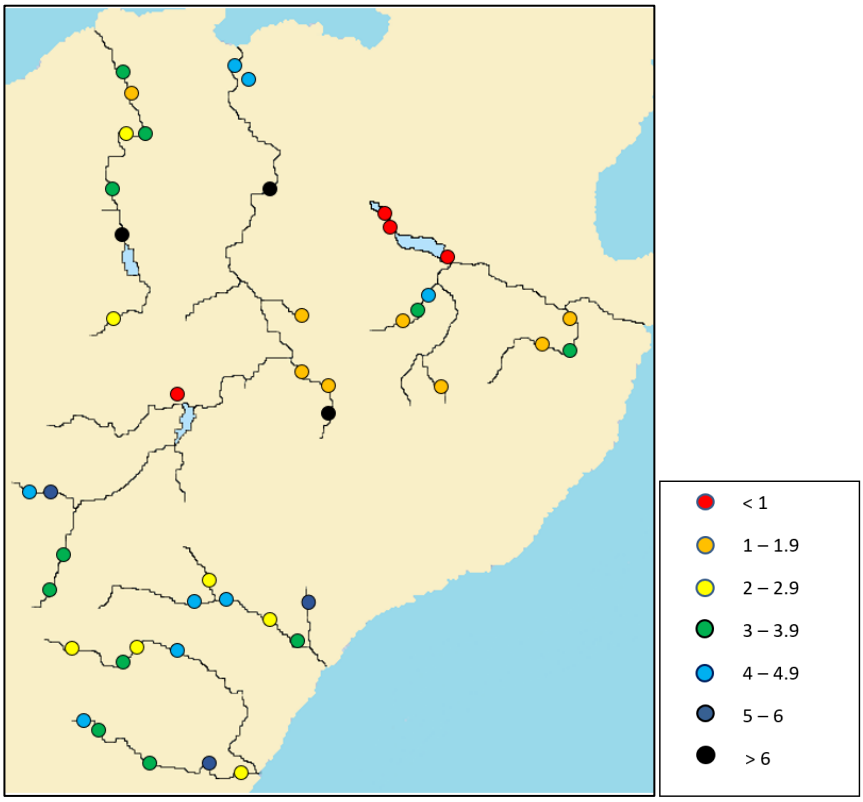


Figure 5. Total biomass density of juvenile salmon (g/m^2) observed for 1-pass electric-fishing

The greatest biomass value (11.25g/m^2) was observed at Hoy on the mainstem of the River Thurso. As expected from the numerical density values discussed above, the least productive sites for salmon were at Gaineimh on Thurso and in the Watten arm of Wick River. Otherwise, no clear spatial patterns are evident in Figure 5 suggesting that the (substantial) variation in the observed total biomass density was associated with local variations in (1) the productivity of sites due to differences in habitat quality and/or (2) the recruitment of young fish due to the patchy patterns in which adult fish spawn. Some of the variation is also likely to be due to the inherent limitations of 1-pass fishing methods (see below).

3.2. 3-Pass electric-fishing

Fully quantitative, 3-pass electric-fishing deals with variation in capture efficiency by using the rate of decline observed on successive passes to estimate its value. Tables 6 and 7 show the observed densities of salmon and trout and the true densities estimated for each of the 27 sites examined by 3-pass fishing.

3.2.1. Densities of salmon fry and parr

Table 6 shows that higher and lower density values for salmon were represented rather evenly across all the river catchments. The greatest densities of fry were identified at Acharole 1 (3.50/m^2) on Wick River, Westfield (3.46/m^2) on Forss and Hoy (2.44/m^2) on Thurso. The greatest densities of parr were identified at Hoy (1.08/m^2) and at Shurrery (0.80/m^2) on the River Forss.

Table 6. O*bserved and estimated true densities of salmon fry and salmon parr at sites subject to 3-pass electric-fishing. Values equal to, or greater than, the median value are indicated by bold text.*

		Salmon			
		Fry		Parr	
River	**Location**	**Observed Density (n/m^2)**	**True Density (n/m^2)**	**Observed Density (n/m^2)**	**True Density (n/m^2)**
Forss	Cnoc glas	0.22	0.22	0.21	0.21
	Lythmore	0.53	0.54	0.14	0.15
	Shurrery	0.77	0.79	0.79	**0.80**
	Broubster	1.41	**1.52**	0.61	**0.66**
	Westfield	3.31	**3.46**	0.27	**0.28**
Thurso	Achlachan 1	0.68	0.68	0.12	0.13
	Grilse Stream	1.29	**1.47**	0.55	**0.58**
	Glutt 2	1.39	**1.45**	0.32	**0.33**
	Glutt 1	1.62	**1.74**	0.24	0.24
	Rumsdale	1.65	**1.74**	0.31	**0.31**
	Hoy	2.32	**2.44**	1.02	**1.08**
Wick	Bower 1	0.00	0.00	0.00	0.00
	Watten Mill	0.00	0.00	0.03	0.03
	Camster	0.41	0.43	0.02	0.02
	Clow	0.60	0.64	0.51	**0.51**
	Puldagon	1.57	**1.68**	0.24	0.24
	Acharole 1	3.23	**3.50**	0.36	**0.36**
Dunbeath	Ballachly	0.14	0.15	0.22	0.22
	Raffin	0.77	**0.80**	0.16	0.16
	Culvid	1.07	**1.11**	0.30	**0.30**
	Pollroy	1.28	**1.32**	0.28	**0.28**
	Achnaclyth	1.25	**1.27**	0.32	**0.32**
Berriedale	Corrichoich 2	0.25	0.25	0.18	0.18
	Gobernuisgach	0.24	0.24	0.15	0.15
	Braemore 1	0.39	0.40	0.55	**0.56**
Langwell	Langwell House	0.05	0.05	0.17	0.17
	Wag	0.92	**1.11**	0.28	**0.29**

The median density value over all 27 sites was $0.80/m^2$ for salmon fry and $0.28/m^2$ for salmon parr. The median values were roughly as expected based on surveys carried out in previous years although strict comparison is not possible due to the large number of new sites.

3.2.2. Densities of trout fry and parr

Table 7 shows that trout fry and trout parr were sparse or absent at the great majority of sites. Otherwise, substantial populations of trout fry were located at single sites in each of the Forss and Thurso catchments and at two sites in the Wick catchment. Substantial populations of trout parr were present only at Watten Mill and Camster on Wick River.

Table 7. O*bserved and estimated true densities of trout fry and trout parr at sites subject to 3-pass electric-fishing. The greatest values are indicated by bold text.*

		Trout			
		Fry		**Parr**	
River	**Location**	**Observed Density (n/m^2)**	**True Density (n/m^2)**	**Observed Density (n/m^2)**	**True Density (n/m^2)**
Forss	Cnoc glas	0.23	**0.24**	0.06	0.06
	Lythmore	0.05	0.05	0.01	0.01
	Shurrery	0.01	0.01	0.03	0.03
	Broubster	0.03	0.03	0.01	0.01
	Westfield	0.02	0.02	0.00	0.00
Thurso	Achlachan 1	0.43	**0.44**	0.11	0.11
	Grilse Stream	0.00	0.00	0.02	0.02
	Glutt 2	0.02	0.02	0.10	0.10
	Glutt 1	0.01	0.01	0.12	0.12
	Rumsdale	0.01	0.01	0.04	0.04
	Hoy	0.00	0.00	0.00	0.00
Wick	Bower 1	1.74	**1.77**	0.00	0.00
	Watten Mill	0.00	0.00	0.19	**0.19**
	Camster	0.64	**0.72**	0.21	**0.29**
	Clow	0.00	0.00	0.00	0.00
	Puldagon	0.07	0.07	0.03	0.03
	Acharole 1	0.00	0.00	0.00	0.00
Dunbeath	Ballachly	0.00	0.00	0.07	0.07
	Raffin	0.00	0.00	0.01	0.01
	Culvid	0.00	0.00	0.04	0.05
	Pollroy	0.00	0.00	0.03	0.03
	Achnaclyth	0.00	0.00	0.06	0.07
Berriedale	Corrichoich 2	0.01	0.01	0.09	0.09
	Gobernuisgach	0.05	0.05	0.09	0.10
	Braemore 1	0.00	0.00	0.07	0.07
Langwell	Langwell House	0.00	0.00	0.02	0.02
	Wag	0.00	0.00	0.03	0.03

3.3.3. Total biomass densities of salmon

Body mass was calculated for individual fish from their body lengths. These values were combined with the true density values given in Table 7 to estimate the biomass densities for fry and parr and the total biomass density of the combined fry and parr for each site (Table 8).

Table 8. Biomass density of salmon based on 3-pass electric-fishing.

