Report on the Occurrence of Farmed Atlantic Salmon in Rivers in the Western River Basin District

August/September 2017

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Contents

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1 Executive summary

In mid-August 2017, anglers began reporting catching suspected escaped farmed salmon in the Bundorragha and Dawros rivers in the Ballinakill Fishery District. Further fish were reported from the Erriff, Bunowen and Newport rivers in September. In total, scales from 34 suspected farmed salmon were made available for analysis out of a total of 66 reported being captured by angling. Seven fish were made available for examination. All seven fish exhibited a combination of morphological features described by Fiske *et al*. (2005) as occurring in farmed salmon enabling these fish to be distinguished as of farmed origin. Examination of scales available from 34 salmon confirmed these fish exhibited scale patterns identifiable as salmon of farmed origin clearly distinguishable from wild salmon (Lund & Hansen, 1991). Scale analysis showed that these fish had a larger smolt size, younger smolt age, more extensive transition phase from freshwater to sea water and the absence of a sea winter band which distinguished them from wild Atlantic salmon. Internal examination revealed that some of the male escaped fish were sexually mature. Genetic stock identification and Bayesian clustering demonstrate that the salmon samples provided were of Norwegian genetic ancestry and were not from any Irish wild populations or from any Irish salmon ranching or mitigation strains.

Recently derived salmon rod exploitation rates were applied to estimate the numbers of farmed salmon in rivers where the escaped fish were detected and results indicate, based on the number of escaped farmed salmon reported captured by angling, that up to five hundred escaped farmed fish in total may have been present in five rivers in the Western River Basin District. This large number of escaped farmed salmon, with a high proportion of males likely to be sexually mature, presents a potential threat to local wild salmon populations from interbreeding and other ecological effects. Where feasible, Inland Fisheries Ireland (IFI) staff will monitor for the presence of farmed salmon during the spawning period and take appropriate action to minimize their influence on wild populations. Longer term genetic studies on the impact of introgression may be required in order to follow up on quantifying the impact of this escapement.

2 Project personnel and acknowledgments

The report was written by Dr Paddy Gargan, Dr Michael Millane, Dr Willie Roche and Darren Craig (IFI). Padraic O'Malley, Osgur Grieve, Donovan Brinklow and Laura Walsh, (National Salmonid Index Catchment, Erriff Fishery, IFI) are thanked for collection and collation of farmed fish samples. Trevor Stafford is acknowledged for contributing to the fish scale assessment. The authors are grateful to David McEvoy (Delphi Fishery) and Nigel Rush (Kylemore Fishery) for provision of farmed fish scales and samples.

3 Introduction

Salmon anglers began to report catching suspected escaped farmed salmon in rivers in the Ballinakill District in the Western River Basin District in mid-August 2017. The first reported farmed fish was captured on the Bundorragha river on 15th August and another was reported from the Dawros river on 17th August. Further likely escapees were captured in late August and throughout September in the Bundorragha, Dawros, Erriff, Bunowen and Newport rivers (Figure 1). Scale samples from 34 rod caught fish were made available to local IFI officers and seven bodies of suspected escaped fish were also available for examination. Experienced fishery owners and anglers (many of whom provided supporting photographs) retained fish, took scale samples or reported captures of likely escapees.

4 Reports of escaped farmed fish from individual rivers

4.1 Bundorragha

On the 15th August 2017, a suspected farmed salmon escapee caught by an angler on the Bundorragha river was reported (Table 1). This fish was not retained for analysis. Subsequently length/weight and scale samples were taken for 15 suspected escaped farmed salmon from Bundorragha between 30th August and 29th September. A further 10 escaped farmed salmon averaging 3-4lbs in weight were reported to have been captured by anglers and returned alive from mid-August to the end of the angling season. Two fish were presented to local IFI staff for further examination.

4.2 Erriff

The first escaped farmed salmon was captured on Beat 9 on the Erriff river on 3rd September 2017. Length/weight data and scale samples were collected from seven escapees on Beat 9 on the Erriff between 3rd and 13th September. A further 10 escaped salmon, averaging 3lbs in weight, were captured by anglers and released on Beat 9 on 6th September 2017. Two escapees were recorded in the upstream trap on the Erriff on 7th September and a third fish was recorded on 24th September. All three fish were retained for analysis. All fish entering the Erriff system upstream of Beat 9 (tidal) must pass through the Erriff trap at Aasleagh falls where they are monitored.

4.3 Dawros

The first suspected escapee was captured by angling on the Dawros river on 17th August 2017. Over the period 5/9/17 to 30/9/17, scale samples were collected from seven suspected escaped salmon and made available to local IFI staff. From late August to end of September, ten additional escapees were reported as being captured and returned to the river.

4.4 Bunowen

Two suspected farmed salmon were captured on the Bunowen river on 8th September 2017. Data on length/weight and scale samples were provided to IFI.

4.5 Newport

Two suspected farmed salmon approximately 3lbs in weight were captured on the Newport river on 29th September 2017 and reported to IFI.

4.6 Collated information

In total, length/weight data and scale samples from 34 suspected escapees and seven confirmed escapees (based on body morphology) were available for analysis (Table 1). A further 32 salmon were recorded as being of escaped farm origin but were returned after capture by anglers (Table 1).

