Electric-fishing Survey of River Wester (2016)

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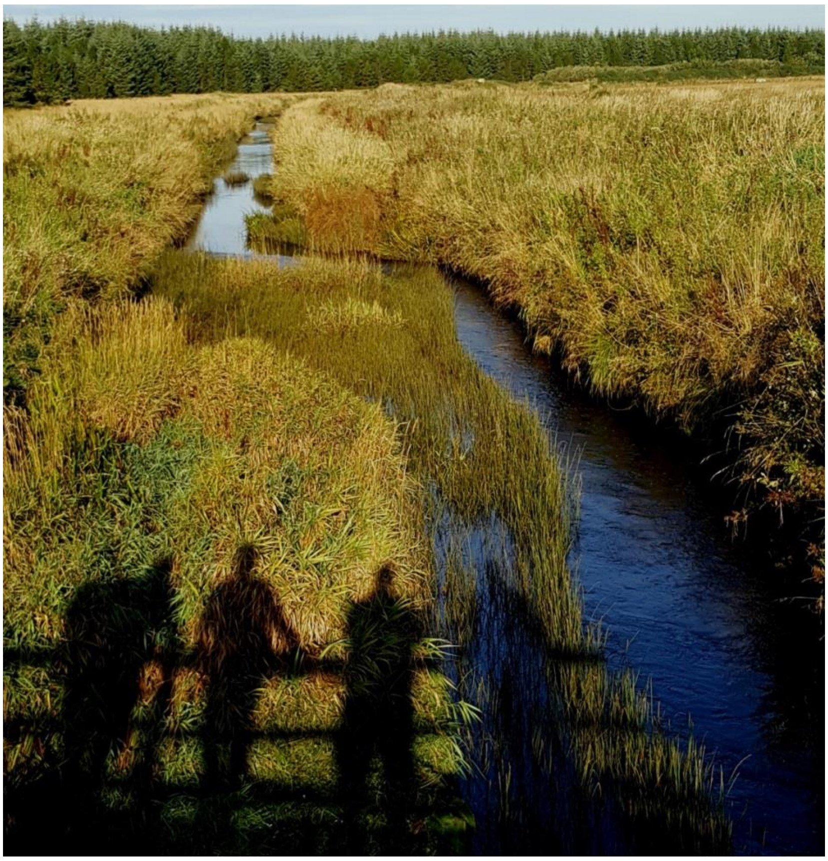
The Flow Country Rivers Trust



The Burn of Lyth at Quintfall looking west.

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Caithness District Salmon Fishery Board

Contents

"The loch of Wester, communicating with the sea, produces plenty of excellent salmon-trout, some of them two feet in length, remarkable for flavour, delicacy and richness".

First Statistical Account of Scotland (1791-1799).

Summary

The Barrock Mill survey site on the River Wester has been electric-fished annually by Caithness District Salmon Fishery Board (CDSFB) since 2013. The densities of young salmon and trout have been shown to be consistently low relative to sites in the other Caithness rivers. However, the few fish present are unusually large for their age, suggesting that the stream is capable of supporting more fish but that the input of very young fish each year is not sufficient to fully re-stock the site. In 2016, a further seven sites in the Wester catchment were electric-fished by the Flow Country Rivers Trust (FCRT) in order to investigate whether Barrock Mill is typical of sites elsewhere in the catchment. The main aim was to identify any scope for improving the status of the Wester fish populations and the Wester fishery. The 2016 survey showed that the density of fish is relatively low at most, but not all, of the Wester sites. It seems likely that radical changes to the streambed caused by drainage works about 150 years ago have resulted in patchy patterns of spawning that impede the initial supply of young fish to some areas. Later on in the life-cycle, these sites support fewer juveniles than expected. The biomass of fish supported by each site was used to gauge the number of juvenile fish that would be expected to result if the input of very young fish was not a limiting factor. It is estimated that in 2016 the Wester survey sites produced around 30 – 50% of their maximum potential density of juvenile salmonids. On this basis, the catchment could probably have produced two or three times more 1+ fish. This would be expected to result in a similar increase in the number of 2-year-old fish leaving the survey areas the following spring to take up residence in the lower catchment or to go to sea.

Introduction

The River Wester is a short, lagoon-like river in eastern Caithness just north of Wick. The river supports a local sports fishery. Formerly, the fishery was widely renowned for its sea-trout but in recent decades it appears to have become more low-key.

The River Wester falls within the Caithness District Salmon Fishery Board's area of responsibility and when the Board set up its annual series of electric-fishing surveys of the Caithness rivers in 2013, a single site at in the Wester catchment was included at Barrock Mill. Since then, as discussed below, the results of four annual surveys (2013–16) of the site have been relatively disappointing. In 2016, the Flow Country Rivers Trust therefore carried out a more extensive survey of the Wester catchment in 2016 in order to investigate the wider fisheries picture.

Description of the Wester catchment

The River Wester runs from Loch Wester, a shallow freshwater loch of about 0.5 km^2 lying at an altitude of only 3m (Figure 1). The river flows eastwards for about 2km before entering the sea in Sinclair Bay.

The loch is fed by three streams The Bower Burn runs eastwards through farmland for 6km before joining the Burn of Lyth about 4km above the loch. The Kirk Burn runs southwards from the peatlands at Stroupster for 8 km and becomes the Burn of Lyth at its confluence with the Bower Burn. The Burn of Lyth runs between farmland and forestry before entering the western end of Loch Wester. Finally, the Burn of Auckhorn enters the loch on its northern edge after draining southwards for 3km through peatland and forest. The periphery of the Wester catchment lies at an altitude of about 30m but the final segment of the stream network falls only 4m over the final 4 km of its course.

Figure 1. The main features of the Wester stream network are identified. The forest in the upper reaches of the Kirk Burn has recently been felled to make way for Stroupster Windfarm.

History of the catchment

The Wester catchment has a complex history and it is highly impacted by agriculture and forestry activity. In particular, long stretches of the various streams have been deepened and straightened to hasten run-off and improve drainage of the surrounding land. Due to channel modification the Scottish Environmental Protection Agency regards the Bower Burn and the Burn of Lyth as being of "bad" overall status[1] and the Kirk Burn as being only "moderate".

Almost all the stream network in the upper part of the Wester catchment (ie. west of Mireland) appears to have been re-aligned. The First Edition of the Ordnance Survey map of the area was prepared in 1873[2] and it shows that much of the channel modification evident today was carried out before this date. It shows extensive sections of unnaturally linear channel with short sections of the original, natural stream. This is clearly evident on the Bower Burn, west of Hecken Bridge near Hastigrow, where a short section of natural meanders occurs between lengths of linear channel (Figure 2). The modern map shows that this section of stream was also subsequently re-aligned.

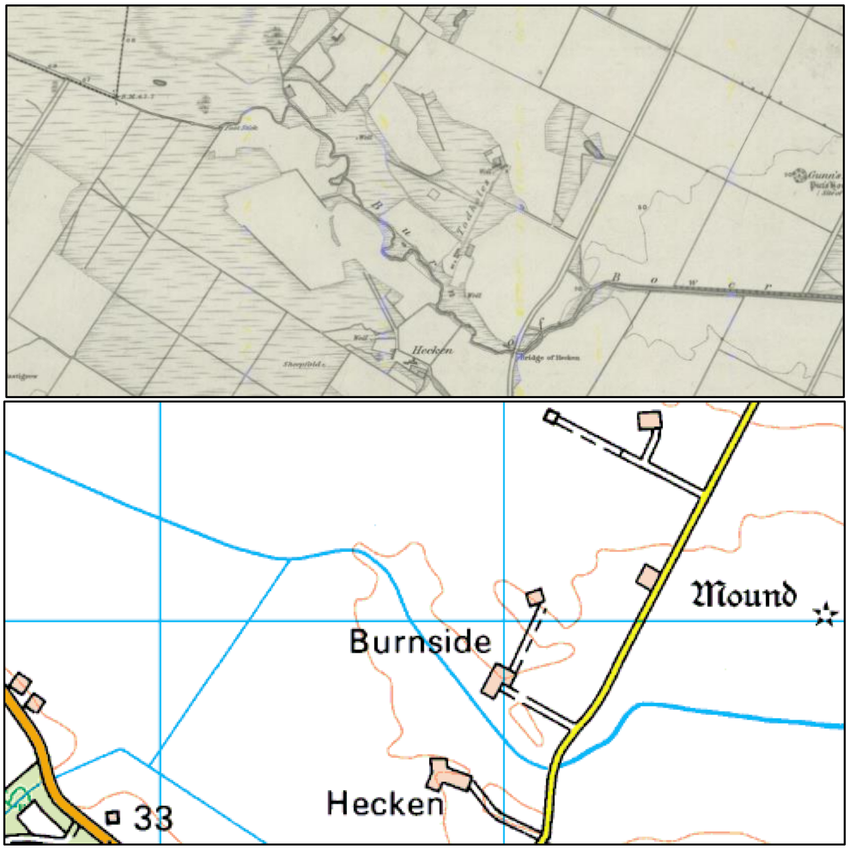

Figure 2. The Bower Burn near Hastigrow. The upper panel is as surveyed in 1873; the lower panel shows the present-day lay-out. The upper panel shows a section of original natural meanders, near what is Burnside farm today, lying between two sections of straightened channel. The lower panel also shows how these meanders were later removed.