		Biomass Density (g/m^2)		
River	**Location**	**Fry**	**Parr**	**Total**
Forss	Cnoc glas	0.50	2.20	2.69
	Lythmore	1.24	1.74	2.98
	Shurrery	1.24	8.48	9.72
	Broubster	1.22	4.39	5.61
	Westfield	3.39	2.26	5.65
Thurso	Achlachan 1	0.94	1.44	2.38
	Grilse Stream	1.65	6.84	8.49
	Glutt 2	1.70	3.36	5.07
	Glutt 1	2.31	2.90	5.20
	Rumsdale	4.00	4.03	8.03
	Hoy	4.86	14.02	18.88
Wick	Bower 1	0.00	0.00	0.00
	Watten Mill	0.00	0.47	0.47
	Camster	0.25	0.43	0.68
	Clow	1.28	3.95	5.23
	Puldagon	3.09	2.57	5.66
	Acharole 1	3.62	2.42	6.04
Dunbeath	Ballachly	0.49	3.73	4.22
	Raffin	1.35	1.71	3.07
	Culvid	1.42	2.46	3.87
	Pollroy	2.92	3.38	6.30
	Achnaclyth	2.55	3.01	5.57
Berriedale	Corrichoich 2	0.36	2.15	2.51
	Gobernuisgach	0.55	2.21	2.76
	Braemore 1	0.72	5.21	5.93
Langwell	Langwell House	0.17	2.53	2.70
	Wag	2.96	3.77	6.73

Figure 6 shows the distribution of total biomass values across all 27 sites. Again, the values and the distribution of values were as expected from previous surveys. The greatest value was for Hoy on the mainstem River Thurso. However, the values for Hoy and for the Grilse Stream on the mainstream River Thurso are not strictly comparable with the other sites due to differences in the approach required to obtain data from wide, fast-flowing mainstem sites and they are therefore distinguished from the others in Figure 6.

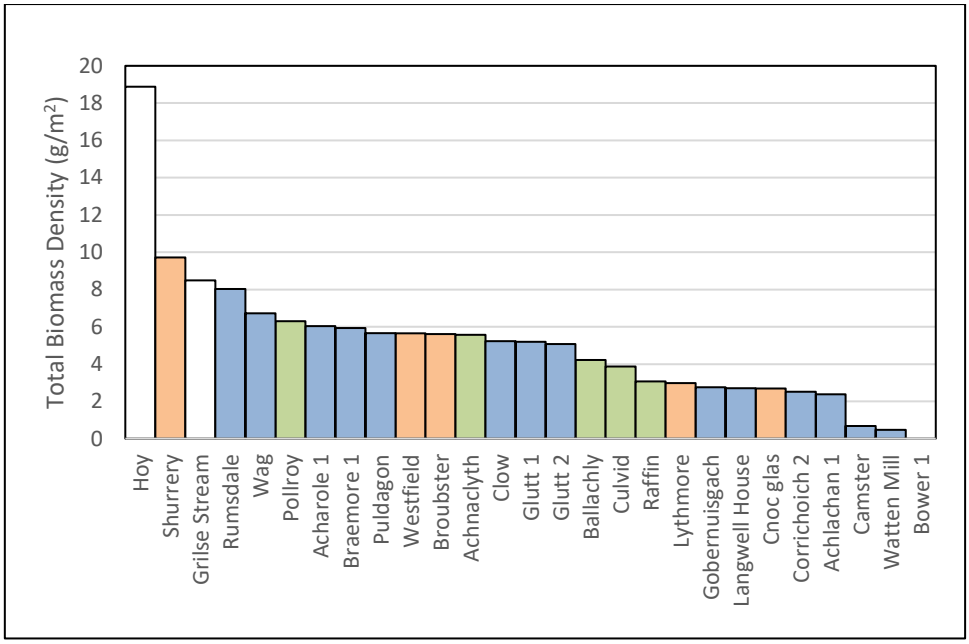


Figure 6. Total biomass density be survey site. Sites on the River Forss are coloured-coded in orange: those on Dunbeath Water in green.

One of the main aims of the survey was to obtain more information on the conditions of the rivers Forss and Dunbeath. In Figure 6 values for the Forss and Dunbeath rivers are highlighted in orange and green, respectively. In both cases, site values were distributed throughout the overall range.

3.2.4. Density, body length and biomass density by age-class.

Scale samples were available for a subset of 13 of the sites which were surveyed by 3-pass fishing. Based on scale-reading, parr aged 1+ or 2+ were distinguished making it possible to split all the values given previously for parr between each of the two main age-classes. This in turn makes it possible to follow the progress of annual cohorts by comparing results for the current survey-year with those available for the same sites in previous years (see Site Assessments section, below).

Table 9 shows that parr populations were dominated by 1+ fish spawned in 2016 and that 2+ parr (spawned in 2015) were generally sparse or absent.

Table 10 shows the mean body length for each age class and the standard deviation.

Figures 8 and 9 show the mean body length values for in 2018 in the context of equivalent values for the same site in previous years.

Table 9. True numerical density by age-class for sites for which scales were obtained.

		Numerical Density (n/m^2)		
River	**Location**	**Fry**	**1+ Parr**	**> 2+ Parr**
Forss	Cnoc glas	0.22	0.21	0.01
	Lythmore	0.54	0.15	zero
	Shurrery	0.79	0.73	0.07
	Broubster	1.52	0.65	0.01
	Westfield	3.46	0.28	zero
Thurso	Achlachan 1	0.68	0.13	zero
	Glutt 2	1.45	0.29	0.04
	Glutt 1	1.74	0.20	0.04
	Rumsdale	1.74	0.27	0.04
Wick	Camster	0.43	zero	0.02
	Clow	0.64	0.50	0.01
	Puldagon	1.68	0.23	0.01
	Acharole 1	3.50	0.35	0.02

Table 10. Average body lengths for fry, 1+ parr and 2+ parr. The standard deviation is given in parentheses in appropriate cases.

		Average Body length (mm)		
River	**Location**	**Fry**	**1+ Parr**	**> 2+ Parr**
Forss	Cnoc glas	60.9 (4.39)	96.6 (8.12)	n/a
	Lythmore	61.3 (5.48)	100.7 (9.23)	n/a
	Shurrery	54.6 (4.88)	94.3 (9.18)	120.8 (5.12)
	Broubster	44.5 (4.38)	83.1 (9.37)	n/a
	Westfield	47.0 (5.40)	89.4 (8.37)	n/a
Thurso	Achlachan 1	44.6 (4.86)	98.8 (6.34)	n/a
	Glutt 2	49.9 (4.89)	90.1 (10.0)	126.8 (3.35)
	Glutt 1	51.9 (4.31)	92.0 (11.2)	128.8 (7.85)
	Rumsdale	61.5 (4.43)	100.1 (5.93)	122.9 (5.79)
Wick	Camster	40.1 (5.22)	n/a	n/a
	Clow	59.1 (3.37)	87.9 (8.07)	n/a
	Puldagon	57.4 (4.46)	95.9 (8.22)	n/a
	Acharole 1	49.0 (4.48)	81.6 (6.30)	n/a

Table 11 combines the values for density and body size to provide separate estimates of the biomass density of fry, 1+ parr and 2+ parr for each site.

Table 11. Biomass density of fry, 1+ parr and 2+ parr.

		Biomass Density (g/m^2)			
River	**Location**	**Fry**	**1+ Parr**	**> 2+ Parr**	**Total**
Forss	Cnoc glas	0.50	2.09	0.11	2.69
	Lythmore	1.24	1.74	0.00	2.98
	Shurrery	1.24	7.05	1.43	9.72
	Broubster	1.22	4.19	0.20	5.61
	Westfield	3.39	2.26	0.00	5.65
Thurso	Achlachan 1	0.94	1.44	0.00	2.38
	Glutt 2	1.70	2.38	0.98	5.07
	Glutt 1	2.31	1.78	1.12	5.20
	Rumsdale	4.00	3.04	0.99	8.03
Wick	Camster	0.25	0.00	0.68	0.68
	Clow	1.28	3.84	0.11	5.23
	Puldagon	3.09	2.31	0.26	5.66
	Acharole 1	3.62	2.16	0.26	6.04

Data on numerical density and biomass density of young salmon obtained by 3-pass electric-fishing were available for 10 survey sites that have been examined by the Board in previous survey years.

Values for the mean body length for salmon fry is available for all 10 sites (Figure 7). Equivalent values for 1+ salmon parr (Figure 8) are available for only the five of the 10 sites at which scales were obtained for age determination of parr.

The body lengths of fry were generally larger than average relative to values obtained in previous years at the same site; values for 1+ parr were near average.