Table 1 Numbers of suspected escapee farmed salmon recorded in five Western river systems.

River	Length/weight scales available	Caught & released by angling, not sampled	Retained for analysis	Total
Bundorragha	15	10	2	25
Erriff	10	10	3*	20
Dawros	7	10	–	17
Bunowen	2	–	2	2
Newport	–	2	–	2
Total	34	32	7	66

*Erriff trap

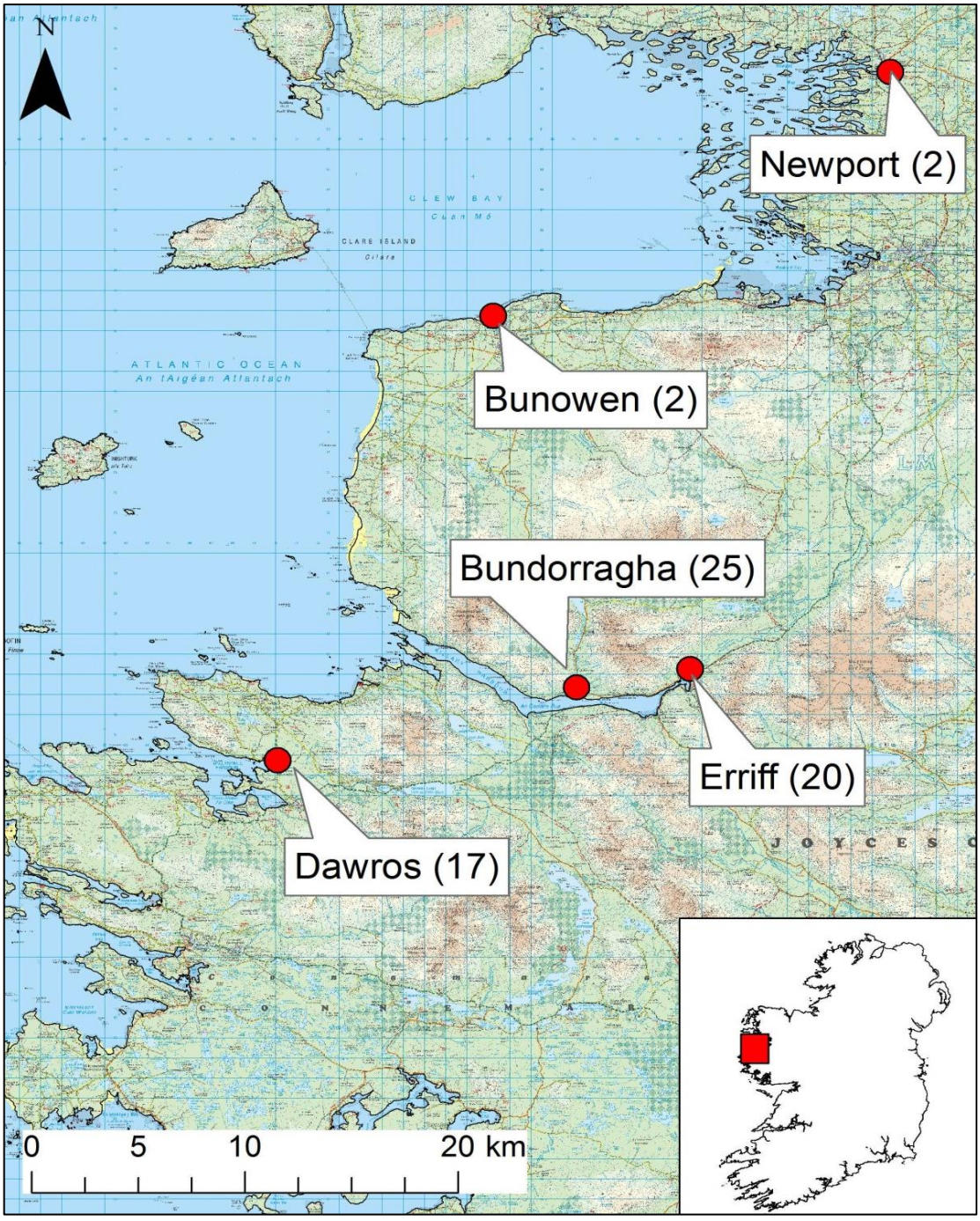

Figure 1 West of Ireland river systems where farmed Atlantic salmon were caught by anglers in August and September 2017 (number of fish caught per river system are indicated in brackets).