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[1] http://www.sepa.org.uk/data-visualisation/water-environment-hub/?riverbasindistrict=Scotland

[2] http://maps.nls.uk/view/74426570

Elsewhere, the 1873 map shows the canalised section of the Burn of Lyth near Quintfall and the meanders of the original, pre-1873 stream isolated in the fields to the north. Even now the "fossilised" meanders are still clearly evident on Google Earth (Figure 3). The realignment at Quintfall was originally designed to protect and improve farmland in the vicinity and the works pre-dated the establishment of the forest by 100 years or more.

Figure 3. The Burn of Lyth at Quintfall. The upper panel shows Quintfall as surveyed in 1873. The stream has been canalised and the original stream meanders are now isolated in the farmland to the north. The lower panel taken from Google Earth shows that the same features of the landscape are largely unchanged today.

John Thomson's earlier map of 1822[3] is less detailed than the first OS map and mistaken in some of its detail but it appears to depict the entire Wester stream network in its complex, natural state. Most of the major drainage works were probably therefore carried out over a relatively brief period in the mid-1800s when the Agricultural Revolution replaced the old systems for working the land with the new, innovative methods being developed at the time. The area of land suited to farming was increased, wherever possible, by draining wet ground via deeper, straighter stream channels and the present pattern of rectangular fields was established. The new streams were thereby pushed to the edge of the cultivated ground and their straight courses then regularised the boundaries of the fields on either side.

At the time, the effects of these works on the streams' ecology and on the fish populations they supported were probably catastrophic. Subsequently, however, the quality of fish habitat in the stream network will have improved again as the channels re-stabilised, albeit in a new form. The new streams are shorter because they have been straightened. Because they are shorter they are also therefore steeper than before. In this particular respect, the new streams may even be more favourable for salmonids because the original slow meanders have been replaced by the faster flowing water that trout and salmon prefer. No doubt occasional set-backs to the new streams' ecology have followed with intermittent maintenance and the continued extension of the network of drains and ditches into the field-system - processes that continue today.

The Barrock Mill site (2013-15)

Caithness District Salmon Fishery Board has electric-fished the site at Barrock Mill (see Figure 4) in September each year since 2013. The electric-fishing results to 2015 are shown in Table 1.

Year	Fish density (number of fish per 100 square meters)								
	Trout				Salmon			Total (salmon + trout)	
	0+	1+	2+		0+	1+		0+	1+
2013	2	1	0		3	2		5	3
2014	4	2	1		12	1		16	3
2015	11	1	0		8	3		19	4

Table 1. Densities of juvenile salmon and trout (number per 100 square meters) at the Barrock Mill electric-fishing site, 2013-15.

It can be seen , for example, that in September 2013 the combined density of salmon and trout that had hatched early in 2013 (designated O+) was five per 100 square meters and the density of fish that had hatched a year earlier in 2012 (designated 1+) was three per 100 square meters.

All the values for each year are unexpectedly low. Based on values for rivers elsewhere in Caithness, the total density of 0+ fish would be expected to be around 80 per square meter and the density of

[3] http://maps.nls.uk/view/74400135

1+ fish to be around 20. So, even in the best year, 2015, the density of both the 0+ and 1+ groups was around 20-25% of the anticipated value.

On the other hand, all the fish at Barrock Mill were unusually large for their age. So, for example, 1+ salmon parr at Barrock Mill mostly ranged from 130 to 160mm whereas elsewhere in Caithness fish of this age are mostly in the 90 to 110mm range. The superior growth of the Barrock Mill fish was even more evident from their body weights. The weight of 1+ salmon ranged from 25 to 50g at Barrock Mill compared with the 8 to 15 grams range that is usual elsewhere in Caithness.

So, although fish at Barrock Mill were consistently few in number, those fish that were present were growing very well, probably as a result of low levels of competition in habitat that was more than capable of supporting them. All this suggests that a consistent shortfall in the input of young fish each year limited the number of fish present at the Barrock Mill site to the small numbers observed.

Over the three years of survey, only a single fish (a trout) at the Barrock Mill site was more than 1+ years old. This shows that the majority of fish move on after the 1+ stage. All the salmon parr must head for the sea in May as 2-years-old smolts. Like the salmon, 2-year-old trout smolts may head for the sea - around Sinclair Bay or further afield perhaps - contributing to the Wester fishery when they return as sea-trout. However, some trout probably restrict their movements to the river itself thereby contributing to the population of older fish in Loch Wester.

For rivers like the Wester that produce only 2-year-old migrants, the number of 1+ parr present at the time of survey (September) more-or-less determines the number of fish that will move on from their rearing areas in the following year. All else being equal, more migrants will eventually result in more adult fish. Because of this, the small number of 1+ parr present at Barrock Mill must restrict the number of migrants leaving the site and, therefore, the number of adult fish that are produced by it. So, if Barrock Mill is typical of the Wester catchment as a whole, then the Wester fishery must be falling short of its full potential.

In view of all this, the FCRT undertook to extend CDSFB's electric-fishing survey in order to investigate the production of salmon and trout more widely throughout the Wester catchment. Electric-fishing was carried out at seven additional sites. The aims were to find out whether the Barrock Mill site is typical of the wider catchment and, if it is, to consider whether management measures to improve the fishery potential of the river as a whole might be possible.

Methods used

Electric-fishing uses a voltage field to temporarily disable fish so that they can be captured by a hand-net and examined after being lightly sedated. All species were recorded during the Wester survey although the salmonid species were the main interest. Individuals were identified as trout or salmon, body length was measured and a sample of scales taken to find out how old each fish was and which annual crop of fish it belonged to. The body weight of each fish was calculated from its length. All the fish were returned to the site unharmed when work was complete.

Each site was electric-fished three times in succession over a period of about three hours. Each electric-fishing pass is about 60% efficient. So, each successive pass produces smaller numbers of fish but by the time that all three passes were complete it is likely that about 95% of all the fish that were present had been captured. Except where indicated, the values given below are the total number of fish that was caught at each site over three electric-fishing passes.

The surface area of each site was determined from its length multiplied by the average width of the stream. In order to allow for variation in the size of sites and to make comparisons possible, fish abundance was expressed as numerical density (ie. the number of fish per 100 square meters) and fish weight was expressed as biomass density (ie. grams of fish per square meter). Density and biomass values were calculated for the separate age-classes of salmon and of trout. In both cases, 0+ fish (those that hatched in the year of survey) and 1+ fish (those that hatched the previous year) were by far the most common although a few older trout were captured.

Sites electric-fished in 2016

In September/ October, 2016, eight sites in the River Wester catchment (including Barrock Mill) were electric-fished in the standard way. The location of each site is shown in Figure 4.