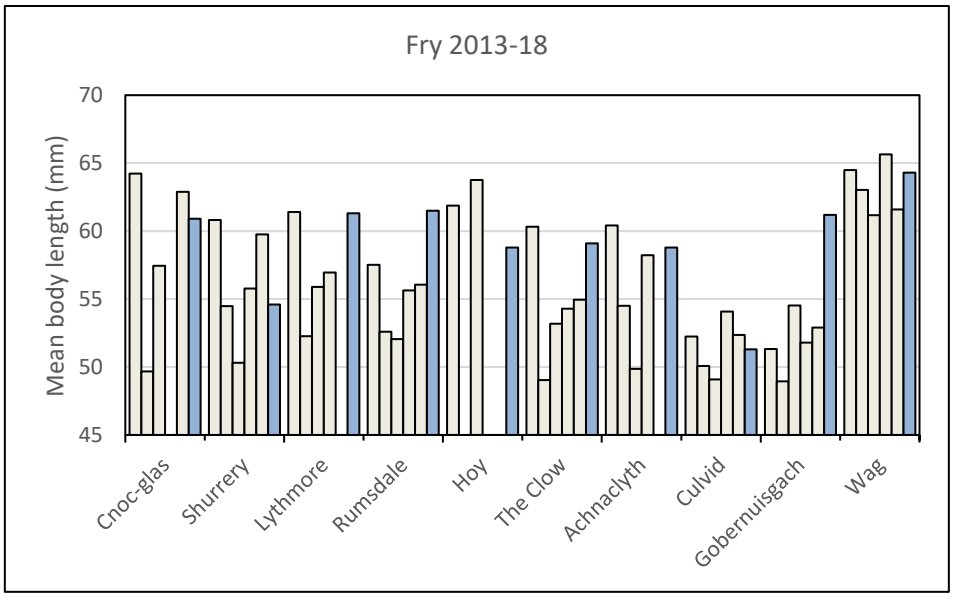


Figure 7. Mean lengths of fry by site for 2013 -2017 (in grey) and for 2018 (in blue).

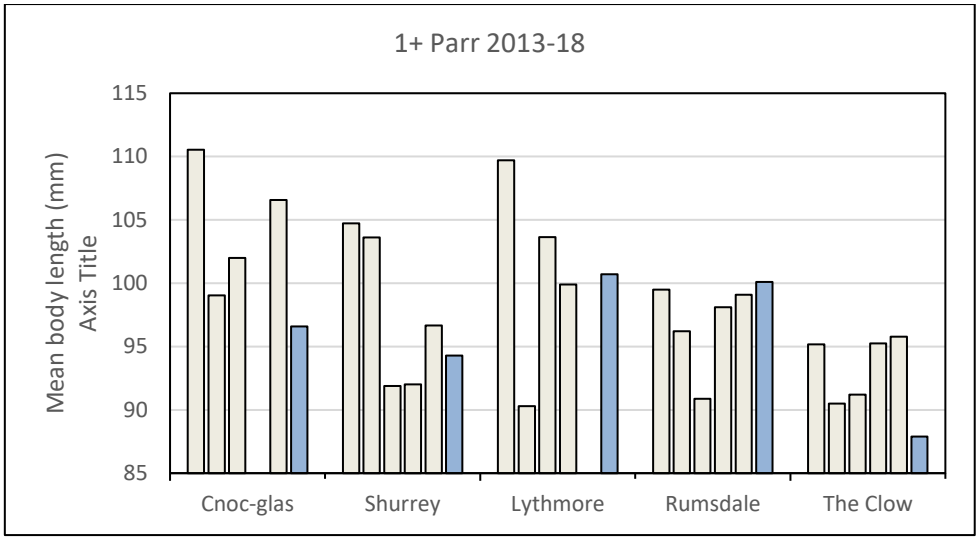


Figure 8. Mean lengths of 1+ parr by site for 2013 -2017 (in grey) and for 2018 (in blue).

3.3. 1-pass v 3-pass electric fishing

Some of the variation in the density of fish obtained by 1-pass fishing is attributable to the deficiencies of single-pass survey methods. Figure 9 shows the estimated efficiency of capture on the first pass of 3-pass electric fishing. The values are calculated by comparing the numbers of salmon fry or parr captured on the first pass with the true number estimated using from 3-pass fishing. The data are for 27 sites fished by three passes but those sites containing only very low densities of fish have been excluded from consideration.

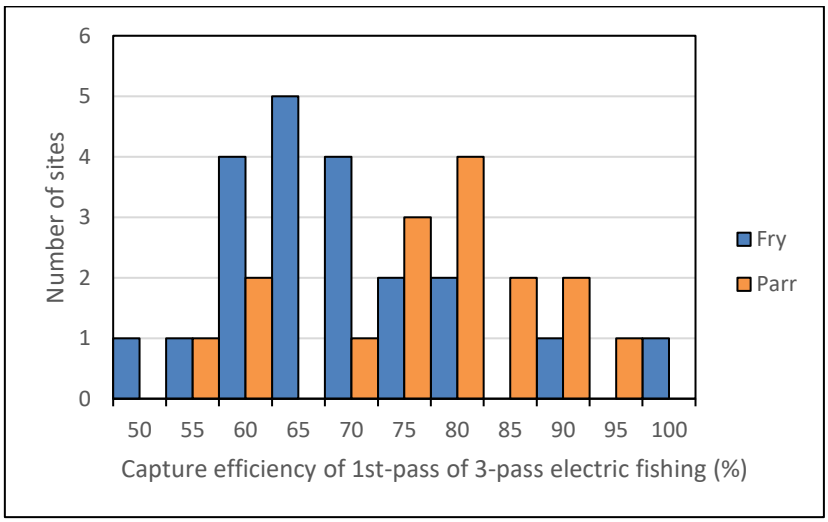


Figure 9. The efficiency of capture of fry and parr in the first pass of 3-pass fishing.

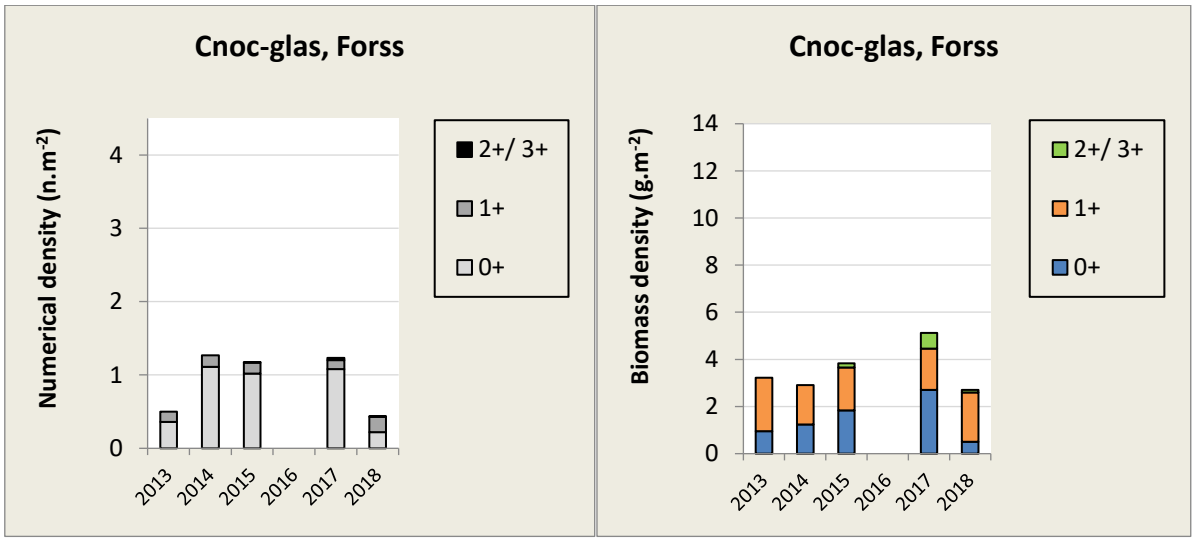
The capture efficiency of parr tended to be greater than for fry. This is as expected because smaller fish (fry) are less sensitive to the electric fishing apparatus than larger ones (parr). The median value for capture efficiency of fry was 64% and 78% for parr.

