Scope of works:

Atlantic salmon smolt tracking programme

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Prepared for: The Marine Alliance for Science and Technology for Scotland (MASTS).

Date: 09/02/2016

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Smolt Tracking Project.

Berriedale Pre-smolt Survey, April 2015.

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Introduction.

A marine smolt-tracking study is proposed for Berriedale in May 2016 using implanted VEMCO acoustic tags[1]. The aim will be to determine the routes taken by smolts as they leave the river mouth and pass through coastal waters in the vicinity. Acoustic tags emit periodic signals that can be picked up by automatic listening stations positioned on the seabed or by a hand-held receiver operated from a boat. In both cases probability of detection is limited by tag size since the larger tag types carry larger batteries which produce stronger acoustic signals and do so for a longer time. However, most smolts are small fish[2] and therefore unsuited to tagging with large devices; in general, only the larger among the smolts (>120mm) are expected to be suited to tagging with any of the range of VEMCO devices that is available.

A prior knowledge of the likely range of body sizes for smolts leaving Berriedale is therefore crucial for planning and, in particular, it is necessary to gauge the maximum tag size that may be deployed. Tag size, via acoustic signal strength, will affect detection range within the proposed array of automatic listening stations. The limitations of small tags will require that either low rates of detection are tolerated or that the array is fine-tuned by increasing the density of listening stations, or by reducing the overall coverage of the array. These factors will affect the capital costs of an optimal array or, alternatively, the quality of the

[1] http://vemco.com/products/?transmitters

[2] I.A. Malcolm, C.P. Millar, and K.J. Millidine (2015). Spatio-temporal variability in Scottish smolt emigration times and sizes. Scottish Marine and Freshwater Science Vol 6 No 2.

information to be gained from the project. A knowledge of the length-frequency distribution of smolts is also necessary to gauge the effort (man x days) and the approach (electric-fishing or rotary screw trap) required to catch up and tag sufficient numbers of smolts consistent with the aims of the project.

Experimental design will therefore involve balancing costs, risks and the quality of the information targeted; tag size, and therefore fish size, will be a key factor in this process.

As a prelude to the main 2016 tracking project, a preparatory study was carried out in April, 2015 to determine the body sizes, and the distribution and frequency of pre-smolts throughout the dual Berriedale/ Langwell system. The approach was to exploit existing information by repeating the electric-fishing survey carried out by the Caithness District Salmon Fishery Board in September, 2014[3]. Four sites on Berriedale River and three on Langwell River were re-surveyed under low-water conditions, in mid-April 2015 shortly before the smolt migration (Late-April and May) was expected to begin.

[3] http://caithness.dsfb.org.uk/publications/

Methods.

Figure 1. Location of seven electric-fishing sites on the Rivers Berriedale and Langwell.

The survey methods used were essentially those described in the Caithness District Salmon Fishery Board reports for 2013 and 2014[4]. The seven Berriedale/ Langwell sites (Figure 1) were re-identified from photographs and bankside measurements made on previous surveys. Stop-nets were positioned to define the limits of each site.

Three-pass depletion fishing was carried out using a battery-powered Electrafish back-back rather than the bankside generator and control box used in the previous Fishery Board surveys. This change to procedure was made because (1) aspects of the survey required the mobility offered by using a back-pack (2) back-pack fishing is a candidate technique for

[4] http://caithness.dsfb.org.uk/publications/

catching up fish for tagging in 2016 and (3) because accurate Zippin estimates of fish density and continuity with the previous Board surveys were not a target of the present survey.

Body-length (fork-length) was measured for all the fish captured on each electric-fishing pass under light sedation using Kusuri Masuizai Koi Sedate[5]. After recovery all fish were returned to the same site.

At the end of each site survey, approximately 10 minutes were allocated to rapidly catching up large fish (< ca. 10 cm) in the near vicinity in order (1) to better define the upper part of the length-distribution relationship and (2) to test the rate at which it was possible to catch fish potentially suited to tagging using back-pack apparatus. These fish were treated in the same way as those captured in the main part of the site survey and released back to their capture locations.

A second length-frequency relationship was constructed for the vicinity of each site by combining data from the extended survey with data from the 3-pass fishing, considering only those additional fish of 120 mm or greater body length.

Results and discussion

3-Pass fishing. One-year-old smolts are unlikely to occur in any of the Berriedale/ Langwell sites because of the relatively low temperature regime associated with the river's northern location. Previous survey work has shown that fish older than 2+ years are essentially absent at any of the Berriedale survey sites by September indicating that, in May, when the smolts leave the river, most do at either two or three years of age.

Scale-reading was not performed for fish captured in April and the age of individual fish is therefore not known. However, the fry (ca. 1 year old in April) and the composite parr group (2 or 3 years old) can be distinguished according the breaks (at around 75mm) in the length-

[5] http://kusuri.co.uk/kusuri-products/kusuri-masuizai-koi-sedate/

frequency distributions shown in Figures 2a-g, below. A cut-off value of 75mm has been used to categorise fry and parr in what follows.

All the parr and especially the larger fish are to be regarded as potential candidates for smolting. All the large fish in the survey were likely to smolt 2 – 6 weeks later but many of the smaller fish will remain in the river for a further year. The length cut-off for smolting in Berriedale fish is not known but it will be substantially lower than the cut-off point for tagging – the main topic of this report.