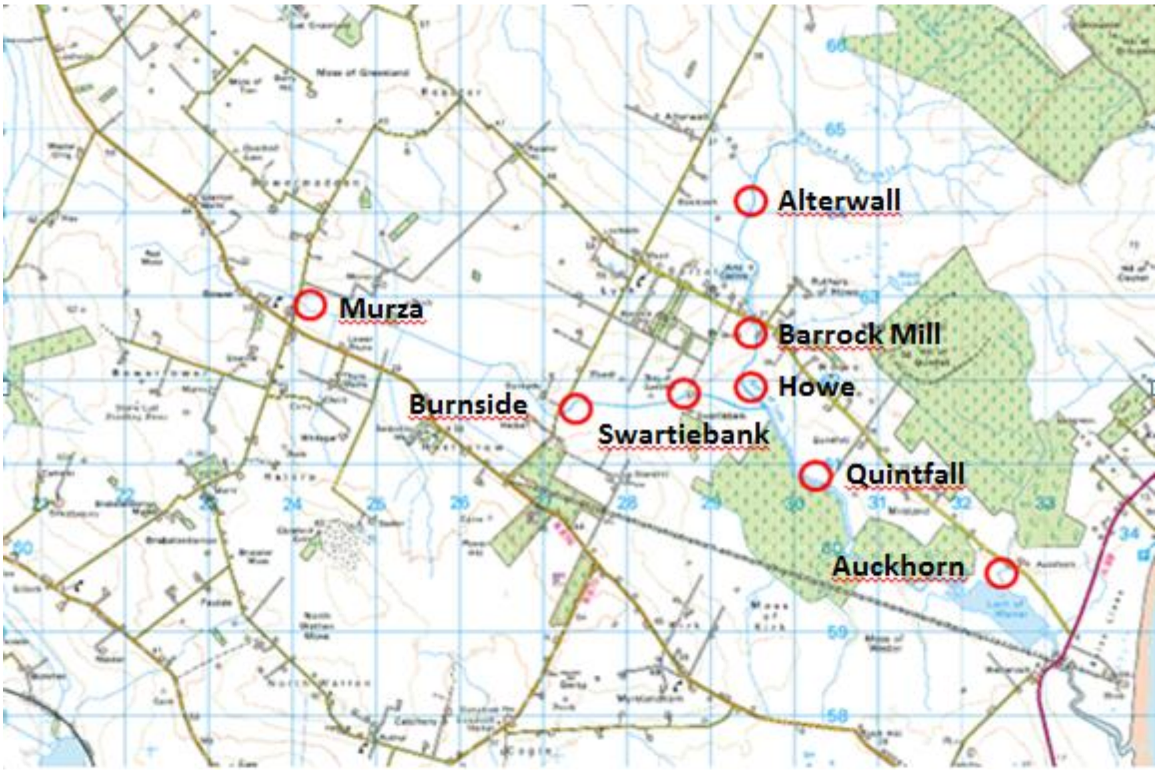

Figure 4. Map of electric-fishing sites in the Wester catchment.

Table 2 shows the area of each site and the number of trout and salmon caught. Eels, sticklebacks and flounders were also widespread and brook lamprey present where suitable silt/ mud substrate was present.

Site	Area (square meters)	Trout (number)			Salmon (number)		Other species
		0+	1+	older	0+	1+	
Alterwall	115.5	14	9	1	3	3	Eel/ stickleback/ flounder/ brook lamprey
Barrock Mill	173.0	15				9	Eel/ stickleback
Howe	122.5	34	1		68	22	Eel/ stickleback/ brook lamprey
Murza	80.5	16					Eel/ stickleback
Burnside 1	80.0	8	2				Eel/ stickleback/ flounder
Burnside 2	74.7	49	10	3	2	5	Eel/ stickleback/ flounder
Swartiebank	121.9	40	5	1	4	1	Eel/ stickleback/ flounder/ brook lamprey
Quintfall	78.5	33	1		37	1	Eel/ stickleback/ flounder/ brook lamprey
Auckhorn	101.0	22	1				Eel/ stickleback/ flounder

Table 2. The area of each site and the number of trout and salmon captured according to age-class. The occurrence of non-salmonid species is also listed.

It should be noted that the Burnside 1 site was electric-fished only over a single pass before being abandoned in favour of Burnside 2, 250m upstream. This decision was made because the stream-bed at Burnside 1 was unexpectedly found to comprise only smooth, bedrock shelves which do not offer adequate habitat for salmonids. This point is considered again later in the report.

Figure 5 shows the densities of 0+ trout expressed in diagrammatic form: Figure 6 shows the equivalent data for 1+ trout parr.

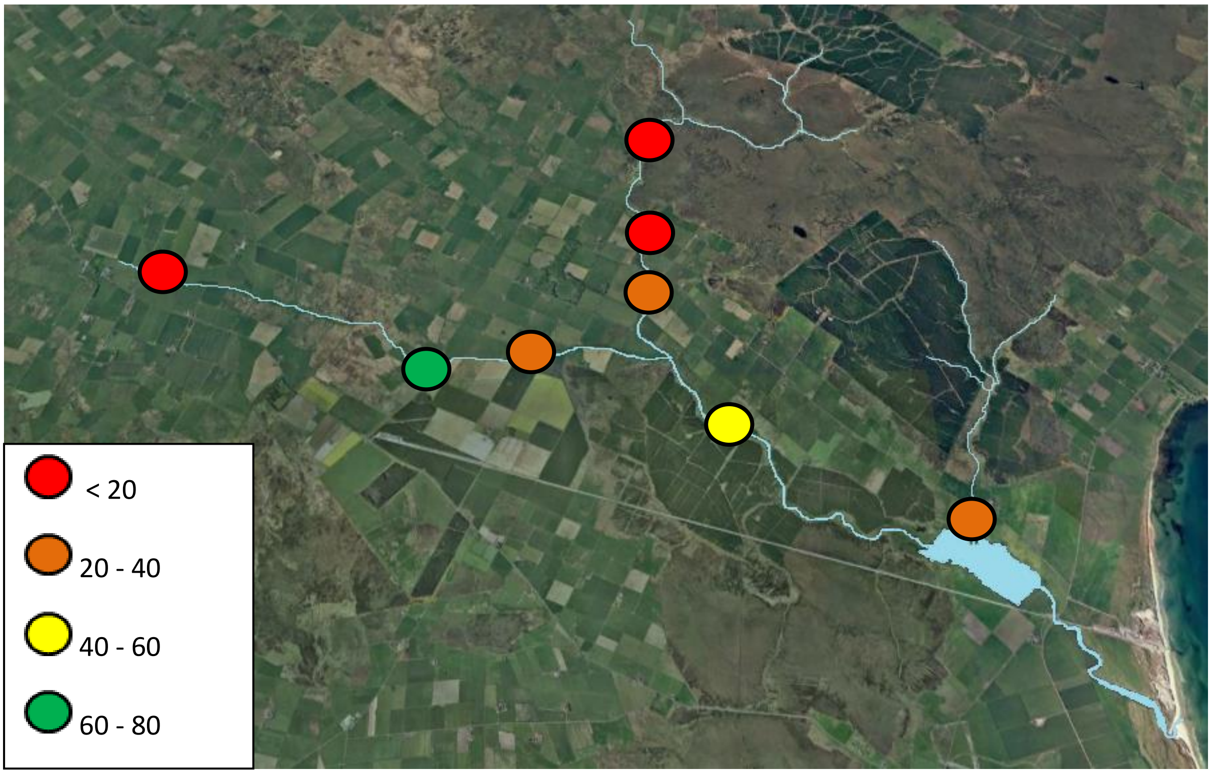

Figure 5. Densities of 0+ trout. The units are number of fish per 100 square meters.