Overall, most of the efficiency values lie between 60% and 80% but a substantial number lie outside this range and between 50% and 100%. In other words, capture efficiency varies by as much as a

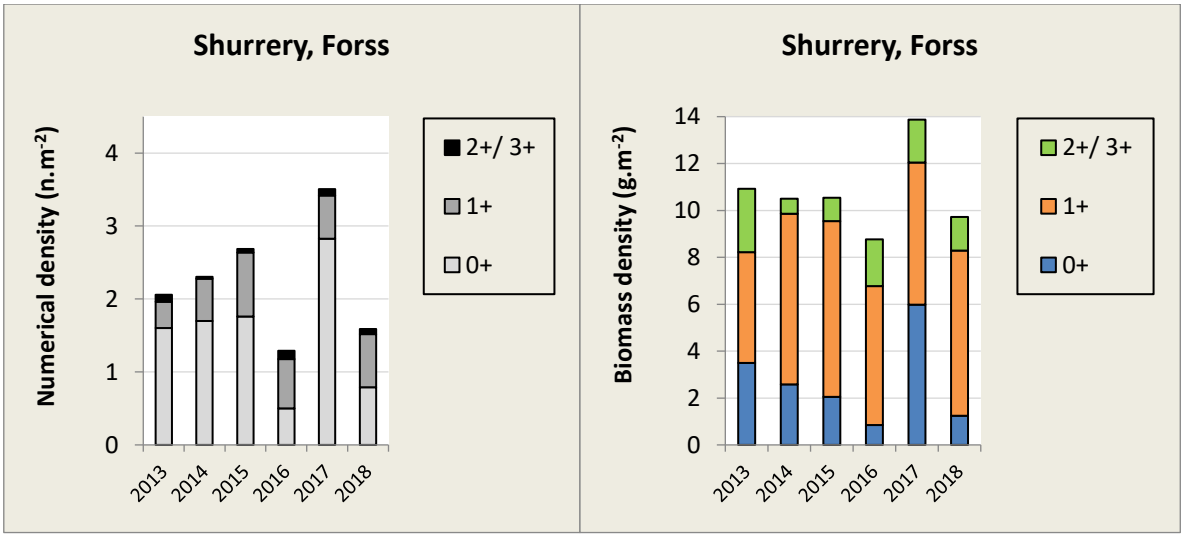
factor of two between the extreme values. Differences in capture efficiency will have contributed to overall variation in the values disclosed in Tables 1, 2 and 5. This can be resolved for 3-pass sites but the data for sites fished by 1-pass will have been affected to an unknown and unpredictable extent.

4. Site Assessments

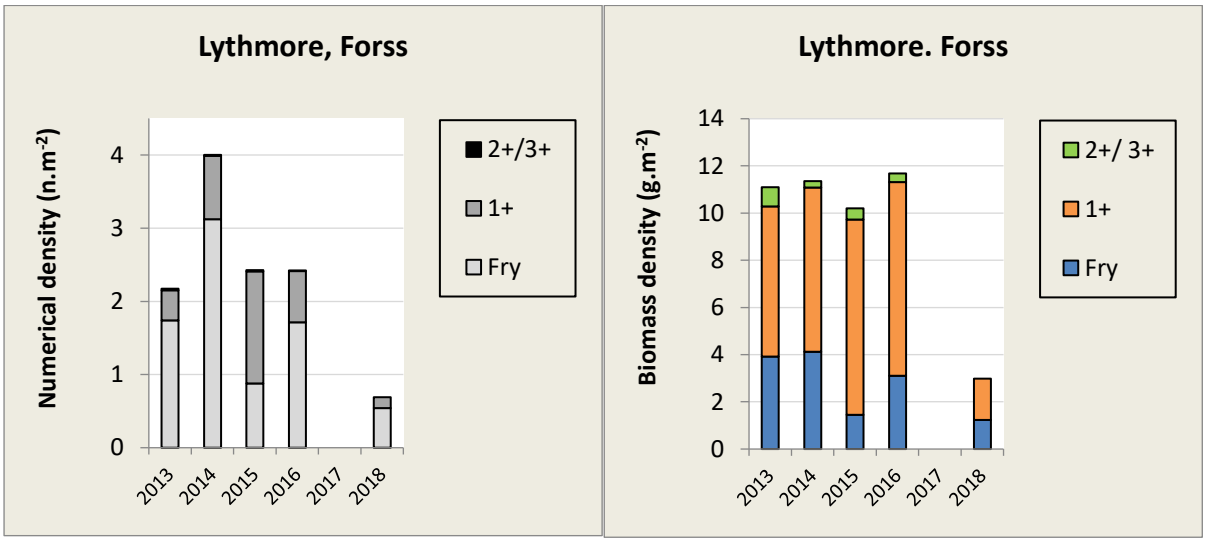
Site assessments for 2018 are presented below in the context of estimates of numerical density and biomass density obtained by 3-pass fishing at the same locations between 2013 and 2017. The left-hand panel shows stacked values for the numerical density of three age-classes present; the right-hand panel shows the equivalent values for biomass density.



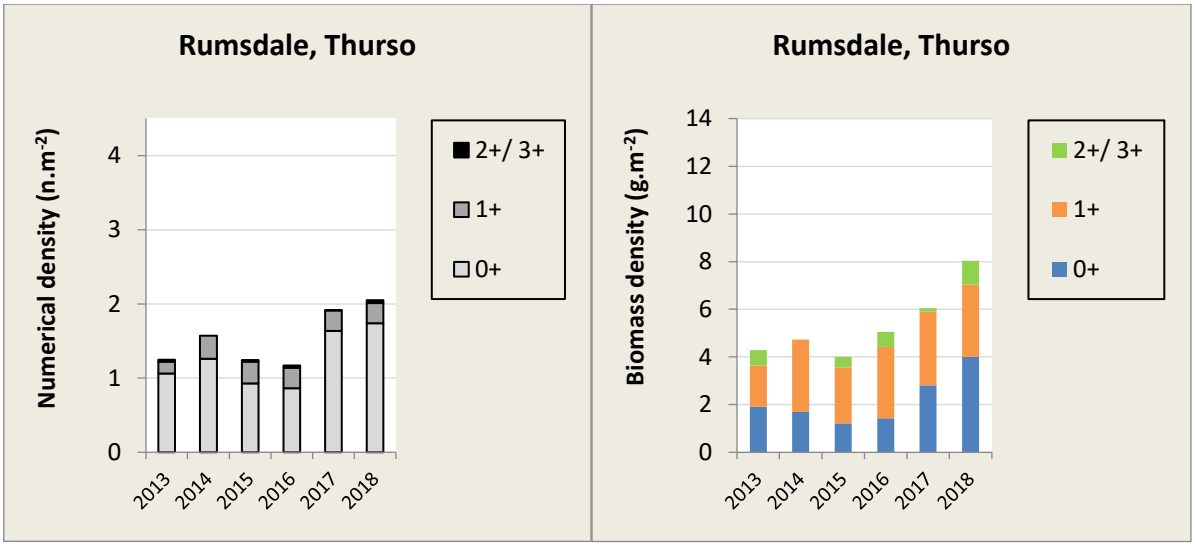
The density of salmon fry at Cnoc-glas was lower in 2018 than previously and only ca. 20% of the maximum values attained. The density of 1+ parr was slightly greater than those previously observed. Fry length was about average for the site but the 1+ parr were smaller than in previous years. Because of the low density of fry and the restrained growth of the parr, total biomass density was slightly lower than previously at around 2.7g/m^2.



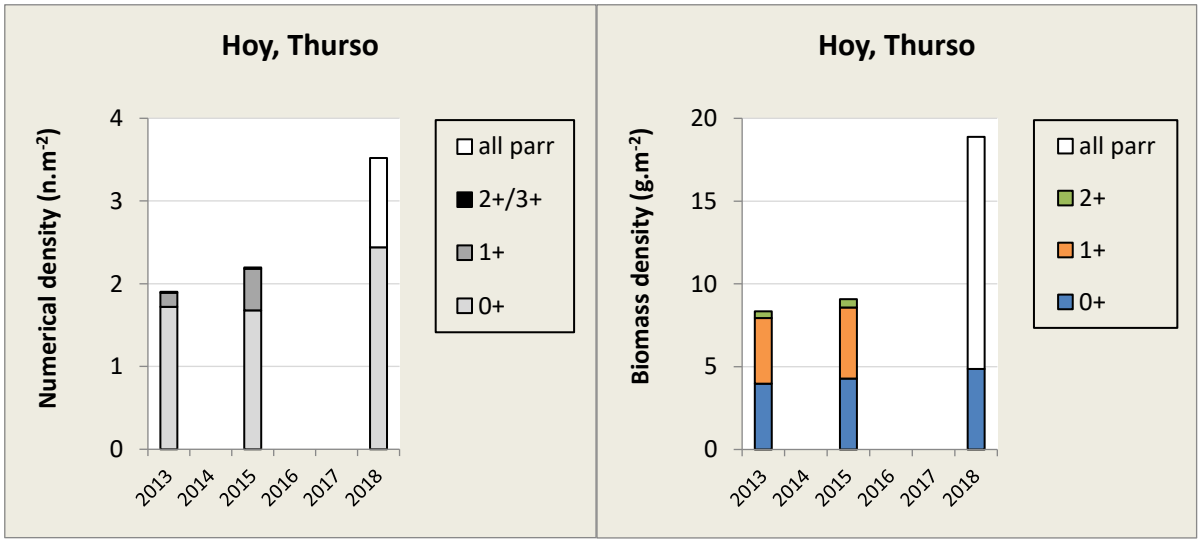
Fry densities at Shurrery, also, were low relative to previous years. The density of 1+ parr was slightly greater than average and high relative to fry density. The growth of both fry and 1+ parr was about average. As in previous years, total biomass density was dominated by the contribution of parr and, at around 9.7g/m^2, was only slightly less than the average value for the site.