The fish were surveyed in Mid-April, towards the start of the rapid annual growth period[6]. Those fish which become smolts 2 – 6 weeks later will probably be larger than their mid-April size. Since the lengths of parr determined in the April survey will tend to underestimate the final length attained by smolts when they leave the river, the length-frequency distributions considered below will be conservative estimates of the size structure of that part of the smolt population that is still potentially available for tagging later than mid-April.

	Fry			**Parr**		
	Electric-fishing pass			**Electric-fishing pass**		
	1st	**2nd**	**3rd**	**1st**	**2nd**	**3rd**
Gobernuisgach	4	1	1	10	3	0
Corrichoich	26	9	2	22	4	1
Wag	27	5	6	20	9	4
Braemore	34	26	6	18	13	3
Aultibea	65	40	22	28	6	1
Coille Braigh	21	25	3	9	3	1
Strathcoull	28	14	7	8	1	3

Table 1. Numbers of fry and for parr captured on each pass of 3-pass fishing

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Table 1 shows the numbers of fry and parr captured at each site on each pass of the 3-pass electric fishing. The declines in capture numbers are generally as expected for depletion fishing. However, electric-fishing is conventionally applied only in the summer and autumn months and seasonal effects on fish behaviour and catchability may make strict comparison of April with September values problematic. Comparisons have therefore been restricted to

observed numbers rather than estimates of true density obtained by Zippin correction. In any case, any constraint of season on catchability will not affect the conclusions of the study because its main focus is operational; the aim is to assess the availability of fish for tagging rather than to obtain precise estimates of density.

Length-frequency relationships.

Length-frequency relationships for each survey site are shown in Figures 2a-g, below.

Separate length-frequency relationships are shown for September and April. For the September survey, ca. 50 fry were sampled for lengthing at sites where fry were very numerous. In these cases, total fry number and sample sizes are indicated in the graph title. The sites are presented in order of decreasing altitude.

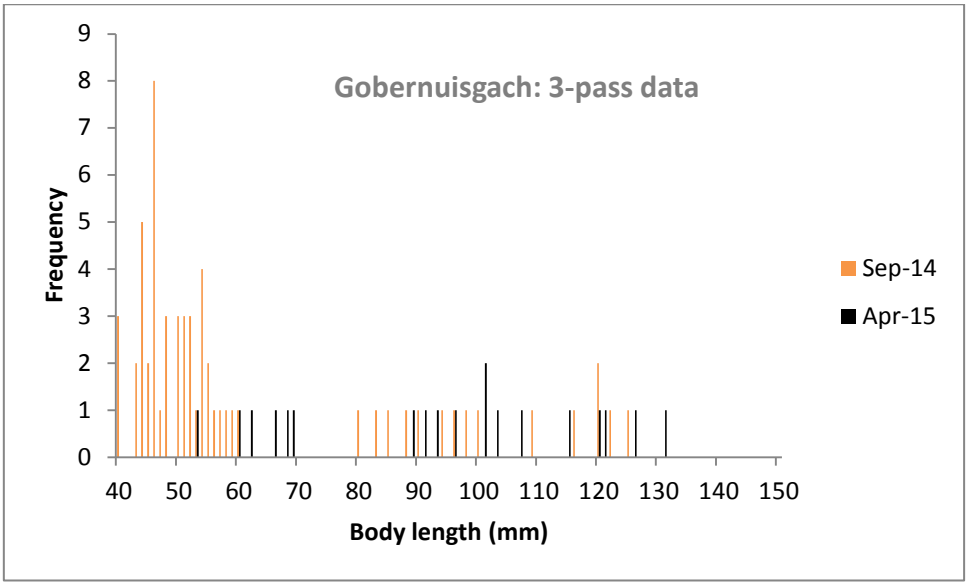

Figure 2a. Gobernuisgach (altitude 250m): length-frequency relationship for fish caught on 3-pass fishing.

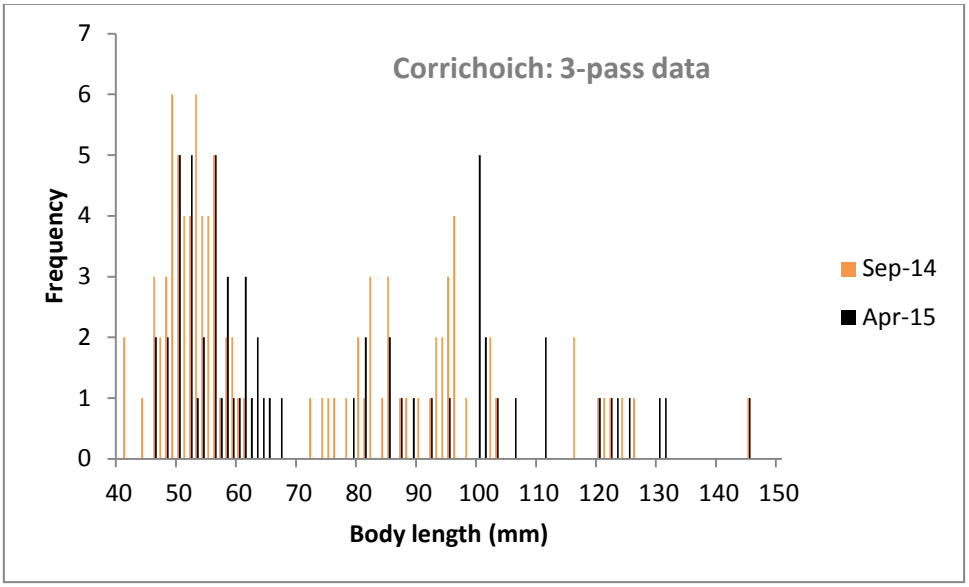

Figure 2b. Corrichoich (altitude 200m): length-frequency relationship for fish caught on 3-pass fishing.