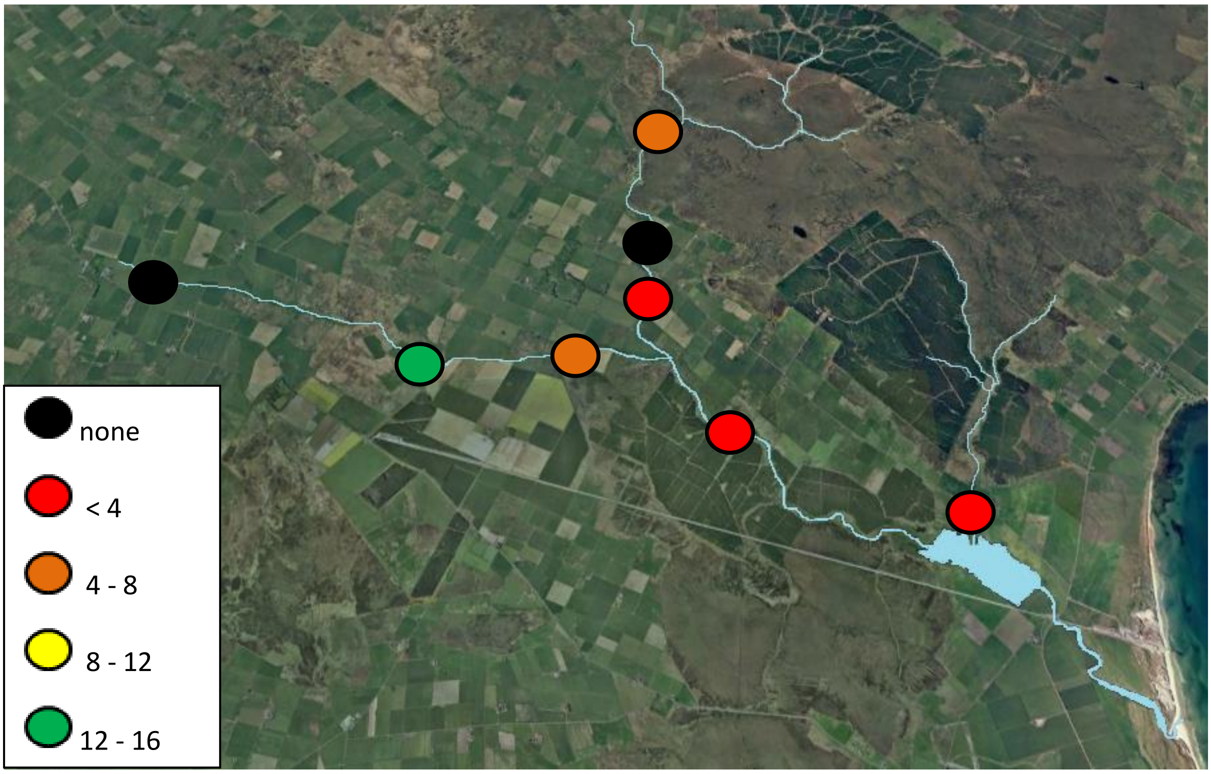

Figure 6. Densities of 1+ trout. The units are number of fish per 100 square meters.

0+ trout were present at all the sites suggesting that spawning had been widespread throughout the catchment in 2015. All the sites except Murza and Barrock Mill also supported 1+ trout. At most sites the densities of both 0+ and 1+ trout were modest or low. However, Burnside 2 was an exception and it supported much higher densities of both age classes of than any of the other sites.

Figures 7 and 8 show the equivalent data for salmon. Figure 7 shows that 0+ salmon were largely restricted to the area around the junction of the Bower and Kirk Burns. 0+ salmon were absent at Murza, Barrock Mill and Auckhorn but were present at low densities at Alterwall, Burnside 2 and Swartiebank. Much higher densities were present at the Howe and Quintfall sites suggesting spawning in 2015 had been focussed on this area.

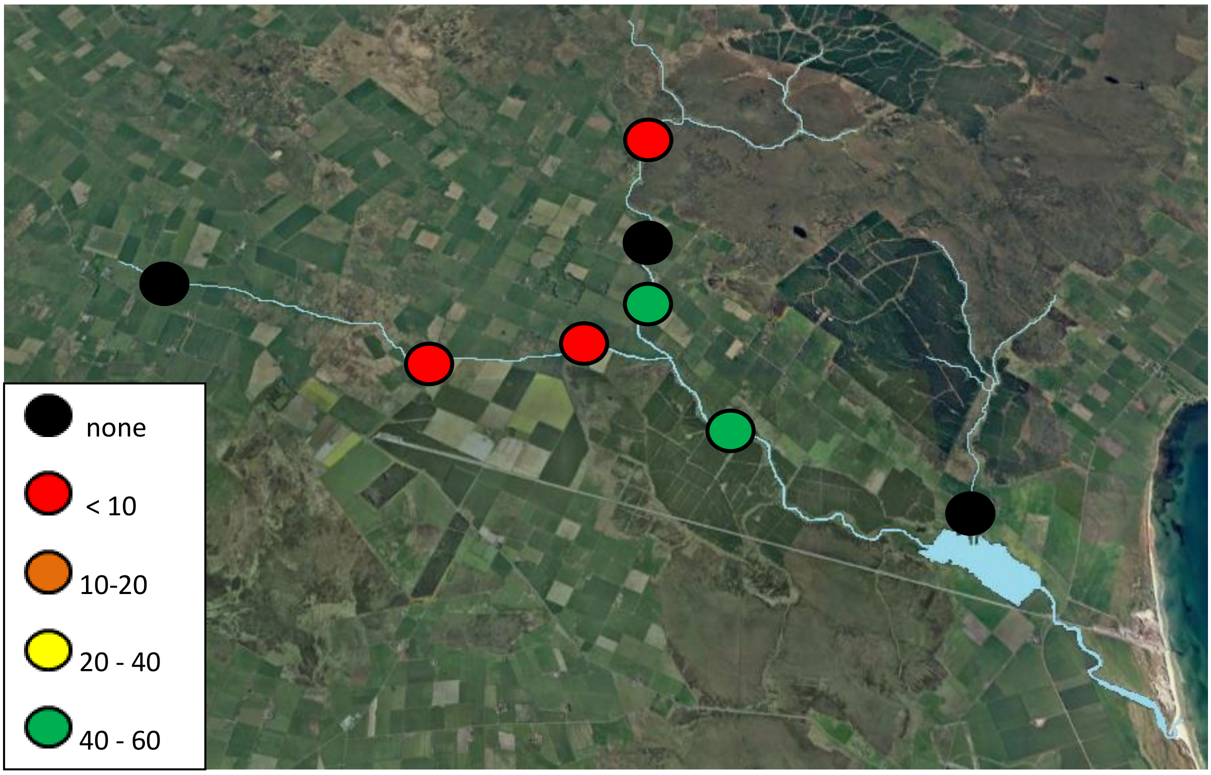

Figure 7. Densities of 0+ salmon. The units are number of fish per 100 square meters.

Figure 8 shows that 1+ salmon parr were more widely distributed that 0+ salmon but still absent from Murza and Auckhorn. The density of 1+ salmon was greatest by far at Howe.

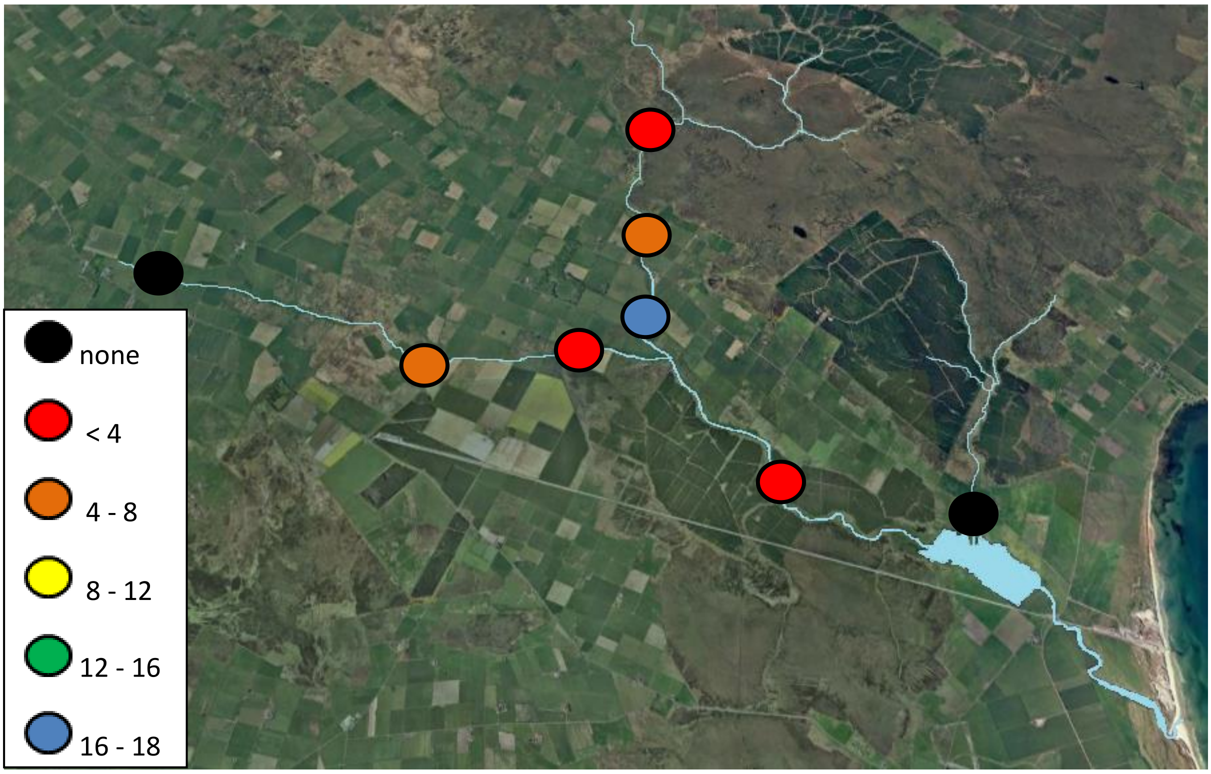

Figure 8. Densities of 1+ salmon. The units are number of fish per 100 square meters.

