Detecting and tracing farmed salmon with otolith tags: developing and validating mark delivery techniques

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Aims

- To evaluate alternate techniques for mass marking farmed Atlantic salmon with alkaline earth elements.
- 1) Marking via injection – Norway vaccinates all Atlantic salmon
- 2) Marking via maternal transfer – 5000 eggs with one injection
- 3) Marking via egg immersion – Immerse 2000 eggs in 1 litre

Main questions for each technique

- Optimization - *marker concentration?*
- Welfare assessment - *side effects?*
- Commercial viability - *applicability, cost?*
- Confirmation – *Guaranteeing 100% differentiation between farm and wild*

Background
ratios of alkaline earth elements

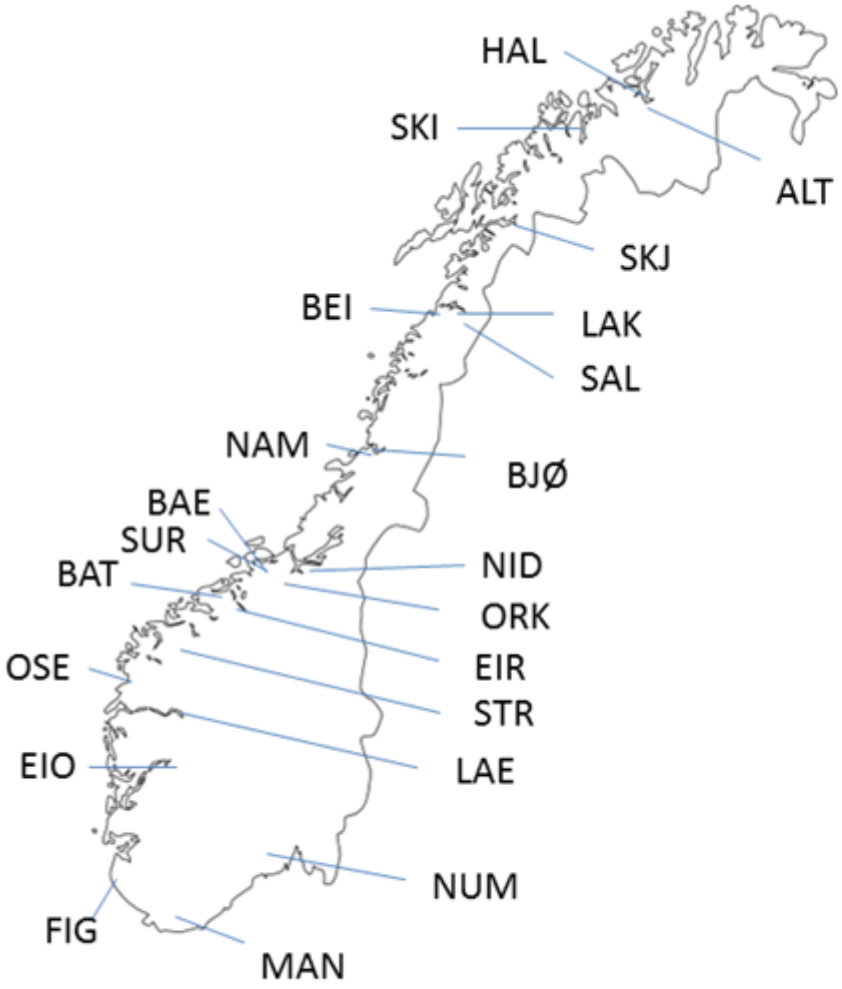
Natural levels of different forms of Ba, Sr & Mg throughout Norwegian wild salmon populations.

Spatially: Samples from 22 rivers from north to south

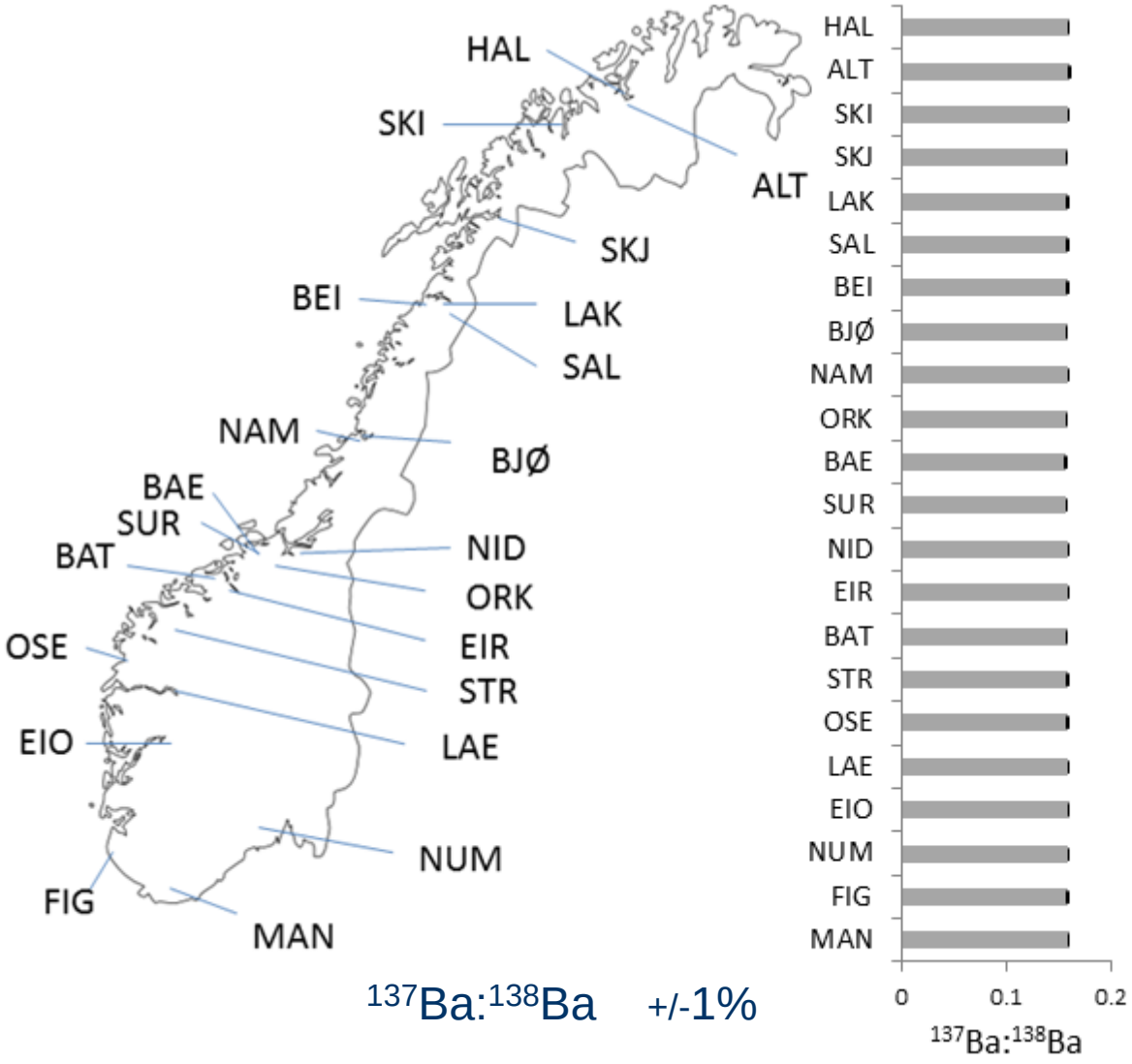
Temporally: Samples from 2 rivers spanning from 1990 to 2010

(Otoliths sourced from NINA archive samples, located in Trondheim, Norway)