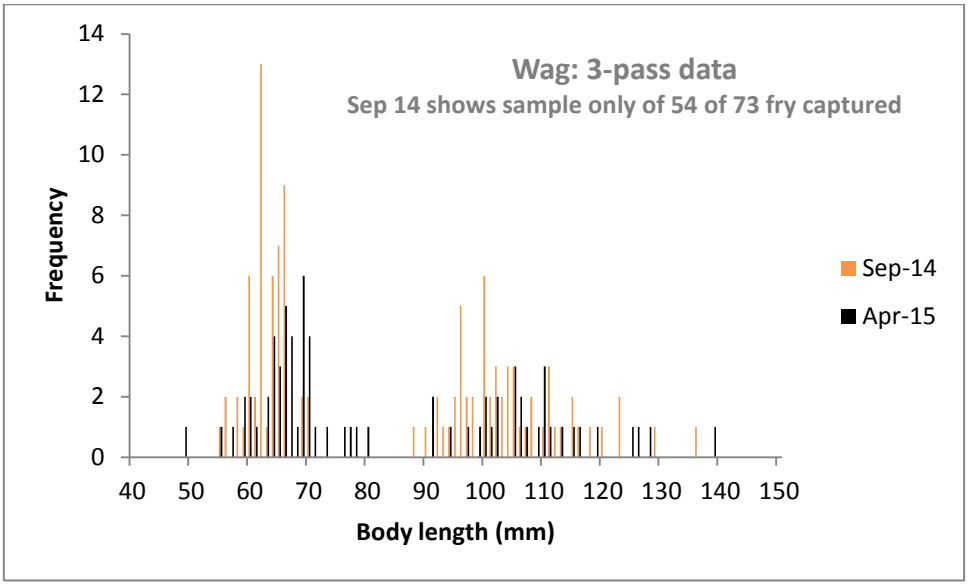

Figure 2c. Wag (altitude 188m): length-frequency relationship for fish caught on 3-pass fishing.

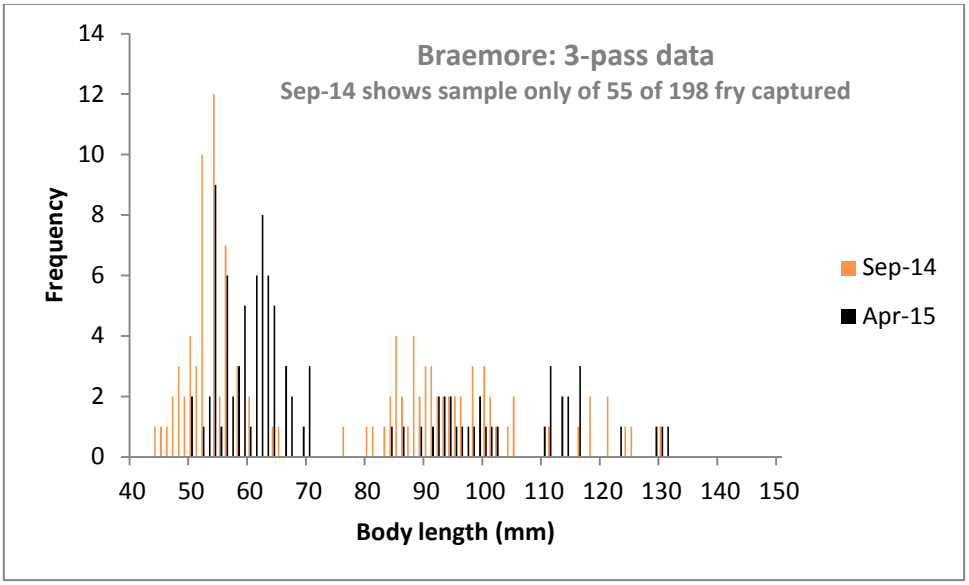

Figure 2d. Braemore (altitude 156m): length-frequency relationship for fish caught on 3-pass fishing.