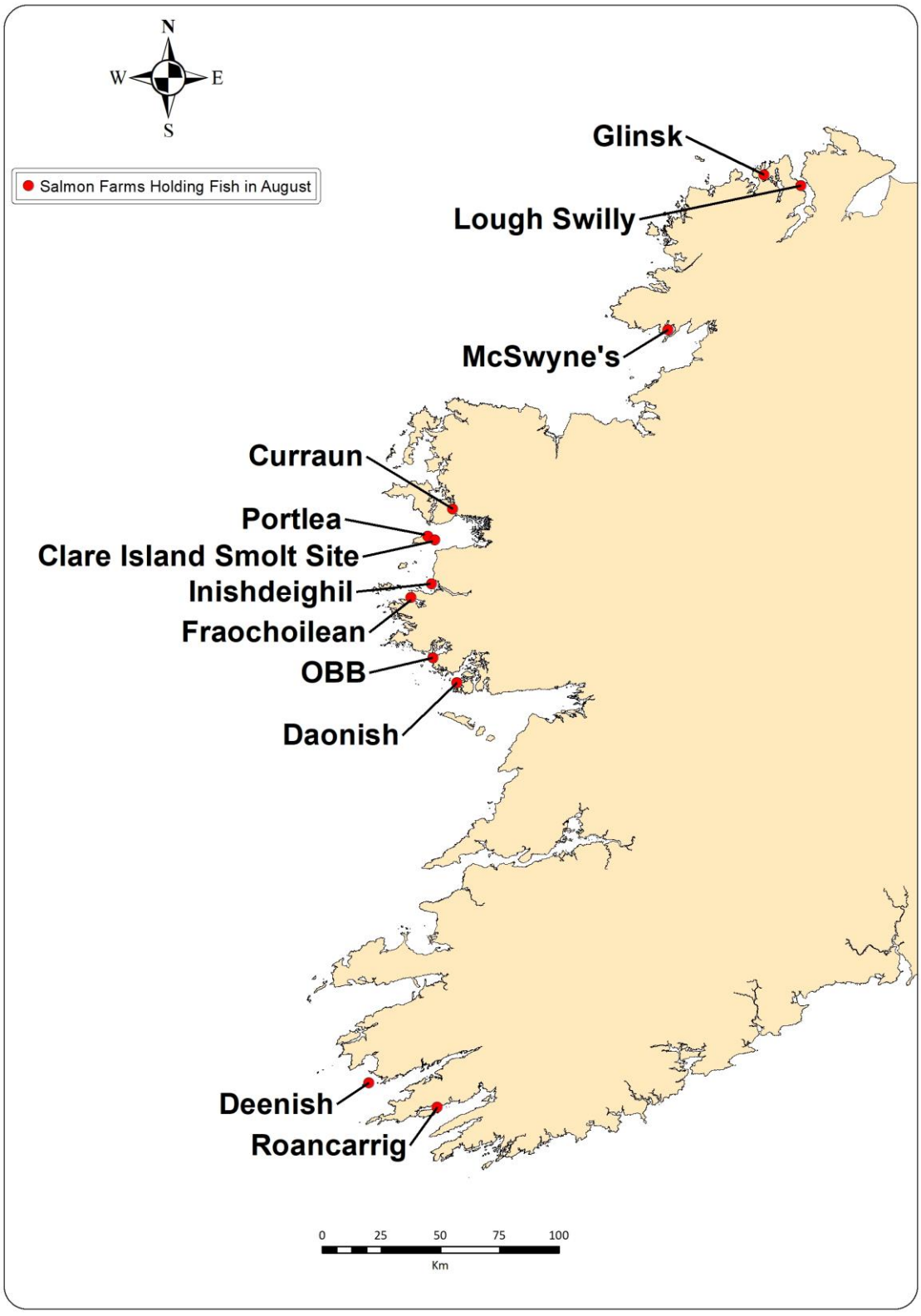

Figure 2. Location of active marine salmon farms in Ireland during August/ September 2017.

Data on date of capture, length, weight and condition factor for farmed rod caught salmon are presented in Table 2 below and 3. The mean length of fish was 50.3cm and mean condition factor (K) was 0.97.

Table 2 Details of farmed salmon captured in rivers in August & September 2017.

River	Date	Method	Weight (kg)	Length(cm)	Condition (K)
Bundorragha	30/08/2017	Fly	1.5	53	1.01
	31/08/2017	Fly	1.4	51	1.06
	03/09/2017	Fly	1.2	49	1.02
	04/09/2017	Fly	1.5	54	0.95
	10/09/2017	Fly	2.05	-	
	11/09/2017	Fly	1.05	49	0.89
	12/09/2017	Fly	1.45	53.5	0.95
	12/09/2017	Fly	1.45	52.5	1.00
	15/09/2017	Fly	0.8	46.5	0.80
	28/09/2017	Fly	0.75	44.5	0.85
	28/09/2017	Fly	1.2	50	0.96
	28/09/2017	Fly	1.2	50.5	0.93
	29/09/2017	Fly	1.15	50	0.92
	29/09/2017	Fly	1.2	50	0.96
	29/09/2017	Fly	1.4	53	0.94
Bunowen	08/09/2017	Fly	1.8	54	1.14
	08/09/2017	Fly	1.2	46	1.23
Dawros	05/09/2017	Fly	1.35		
	06/09/2017	Fly	0		
	09/09/2017	Fly	1.15		
	09/09/2017	Fly	1.35		
	12/09/2017	Fly	0.9		
	28/09/2017	Fly	1.6		
	30/09/2017	Fly	1.05		
Erriff	03/09/2017	Fly	1.25	50	1.00
	04/09/2017	Fly	1.1	47.7	1.01
	06/09/2017	Fly			
	07/09/2017	Trap	1.4	51.9	1.00
	07/09/2017	Trap	1.2	50.5	0.93
	09/09/2017	Fly	1.35		
	10/09/2017	Fly	1.35	51.5	0.99
	12/09/2017	Fly	1.35		
	13/09/2017	Fly	1.7		
	24/09/2017	Trap	1	48.2	0.89
Newport	29/09/2019	Fly	1.36		
	29/09/2019	Fly	1.36		
Mean				**50.3**	**0.97**
Median				**50.25**	**0.96**