This report covers two year-classes of fish that were spawned in different years. The 1+ fish were spawned in 2014 and the 0+ in 2015. The distribution of spawners may have been different in 2014 and 2015 and this may have affected the relative distributions of the two age-classes when the survey was carried out. In addition, the loch and the lower river are not suited to electric-fishing and, except for Auckhorn, fish data are not available for the lower catchment. For both these reasons it is necessary to be cautious in interpreting some of the results.

Bearing this in mind, the following general points can be made.

1. The sites at Auckhorn and Murza ranked low for both trout and salmon relative to the other Wester sites. However, both sites are on narrow streams near the periphery of the catchment.

2. 0+ trout were distributed more widely than 0+ salmon. This may reflect differing patterns of spawning in the two species given that small river trout are generally better-suited to spawning in smaller streams while salmon and sea-trout tend to target larger areas of suitable substrate in wider streams and deeper water.

3. The Howe and Quintfall sites ranked highly for 0+ fish of both species indicating that spawning may have been concentrated around this part of the catchment.

4. Quintfall did not rate highly for 1+ fish of either species. This is probably because the stream substrate is sand/ silt and uniformly plain due to dredging.

5. Burnside 2 ranked very highly for 1+ salmon although 0+ salmon were absent suggesting the young salmon may move in from the Howe/ Quintfall area after the 0+ stage. Young fish may move into the Barrock Mill site in much the same way.

6. Previous CDSFB surveys of the Barrock Mill site pinpointed the requirement to investigate the wider Wester catchment. The 2016 survey of the Barrock Mill site confirmed its poor status relative to other sites in Caithness. However, the 2016 survey also showed that Barrock Mill site ranked low relative to the other Wester sites.

7. The Wester catchment differs from the other Caithness rivers included in the CDSFB's annual survey because both trout and salmon are present in substantial numbers whereas all the sites on the other Caithness rivers are dominated by salmon. The mixture of two species adds complexity to the Wester catchment because salmon and trout will compete with one another to some extent. Thus, the presence of salmon will tend to reduce trout numbers and the presence of trout will tend to depress salmon numbers. Therefore, direct comparison of salmon densities in the Wester sites with salmon densities sites in the other Caithness rivers is not appropriate. For the Wester sites, it is necessary to consider the combined production of salmon and trout, as shown in Table 3, below.

The productivity of sites

Table 3 shows the density values used to generate Figures 5 – 8, above. In addition, the two right-hand columns show the values for the combined density of 0+ salmon and 0+ trout and the combined density 1+ salmon and 1+ trout for each site.

The density of the combined 0+ fish varied from a low value of 8.7 per 100 square meters at Barrock Mill to a high value of 89.1 per 100 square meters at Quintfall. The density of 1+ fish ranged from 1.0 to 21.4 per 100 square meters. The values for 1+ fish at Howe and Burnside 2 were much greater than the values for any of the other sites.

Site	Fish density (number of fish per 100 square meters)									
	Trout				Salmon			Trout + salmon	
	0+	1+	older		0+	1+		0+	1+
Alterwall	12.1	7.8	0.9		2.6	2.6		**14.7**	**10.4**
Barrock Mill	8.7					5.2		**8.7**	**5.2**
Howe	27.8	0.8			55.5	18.0		**83.3**	**18.8**
Murza	19.9							**19.9**	
Burnside 2	65.6	14.7	2.7		2.7	6.7		**68.3**	**21.4**
Swartiebank	32.8	4.1	0.8		3.3	0.8		**36.1**	**4.9**
Quintfall	42.0	1.3			47.1	1.3		**89.1**	**2.6**
Auckhorn	21.8	1.0						**21.8**	**1.0**

Table 3. Numerical density of trout and salmon by age-class in the Wester catchment, 2016.

As above, trout are very uncommon at all the sites on the other Caithness rivers that are routinely electric-fished by CDSFB. However, for salmon, average density values at the Caithness sites are around 80 per 100 square meters for 0+ fish and 20 per 100 square meters for 1+ fish. On this basis, the density of 0+ fish (trout and salmon combined) reached average Caithness values only at Howe, Quintfall and perhaps Burnside 2. The combined values for 1+ fish reached average Caithness values only at Burnside 2 and perhaps Howe. All the other Wester sites fell far short of average Caithness values.

There are four factors that must be considered in relation to the variation in fish densities observed in the Wester sites.

1. Water quality. Any effect of water quality can probably be discounted since high-ranking sites were present on each of the main Wester sub-catchments - the Kirk Burn (Howe), the Bower Burn (Burnside 2) and the Burn of Lyth (Quintfall). In addition, the fish were growing rapidly and moving on at a relatively young age at all the sites because 2+ salmon were not detected and 2+ trout were uncommon.

2. Distribution of spawning. The supply of hatchlings each year affects the relative number of 0+ fish supported by particular locations since small fish can reach sites near to spawning locations more easily than sites at a greater distance. There are probably three types of fish spawning in the Wester catchment. Resident brown trout will have access to the widest range of spawning locations. Because they are relatively small these spawners can reach potential spawning sites on narrow streams in places like Alterwall, Murza and Auckhorn. By contrast, salmon and sea trout spawners are larger and they tend to target wider streams. For both salmon and trout, 0+ fish were present at the greatest densities at the Howe and Quintfall sites, suggesting that spawning by both species was concentrated in this vicinity. As juveniles become older and larger, they are able to colonise at greater distance and, in line with this, the distribution of 1+ salmon among the survey sites was more even than the distribution of 0+ salmon.

3. Habitat quality. Stream areas differ in their capacity to support fish, mainly due to differences in gradient, and therefore current speed, and because of differences in bank-side cover and the quality of cover offered by the roughness of the stream-bed. Comparison of Burnside 1 and Burnside 2 illustrates this point. The sites are in close proximity. The sites cannot be compared using data for three-pass electric-fishing because, as discussed above, the Burnside 1 site was fished only once. However, the density of 0+ fish detected on the first electric-fishing pass at Burnside 1 was 10 per 100 square metres and the density of 1+ fish was 3 per 100 square meters. The equivalent values at Burnside 2, only 250m upstream, were much greater at 36 and 15, respectively.

4. Competition. When juvenile fish are present at high density their growth tends to be depressed by the effects of increased competition. The body lengths of fish captured at different sites in the Wester varied. For example, the average length of 0+ trout at Murza where there were relatively few fish was 93mm while at Quintfall it was 75mm. When the length values are converted to estimates of body weight, the disparity in body size becomes more clearly evident - 9g versus 4g. Similarly, the average body weight of 1+ salmon at Barrock Mill where there were relatively few fish was 34g but just downstream at Howe 1+ density was much greater and the corresponding value was only 23g.

Performance of sites

The availability of fish to colonise sites, the habitat quality of the sites and competition among fish present at sites all interact of determine the number of fish present and their size. Without a full-scale research project, it is not possible to disentangle the separate effects of each factor.

However, from a practical point of view, biomass density (the weight of fish per unit area of stream) combines consideration of the number of fish present and their size in a single measure of the production achieved by particular sites. Biomass density values are shown in Table 4. Values ranged from 1.85 grams per square meter at Murza to 14.4 grams per square meter at Burnside 2. The range is broadly in line with values for sites elsewhere in Caithness.