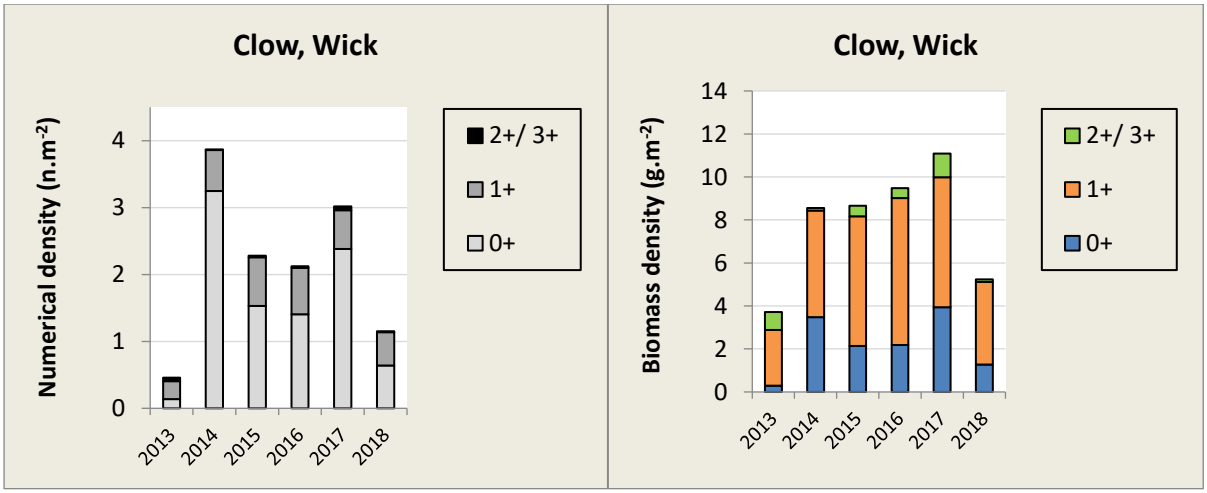
At Lythmore, the densities of both fry (0.54/m^2) and 1+ parr (0.15/m^2) were the lowest in the series. Both groups had grown relatively well for the site but, despite this, and in the absence of 2+ parr, total biomass density was much lower than previously. Biomass density at Lythmore has consistently been around 10 or 12 g/m^2 but the value in 2018 was only 3g/m^2. There is no obvious reason for this.



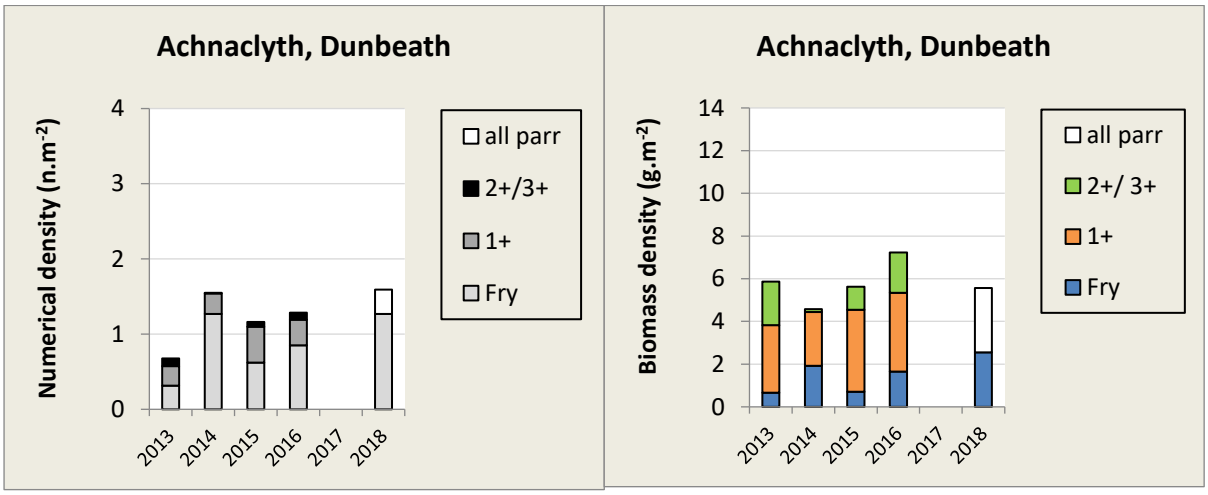
Uptake of fry at Rumsdale was higher than previously at 1.7/m^2; parr numbers were average for the site. Both fry and 1+ parr showed better growth than in previous years. As a result of high numbers and good growth, total biomass density was the greatest in the series at around 8g/m^2.



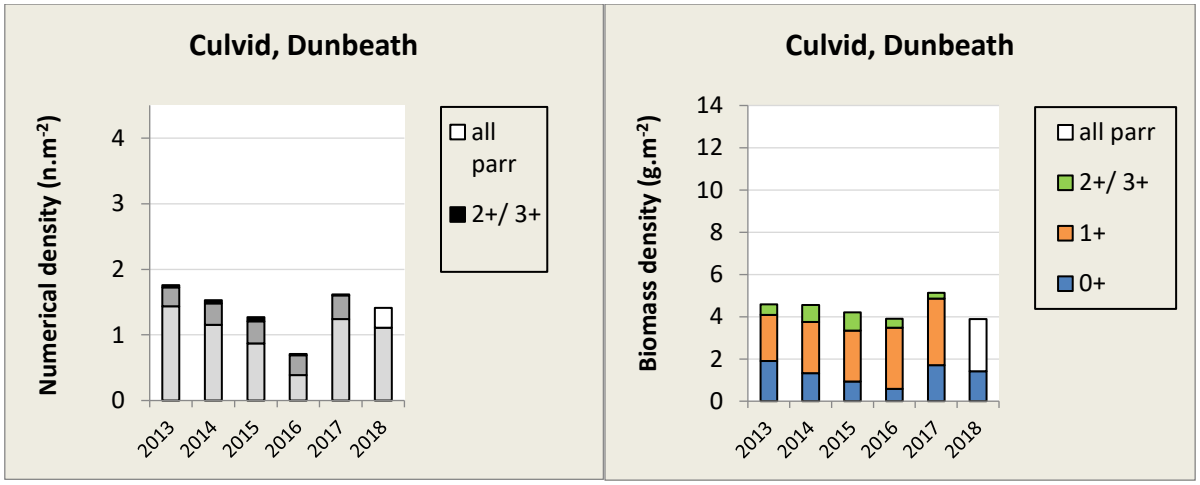
The Hoy site is on the mainstem of the River Thurso and because of its usually high flow and wide width, the site can only be fished in years when water levels are suitably low. The data series for Hoy is therefore short. No scales were available for Hoy and the parr are not therefore categorised by age. In 2018, both fry (2.4/m^2) and parr densities (1.1/m^2) were much greater than in either of the two previous years for which data is available. The total biomass density was about 19g/m^2, the greatest value observed for any of the Caithness sites in any survey year. Note that the y-axis scale on the right-hand panel differs from the scale shown for all the other sites.



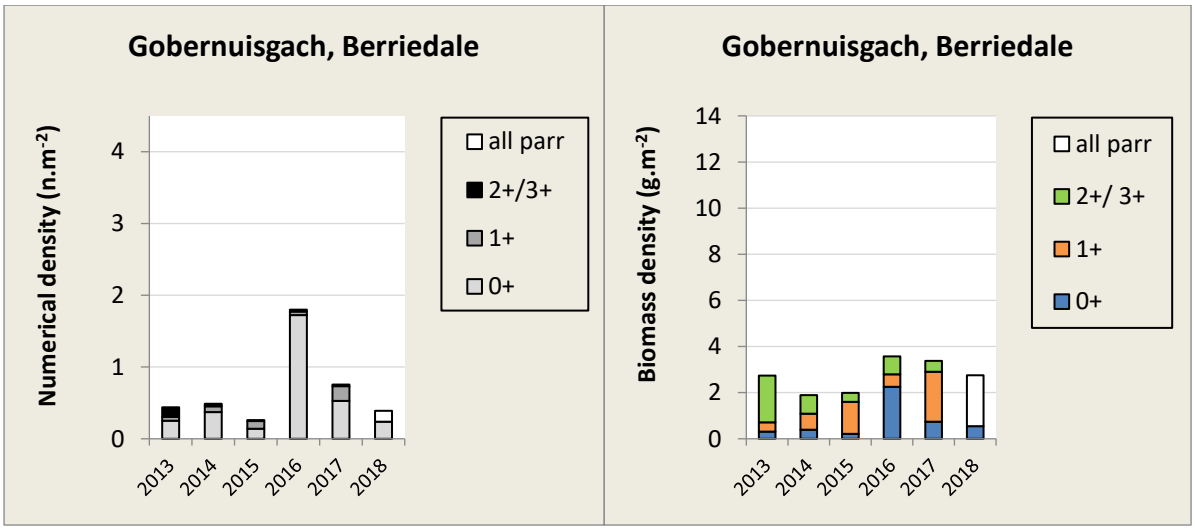
Uptake of fry at The Clow (0.64/m^2) was lower than average and the density of 1+ parr (0.50/m^2) was also slightly lower than average. The fry were larger than average and the 1+ parr were smaller. The total biomass density (5.1g/ m^2) was markedly lower than in most previous years. Note that the 2018 patterns were most similar to those of 2013 which was also a drought year.