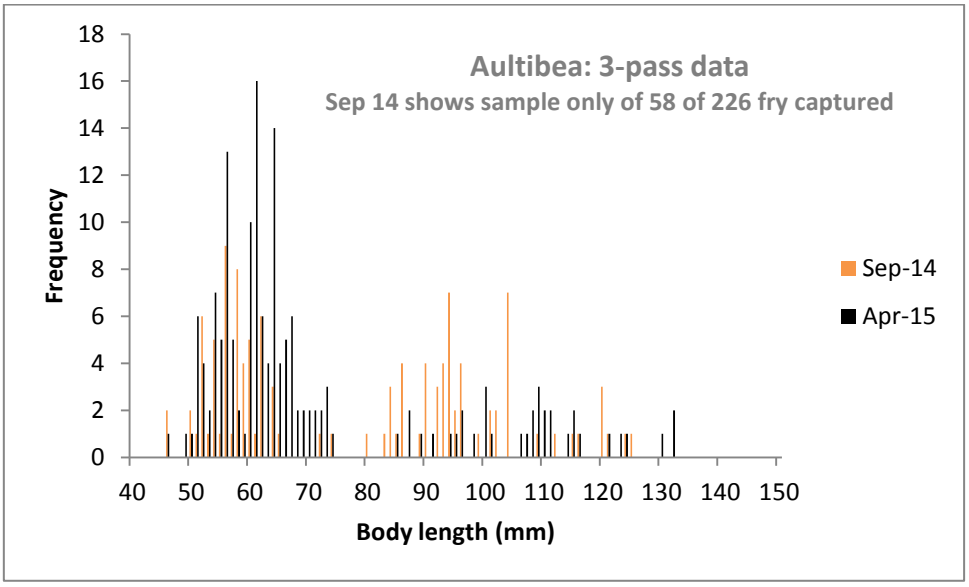

Figure 2e. Aultibea (altitude 125m): length-frequency relationship for fish caught on 3-pass fishing.

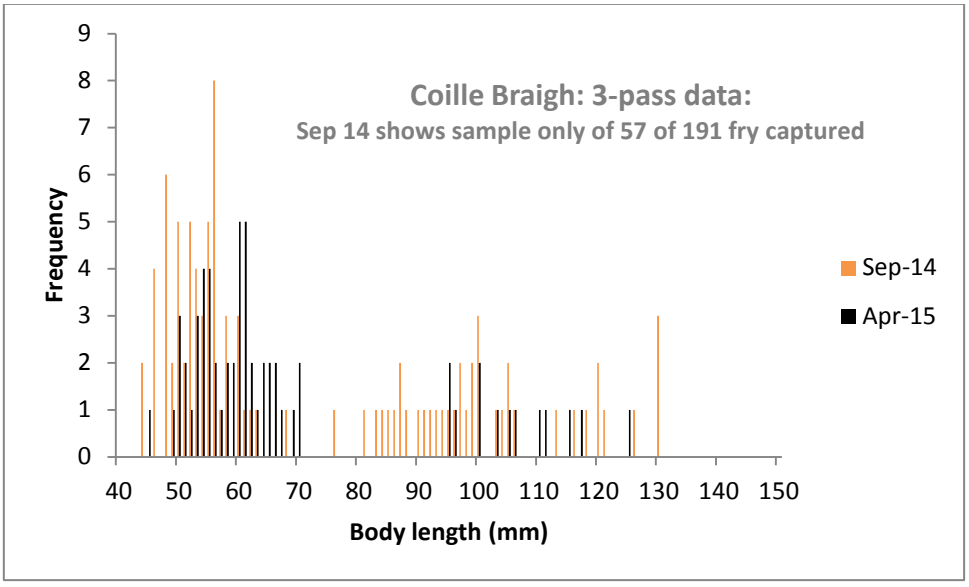

Figure 2f. Coille Braigh (altitude 93m): length-frequency relationship for fish caught on 3-pass fishing.

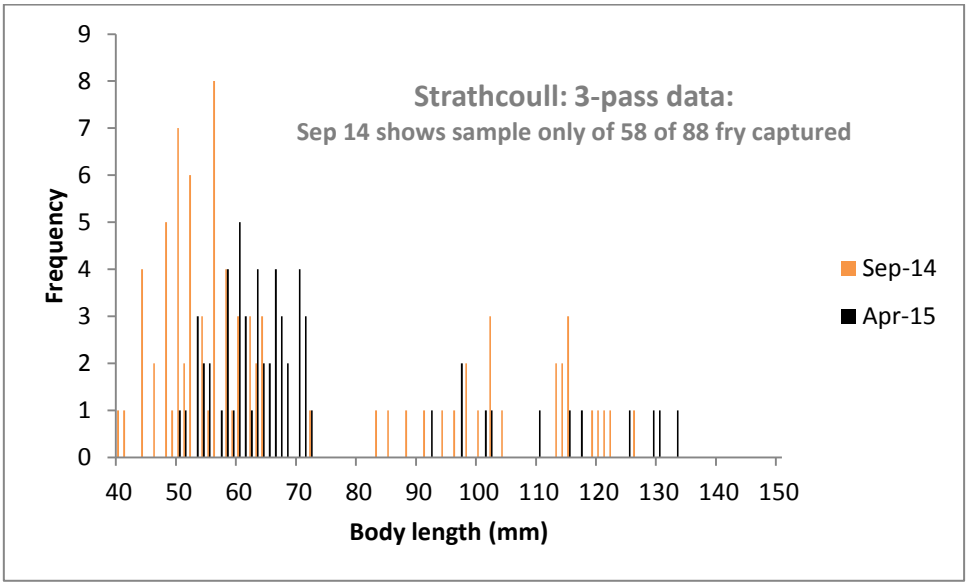

Figure 2g. Strathcoull (altitude 38m): length-frequency relationship for fish caught on 3-pass fishing.