Site	Fish biomass (grams per square meter)						
	Trout			Salmon			Trout + salmon
	0+	1+	total	0+	1+	total	total
Alterwall	0.63	3.20	3.83	0.10	0.77	0.87	4.70
Barrock Mill	0.63		0.63		1.80	1.80	2.43
Howe	1.71	0.32	2.03	1.86	3.97	5.83	7.86
Murza	1.85		1.85				1.85
Burnside 2	4.61	7.78	12.39	0.20	1.81	2.01	14.40
Swartiebank	2.52	1.62	4.14	0.19	0.38	0.57	4.71
Quintfall	2.01	0.76	2.77	1.29	0.30	1.59	4.36
Auckhorn	1.65	0.54	2.19				2.19

Table 4. Biomass density of 0+ and 1+ trout and salmon in the Wester catchment, 2016.

As above, at the point where competition begins to limit the growth of fish and therefore a site's capacity to produce biomass, the site will still be capable of supporting greater densities of fish. But if the numbers of fish are greater, and since the biomass will remain more or less unchanged, the fish will necessarily be smaller in size. It can be judged whether any of the Wester sites is near its productive limit by scrutinising the body sizes of the fish present at each site. All the length data for each site are shown in the Appendix. Most of the sites do not contain sufficient fish to justify robust comparisons. However, 0+ trout and salmon at Howe and Quintfall were small in size relative to fish at other sites and Howe and Quintfall may therefore be nearing their maximum capacity to produce fish biomass.

Comparison with Lythmore, Forss

The purpose of this report is to assess the status of fish populations in the River Wester. This necessitates comparison with some standard. So far the comparisons have been limited to comparisons among the Wester sites themselves. However, this approach is impeded by the small numbers of fish present in one or both age-classes at many of the sites and the absence of particular age-classes in some of them. It also lacks scope.

One way of judging how well the Wester population is performing is to compare it with a similar population elsewhere. The range of possible comparisons is effectively limited to the Caithness rivers because comparable data are lacking elsewhere. In particular, biomass densities are available only for the CDSFB survey sites. However, the River Wester is unusual in that trout and salmon are both represented in substantial proportions whereas trout are essentially absent at all the other CDFFB sites. This means that comparisons of Wester and non-Wester sites must necessarily be biased towards consideration of salmon rather than trout.

All the average values for the length of salmon in the 20+ DSFB sites surveyed each year between 2013 and 2015 are given in Table 4 of the CDSFB report[4]. In summary, the average length of 0+ salmon at sites outside the Wester ranged from 47.1mm to 64.5mm; in 2016 the corresponding value for the Wester as a whole was 66.6mm. For 1+ salmon the average length outside the Wester ranged from 84.5 to 112.3mm; the corresponding value for Wester in 2016 was 129.6mm. Wester salmon were therefore unusually large for their age. This may be because of low levels of competition in the Wester due to the presence of low densities of fish, although environmental quality may also be a factor.

From the environmental point of view, the CDSFB site at Lythmore on the River Forss is probably most similar in nature to the Wester sites. Like the Wester, the Forss is a relatively small river. The Lythmore site lies at an altitude of 24m, which probably makes it similar to the Wester catchment in terms of stream temperature, and it also is of modest gradient. As for the Wester, fish older than 1+ are rare at Lythmore because most fish grow sufficiently quickly to smolt as two-year-olds.

Fish were present in very much greater numbers at Lythmore than at any of the Wester sites and they were much smaller, too. In 2013, for example, 0+ salmon were present at 174 per 100 square metres and their average length was 61.4mm. 1+ salmon were present at 42 per 100 square meters and their average body length was 109.7mm. Although the numerical densities of both 0+ and 1+ salmon at Lythmore varied considerably between years, the biomass density remained more-or-less constant. In 2013 and 2014, biomass density was around 11g per square meter and, in 2015, the value was about 10. This consistency suggests that the natural limit on total biomass production at the Lythmore site is around 10 or 11 grams per square meter.

[4] http://caithness.dsfb.org.uk/files/2016/02/Consolidated-EF-Report-9-2-16.pdf

Potential production in the Wester catchment

In what follows, biomass production at the Wester sites has been considered in the context of Lythmore in order to speculate about the potential capacity of Wester to produce smolts and to gauge any scope for improving the Wester fishery. The aim is to estimate potential levels of smolt production if the status of the Wester was similar to that of Lythmore and, in particular, if the supply of young fish to the Wester sites was not a significant constraint on production.

Lythmore has been chosen for reasons discussed above and the 2013 survey data for Lythmore have been chosen because the ratio of 0+ fish to 1+ fish that year was close to the overall Caithness average of about 4 to 1. In other words, when populations are relatively stable roughly four 0+ fish are required to generate one 1+ fish by the following year. The smallest unit of fish production can therefore be regarded as four 0+ fish plus one 1+ fish and, at Lythmore in September 2013, the average weight of this unit was 24.3 grams. This Lythmore value can be used to estimate potential production at the Wester sites, as follows.

The total biomass density value for the combined salmon and trout, for each age-class, at all the Wester sites are given in Table 4. These values can be divided by the 24.3 fish unit value derived from the Lythmore data to generate the number of fish units per square meter that the Wester sites might be capable of supporting if their fish populations were of similar status to Lythmore. The potential numerical density of 0+ fish is then four times the number of fish units since each unit contains four 0+ fish. For the 1+ fish, the potential numerical density has the same value as the number of fish units since each unit contains one 1+ fish. The observed fish densities for each of the Wester sites and the corresponding potential values based on comparison with Lythmore are shown in Table 5. The observed values are for trout and salmon combined but the potential values are in “salmon equivalents” (see below).

	Numerical density (per 100 square meters)			
	0+ fish		1+ fish	
Site	Observed	Potential (in salmon equivalents)	Observed	Potential (in salmon equivalents)
Alterwall	14.7	**77.4**	10.4	**19.3**
Barrock Mill	8.7	**40.0**	5.2	**10.0**
Howe	83.3	**129.4**	18.8	**32.4**
Murza	19.9	**30.5**	zero	**7.6**
Burnside 2	68.3	**237.1**	21.4	**59.3**
Swartiebank	36.1	**77.5**	4.9	**19.4**
Quintfall	89.1	**71.8**	2.6	**17.9**
Auckhorn	21.8	**36.1**	1.0	**9.0**
Average	42.7	**87.5**	8.0	**21.9**

Table 5. Indicative potential values for fish density (in salmon equivalents) by age-class based on observed biomass density for each site and compared with Lythmore. The observed values are also shown.

On this basis, it can be seen that each of the Wester sites is probably capable of supporting higher densities of fish than were observed in 2016. The average potential values exceed the observed values by X 2.0 for 0+ fish and by X 2.7 for 1+ fish. So, if the eight Wester sites are representative of the catchment as a whole, then these levels of gain could be expected to be achievable over the catchment as a whole. In fact, the projected levels of gains are likely to be under-estimates because in other years some or all of the sites, with the possible exceptions of Howe and Quintfall, are likely to be capable of producing higher biomass densities than those observed in 2016.

In Table 6, therefore, the potential density values have been re-calculated based on the average of the observed biomass density values at Howe and Quintfall (6.11 grams per 100 square meters) because, based on fish size, only these sites can be judged to have been near their natural limit, as is discussed above. The Table 5 values are retained for Howe and Quinfall because they are considered to be near to their natural limit and, in addition, the value for Burnside 2 is retained because the biomass density observed there exceeded the Howe/ Quintfall average. For the other sites (Alterwall, Barrock Mill, Murza, Swartiebank and Auckhorn), it can be seen that the potential values given in Table 6 are identical; this is because they are derived from the same biomass density value (ie. the average value for Howe and Quintfall).

	Numerical density (per 100 square meters)			
	0+ fish		**1+ fish**	
Site	**Observed (salmon + trout)**	**Potential (salmon equivalents)**	**Observed (salmon + trout)**	**Potential (salmon equivalents)**
Alterwall	14.7	**100.6**	10.4	**25.1**
Barrock Mill	8.7	**100.6**	5.2	**25.1**
Howe	83.3	**129.4**	18.8	**32.4**
Murza	19.9	**100.6**	zero	**25.1**
Burnside 2	68.3	**237.1**	21.4	**59.3**
Swartiebank	36.1	**100.6**	4.9	**25.1**
Quintfall	89.1	**71.8**	2.6	**17.9**
Auckhorn	21.8	**100.6**	1.0	**25.1**
average	42.7	**117.7**	8.0	**29.4**

Table 6. Indicative potential values (in "salmon equivalents") for fish density by age-class based on average of biomass densities observed at Howe and Quintfall. The observed values are also shown.