Background ratios

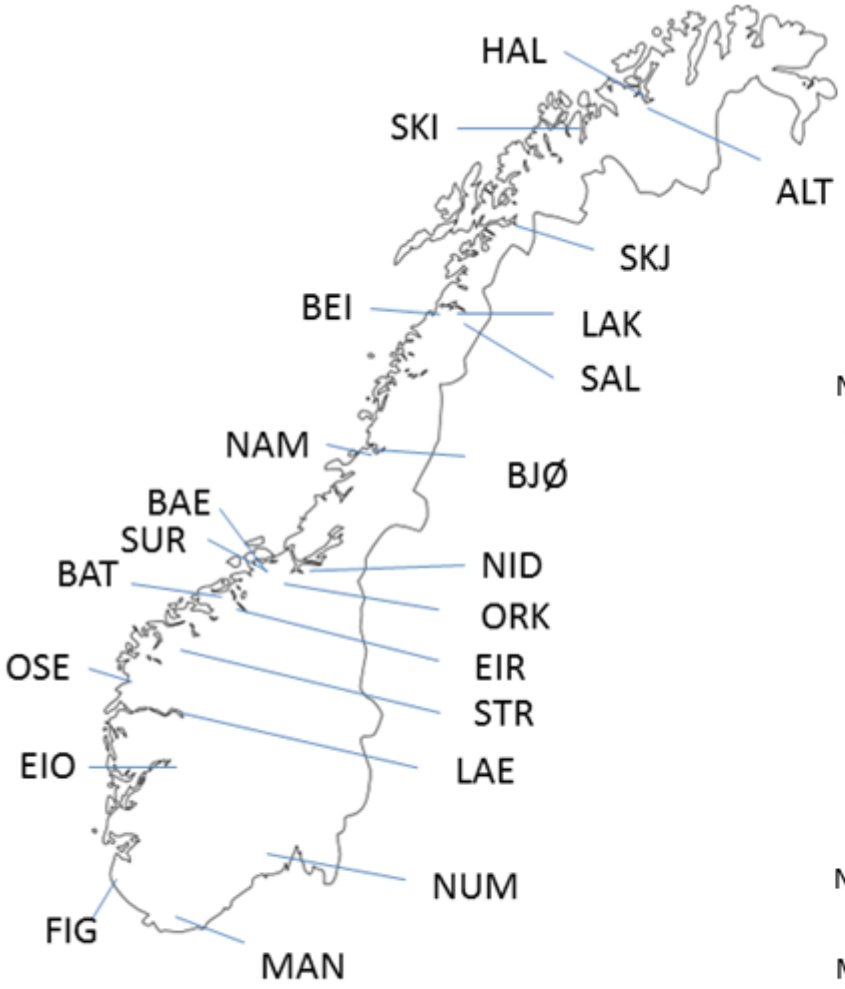


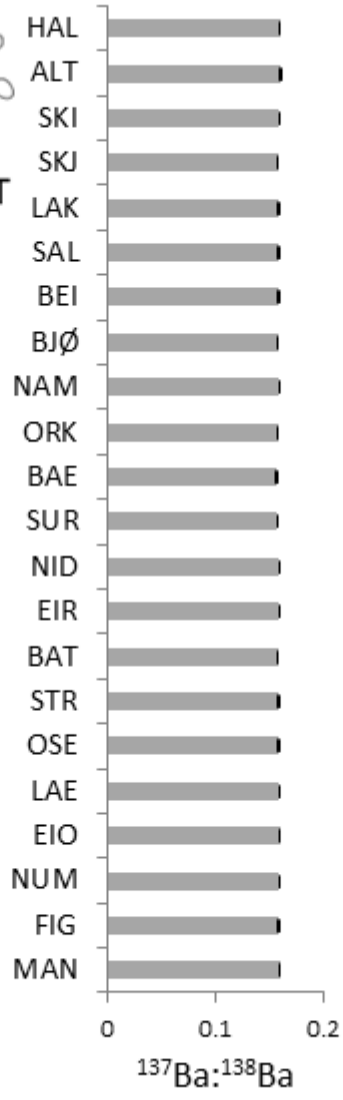
Background ratios

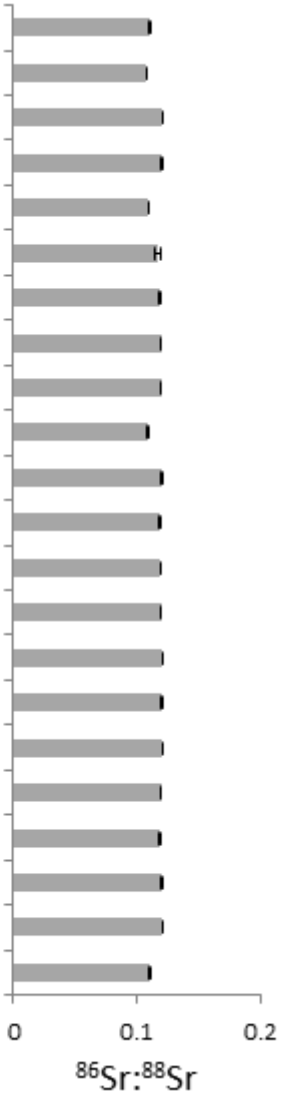


$^{137}Ba:^{138}Ba$ +/-1%

Background ratios



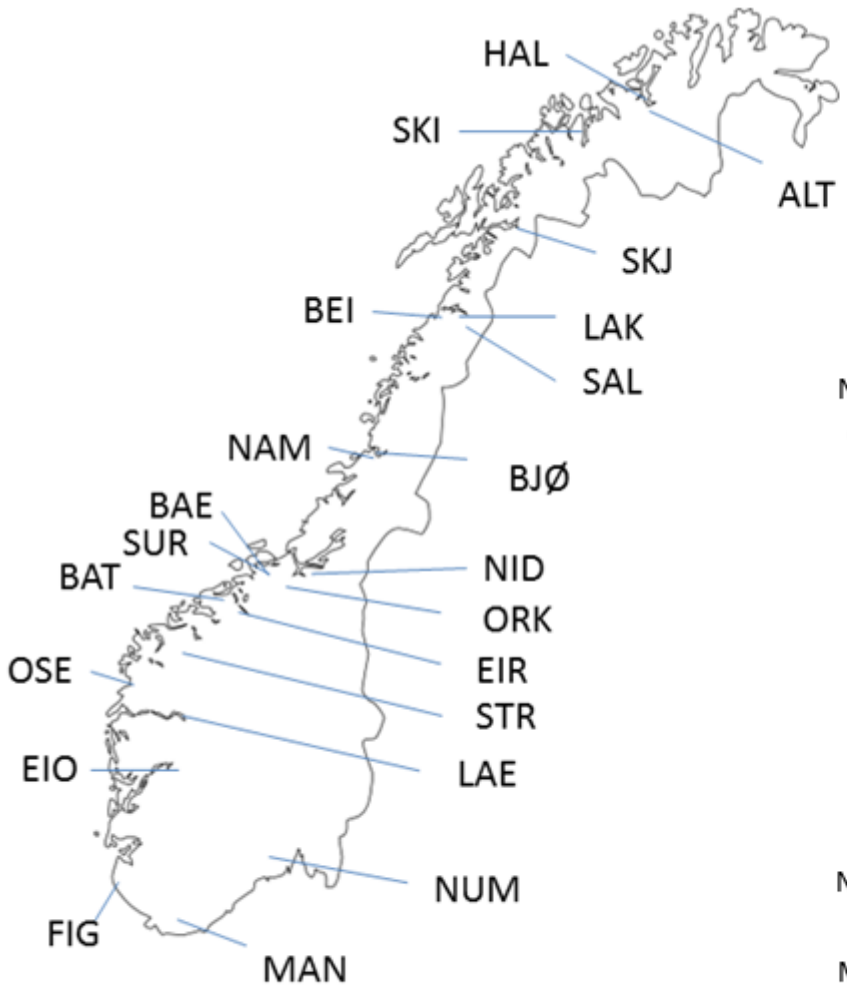


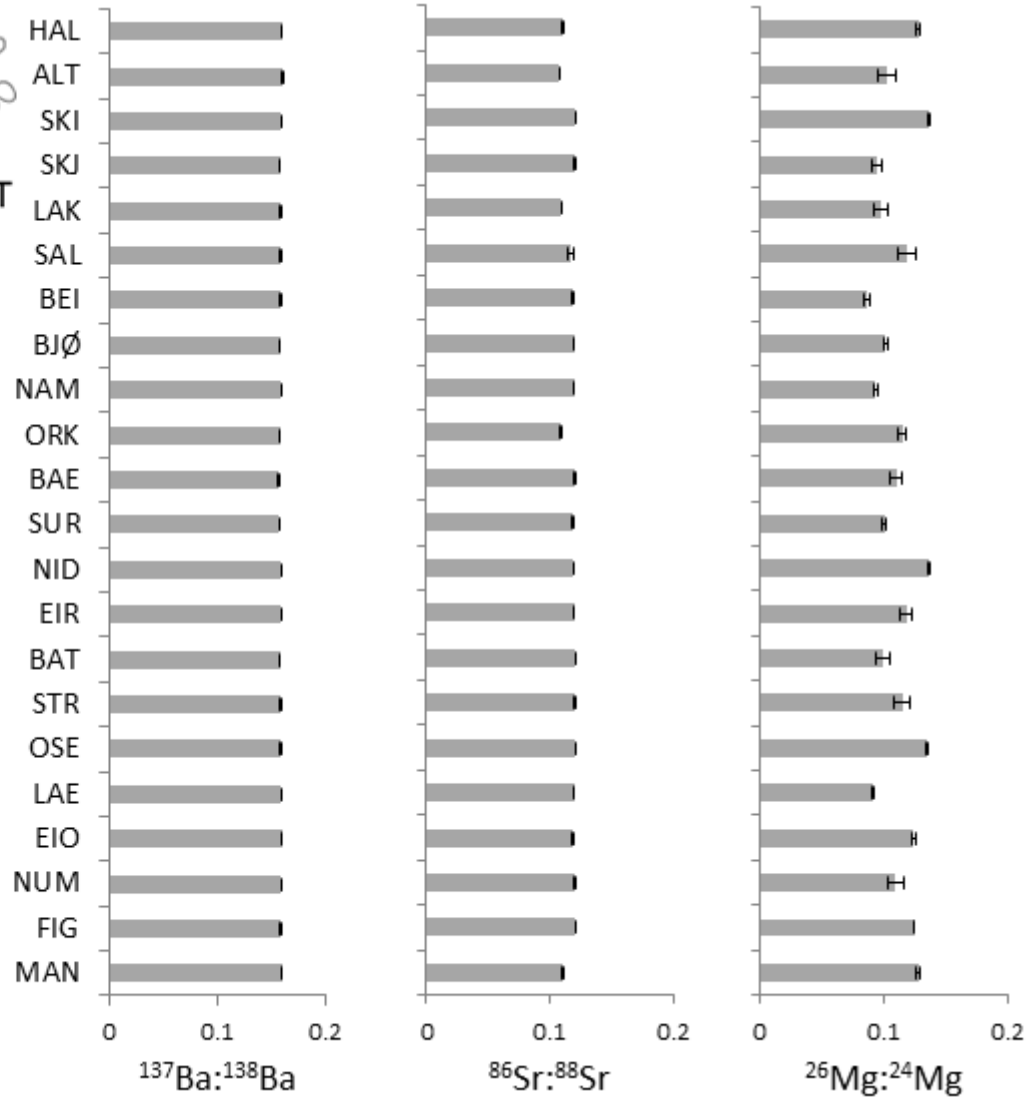


$^{137}Ba:^{138}Ba$ +/-1%

$^{86}Sr:^{88}Sr$ +/- 5%

Background ratios



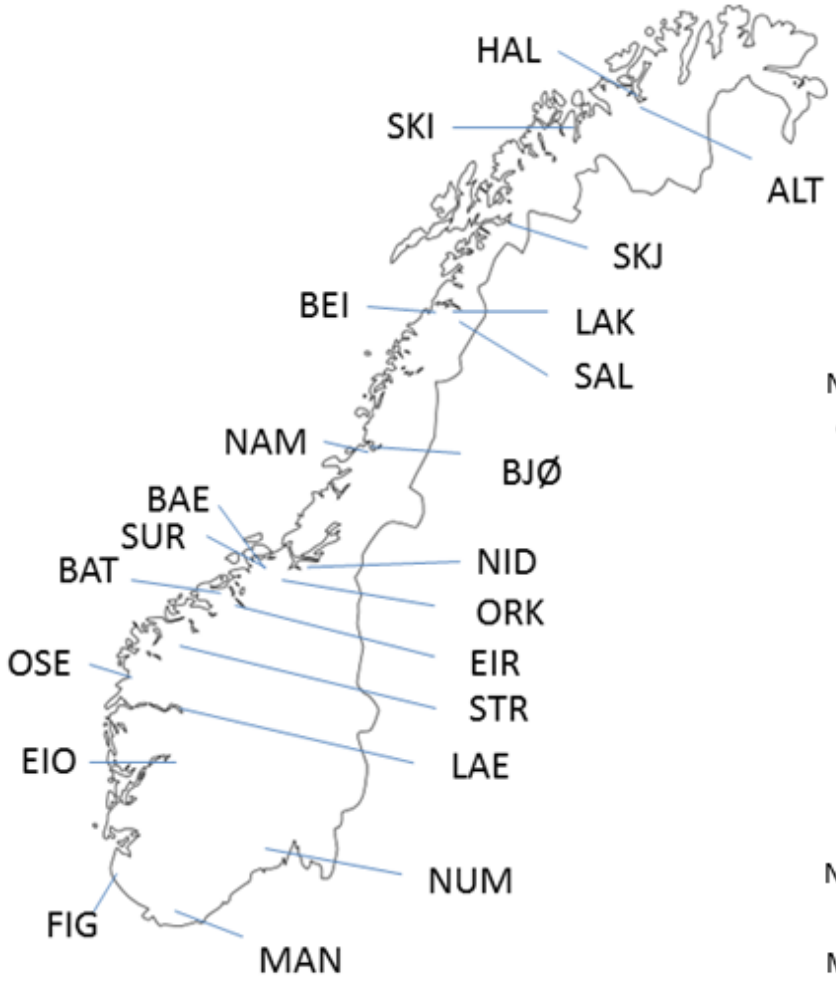


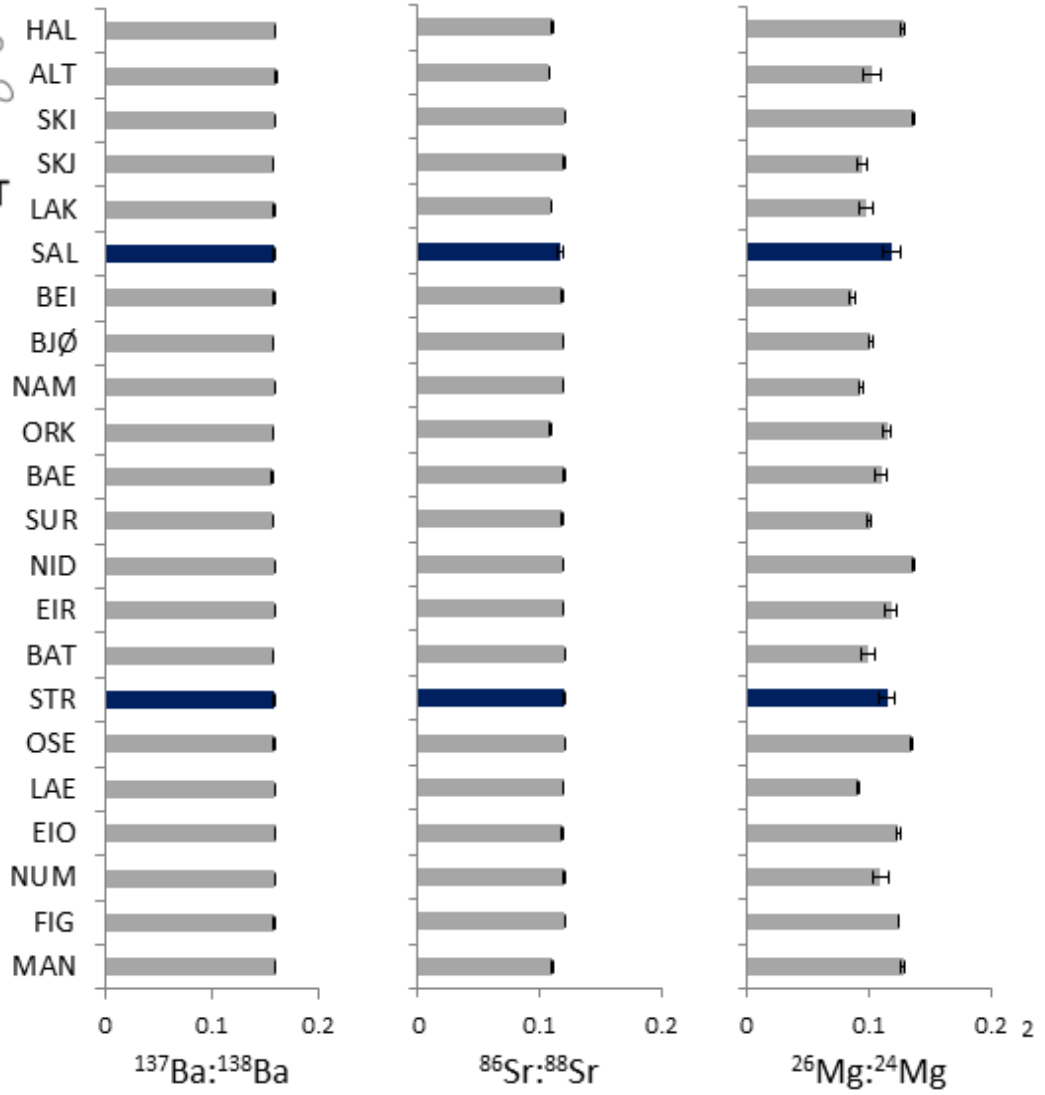