Summary of sizes and numbers.

Summary data for Figures 2a-g are given for fry and parr, respectively, in Tables 2 and 3.

	Observed number of fry			Median body length of fry (mm)		
	Sep. 2014	Apr. 2015	Residual (%)	Sept. 2014	Apr. 2015	Increment (%)
Gobernuisgach	45	6	13	48	64	25
Corrichoich	58	37	64	52	56	8
Wag	73	39	53	63	66	6
Braemore	198	66	33	54	61	13
Aultibea	226	127	56	58	61	5
Coille Braigh	191	49	26	53	59	11
Strathcoull	88	49	56	53	63	19

Table 2. Observed number and median body length of fry in September 2014 and April 2015.

Table 2 shows summary information for fry derived from the length frequency relationships given in Figs 2a-g. For all sites, fry numbers decreased between September and April and the median body length of fry increased. Natural mortality, relocation from survey sites to alternative habitat types, and size dependent effects for both mortality and relocation may all be effects on the observed values. The residual % of fry and the increment in median body length were both highly variable but not apparently related. There was no evident relationship between site altitude and residual numbers or growth.

	Observed number of parr			Median body length of parr (mm)		
	Sep. 2014	Apr. 2015	Residual (%)	Sept. 2014	Apr. 2015	Increment (%)
Gobernuisgach	15	13	87	98	103	5
Corrichoich	40	27	68	94	105	12
Wag	55	33	60	102	105	3
Braemore	56	34	61	93	101	9
Aultibea	57	35	61	94	108	15
Coille Braigh	39	13	33	99	105	6
Strathcoull	25	12	48	104	113	9

Table 3. Observed number and median body length of parr in September 2014 and April 2015.

Table 3 shows summary data for parr. As for the case of the fry, parr numbers decreased and median body length increased between September and April for all the survey sites. Again, natural mortality and relocation may be effects - as may size-dependent effects for both. Both the residual % numbers and the change in median length were highly variable. However, no relationships are evident between the change in parr numbers and body size and no relationship is apparent between these values and site altitude. Nor are there obvious parallels between the fry and parr data.

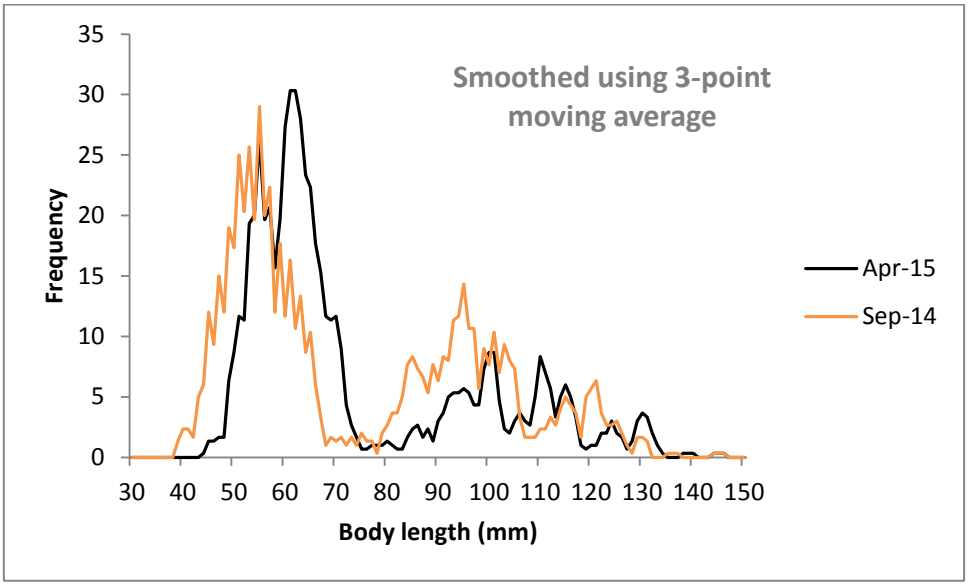

Figure 3. Length distributions for all Berriedale/ Langwell sites in September, 2014 and April, 2015. For September 2014, the number of fry (< 75mm) represented is a sample, only, of all the fry captured.

Given the apparent lack of systematic variation between sites, Figure 3 combines the individual site data to show the overall length-frequency relationships for both September 2014 and April 2015; the data are slightly smoothed using a 3-point moving average.

On this basis, despite lacking an understanding of the causes of the variations in changes in number and size of fry and parr over the winter period, values derived from a September survey could probably be used to make indicative predictions about fish size for the following April. The Fishery Board has proposed a 3-pass electric-fishing survey for September, 2015 which could be used in this way to make predictions for April, 2016 when it is planned to carry out the smolt tagging/ tracking project.