On this basis, the average potential values for fish numbers were greater than those given in Table 5 and they exceed the observed values by X 2.8 for 0+ fish and by X 3.7 for 1+ fish. Judged on this basis, therefore, the density of 1+ fish produced was only around 30% of the predicted value based on "salmon equivalents".

For the Wester in particular, the "salmon equivalent" values are not fully appropriate because the river contains both salmon and trout. It is commonly observed that trout are larger than salmon at any given age in streams where the two species co-exist. The total Wester catch in 2016 is detailed in Table 7.

	Number	Average length (mm)	Average weight (grams)
0+ salmon	114	66.6	2.9
0+ trout	231	84.2	6.4
1+ salmon	41	129.6	26.5
1+ trout	29	151.8	44.7

Table 7. Total Wester catch of trout and salmon.

The average body weight of 0+ trout was X 2.16 greater than for 0+ salmon while the average body weight of 1+ trout was X 1.69 greater than for 1+ salmon. The greater body size of trout could reflect their greater efficiency than salmon in transforming stream resources into body tissue or it could result from trout making proportionately greater demands on the resource than salmon do. If the former is the case, "salmon equivalent" and "trout equivalent" values will be similar. If the latter is the case, then the "trout equivalent "unit will be greater than the "salmon equivalent" unit and the values for potential density as given in Table 6 will over-estimate the potential of the Wester's mixed population of trout and salmon.

In what follows, greater demand rather than greater efficiency has been (conservatively) assumed to apply. Based on the data given in Table 7, the trout and salmon values for each age-class have been used to adjust the weight of the Lythmore "salmon equivalent" unit (24.3 g, as specified above) to generate an alternative "trout equivalent" unit, being the combined weight of four notional 0+ trout plus one notional 1+ trout. The derived value for a trout unit is calculated to be 45.3g.

In Table 8 the potential densities at each site are re-calculated as "trout equivalents" using the 45.3 trout unit value.

	Numerical density (per 100 square meters)			
	0+ fish		**1+ fish**	
Site	**Observed (salmon + trout)**	**Potential (trout equivalents)**	**Observed (salmon + trout)**	**Potential (trout equivalents)**
Alterwall	14.7	**54.3**	10.4	**13.5**
Barrock Mill	8.7	**54.3**	5.2	**13.5**
Howe	83.3	**69.9**	18.8	**17.5**
Murza	19.9	**54.3**	zero	**13.5**
Burnside 2	68.3	**128.0**	21.4	**32.0**
Swartiebank	36.1	**54.3**	4.9	**13.5**
Quintfall	89.1	**38.8**	2.6	**9.7**
Auckhorn	21.8	**54.3**	1.0	**13.5**
Average	42.7	**63.5**	8.0	**15.8**

Table 8. Observed and indicative potential values (in "trout equivalents") for fish density by age-class based on average of biomass densities observed at Howe and Quintfall.

On this basis, the average potential values for fish numbers were less than those given in Table 6 but they still exceed the observed values - by an average of X 1.5 in the case of 0+ fish and by X 2.0 for 1+ fish. The number of 1+ fish produced was therefore around 50% of predicted values based on "trout equivalents", again indicating that the Wester was operating below its natural capacity in 2016.

Overall, based on the values presented in Tables 6 and 7, the Wester was probably operating at 30% – 50% capacity in 2016. The exact value will depend on the precise admixture of trout and salmon that is considered to apply but, in any case, the alternative estimates are really rather similar.

Further data requirements

1. The Wester data is for a single year only but it contains information on two age-classes spawned in two different years. Various measures of performance indicate that in both years an inadequate supply of eggs or young fish limited production. Four consecutive years of data (2013-16) are available from CDSFB for the Barrock Mill site. They show that fish densities there were consistently

low relative to sites elsewhere in Caithness, indicating that shortfalls in spawning probably extend back to 2011. Even so, a repeat of the full Wester survey in 2017 would test the validity of the conclusions drawn in the present report. In particular, the variation in (a) the distribution of age classes and (b) levels of biomass production at particular sites should be checked again.

2. Assessment of the mixed trout/ salmon population of Wester is hampered by the lack of suitable reference data on the structure of trout populations elsewhere. In this regard, a survey of the fish population of the Gill Burn at nearby Freswick (10km distant) is worth considering. Most importantly, the Gill Burn is not much affected by drainage works and in most other respects appears similar to the Wester. Nothing is currently known of the Gill Burn's fish population. It almost certainly contains resident trout and it is also accessible to salmon and sea-trout. An electric-fishing survey of the Gill Burn would be likely to provide a suitable reference comparison for the performance and production of Wester trout.

3. Streambed habitat in Wester is profoundly affected by historical river works. Information on habitat is currently restricted to informal assessment of the survey sites themselves and these differ greatly in character. More generally, the stream network is probably a mosaic of altered habitats that have been affected by channel modification in different ways. A full-scale habitat survey of the stream network would clarify the picture and provide greater detail on the likely scope for improvement in particular areas.

4. The production of the Wester is estimated to be 30 – 50% of its potential. This value is based on the assumption that average levels of potential biomass production at the Wester sites are similar to the values achieved in 2016 at Quintfall and Howe. If this is incorrect, the shortfall in production will differ from the value implied by the 30 – 50% estimate. In order to tighten up the estimate, saturation stocking could be used to provide specific values for the natural limits on biomass production at sites on the catchment periphery like Murza, Auckhorn and Alterwall. The more productive sites at key locations like Howe, Quintfall and Burnside 2 should not be stocked, in order to avoid disturbing their natural fish populations. More generally, trout should not be used for stocking, in order to conserve the Wester trout population. From a practical point of view, salmon for stocking would have to be sourced outside the Wester, perhaps from the Wick River which lies 8km to the south. This would probably be considered legitimate given the long history of intense stocking reportedly carried out by local salmon netsmen some years ago.

5. The present survey is restricted to the upper catchment above Loch Wester. An attempt was made to find a suitable survey site on the lower river but this proved unsuccessful because the river is slow-moving and relatively deep. Nevertheless, further consideration might be given to finding ways to discover how the fish populations of the lower river and Loch Wester are linked to those of the upper catchment.

Management options

1. If stream maintenance is proposed for the Wester catchment, particularly for main spawning areas in the vicinity of Howe or Quintfall, the works should be timed to avoid the period when eggs or alevins are present in streambed gravels (November to May) to avoid the destruction of young stock.

2. If stream works are proposed, it will be feasible and practicable to remove fish from the targeted area by electric-fishing and to re-locate them to areas elsewhere in the Wester catchment that are not already saturated with fish.

3. The 2016 survey suggests that Wester is producing 1+ fish at 30-50% of its potential due to shortfalls in the availability of young fish. It is likely that this is mostly due to the uneven distribution of spawning gravels which appear to be overly concentrated in the area around Howe. This imbalance might be circumvented by redistributing eggs/ alevins away from Howe to other parts of the catchment via a hatchery. However, the more sustainable alternative is to create or restore spawning habitat in areas where it is lacking in order to make hatching fish more freely available to all the potentially productive areas of the catchment.

Conclusions

The fortunes of the Wester fishery are tied up in the catchment's history of modification due to drainage works of various types. A comprehensive account of the effect of these works on the streambed is not available at present but the general condition of the survey sites themselves is known. At places like Murza and Burnside 1 deepening of the stream channel has exposed flagstone shelves. Spawning is not possible in these places and they are also generally unsuited to supporting young fish because of the smoothness and plainness of the streambed. At places like Quintfall and Swartiebank, the streambed is again plain but dominated by silt and sand which is also not suited to spawning or to the presence of large densities of salmonids and especially of salmon. Despite this, both these sites contained surprisingly high numbers of young fish. The site at Howe is among the most radically modified of the Wester sites. Yet, it appears to contain the most favourable spawning substrate of all and it also supported large numbers of young fish. Overall, therefore, the Wester catchment supports a fish population that is in surprisingly good condition given the extent to which the various streams have been impacted in the past.