$^{137}Ba:^{138}Ba$ +/-1%

$^{86}Sr:^{88}Sr$ +/- 5%

$^{26}Mg:^{24}Mg$ +/-15%

Background ratios



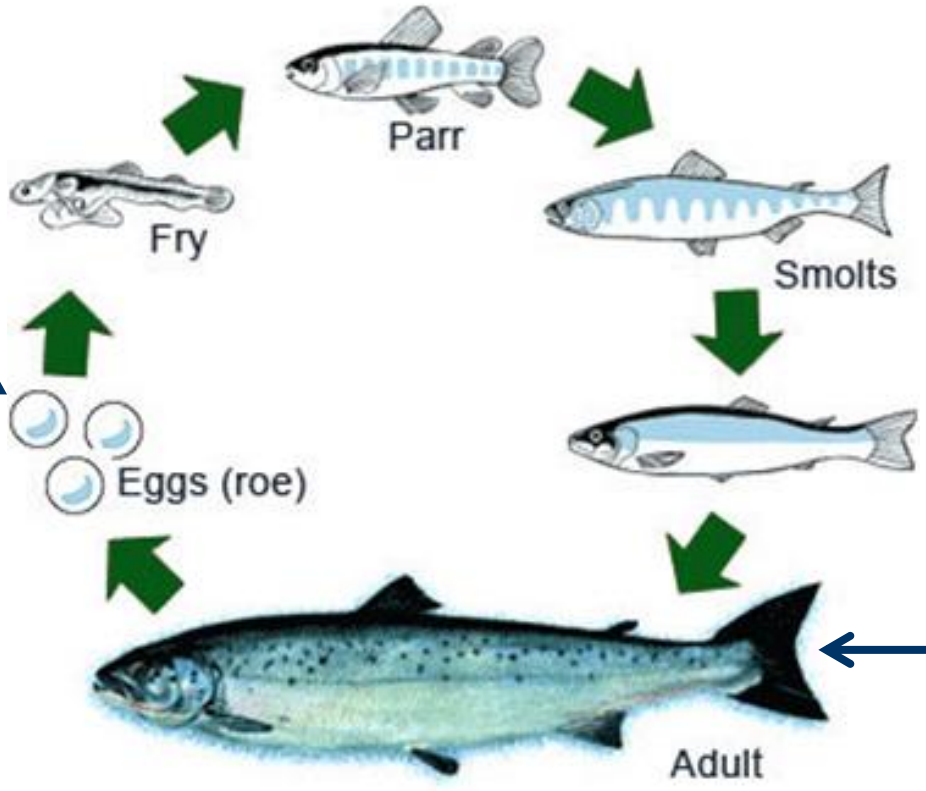


SAL: Saltdalselva 1990 to 2010
STR: Strynselva 1990 to 2009

Mark application points

Vaccination

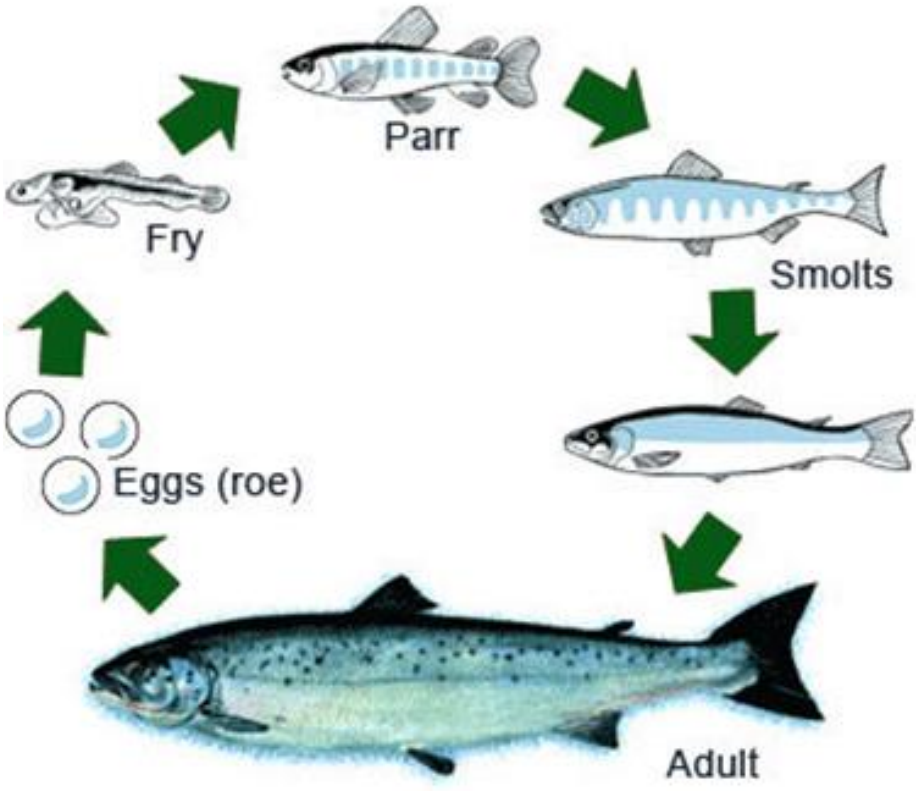
Egg immersion



Maternal Transfer

Mark application points

Vaccination



Mass marking via vaccination

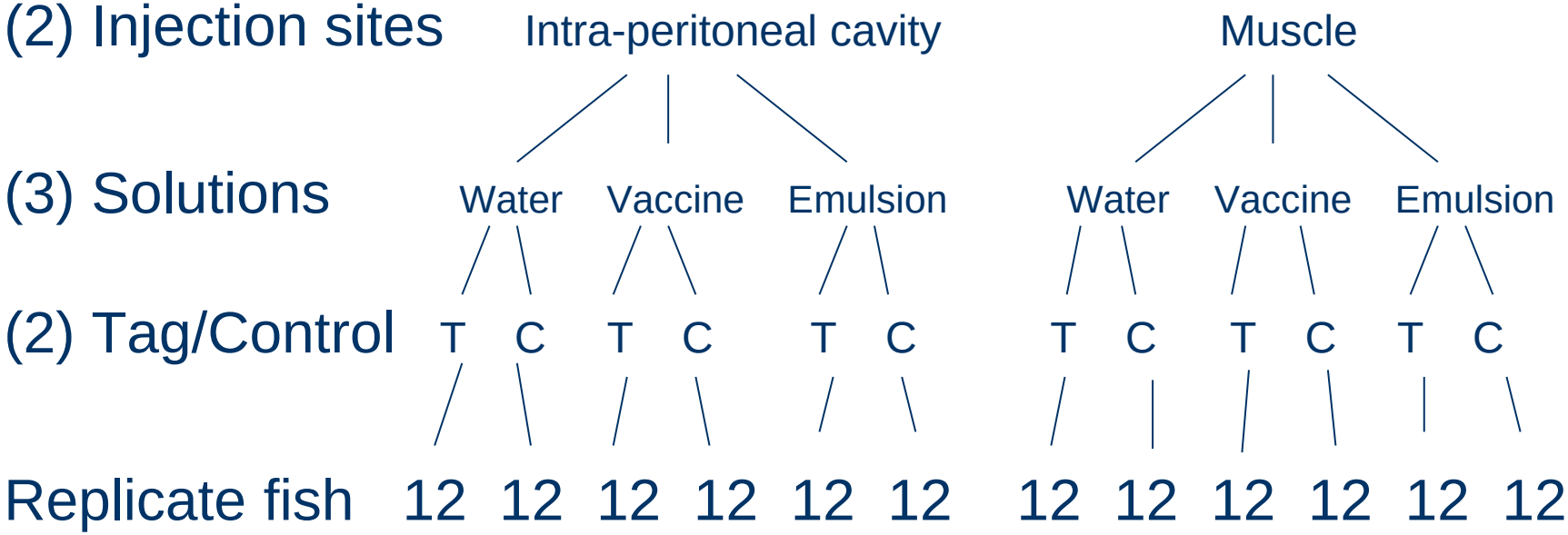
