

Otolith Fingerprint Signatures: A mass marking technique for marking farmed Atlantic Salmon Salmo salar



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Farmed fish escapee

"Escapees can have **detrimental genetic and ecological effects** on populations of wild conspecifics, and the present level of escapees is regarded as a **problem for the future** sustainability of sea-cage aquaculture" (Naylor et al., 2005).

To understanding the impacts **Identify** and **trace**



Identification of escapees

Genetic markers - ID 60-90%, Traceability 60-90%

(continuous data library required)

- Adipose fin clipping ID 100%, Traceability not possible (welfare issues)
 - Scale readings ID 90%, Traceability not possible

(data library required)

Physical tags – coded wire; t-bar tags ID 95%, Traceability possible (welfare issues, and costly)

Fluorescence markers – ID 95%, Traceability not possible

Current methods fail either in 100% mark detectability, traceability, have welfare issues, or are costly

Identification using stable isotope "otolith fingerprinting"

- 100% marking and traceability of escapees
- Otolith formed during embryogenesis
- Grow continuously
- Metabolically inert
- Incorporated impurities into the otolith matrix (e.g. isotopes of Ba, Sr, Mg)
- Used to create permanent, unique isotopic fingerprint signatures



FHF





Barium isotopes (Ba)

































Ba compared to ¹³⁸Ba Sr compared to ⁸⁸Sr

Adding ¹³⁴Ba







Ba compared to ¹³⁸Ba Sr compared to ⁸⁸Sr

Adding ⁸⁶Sr





How many unique fingerprints?

1 isotope $(2^1 - 1) = 1$ mark 2 isotopes $(2^2 - 1) = 3$ markers 3 isotopes $(2^3 - 1) = 7$ markers 7 isotopes $(2^7 - 1) = 127$ markers

Number of possible markers = $(2^{number of isotopes} - 1)$ Possible to create > 1000 combinations

Enough for each fish farm to have its own individual unique fingerprint marker





LA-ICP-MS analysis of fish otoliths













LA-ICP-MS analysis of fish otoliths







Detecting a successful mark (137Ba)







Aims

To develop 3 different stable isotope mark delivery techniques for Atlantic salmon

- 1) Vaccination (parr stage)
- 2) Maternal transfer (brood stock)
- 3) Egg immersion (fertilised eggs)
- Confirmation Can we create unique marks?
- Optimization how well does each technique work?
- Welfare side effects?
- Commercial viability applicability, cost?







Mark application points



Application points









Vaccination 100% mark success

¹³⁷Ba Require 0.001 µg per g of parr







Maternal transfer 100% mark success



¹³⁴Ba Require 0.2 µg per g of brood fish ¹³⁶Ba







Egg immersion 100% mark success

¹³⁷Ba
¹³⁵Ba
Require 100 µg per litre

¹³⁶Ba Require 1000 µg per litre







Monitoring of fish health parameters found:

No effect on Growth

No effect on Condition

No effect on Mortality





Cost projections

Scenario 1: Marking 100% of production with 1 marker (achievable)





Cost projections Scenario 1

Marking 300 million farmed Atlantic salmon with 1 Ba code

Vaccination (50 g fish)	Material Cost (\$US)	Total
¹³⁷ Ba @ 0.001 μg. g ⁻¹ fish weight	\$4.36 per mg	
(15 g for 300 million parr)	(~ \$0.0006 per parr)	\$65400

Egg immersion (2000 eggs L ⁻¹)	Material Cost (\$US)	Total
¹³⁷ Ba @ 100 μg. L ⁻¹	\$4.36 per mg	_
(150,000 L for 300 million eggs)	(~ \$0.44 per litre)	\$65400

Maternal Transfer (5000 eggs per 10 kg brood fish)	Material Cost (\$US)	Total
¹³⁷ Ba @ 0.02 μg. g ⁻¹ brood fish weight	\$4.36 per mg	
(60000 brood fish for 300 million eggs)	(~ \$0.872 per brood fish)	Ş52320





Cost projections

Scenario 2: Marking 100% of production (54 Companies) (achievable)



Cost projections Scenario 2



54 companies, 300 million salmon, 2 delivery methods, 54 codes

Method: Marking fish with Ba codes either via vaccination or maternal transfer or marking with a combination of maternal transfer and vaccination.

5 largest companies make up 53% of production: Marine Harvest 22%, Lerøy Seafoods 13%, Salmar 9%, Cermaq 5% and Grieg Seafoods 4%.

19 medium companies make up a further 27% of production: Average size 1.43% each.

30 small companies make up the final 20% of production: Average size 0.67% each.