The Wester contains a mixed population of trout and salmon which is unusual in the Caithness context. The trout component and, and particularly the sea-trout component, is of greater management priority than the salmon population because the sea-trout fishery is considered dominant. In this respect, the Wester fishery is a unique and valuable local asset particularly if current levels of productivity can be sustainably enhanced. The present project has shown that there is likely to be scope for fishery improvement because, in 2016, the number of 1+ fish produced was estimated to be 30 – 50% of what could reasonably be expected. The management actions appropriate for improvement of the fishery have been provisionally identified and they could be carried out sustainably and at relatively low cost.

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Appendix

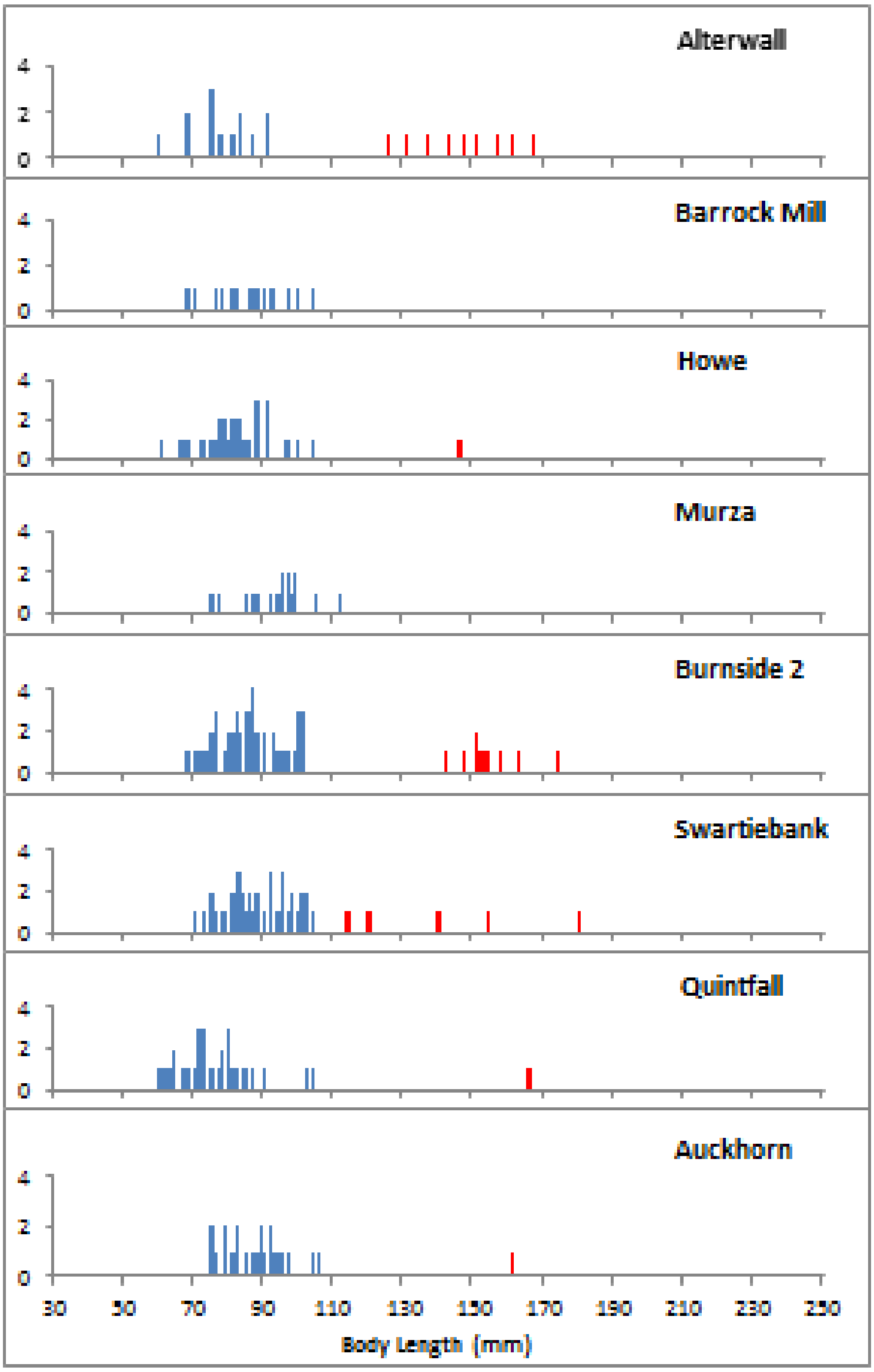

Figure 9. Length distribution of 0+trout (blue) and 1+ trout (red).

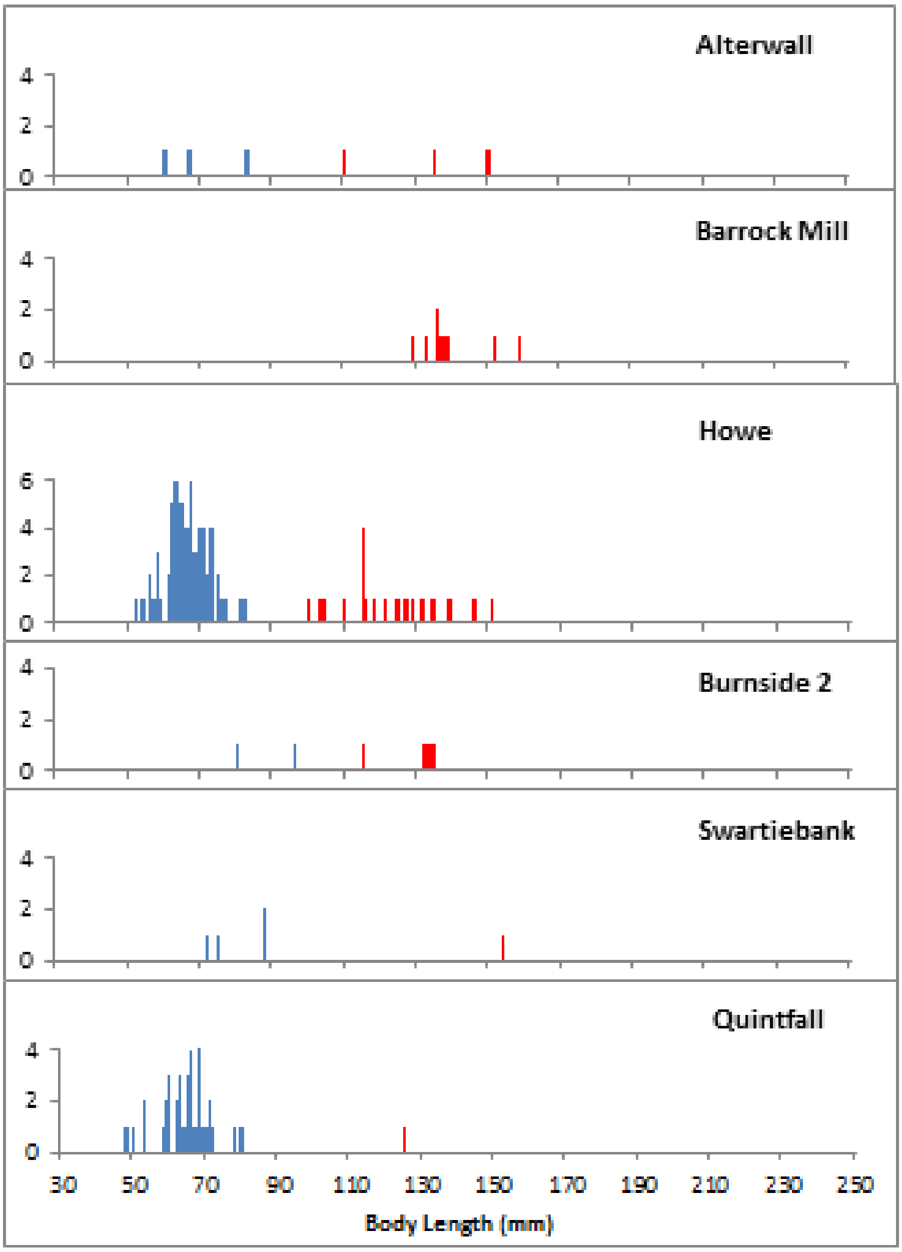

Figure 10. Length distribution of 0+ salmon (blue) and 1+ salmon (red).