Vaccination 1

Question: Is carrier solution or injection site important for marker uptake?

Method:

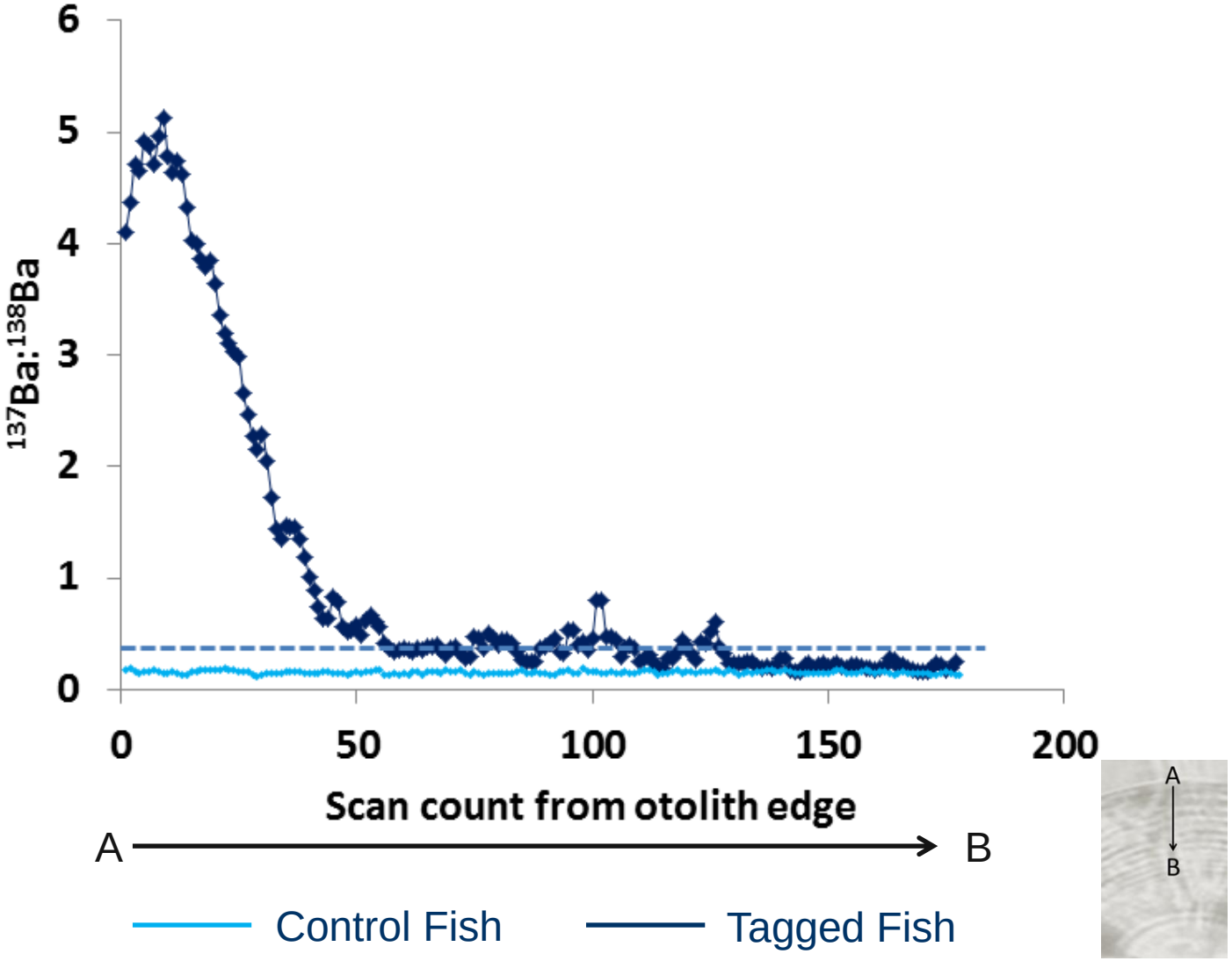
- Fish were pit tagged 2 months prior
- 3 tags used: ^{137}Ba, ^{86}Sr, and ^{26}Mg
- Concentration 2 µg per g fish weight
  (Average weight was 57 grams (SE +/- 0.1 g)
- Otolith samples 2 weeks post injecting

Experimental design



Total of 144 fish, spread amongst 3 tanks (48 per tank)