	>120mm	>125mm	>130mm	>135mm	>140mm	Site area (m^2)
Gobernuisgach	4 (30%)	3 (23%)	2 (15%)	0	0	157
Corrichoich	7 (26%)	4 (15%)	3 (11%)	1 (4%)	1 (4%)	130
Wag	4 (12%)	4 (12%)	1 (3%)	1 (3%)	0	202
Braemore	4 (12%)	3 (9%)	2 (6%)	0	0	175
Aultibea	5 (14%)	3 (9%)	3 (9%)	0	0	170
Coille Braigh	1 (7%)	1 (7%)	0	0	0	163
Strathcoull	4 (33%)	4 (33%)	2 (17%)	0	0	110
Totals	29 (19%)	22 (15%)	13 (9%)	2 (1%)	1 (1%)	1107

Table 4. Observed numbers of fish exceeded potential cut-off values for tagging. The % contribution among all the parr are given in parentheses. Site area is also indicated.

The numbers of fish captured by 3-pass fishing that equalled, or exceeded, potential body length thresholds for tagging is shown in Table 4. It should be noted that large individuals contribute also to the smaller threshold categories.

Inevitably, all the numbers are small. But there is no evident pattern in the representation of larger parr with altitude. Fish greater than 135mm were uncommon indicating that using this value as a cut-off value for tagging may not be feasible (but see below). Overall, 9% of the parr captured exceeded 130mm, 15% exceeded 125mm and 19% exceeded 120mm. Based only on the 3-pass survey data, these body size categories are probably feasible cut-off values to be considered against tag design.

As a measure of the effort required to obtain fish belonging to the various categories, fish greater than 130 mm, for example, were observed at an average density of ca. 1/ 100m^2.

Targeted fishing for large parr.

As a further measure of potential effort, and in order to better define the upper extremity of each length-frequency distribution, electric-fishing was continued for ca. 10 minutes near to the survey site, targeting large parr only. This approach was not adopted at Coille Braigh due to the unsuitable nature of the surrounding terrain.

Fish greater than 120mm were added to the length frequency distributions in Figures 3a-g, below.

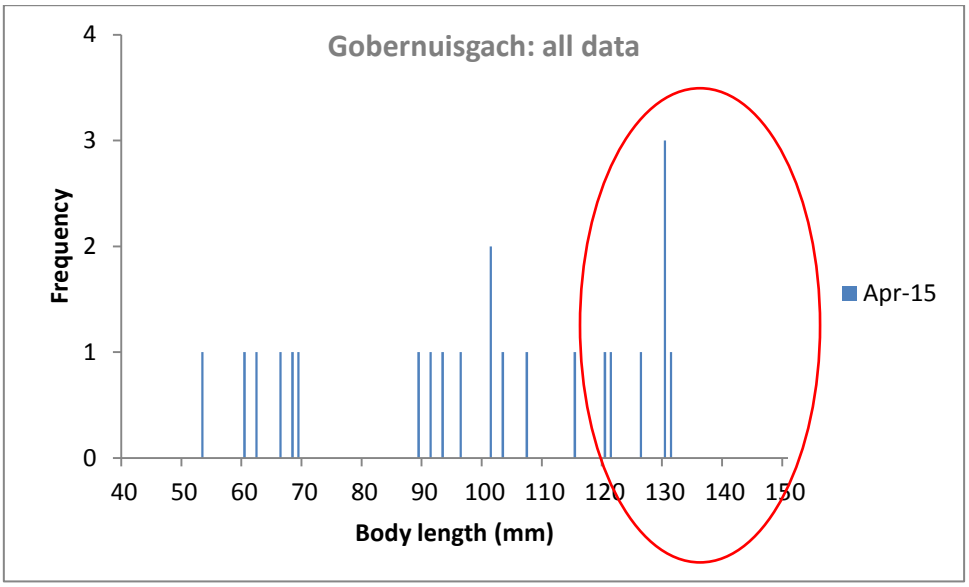

Figure 4a. Gobernuisgach: length-frequency relationship for all fish.

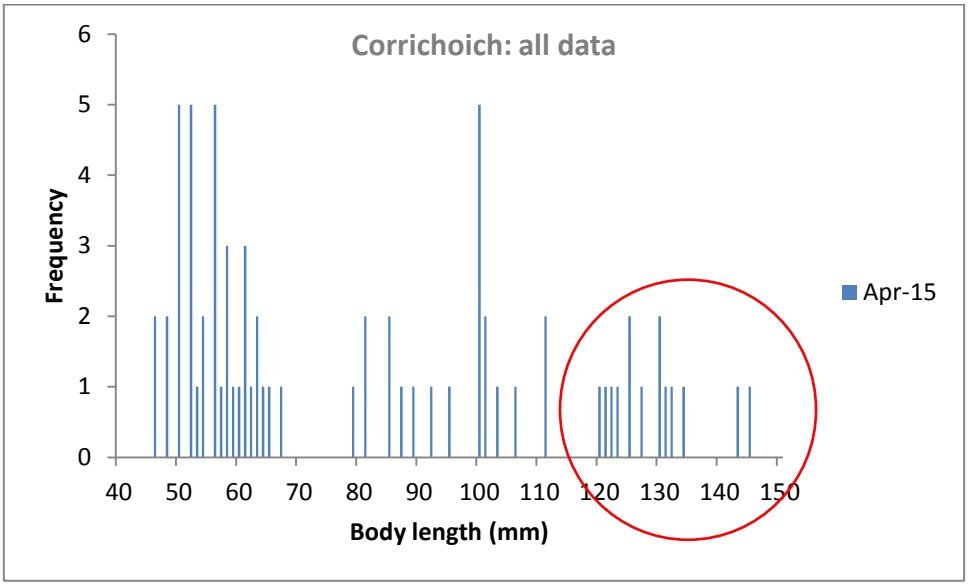

Figure 4b. Corrichoich: length-frequency relationship for all fish.