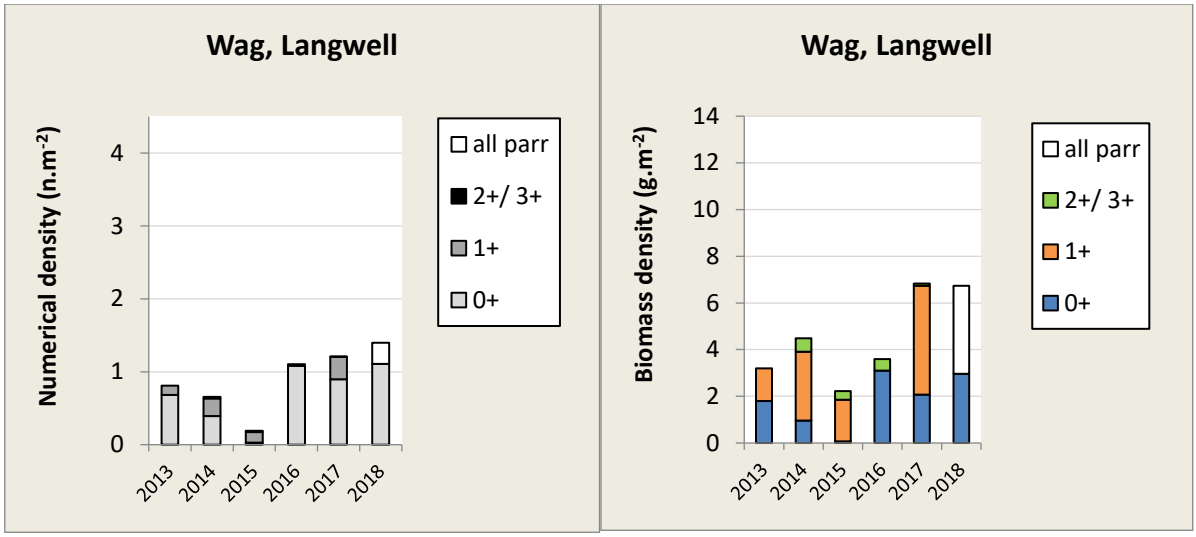
The density of fry at Achnaclyth (1.27/m^2) was greater than in most previous years and the fry were larger than usual. As a result, the biomass density of fry (2.55 g/m^2) was the greatest in the series. The density of (unclassified) parr was smaller than usual and the parr biomass was relatively modest. Total biomass density (5.6 g/m^2) was similar to the values observed in previous years.



Fry and parr densities at Culvid were in line with expectations for the site. Total biomass density (3.9 g/m^2) was roughly the same as for previous years.



Fry density, parr density and biomass density were all as expected for the site, noting that the values for 2016 and 2017 were perturbed by the aftermath of the poor spawning of 2014 (as explained in previous reports).



The uptake of fry at Wag was higher than previously and the fish had grown well. Total biomass density was higher than expected based on previous years - bearing in mind that, like Gobernuisgach, values at Wag in 2016 and 2017 were perturbed by the ramifications of the poor spawning-year of 2014.

5. Discussion.

Photo J. Mackay

In 2018 all the rivers were affected by a consistently severe summer drought. The picture above shows water conditions at The Clow site on Wick River when it was electric-fished on 27th August.

By contrast, conditions in 2017 were unusually cool and wet. In 2017 densities of fry were high, the growth of both fry and parr was good and, for most sites, total biomass density was higher than in previous years.

In counterpoint, therefore, it might be expected that the extremely low flows of 2018, shrunken streambeds and high day-time temperatures will have adversely affected the fish populations.

5.1. Water temperature

Water temperature is monitored on the Thurso River as part of the MSS National River Temperature Monitoring Network. Twelve automatic loggers are distributed throughout the catchment and they record water temperature at 15-minute intervals throughout the year. Figure 10 shows the 2018 temperature record for the logger located at Aimster on Beat 2. However, all the loggers showed broadly the same patterns.

Day-time temperature regularly exceeded 20°C (shown by the red bands) for periods during June and July, reaching 25°C on occasion. Salmon are adapted to life in cool water and temperatures of this magnitude are unusual and potentially harmful.

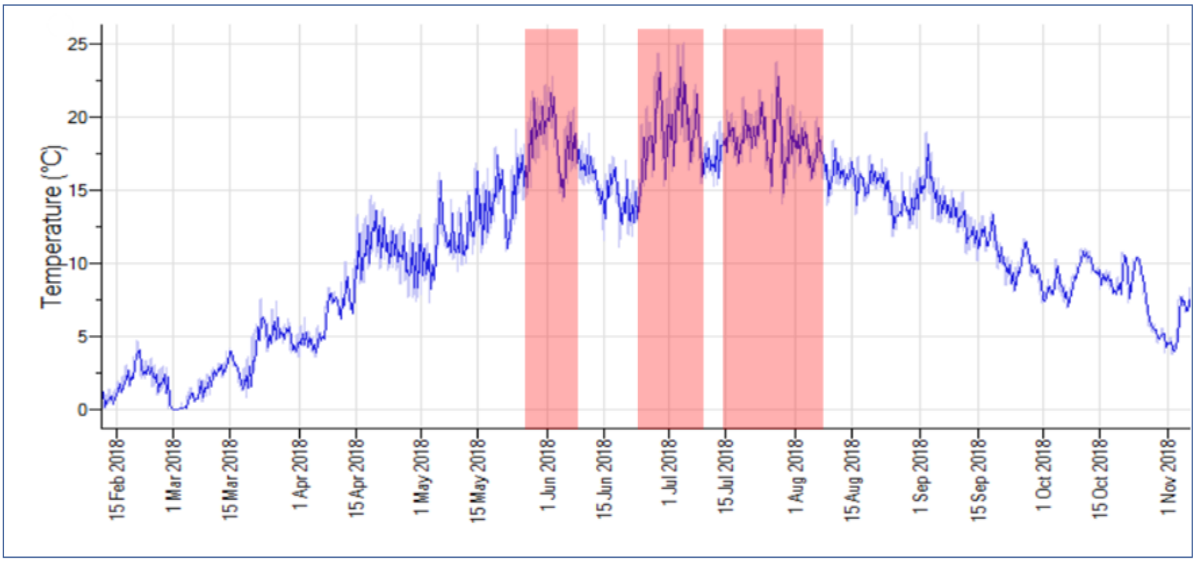


Figure 10. River water temperature at Aimster on the lower River Thurso in 2018.

5.2. River flow

River levels are continuously monitored by SEPA at the Tarroul Gauging Station on Wick River. SEPA converts measurements of river height (m) to estimates of river discharge (m^3/s) and uses them to derive a daily summary value for mean discharge.

Table 12 shows the median daily discharge rate for each year of the current sequence of Board surveys (2013-18). The median value is for the period 1st May to 31st August. This period is taken to represent the interval over which fry are susceptible to the effects of variable discharge rate between their emergence in late spring and the electric-fishing survey date which is set to be in late summer each year.

It can be seen from Table 12 that median summer discharge rate was extremely low in 2018 and extremely high in 2017, relative to the earlier years in the sequence. Previously, the 2013 value had been the lowest value in the sequence.

Table 12. Median values for average daily discharge (1st May to 31st August) at Tarroul Gauging Station on Wick River, 2013-18.

	Median discharge (m^3/s)
2013	0.24
2014	0.66
2015	1.22
2016	0.83
2017	4.26
2018	0.07

Figure 11 shows the distributions of the daily values for all survey years; the values for 2018 (red) and 2017 (blue) are highlighted. There was no overlap in the 2017 and 2018 distributions.