Results
$^{137}Ba:^{138}Ba$



Results
$^{137}Ba:^{138}Ba$

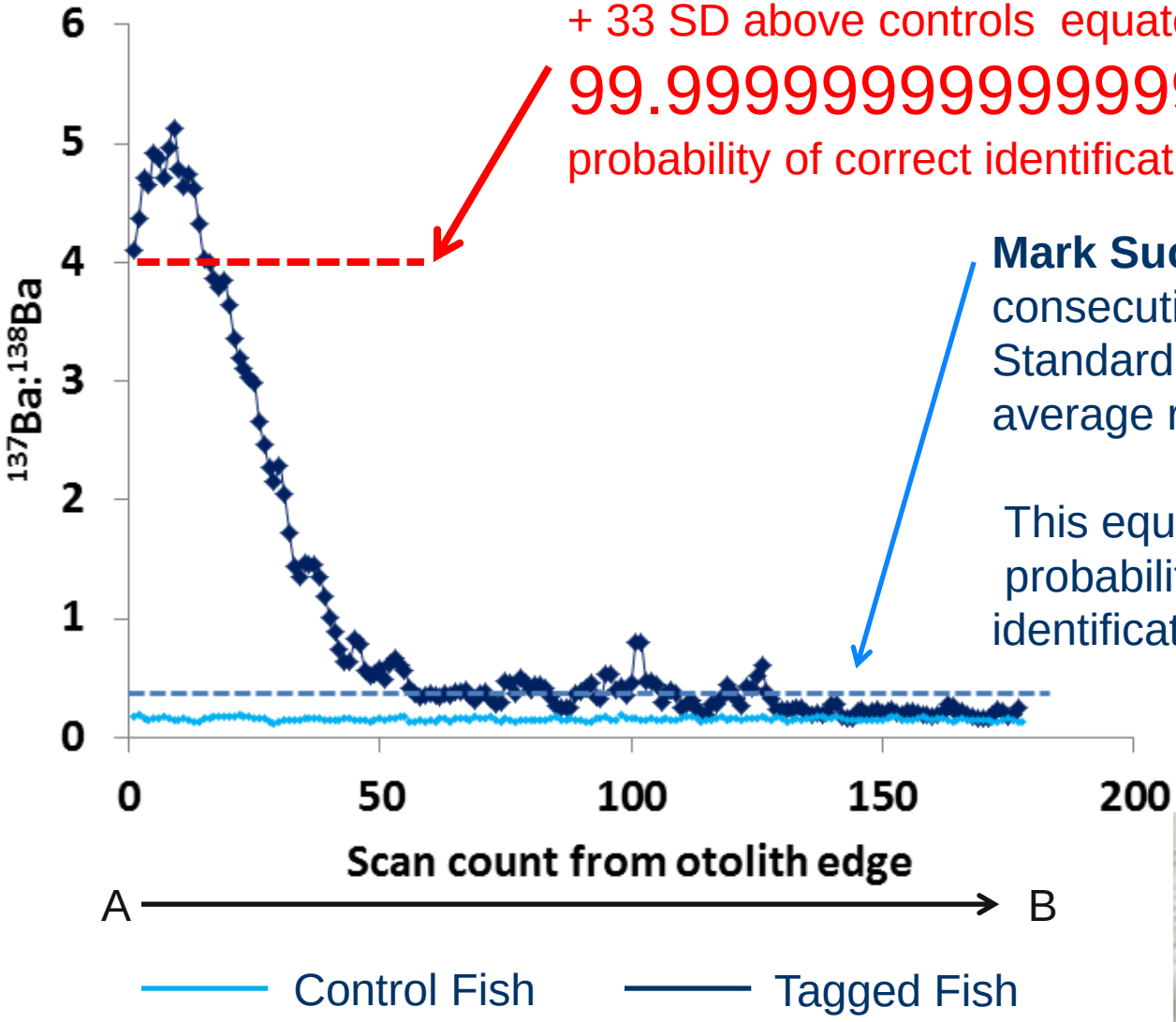
+ 33 SD above controls equates to a

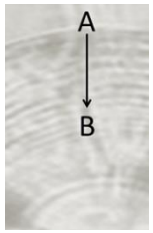
99.9999999999999%

probability of correct identification

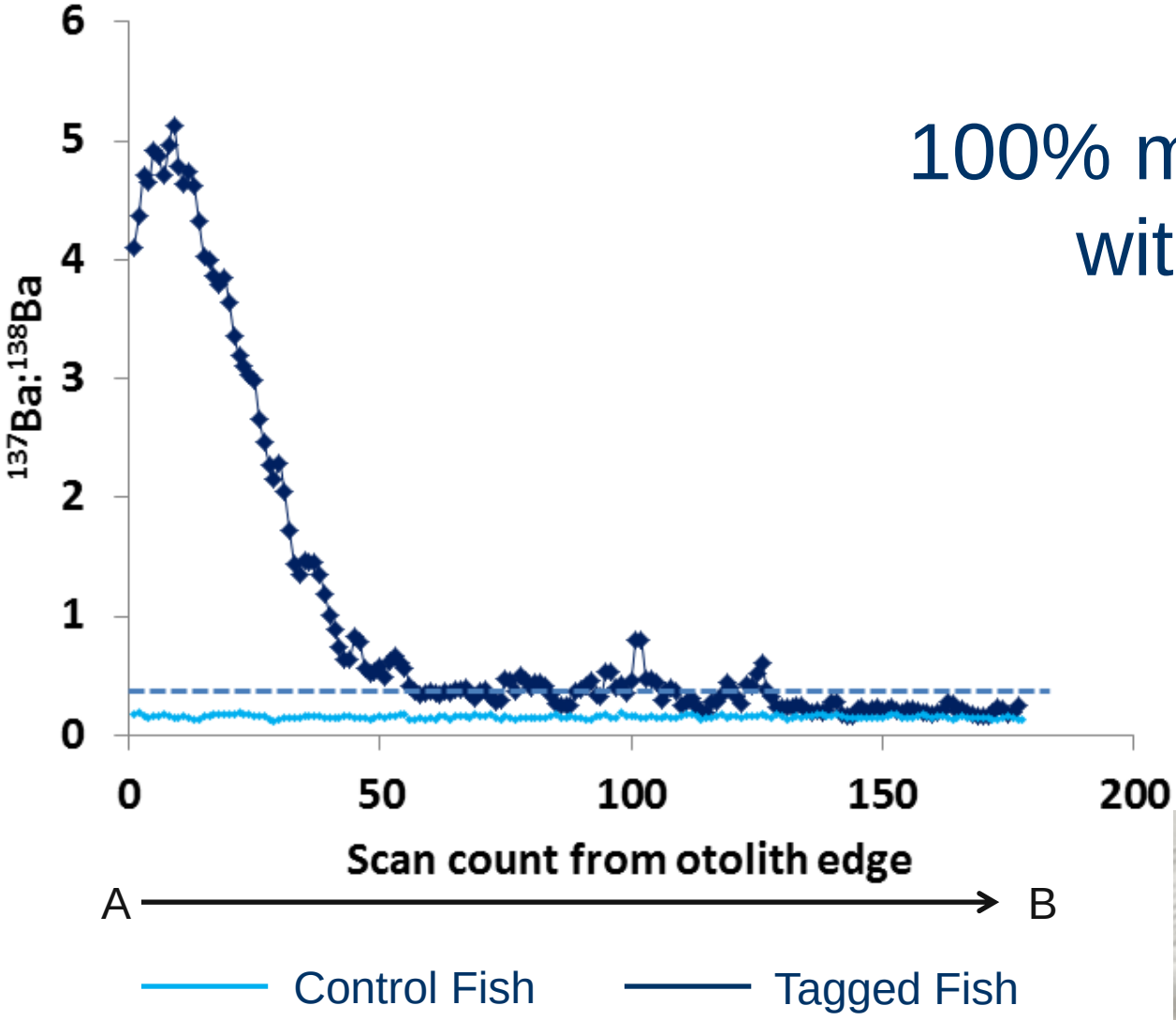
Mark Success: defined as 3 consecutive ratios 3.3 Standard Deviations above the average ratio of control fish.