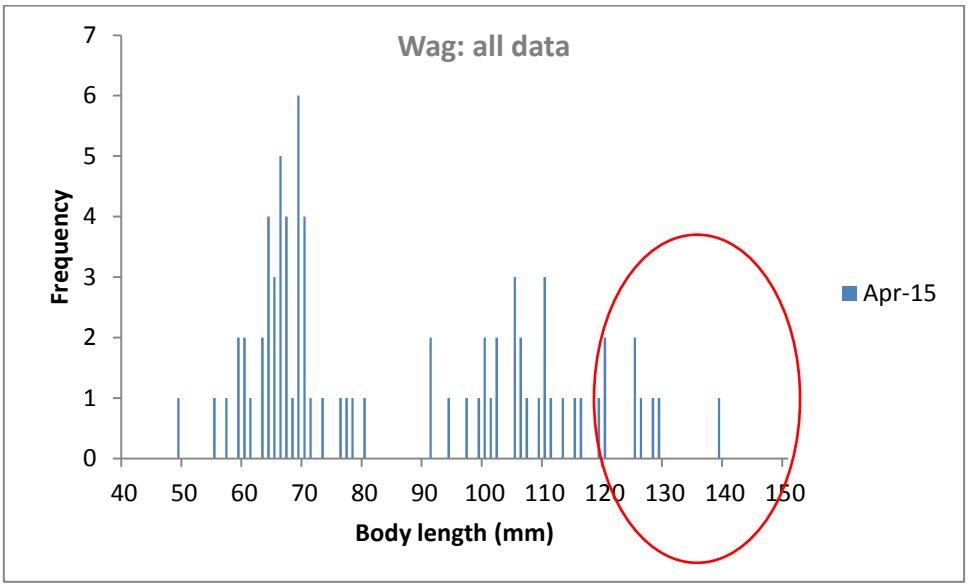

Figure 3a. Figure *Figure 4c. Wag: length-frequency relationship for all fish.*

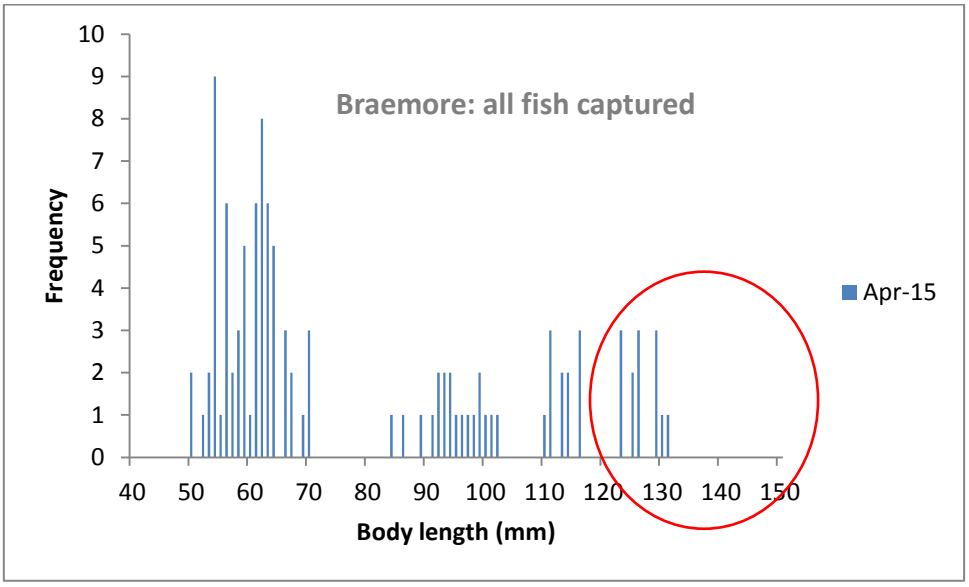

Figure 4d. Braemore: length-frequency relationship for all fish.