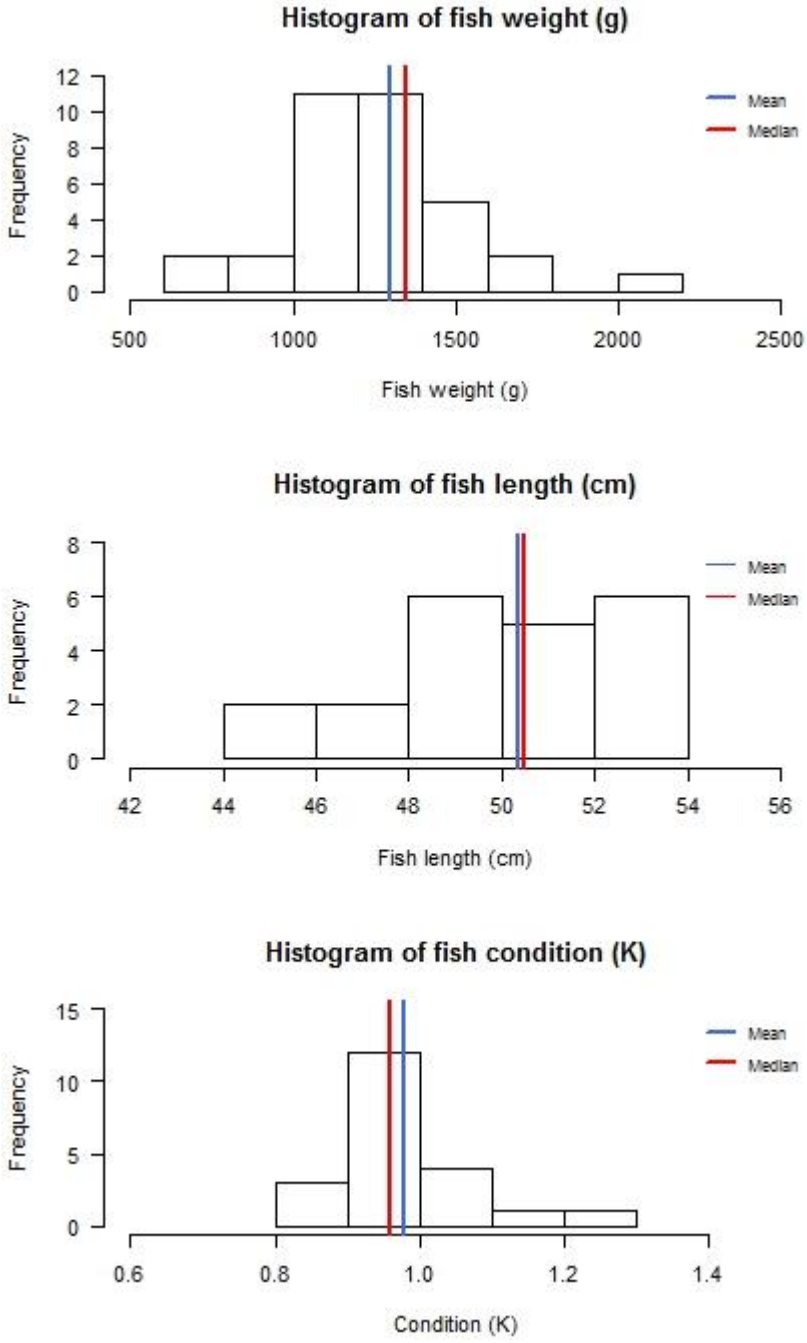

Figure 3 Historgam of salmon weight (g), length (cm) and condition (K). Mean (blue) and median (red) values are also shown.

5 Internal examination

Seven salmon retained for analysis were sexed and their maturity status and stomach content were examined. Six fish were male, three of which were fully mature (Plate 1), and the three remaining males were immature (Table 3). The three mature male fish had entered Aasleagh trap on the Erriff river. The single female salmon was immature. Additional data shows that two escapees from the Bundorragha were mature males and two others from the Dawros were also ripe males. No food was present in the intestine of six of the farmed salmon examined while a single shrimp (*Palaemon serratus*) was found in one fish.

Table 3 Sex and maturity status of farmed salmon.

River	Date of capture	Weight (kg)	Fork length(cm)	Sex	Maturity
Bundorragha	03/09/2017	1.2	49	male	immature
Bundorragha	04/09/2017	1.5	54	male	immature
Bunowen	08/09/2017	1.8	54	male	immature
Bunowen	08/09/2017	1.2	46	female	immature
Erriff Trap	07/09/2017	1.4	51.9	male	mature
Erriff Trap	07/09/2017	1.2	50.5	male	mature
Erriff Trap	24/09/2017	1	48.2	male	mature

Plate 1 Sexually mature male escaped farmed salmon captured in Aasleagh trap, Erriff river.