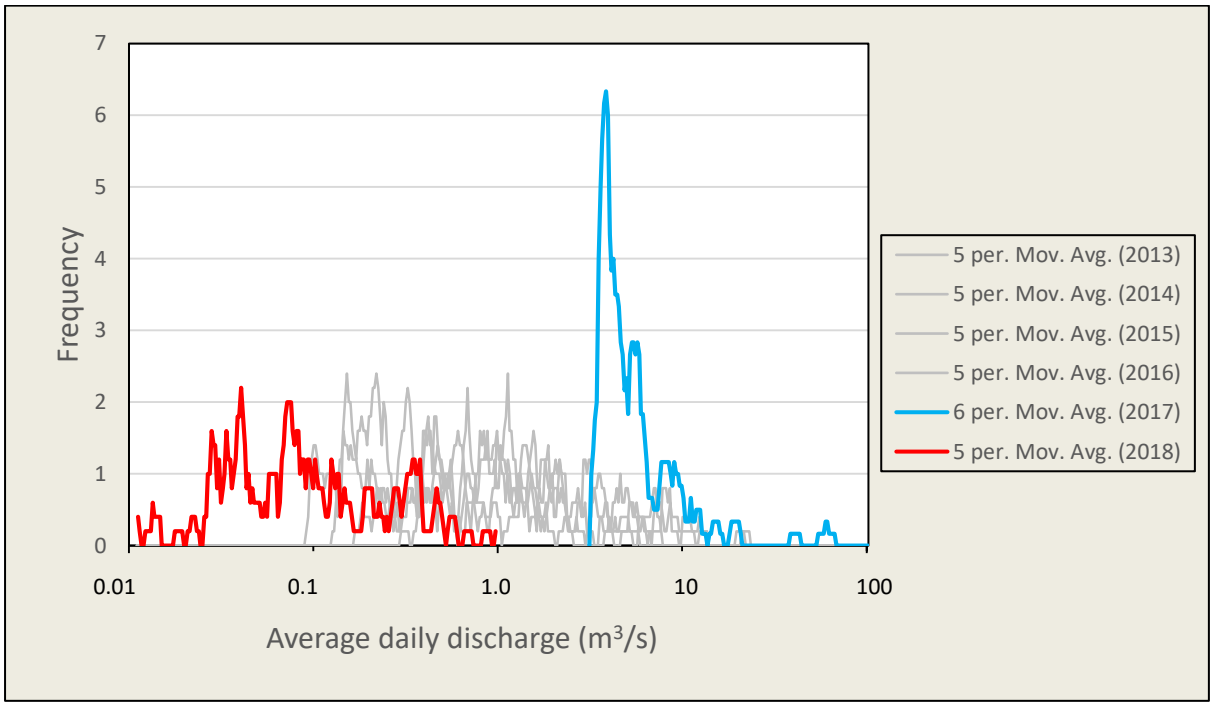


Figure 11. Distribution of mean daily flows at Tarroul Gauging Station on Wick River, over the period 1st May to 31st August, for the years 2013-18. 2017 (blue) and 2018 (red) are highlighted. The values have been smoothed using 5-point running means. Note that the x-axis scale is logarithmic.

6. Conclusions

From the Board's point of view, the National Electro-Fishing Programme offered an opportunity to examine a greater number of sites than would usually be possible. In general, the results align with the results of previous Board surveys in showing (1) that salmon are widely distributed in all the Caithness rivers, (2) salmon are absent or scarce in unsuitable habitat and (3) trout are sparse or absent in most places.

The survey data also suggest that, in 2018, salmon fry and parr were again abundant in the Caithness rivers. The median value for the first-pass of electric-fishing for all 44 sites was 0.48/ m^2 for fry and 0.19/m^2 for parr. Godfrey's criteria are the only reference data that are currently available and, for both fry and parr, the median values for 2018 fall in the upper part of the expected ranges. The weakness of the 1-pass survey data is that it is less accurate than 3-pass data and therefore less suitable for comparing sites or for providing an assessment of single survey sites in different years.

The site assessment section, above, is based on 3-pass data. It might be expected that the site assessments for 2018 would reflect the extreme (presumably adverse) conditions over the summer. Although Lythmore and Clow performed notably worse than in former years most sites appeared unaffected by the drought. Indeed, Rumsdale and Wag performed markedly better than formerly. Overall, therefore, salmon populations at most of the sites appear to have been resilient to the drought conditions. In view of this, the simplest explanation for the exceptional sites is that fish had moved away from now-unfavourable sites like Lythmore and Clow to more conducive conditions in places like Rumsdale and Wag. In the case of the fry, it will be possible to check their apparent resilience in 2019 when the density of the upcoming cohort of 1+ parr is known.

One of the main aims of this survey was to obtain more extensive data than previously for the Forss and Dunbeath rivers. Seven sites were electric-fished on the Forss of which four were new; six were fished on Dunbeath of which four were new.

On Forss, fry densities from 3-pass fishing were markedly lower than usual at the three established Board sites - Cnoc-glass, Shurrery and Lythmore. As expected, fry were more or less absent at the new MSS site on the cataract at Forsie Bridge. The density of fry was very high at the new MSS sites at Broubster and Westfield. The average fry density on the first pass of fishing was 0.66/m^2 placing the river, as a whole, in the highest fry quintile proposed by Godfrey. Similarly, the average density of parr on the first pass was 0.24/m^2, placing the river in the highest parr quintile. In summary, even given the relatively poor performance of some sites in 2018, the fry and parr populations of the Forss were classed as being in very good condition (ie. equivalent to light blue colour-coding).

On Dunbeath, fry and parr densities were modest at the Ballachly site on the high-gradient, lower reach of the river. Otherwise, all the sites on Dunbeath had performed well. The average fry density on the first pass over all six sites was 0.75/m^2 and the average parr density was 0.25/m^2. For Dunbeath as a whole, these values place the fry in highest category (ie. coded dark blue) and the parr in the highest quintile as proposed by Godfrey (ie. colour coded light blue).

In summary, therefore, in 2018 juvenile salmon populations in Caithness were again judged to be robust. No incipient problems were identified. At some sites the performance of the fish was not fully consistent with past patterns perhaps because of the extreme summer drought. Some of the anomalous sites performed better than expected and some worse. The local ramifications of this variation, if any, can be checked by surveying the sites again in 2019.

7. Acknowledgements.

Cammie Chapman, George Doull Jnr, Neil Groat, Jamie McCarthy, John Mackay and David Miller all participated in the fieldwork at various times. Neil Groat read the scales. Shaun Stanworth of SEPA made available the discharge data for Tarroul Gauging Station.

8. Appendix

Table 1. *Site details for all the survey sites.*

River	Location	OS Grid Ref	Date	Length (m)	Area (m^2)	Scales	Passes
Forss	Forsie	ND 05031 63420	27/07	13.8	175		1
	Cnoc glas	Existing Board site	28/08		193	√	3
	Lythmore	Existing Board site	25/08		184	√	3
	Lythmore 1	ND 04551 66593	25/08	28.5	173	√	1
	Shurrery	Existing Board site	26/08		90	√	3
	Broubster	ND 03503 59886	28/08	20 0	119	√	3
	Westfield	ND 05652 63738	26/08	22.8	130	√	3
Thurso	Gaineimh	ND 05534 46590	21/07	34.6	124	√	1
	Tacher 2	ND 16778 47444	2/08	23.3	96	√	1
	Inshag 1	ND 15116 48633	9/08	21.1	128	√	1
	Tacher 1	ND 17113 45893	26/07	37.5	195	√	1
	Achlachan 1	ND 14686 51791	17/07	72.0	107	√	3
	Grilse Stream	ND 11545 66331	30/08	n/a	196		3
	Rumsdale 1	NC 98069 40717	29/08	26.0	137	√	1
	Glutt 2	NC 99633 36120	29/08	35.0	129	√	3
	Glutt 1	ND 00246 38021	10/08	30.2	121	√	3
	Rumsdale	Existing Board site	29/08		182	√	3
	Hoy	Existing Board site	30/08		156		3
	Carsgoe Burn	ND 14108 62639	15/08	14.0	36	√	1
Wick	Bower 1	ND 11981 59855	15/08	31.0	77	√	3
	Bower 2	ND 29118 59725	18/07	39.2	87	√	1
	Watten Mill	ND 24815 54925	18/07	43.0	168	√	3
	Achairn	ND 30611 49547	20/08	23.4	120	√	1
	Camster	ND 25870 43820	30/07	60.2	121	√	3
	Clow	Existing Board site	27/08		160	√	3
	Haster	ND 33087 50912	31/07	21.3	132	√	1
	Puldagon	ND 32698 49028	20/08	22.0	165	√	3
	Acharole	ND 23102 51430	24/07	25.6	133	√	1
	Acharole 1	ND 23210 51752	27/08	29.0	134	√	3
Dunbeath	Ballachly	ND 15424 30423	5/09	19.9	174		3
	Raffin	ND 09281 34215	1/09	48.0	148		3
	Culvid	Existing Board site	4/09		215		3
	Pollroy	ND 08818 33597	1/09	19.6	148		3
	Achnaclyth	Existing Board site	4/09		129		3
	Houstry	ND 15280 33979	16/08	25.3	90	√	1
Berriedale	Corrichoich 2	ND 03762 30014	31/08	31.0	217		3
	Gobernuisgach	Existing Board site	9/09		131		3
	Braemore 1	ND 06607 35965	8/09	10.0	167		3
	Corrrichoich 1	ND 03018 29556	31/08	26.2	307		1
Langwell	Langwell Ho.	ND 11630 22550	5/09	12.7	292		3
	Aultibea 1	ND 03735 24462	3/09	20.0	202		1
	Wag 1	ND 01867 25419	6/09	14.0	128		1
	Wag	Existing Board site	6/09		212		3
	Cadha Fionn	ND 08711 23071	3/09	13.7	139		1