This equates to a 99.94% probability of correct identification of a tagged fish

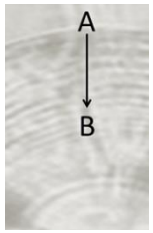




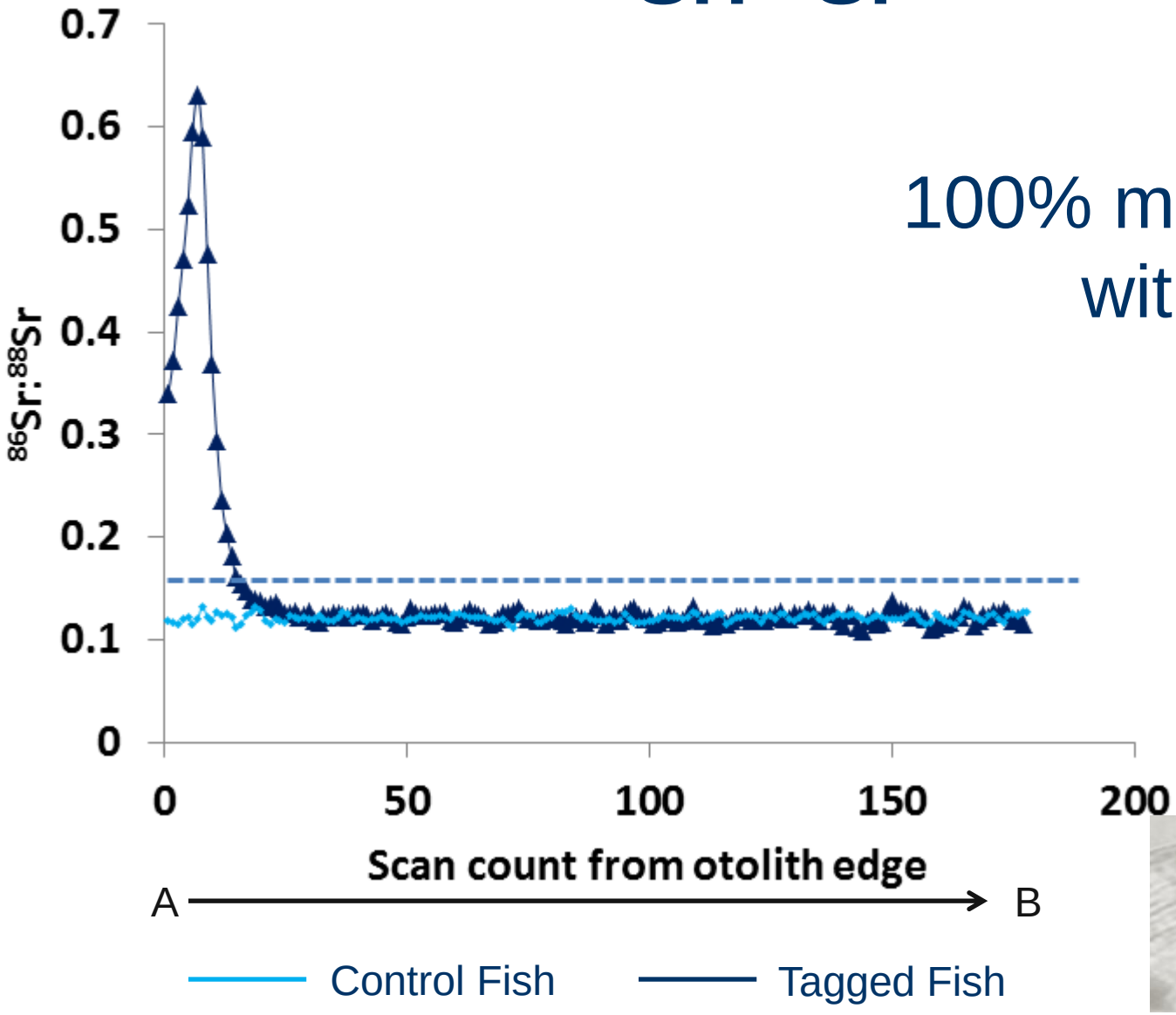
Mark Success
^{137}Ba:^{138}Ba



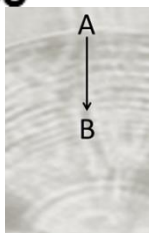
100% mark uptake with ^{137}Ba



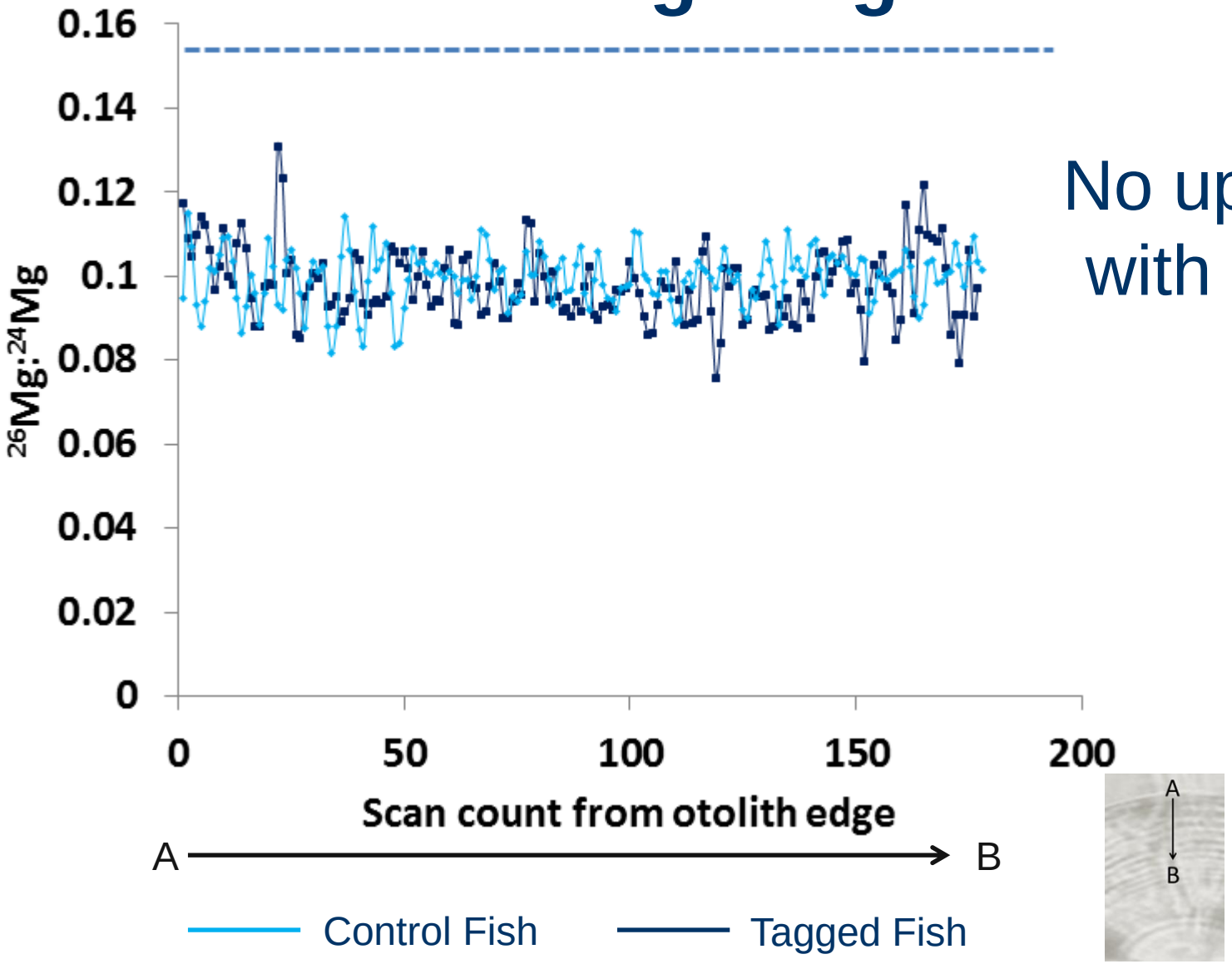
Mark Success
$^{86}Sr:^{88}Sr$



100% mark uptake with ^{86}Sr



Mark Success
$^{26}Mg:^{24}Mg$



No uptake with ^{26}Mg

Results

Injection site:

Intra-peritoneal cavity overall produced stronger marks compared to muscle injection for **both ^{137}Ba and ^{86}Sr**

Results

Injection site:

Intra-peritoneal cavity overall produced stronger marks compared to muscle injection for **both ^{137}Ba and ^{86}Sr**

Carrier solution:

Water and emulsion solutions produced stronger marks compared to the vaccine solution for **^{137}Ba**

Results

Injection site:

Intra-peritoneal cavity overall produced stronger marks compared to muscle injection for **both ^{137}Ba and ^{86}Sr**

Carrier solution:

Water and emulsion solutions produced stronger marks compared to the vaccine solution for **^{137}Ba**

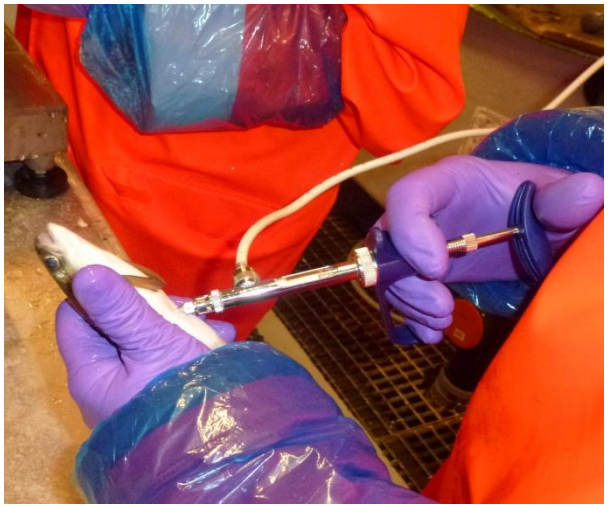
Vaccine and emulsion solutions produced stronger marks compared to water for **^{86}Sr**

Conclusions

- Best to inject into the intra-peritoneal cavity
- MINOVA 6 as a carrier is appropriate to use
- ^{137}Ba and ^{86}Sr markers highly successful

Vaccination 2

Method: Deliver multiple concentrations and combinations of markers via injection



Combinations:

- **1** : ^{137}Ba
- **4** : ^{137}Ba, ^{135}Ba, ^{136}Ba, ^{86}Sr
- **7** : ^{137}Ba, ^{136}Ba, ^{135}Ba, ^{134}Ba, ^{87}Sr, ^{86}Sr &^{26}Mg

Concentrations:

(µg. g^{-1} fish weight)

(Average weight 102 +/- 0.6 g)

1 µg

0.1µg

0.01 µg

0.001 µg

Experimental design

(3) Combinations: Single, Four, Seven

(4) Concentrations (µg. g^{-1} fish weight): 1, 0.1, 0.01, 0.001 | 1, 0.1, 0.01, 0.001 | 1, 0.1, 0.01, 0.001

Replicate fish: 50 50 50 50 | 50 50 50 50 | 50 50 50 50

Plus 50 control fish injected with vaccine only

- Fish spread amongst 5 tanks (130 per tank)
- Standard vaccination volume (0.1 ml)
- Otolith samples collected 3 months post vaccination

Results

		Mark uptake						
Number of Markers	**Concentration** (µg. g^{-1} fish)	**^{137}Ba**						
1	1 0.1 0.01 0.001							

Results

		Mark uptake						
Number of Markers	**Concentration** (µg. g^{-1} fish)	**^{137}Ba**						
1	1	**100%**						
	0.1	**100%**						
	0.01	**100%**						
	0.001	**100%**						

Results

Number of Markers	Concentration (µg. g^{-1} fish)	Mark uptake						
		^{137}Ba	^{136}Ba	^{135}Ba	^{86}Sr			
1	1	100%						
	0.1	100%						
	0.01	100%						
	0.001	100%						
4	1							
	0.1							
	0.01							
	0.001							

Results

		Mark uptake						
Number of Markers	**Concentration** (µg. g^{-1} fish)	**^{137}Ba**	**^{136}Ba**	**^{135}Ba**	**^{86}Sr**			
1	1	100%						
	0.1	100%						
	0.01	100%						
	0.001	100%						
4	1	**100%**	**100%**	**100%**	**100%**			
	0.1	**100%**	**100%**	**100%**	30%			
	0.01	**100%**	**100%**	**100%**	0%			
	0.001	80%	20%	80%	0%			

Results

Number of Markers	Concentration (µg. g^{-1} fish)	Mark uptake						
		^{137}Ba	^{136}Ba	^{135}Ba	^{86}Sr	^{134}Ba	^{87}Sr	^{26}Mg
1	1	100%						
	0.1	100%						
	0.01	100%						
	0.001	100%						
4	1	100%	100%	100%	100%			
	0.1	100%	100%	100%	30%			
	0.01	100%	100%	100%	0%			
	0.001	80%	20%	80%	0%			
7	1							
	0.1							
	0.01							
	0.001							

Results

Number of Markers	Concentration (µg. g^{-1} fish)	Mark uptake						
		^{137}Ba	^{136}Ba	^{135}Ba	^{86}Sr	^{134}Ba	^{87}Sr	^{26}Mg
1	1	100%						
	0.1	100%						
	0.01	100%						
	0.001	100%						
4	1	100%	100%	100%	100%			
	0.1	100%	100%	100%	30%			
	0.01	100%	100%	100%	0%			
	0.001	80%	20%	80%	0%			
7	1	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	0%
	0.1	**100%**	**100%**	**100%**	20%	**100%**	60%	0%
	0.01	**100%**	**100%**	**100%**	0%	**100%**	0%	0%
	0.001	70%	20%	70%	0%	0%	0%	0%

Conclusions

- **^{137}Ba as a single marker** can be used at concentrations as low as **0.001 µg** per gram of fish

Conclusions

- **^{137}Ba as a single marker** can be used at concentrations as low as **0.001 µg** per gram of fish