6 Morphological examination

A combination of external morphology and scale pattern is used routinely to identify escaped farmed salmon from wild salmon (Lund & Hansen, 1991; Fiske *et al*. 2001, 2005). Fiske *et al*. (2005) provide a comprehensive description of differences in the external morphology of farmed and wild salmon that can be used to distinguish both forms. In reared fish, damage on fin tissue frequently causes the fin rays to grow together and lose evenly arched or straight rays as seen in wild fish. Fins of reared fish lose their normal shape and often appear wavy and eroded. Fin ray defects may be recognised as a breakage or a wavy shape on the two outermost fin rays (Fiske *et al*. 2005). The tail fin of wild salmon normally forms marked tips where the two outermost fin rays are the longest. On farmed fish, these tips are often strikingly worn and rounded (Plate 2), (Fiske *et al*. 2005). Another feature of farmed salmon is gill cover shortening which is rarely seen in wild salmon. Snout and jaw deformities such as undershot jaw are also common in farmed salmon but are very rare in wild salmon.

Seven suspected escapees were examined using the morphological features described by Fiske *et al*. (2005) to distinguish farmed from wild salmon (Table 4). All seven fish exhibited a combination of morphological features described by Fiske *et al*. (2005a) as occurring in farmed salmon which demonstrated that these fish were of farmed origin. Examples of these fish are shown in Plate 3 (Erriff), Plate 4 (Bunowen) and Plate 5 (Bundorragha).

Table 4 External morphological features of escapee salmon examined from the Bundorragha, Erriff and Bunowen rivers.

River	FL (cm)	Snout & jaw deformaties	Gill cover	Pectoral fin	Pelvic fin	Dorsal fin	Caudal fin
Bundorragha	49	Shortened snout	Shortened	Shortened	Shortened	Kinked/ eroded	Rounded/ eroded
Bundorragha	54	Shortened/ flattened	Shortened	Shortened	Shortened	Kinked/ eroded	Rounded/ eroded
Bunowen	54	Shortened snout	Slightly shortened	Shortened/ eroded	Shortened	Kinked/ eroded	Rounded/ eroded
Bunowen	46	Shortened/ flattened	–	Shortened/ eroded	Shortened	Kinked/ eroded	Rounded/ eroded
Erriff trap	51.9	Shortened/ flattened	–	Shortened/ eroded	Shortened	Kinked/ eroded	Rounded/ eroded
Erriff trap	50.5	–	–	Shortened/ eroded	–	Kinked/ eroded	Rounded/ eroded
Erriff trap	48.2	Shortened/ flattened	Shortened	Shortened/ eroded	Shortened	Kinked/ eroded	Rounded/ eroded

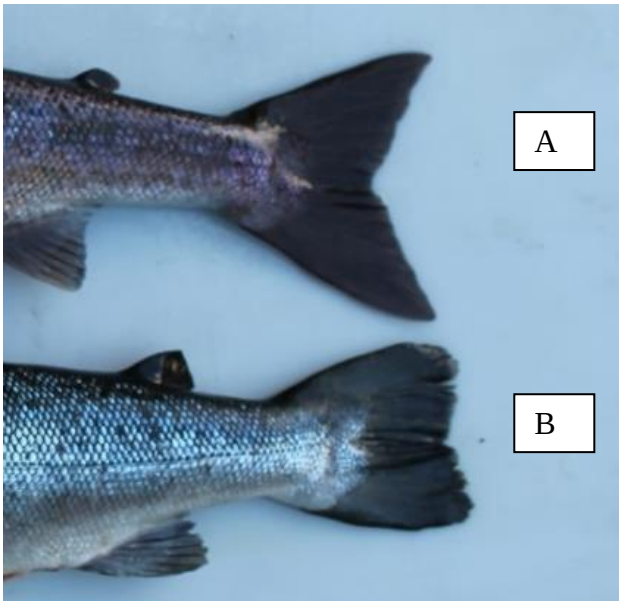

Plate 2 Marked tips on the tail of a wild salmon captured in the Erriff in September 2017(A) compared to the worn and rounder tail of a farmed salmon captured in the Erriff in September 2017(B).

Plate 3 Three escapee salmon captured in Aasleagh trap on the Erriff river in September 2017.

Plate 4 Farmed escapee salmon captured by angling in the Bunowen river in September 2017.

Plate 5 Farmed escapee salmon captured by angling in the Bundorragha river in September 2017.

7 Scale analysis

Detailed scale analysis undertaken after scales were prepared and cleaned. Lund & Hansen (1991) use a number of differences in scale characteristics to distinguish between wild and farmed Atlantic salmon.

(1) **Smolt size**. *When the back-calculated length at smolt stage is larger than 95% of the observations on wild smolts from the same area.*
The mean observed length of wild salmon smolts captured by trapping on the river Erriff in 2015 was 12.89cm (range 8.7-18cm; n=1022). The mean back-calculated length of the farmed escapee salmon examined was 22.7cm (range 18.6-25.5cm. n=20).

(2) **Smolt Age**. *When smolt age is outside the range of 95% of the wild salmon in the area*. White *et al*. (2016) showed that 85% of Erriff salmon smolts are two-years-old and 14% are three-years-old. All of the farmed salmon aged in the present analysis were one-year-old smolts.

(3) **Transition from freshwater to saltwater**. *When the scales show diffuse transition between the freshwater and saltwater zones.*
The transition zone from freshwater to saltwater in wild salmon is short and easily defined whereas on farmed salmon this zone is often large and very diffuse. There was more evidence of a diffuse transition pattern in the escaped farmed salmon scales examined (Plate 6a) compared to wild salmon (Plate 6b).