Table 2. Fish *densities observed for sites obtained by 1-pass electric-fishing or for the first pass, only, of 3-pass fishing*.

		Density (n/m^2)			
		Salmon		Trout	
River	**Location**	**Fry**	**Parr**	**Fry**	**Parr**
Forss	Forsie	0.01	0.17	0.00	0.00
	Cnoc glas	0.14	0.19	0.18	0.04
	Lythmore	0.43	0.08	0.05	0.01
	Lythmore 1	0.44	0.16	0.04	0.01
	Shurrery	0.52	0.56	0.01	0.03
	Broubster	0.86	0.35	0.01	0.01
	Westfield	2.22	0.20	0.02	0.00
Thurso	Gaineimh	0.01	0.00	0.00	0.00
	Tacher 2	0.23	0.09	0.00	0.00
	Inshag 1	0.29	0.13	0.00	0.02
	Tacher 1	0.49	0.91	0.00	0.06
	Achlachan 1	0.51	0.10	0.29	0.10
	Grilse Stream	0.74	0.34	0.00	0.02
	Rumsdale 1	0.86	0.17	0.01	0.09
	Glutt 2	0.91	0.22	0.02	0.07
	Glutt 1	1.05	0.17	0.00	0.12
	Rumsdale	1.10	0.25	0.01	0.03
	Hoy	1.56	0.63	0.00	0.00
	Carsgoe Burn	3.29	0.03	0.39	0.00
Wick	Bower 1	0.00	0.00	1.21	0.00
	Bower 2	0.00	0.00	0.88	0.09
	Watten Mill	0.00	0.01	0.00	0.13
	Achairn	0.07	0.12	0.02	0.13
	Camster	0.26	0.02	0.37	0.11
	Clow	0.40	0.44	0.00	0.00
	Haster	0.49	0.05	0.10	0.02
	Puldagon	0.97	0.20	0.05	0.03
	Acharole	1.14	0.08	0.00	0.02
	Acharole 1	2.02	0.28	0.00	0.00
Dunbeath	Ballachly	0.12	0.21	0.00	0.06
	Raffin	0.55	0.12	0.00	0.01
	Culvid	0.73	0.22	0.00	0.04
	Pollroy	0.84	0.22	0.00	0.02
	Achnaclyth	0.93	0.25	0.00	0.05
	Houstry	1.31	0.48	0.01	0.01
Berriedale	Corrichoich 2	0.22	0.15	0.00	0.04
	Gobernuisgach	0.24	0.11	0.03	0.05
	Braemore 1	0.28	0.41	0.00	0.01
	Corrrichoich 1	0.31	0.23	0.00	0.03
Langwell	Langwell House	0.04	0.14	0.00	0.01
	Aultibea 1	0.19	0.21	0.00	0.02
	Wag 1	0.41	0.14	0.00	0.02
	Wag	0.58	0.23	0.00	0.01
	Cadha Fionn	1.45	0.37	0.00	0.01

Table 4. Body lengths of salmon.

		Fry	Parr
River	**Location**	**Average length (mm)**	**Median length (mm)**
Forss	Forsie	n/a	101
	Cnoc glas	60.9 (4.39)	97
	Lythmore	61.3 (5.48)	100
	Lythmore 1	61.7 (4.97)	109
	Shurrery	54.6 (4.88)	96
	Broubster	44.5 (4.38)	82
	Westfield	47.0 (5.40)	88
Thurso	Gaineimh	n/a	n/a
	Tacher 2	50.7 (4.83)	92
	Inshag 1	52.8 (4.00)	90
	Tacher 1	46.2 (4.02)	80
	Achlachan 1	44.6 (4.86)	97
	Grilse Stream	49.1 (5.11)	99
	Rumsdale 1	59.9 (5.16)	110
	Glutt 2	49.9 (4.89)	90
	Glutt 1	51.9 (4.31)	97
	Rumsdale	61.5 (4.33)	103
	Hoy	58.8 (4.39)	101
	Carsgoe Burn	49.0 (5.63)	n/a
Wick	Bower 1	n/a	n/a
	Bower 2	n/a	n/a
	Watten Mill	n/a	103
	Achairn	57.1 (3.26)	105
	Camster	40.2 (5.22)	n/a
	Clow	59.1 (3.37)	89
	Haster	63.3 (6.50)	107
	Puldagon	57.4 (4.46)	95
	Acharole	49.0 (4.48)	81
	Acharole 1	48.0 (4.70)	83
Dunbeath	Ballachly	68.3 (4.80)	112
	Raffin	55.4 (7.14)	95
	Culvid	51.3 (4.65)	90
	Pollroy	60.3 (4.58)	102
	Achnaclyth	58.8 (5.02)	93
	Houstry	47.1 (4.92)	83
Berriedale	Corrichoich 2	53.2 (4.87)	99
	Gobernuisgach	61.2 (6.86)	107
	Braemore 1	57.4 (3.81)	90
	Corrrichoich 1	56.0 (4.50)	99
Langwell	Langwell House	67.2 (3.85)	108
	Aultibea 1	60.8 (4.62)	100
	Wag 1	62.2 (4.67)	108
	Wag	64.3 (4.65)	104
	Cadha Fionn	55.5 (5.02)	92

Table 5. Biomass density of salmon based on 1-pass electric-fishing.

		Biomass Density (g/m²)		
River	**Location**	**Fry**	**Parr**	**Total**
Forss	Forsie	0.03	2.05	2.08
	Cnoc glas	0.31	1.98	2.29
	Lythmore	0.99	0.97	1.96
	Lythmore 1	1.04	2.41	3.45
	Shurrery	0.82	5.89	6.71
	Broubster	0.69	2.33	3.02
	Westfield	2.17	1.61	3.78
Thurso	Gaineimh	0.00	0.00	0.00
	Tacher 2	0.28	1.18	1.46
	Inshag 1	0.40	1.13	1.53
	Tacher 1	0.44	6.01	6.45
	Achlachan 1	0.70	1.13	1.83
	Grilse Stream	0.83	4.06	4.89
	Rumsdale 1	1.84	2.58	4.42
	Glutt 2	1.08	2.24	3.32
	Glutt 1	1.39	2.10	3.49
	Rumsdale	2.54	3.29	5.83
	Hoy	3.12	8.13	11.25
	Carsgoe Burn	3.70	0.34	4.04
Wick	Bower 1	0.00	0.00	0.00
	Bower 2	0.00	0.00	0.00
	Watten Mill	0.00	0.16	0.16
	Achairn	0.13	1.59	1.73
	Camster	0.15	0.36	0.51
	Clow	0.80	3.37	4.17
	Haster	1.26	0.70	1.96
	Puldagon	1.79	2.12	3.91
	Acharole	1.26	0.49	1.75
	Acharole 1	2.09	1.88	3.97
Dunbeath	Ballachly	0.39	3.54	3.93
	Raffin	0.93	1.32	2.25
	Culvid	0.94	1.77	2.71
	Pollroy	1.86	2.65	4.52
	Achnaclyth	1.87	2.33	4.20
	Houstry	1.28	3.75	5.03
Berriedale	Corrichoich 2	0.32	1.87	2.19
	Gobernuisgach	0.55	1.55	2.10
	Braemore 1	0.51	3.81	4.33
	Corrrichoich 1	0.53	2.87	3.39
Langwell	Langwell House	0.12	2.03	2.14
	Aultibea 1	0.42	2.59	3.01
	Wag 1	0.98	2.18	3.16
	Wag	1.53	2.99	4.53
	Cadha Fionn	2.41	3.53	5.94