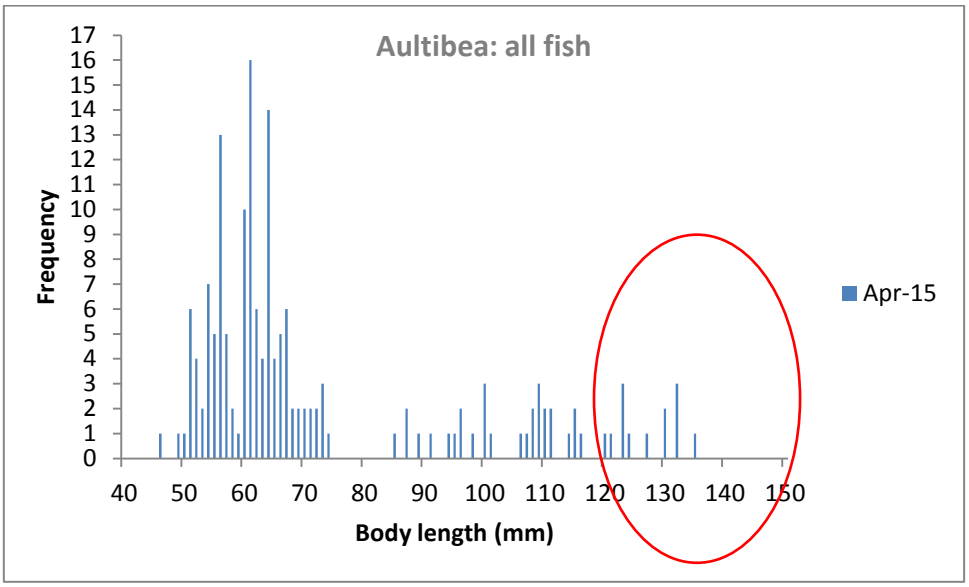

Figure 4e. Aulibea: length-frequency relationship for all fish.

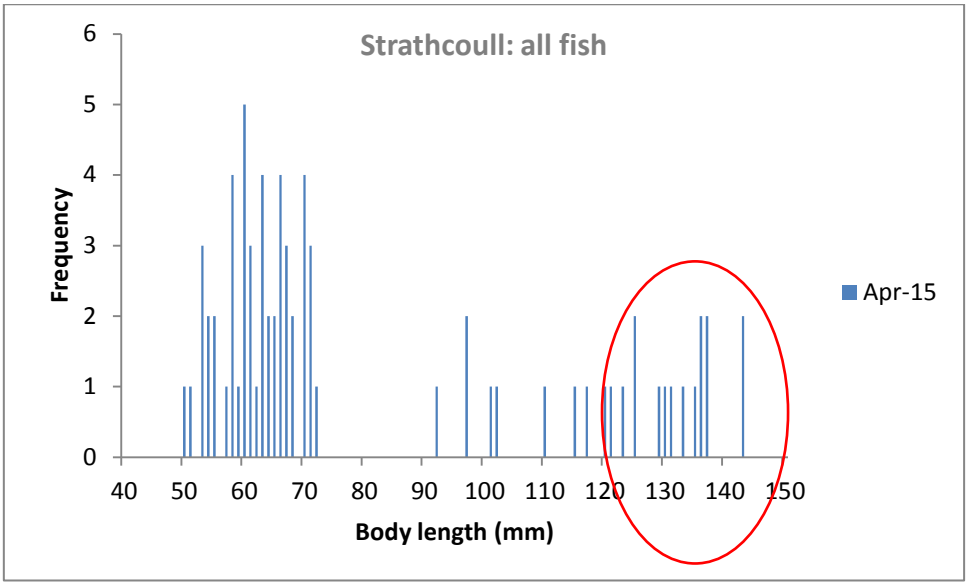

Figure 4e. Strathcoull: length-frequency relationship for all fish.

Table 5 shows the lengths of fish > 120mm captured during ca. 10 minutes of targeted electric-fishing near each survey site. Again, it must be noted that the larger fish are also included in each lower size category.

	>120mm	>125mm	>130mm	>135mm	>140mm
Gobernuisgach	3	3	3	0	0
Corrichoich	7	6	4	1	1
Wag	5	2	0	0	0
Braemore	9	7	0	0	0
Aultibea	7	4	3	1	0
Strathcoull	9	6	4	4	1
Totals	40	28	14	6	2

Table 5. Body length by category for large parr captured near each survey site by targeted electric-fishing for ca. 10 min.

The values are generally in line with those generated by 3-pass electric fishing with the important exception that the >135 mm category must now also be considered to a feasible target for tagging. Thus, based on a total sampling time of ca. 60 minutes across all six sites, an average of one individual of > 135mm was captured per 10 minutes of fishing time.

Silvering

None of the fish captured at any of the sites was fully silvered at the time of the survey; even partially-silvered fish were very infrequent. This indicates that the smolting process was not generally advanced by mid-April and that all or most of the potential smolts remained in the river. This, in turn, indicates that capture and tagging could be deferred beyond mid-April if, for example, high water conditions delayed scheduled electric-fishing. Or, tagging could be deferred beyond mid-April in order to conserve battery life and reduce levels of natural mortality among tagged, pre-migratory fish. On the other hand, tagging in mid-April would sample all the smolt population and allow a period for post-tagging recovery prior to migration, probably varying between a minimum of two to a maximum of six weeks.

Conclusions

1. Capturing parr for tagging by backpack electric-fishing in mid-April, near smolting time, was effective.

2. The main smolt migration had probably not commenced by mid-April and all or most potential smolts were probably therefore available for capture at this time.

3. Very large parr (>140 mm) were present in mid-April but infrequent.

4. Large parr > 130mm, and probably > 135mm, were sufficiently numerous to be a feasible target for tagging in the proposed 2016 project and could be cost-effectively captured by backpack electric-fishing rather than using a rotary trap.

5. There were no discernible, systematic patterns in the spatial distribution of large parr and, therefore, no particular sites can be identified as targets for obtaining fish for tagging.

6. Unknown inter-year effects, which cannot be disclosed by a single survey, may adversely affect predictions (as in 4, above) based on findings for 2015. Any such effects could be partially identified, and risks to planning for 2016 further mitigated, by repeating the survey in September, 2015.