(4) **Sea-winter band**. Lund & Hansen (1991) describe the difference in location of sea winter bands on wild and farmed fish. Wild salmon smolts migrate to sea in spring and return as adults to spawn after one or more years at sea as is evidenced on the scale by a minimum of one sea-winter band. No sea-winter band was present on any of the farmed fish examined.

freshwater growth phase ----
saltwater growth phase ----

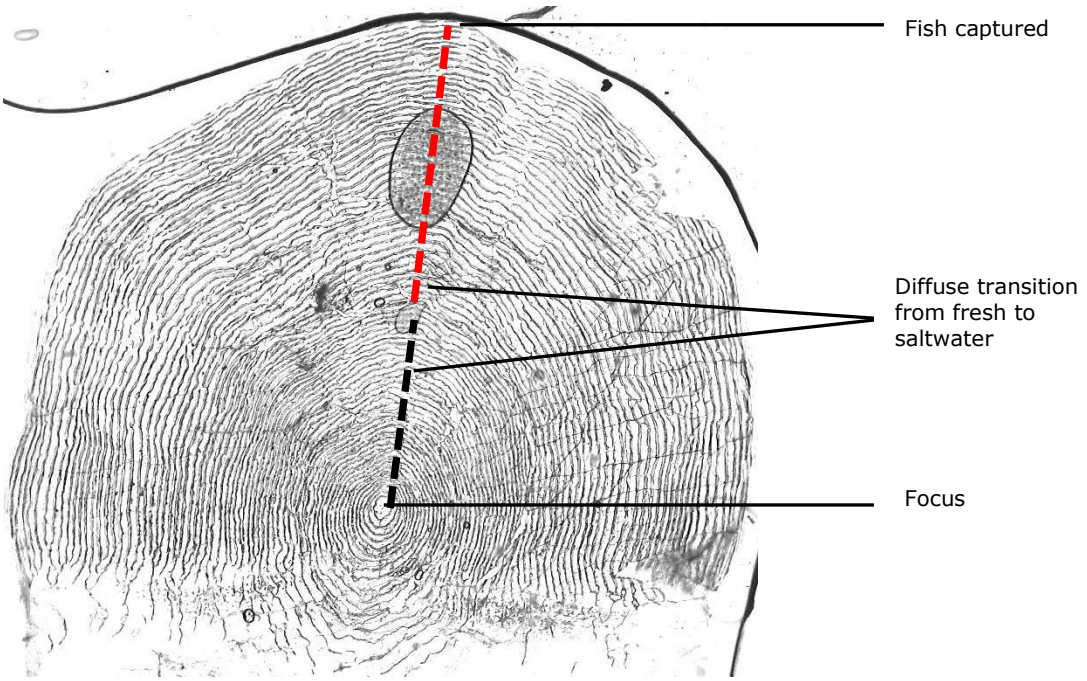

Plate 6a Scale from an escapee farmed salmon captured in the Erriff river. Note the large and diffuse transition zone between freshwater and saltwater and the absence of a sea-winter band.

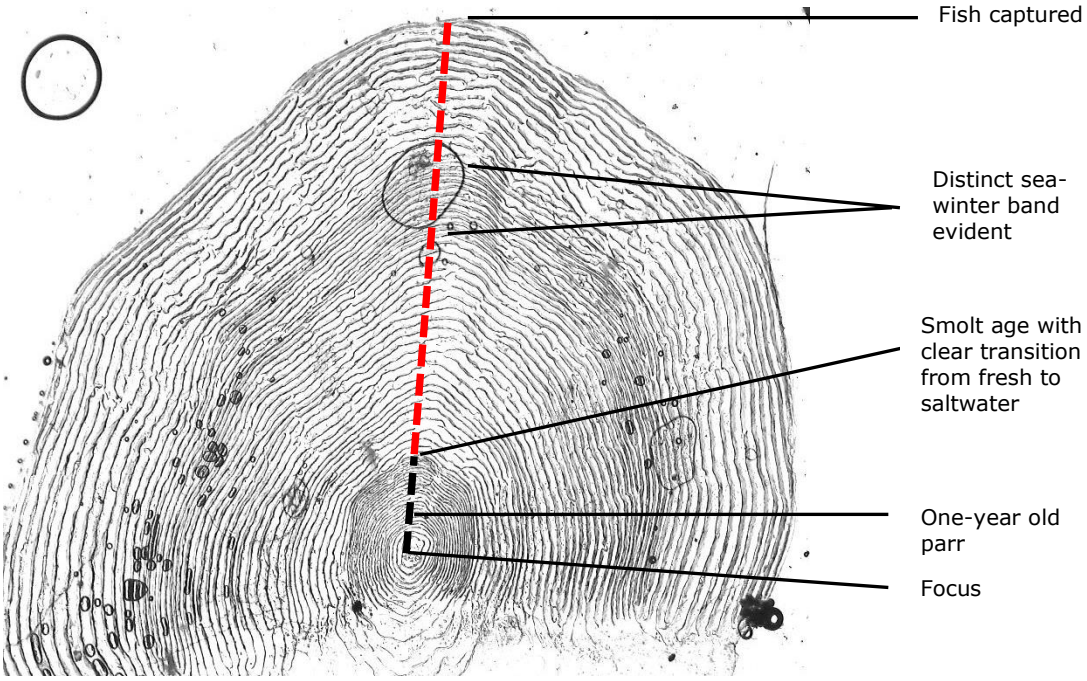

Plate 6b Scale from a wild salmon captured in the Erriff river after return from the sea. Note the short transition zone between freshwater and saltwater and the presence of a sea-winter band.