Cost projections Scenario 2

CFHF

54 companies, 300 million salmon, 2 delivery methods, 54 codes

	Company (76 size)	Production (n fish)	Code number	Cost per fish	Cost per company
Marine Harvest	22%	66000000	2MT	\$0.0002	\$11,510
Lerøy	13%	39000000	1V	\$0.0002	\$8,502
Salmar	9%	27000000	3V	\$0.0003	\$8,910
Cermaq	5%	15000000	1V2MT	\$0.0004	\$5,886
Grieg	4%	12000000	3V2MT	\$0.0005	\$6.053
6	1.42%	4263158	4MT	\$0.0005	\$2,201
7	1.42%	4263158	5V	\$0.0006	\$2,752
8	1.42%	4263158	16MT	\$0.0007	\$2,945
9	1.42%	4263158	1V4MT	\$0.0007	\$3,131
10	1.42%	4263158	5V2MT	\$0.0008	\$3,495
11	1.42%	4263158	3V4MT	\$0.0008	\$3,608
12	1.42%	4263158	1V16MT	\$0.0009	\$3,874
13	1.42%	4263158	7V	\$0.0010	\$4,272
14	1.42%	4263158	5V4MT	\$0.0010	\$4,352
15	1.42%	4263158	5V4MT	\$0.0012	\$4,953
16	1.42%	4263158	7V2MT	\$0.0012	\$5,015
17	1.42%	4263158	5V16MT	\$0.0013	\$5,697
18	1.42%	4263158	7V4MT	\$0.0015	\$6,473
19	1.42%	4263158	7V16MT	\$0.0017	\$7,217
20	1.42%	4263158	6MT	\$0.0026	\$11,255
21	1.42%	4263158	15MT	\$0.0028	\$11,998
22	1.42%	4263158	1V6MT	\$0.0029	\$12,184
23	1.42%	4263158	3V6MT	\$0.0030	\$12,662
24	1.42%	4263158	1V15MT	\$0.0030	\$12,928
25	0.67%	2000000	3V15MT	\$0.0031	\$6,289
26	0.67%	2000000	18MT	\$0.0032	\$6,313
27	0.67%	2000000	5V6MT	\$0.0033	\$6,571
28	0.67%	2000000	26MT	\$0.0033	\$6,662
29	0.67%	2000000	1V18MT	\$0.0034	\$6,749
30	0.67%	2000000	5V15MT	\$0.0035	\$6,920
31	0.67%	2000000	3V18MT	\$0.0035	\$6.973
32	0.67%	2000000	1V26MT	\$0.0035	\$7.098
33	0.67%	2000000	7V6MT	\$0.0036	\$7.284
34	0.67%	2000000	3V26MT	\$0.0037	\$7,322
35	0.67%	2000000	5V18MT	\$0.0038	\$7.604
36	0.67%	2000000	7V15MT	\$0.0038	\$7.633
37	0.67%	2000000	5V26MT	\$0.0040	\$7.953
38	0.67%	2000000	7V18MT	\$0.0042	\$8.317
39	0.67%	2000000	7V26MT	\$0.0043	\$8.666
40	0.67%	2000000	9V	\$0.0055	\$10,960
41	0.67%	2000000	9V2MT	\$0.0057	\$11,309
42	0.67%	200000	9V4MT	\$0.0060	\$11,993
43	0.67%	2000000	9V16MT	\$0.0062	\$12,342
44	0.67%	2000000	8MT	\$0.0080	\$16.032
45	0.67%	2000000	9V6MT	\$0.0081	\$16,240
46	0.67%	200000	17MT	\$0.0082	\$16,381
47	0.67%	2000000	1V8MT	\$0.0082	\$16.468
48	0.67%	2000000	9V15MT	\$0.0083	\$16,589
49	0.67%	2000000	3V8MT	\$0.0083	\$16.692
50	0.67%	200000	20MT	\$0,0085	\$17,065
51	0.67%	2000000	10V	\$0.0086	\$17,270
52	0.67%	2000000	9V18MT	\$0.0086	\$17,273
53	0.67%	2000000	5V8MT	\$0.0087	\$17,323
54	0.67%	2000000	28MT	\$0,0087	\$17,020

5 largest companies (53% production) \$0.0003 per fish to mark

19 medium companies (27% production) \$0.0015 per fish to mark

30 small companies (20% of production) \$0.0057 per fish to mark

In total 54 companies (100% of production) Average cost of \$0.0017 per fish to mark. **Total material cost**: **\$500,000**

Summary

All three techniques could be used for mass marking Atlantic salmon with 100% mark success

Vaccination:63 unique fingerprintsMaternal Transfer:63 unique fingerprintsEgg immersion:7 unique fingerprints

Ba markers are cheaper and require less isotope than Sr markers to achieve 100% mark success



Thank you