8 Estimation of numbers of escaped salmon in rivers

Estimates of the total abundance of escaped salmon potentially present in each river system where these salmon were captured can be inferred by using known Irish angling exploitation rates derived from actual long-term salmon rod catch and fish counter data (Millane *et al*. 2017). Depending on the system, angling can exploit 10-20% of a given population which suggests that the total numbers of escapees in these systems is substantially higher than those detected in angling catches (Table 5). For example, in the Dawros river, it has been determined that 11.8% of the total salmon population present each year is exploited by anglers (Millane *et al*. 2017). As 17 farmed fish were recorded in the angling catch, this suggests that a total of 144 farmed fish may actually have been present in the river (range 92-279). Fish counters on the Dawros, Erriff and Bunowen allow use of river-specific rod exploitation rates. A rod exploitation rate based on "river system type" was applied to the Bundorragha and Newport rivers where there are no fish counters present. Estimates of the number of farmed fish in rivers range from <20 in the Bunowen and Newport to over one hundred in Bundorragha, Erriff and Bunowen with an overall total abundance of 468 escaped farmed salmon estimated to be present in five western rivers during the August/September 2017 period (Table 5).

Table 5 Estimated total abundance of escapee farmed salmon present in each river system based on median angling exploitation rates (Millane *et al*. 2017).

River	Number of fish detected	Exploitation rate (%)	Estimated total abundance*
Bundorragha	25	13.6	184 (114 – 272)
Bunowen	2	15.3	13 (13 – 23)
Dawros	17	11.8	144 (92 – 279)
Erriff	20	17.9	112 (91 – 146)
Newport	2	13.6	15 (9 – 22)
Total	**66**		**468**

*numbers in brackets represent the interquartile range around the estimate.

9 Genetic Analysis

Genetic analyses was undertaken by the School of Biological, Earth and Environmental Sciences (BEES), University College Cork, on samples taken from six suspected farm-escaped Atlantic salmon collected in the Bunowen, Erriff and Bundorragha rivers (hereafter 'test samples'). DNA was extracted from the fin-clips provided and used as template to amplify 13 microsatellite DNA loci. The loci were screened on an ABI capillary DNA sequencer and scored using GENEMARKER software, using the same allele size designations as the NGSI baseline and a calibrated SALSEA (pan-European) baseline. For comparison, the test samples were run alongside DNA extracted from samples of wild salmon from the Burrishoole river traps (n=4) and samples of salmon taken from an Irish salmon farm (n=19).

Exclusion of capture source as population of origin

For assignment to origin, exclusion/inclusion analysis was first used as implemented in GENECLASS. This analysis essentially informs as to whether test samples have potential to originate from particular baseline population samples or more importantly, if these populations can be excluded as native origins of the test samples in question. In this case, the samples were compared to baseline population samples from the Bunowen, Erriff, Bundorragha and Shramore rivers (taken from the NGSI database). These rivers can be significantly excluded as possible native origin of the test samples and of the known farmed salmon (probability of origin (for all these samples) among these rivers, $p<0.001$). However, the Burrishoole comparison samples were significantly assigned to the Burrishoole baseline population samples (probability that these comparison samples were native to the Burrishoole, $p>0.95$).

Conclusion 1. The test samples provided were from fish not native to the rivers in which they were caught.

Identifying origin of capture samples

Given that these test samples were not native to the rivers in which they were caught, the SALSEA baseline (supplemented with the complete NGSI baseline) was used to attempt to identify actual natal origin. Using the mixed stock fishery and assignment analysis software, cBAYES, the Burrishoole samples used here were assigned to the Burrishoole baseline population samples with very high confidence. However, the test samples provided by IFI and the samples of known salmon farm origin, assigned variously to a number of Norwegian baseline populations (mid- and south-Norway). The confidence of these assignments fluctuated among different rivers but summed to high confidence for Norwegian-origin overall suggesting that these fish (the test samples and salmon from an Irish farm) were not native to any particular Norwegian wild population but rather that the fish were genetically of Norwegian ancestry.

These findings were confirmed using Bayesian clustering as revealed by STRUCTURE analysis. Using the SALSEA baseline analysis, European Atlantic salmon populations partition robustly among three major genetic clusters or lineages. These are Icelandic, Northern European (Sweden, Norway and Russia) and Southern European (Denmark, Britain and Ireland, France and Spain) population clusters. These divisions were exploited and the current samples were partitioned among these groups. The Burrishoole samples strongly correspond to Southern Europe (as expected) (Fig 1) whereas the test samples and Irish farmed salmon are fundamentally Northern European in Ancestry.

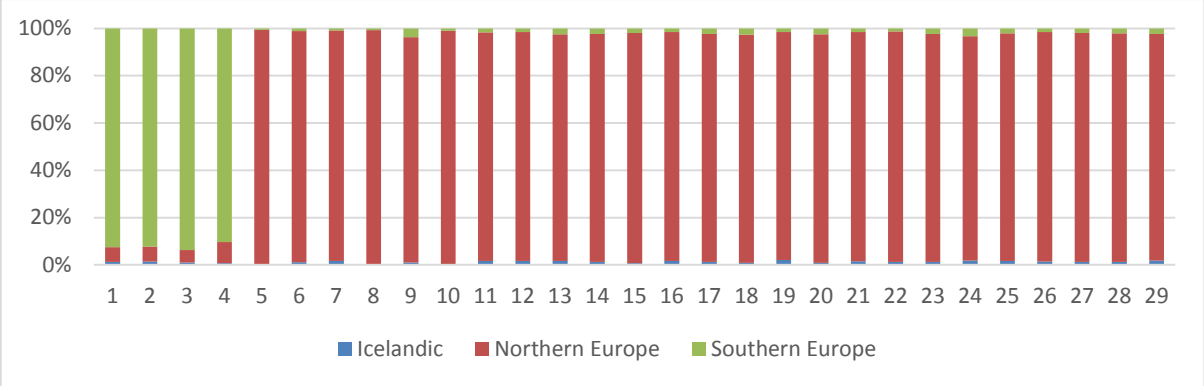

Figure 1 Partitioning of samples among the three major genetic lineages identified across eastern Atlantic salmon populations as revealed by Bayesian clustering analysis (STRUCTURE, k=3). Here, 1-4 are samples from the Burrishoole; 5-10 are the test samples from the Bunowen, Erriff and Bundorragha, respectively as listed above; 11-29 are the samples of known salmon farm origin.

Conclusion 2. Genetic stock identification and Bayesian clustering demonstrate that the test samples are of Norwegian genetic ancestry and are not from any Irish wild populations or from any Irish salmon ranching or mitigation strains.

In summary, the salmon captured from the Bunowen, Erriff and Bundorragha and provided for genetic analysis are fish-farm escapes of Norwegian ancestry.

10 Discussion

External morphology and scale analysis from available samples demonstrated that farmed salmon were present in five rivers in western Ireland in August/September 2017. External morphology is an effective identification criterion for recently escaped fish (Crozier 1998), and a combination of external morphology and scale pattern is used routinely to identify escaped farmed salmon from wild salmon (Lund & Hansen 1991; Fiske *et al*. 2001, 2005). Lund & Hansen (1991) described differences in scale characters between farmed and wild salmon and used these differences to develop a methodology to distinguish these groups. Examination of scales available from 34 salmon confirmed these fish exhibited scale patterns identifiable as salmon of farmed origin which are clearly distinguishable from wild salmon (Lund & Hansen 1991). These fish had a larger smolt size, younger smolt age, more extensive transition phase from freshwater to sea water and the absence of a sea-winter band. All of these features distinguish these fish from wild Atlantic salmon.

Genetic stock identification and Bayesian clustering demonstrated that six samples of escaped salmon from three west coast rivers were of Norwegian genetic ancestry and were not from any Irish wild populations or from any Irish salmon ranching or mitigation strains.

Examination of sexual maturity revealed that 50% of the male escaped salmon examined were ripe and had the potential to spawn. Use of rod exploitation rates (Millane *et al*. 2017) indicate that up to five hundred escaped farmed salmon may have entered western salmon rivers during the August/September period 2017. The presence of sexually mature farmed salmon in rivers poses a potential threat of interbreeding with wild salmon in winter 2017 and the subsequent negative effects known to occur.

There is a large body of published literature on the negative interaction of farmed and wild stocks. McGinnity *et al*. (2003) reported on a two generation experiment examining the estimated lifetime successes, relative to wild natives, of farm, generation 1 (F1) and F2 hybrids to wild and farm salmon. Offspring of farm and 'hybrids' showed reduced survival compared to wild salmon but grew faster as juveniles, and displaced wild parr, which as a group were significantly smaller. Where suitable habitat for these emigrant parr is absent, this competition would result in reduced wild smolt production. In the experimental conditions, where emigrants survived downstream, the relative estimated lifetime success ranged from 2% (farm) to 89% (Back Cross 1 wild) of that of wild salmon, indicating additive genetic variation for survival. They concluded that the interaction of farm with wild salmon results in lowered fitness, with repeated escapes causing cumulative fitness depression and potentially an extinction vortex in vulnerable populations. Thorstad *et al*. (2008) conducted a large scale review of the incidence and impacts of escaped farmed Atlantic salmon in nature. Large-scale experiments undertaken in Ireland (Burrishoole) and Norway (Imsa) gave similar results, both showing highly reduced survival and lifetime success of farm and hybrid salmon compared to wild salmon.

It is estimated that up to five hundred escaped farmed fish may have been present in five rivers in the Western River Basin District in autumn 2017. These large numbers of escaped farmed salmon, with a high proportion of males likely to be sexually mature, presents a potential threat to local wild salmon populations from interbreeding and other ecological effects. Where feasible, IFI staff will monitor for the presence of farmed salmon during the winter spawning period and take appropriate action to minimize their influence on wild populations. Longer term genetic studies on the impact of introgression may be required in order to follow up on quantifying the impact of this escapement.

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