- Combinations of **^{134}Ba, ^{135}Ba ^{136}Ba** and **^{137}Ba** can be used at concentrations as low as **0.01 µg** per gram of fish

Conclusions

- **^{137}Ba as a single marker** can be used at concentrations as low as **0.001 µg** per gram of fish

- Combinations of **^{134}Ba, ^{135}Ba ^{136}Ba** and **^{137}Ba** can be used at concentrations as low as **0.01 µg** per gram of fish

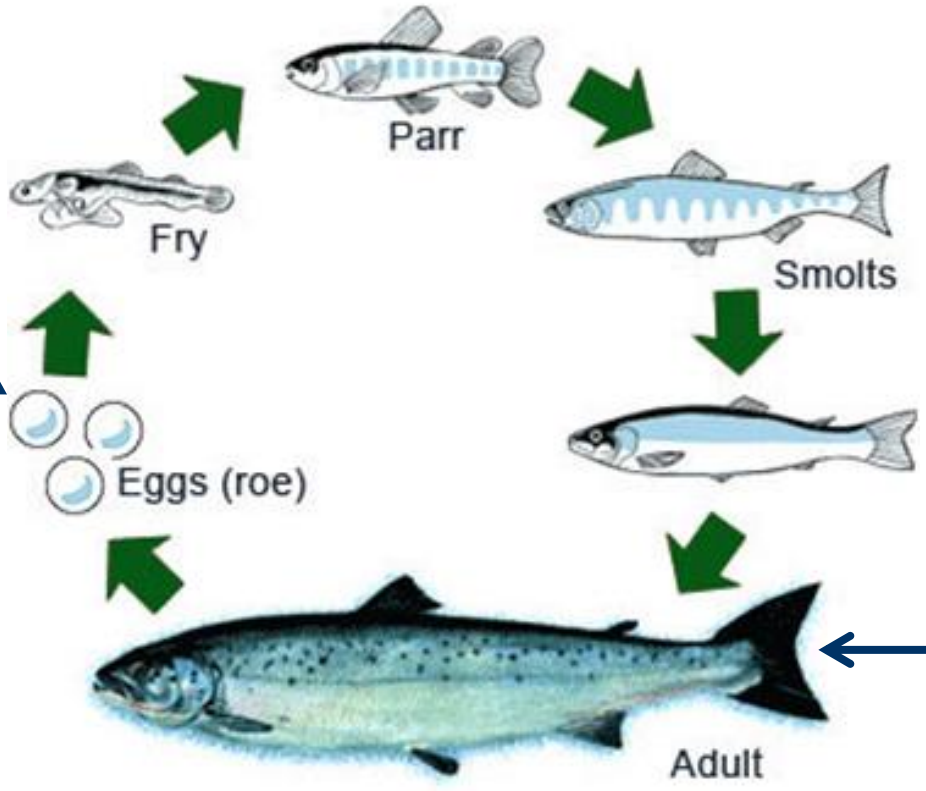
- Combinations using **^{86}Sr and ^{87}Sr** can be used at concentrations as low as **1 µg** per gram of fish.

Mass Marking Via Maternal Transfer

Mark application points

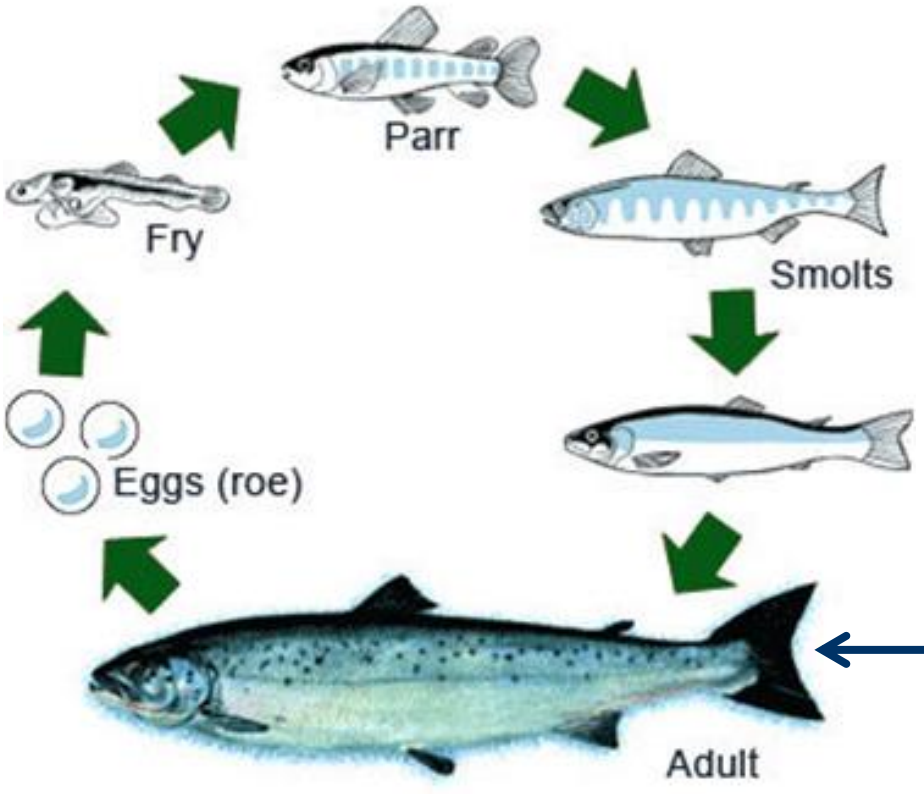
Vaccination

Egg immersion



Maternal Transfer

Mark application points



Maternal Transfer

Maternal Transfer

Method: Multiple concentrations using a seven marker combination

- Injected 30 female brood stock
- Standard injection volume of 60 ml
- Combination of ^{137}Ba, ^{136}Ba, ^{135}Ba, ^{134}Ba, ^{87}Sr, ^{86}Sr & ^{26}Mg

Experimental design

(1) Combination — Seven markers

(4) Concentrations — 1, 0.1, 0.01, 0.001

(µg isotope per g brood fish weight)

Replicate fish — 6 6 6 6

Plus 6 control fish injected with saline solution .

~1500 eggs per brood fish were stripped and fertilised

First samples were taken before first feeding

Results

Spawning Date	# Brood fish Spawned	Concentration µg. g^{-1} brood fish	Mark uptake						
			^{137}Ba	^{136}Ba	^{135}Ba	^{134}Ba	^{87}Sr	^{86}Sr	^{26}Mg
Week 1	4	2							
Week 2	0								
Week 3	2								

Results

Spawning Date	# Brood fish Spawned	Concentration µg. g^{-1} brood fish	Mark uptake						
			^{137}Ba	^{136}Ba	^{135}Ba	^{134}Ba	^{87}Sr	^{86}Sr	^{26}Mg
Week 1	4	2	100%	100%	100%	100%	15%	3%	10%
Week 2	0								
Week 3	2		100%	100%	100%	100%	100%	100%	30%

Results

Spawning Date	# Brood fish Spawned	Concentration µg. g^{-1} brood fish	Mark uptake						
			^{137}Ba	^{136}Ba	^{135}Ba	^{134}Ba	^{87}Sr	^{86}Sr	^{26}Mg
Week 1	4	2	100%	100%	100%	100%	15%	3%	10%
Week 2	0								
Week 3	2		100%	100%	100%	100%	100%	100%	30%
Week 1	1	0.2	95%	10%	100%	5%	0%	0%	0%
Week 2	4		100%	98%	100%	90%	5%	5%	8%
Week 3	1		100%	100%	100%	100%	10%	0%	0%

Results

Spawning Date	# Brood fish Spawned	Concentration µg. g^{-1} brood fish	Mark uptake						
			^{137}Ba	^{136}Ba	^{135}Ba	^{134}Ba	^{87}Sr	^{86}Sr	^{26}Mg
Week 1	4	2	100%	100%	100%	100%	15%	3%	10%
Week 2	0								
Week 3	2		100%	100%	100%	100%	100%	100%	30%
Week 1	1	0.2	95%	10%	100%	5%	0%	0%	0%
Week 2	4		100%	98%	100%	90%	5%	5%	8%
Week 3	1		100%	100%	100%	100%	10%	0%	0%
Week 1	2	0.02	95%	0%	100%	0%	0%	0%	0%
Week 2	1		100%	10%	100%	10%	0%	0%	10%
Week 3	0								

Results

Spawning Date	# Brood fish Spawned	Concentration µg. g^{-1} brood fish	Mark uptake						
			^{137}Ba	^{136}Ba	^{135}Ba	^{134}Ba	^{87}Sr	^{86}Sr	^{26}Mg
Week 1	4	2	100%	100%	100%	100%	15%	3%	10%
Week 2	0								
Week 3	2		100%	100%	100%	100%	100%	100%	30%
Week 1	1	0.2	95%	10%	100%	5%	0%	0%	0%
Week 2	4		100%	98%	100%	90%	5%	5%	8%
Week 3	1		100%	100%	100%	100%	10%	0%	0%
Week 1	2	0.02	95%	0%	100%	0%	0%	0%	0%
Week 2	1		100%	10%	100%	10%	0%	0%	10%
Week 3	0								
Week 1	0	0.002	0%	0%	0%	0%	0%	0%	0%
Week 2	4		30%	0%	65%	0%	0%	0%	8%
Week 3	2		75%	0%	80%	0%	0%	0%	0%

Conclusions

- Mark uptake depends on:

  A) Concentration of marker

  B) Time between injection and spawning

Conclusions

- Mark uptake depends on:

  A) Concentration of marker

  B) Time between injection and spawning

- Combinations using **^{137}Ba** and **^{135}Ba** can be created at concentrations as low as **0.02 µg**. g^{-1} brood stock

Conclusions

- Mark uptake depends on:

  A) Concentration of marker

  B) Time between injection and spawning

- Combinations using **^{137}Ba** and **^{135}Ba** can be created at concentrations as low as **0.02 µg**. g^{-1} brood stock

- Combinations using **^{136}Ba** and **^{134}Ba** can be created at a concentrations as low as of **0.2 µg**. g^{-1} brood stock

Conclusions

- Mark uptake depends on:

  A) Concentration of marker

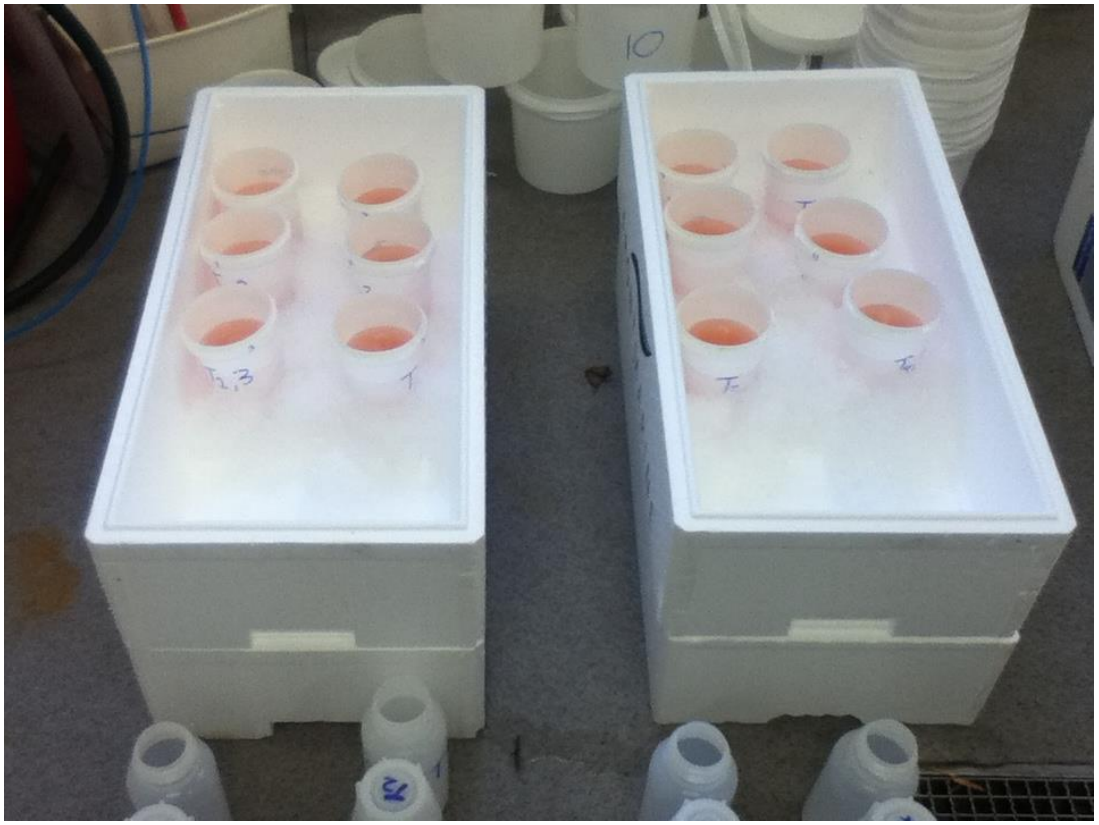
  B) Time between injection and spawning

- Combinations using ^{137}**Ba** and ^{135}**Ba** can be created at concentrations as low as **0.02 µg**. g^{-1} brood stock

- Combinations using ^{136}**Ba** and ^{134}**Ba** can be created at a concentrations as low as of **0.2 µg**. g^{-1} brood stock

- Combinations using ^{87}**Sr** and ^{86}**Sr** can be created at a concentration as low as **2 µg**. g^{-1} brood stock

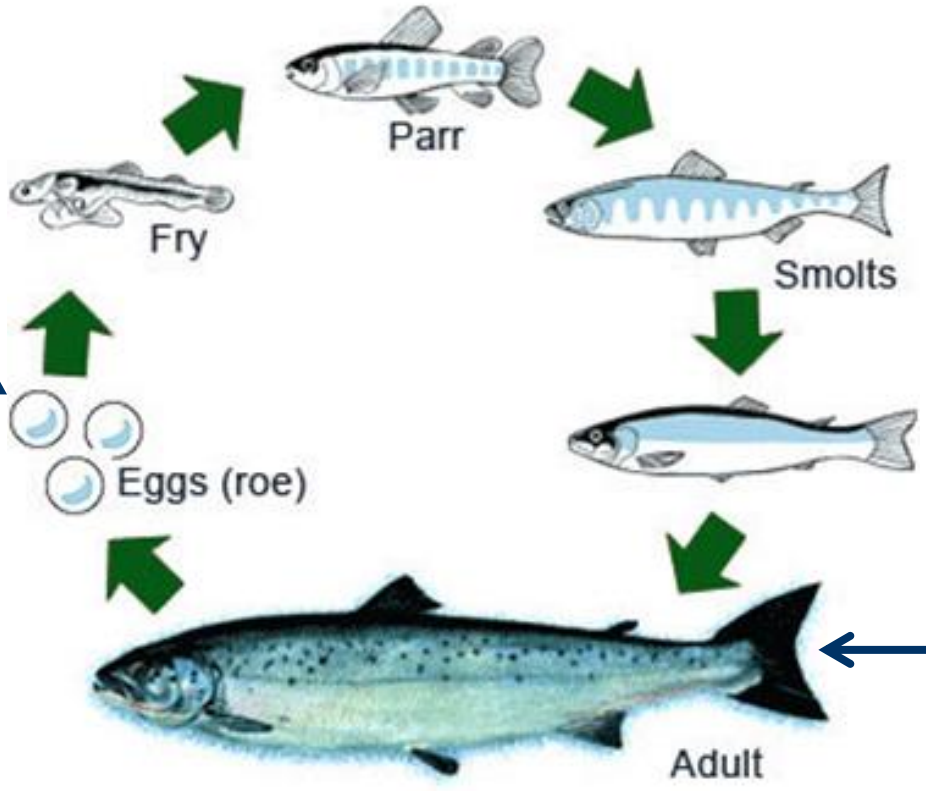
Mass Marking Via Egg Immersion



Mark application points

Vaccination

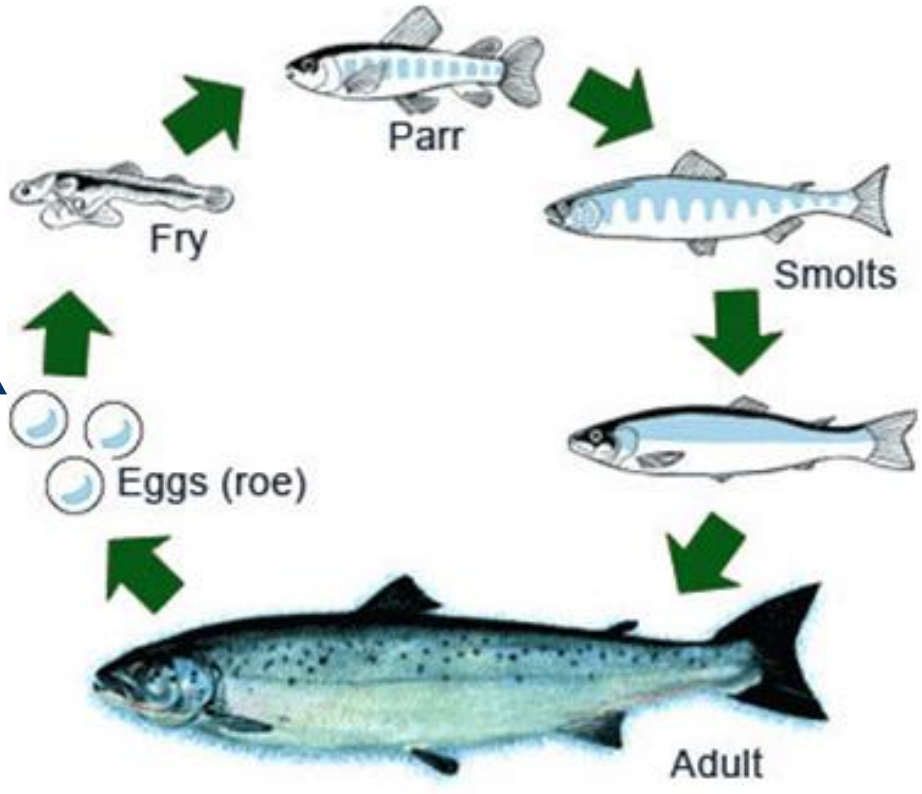
Egg immersion



Maternal Transfer

Mark application points

Egg immersion



Egg Immersion

Method: Multiple concentrations using a seven marker combination.

- Standard immersion volume (300 ml)
- Standardised egg volume (175 ml)
- Combination of ^{137}Ba, ^{136}Ba, ^{135}Ba, ^{134}Ba, ^{87}Sr, ^{86}Sr & ^{26}Mg
- 2 hour immersion time

Experimental design

(1) Combination — Seven markers

(4) Concentrations Ba (µg per litre water)

	1000	100	10	1
Mg & Sr	2500	250	25	2.5
Replicate batches	3	3	3	3

Plus 3 control batches immersed in pure water

Each batch contained ~1000 fertilised eggs

First otolith samples taken before first feeding

Results

Marker Concentrations (μg. L^{-1})		Mark uptake						
^{137}Ba, ^{136}Ba, ^{135}Ba, ^{134}Ba	^{87}Sr, ^{86}Sr, ^{26}Mg	**^{137}Ba**	**^{136}Ba**	**^{135}Ba**	**^{134}Ba**	**^{87}Sr**	**^{86}Sr**	**^{26}Mg**
1000	2500							
100	250							
10	25							
1	2.5							

Results

Marker Concentrations (µg. L^{-1})		Mark uptake						
^{137}Ba, ^{136}Ba, ^{135}Ba, ^{134}Ba	^{87}Sr, ^{86}Sr, ^{26}Mg	**^{137}Ba**	**^{136}Ba**	**^{135}Ba**	**^{134}Ba**	**^{87}Sr**	**^{86}Sr**	**^{26}Mg**
1000	2500	**100%**	**100%**	**100%**	93%	7%	0%	4%
100	250	**100%**	3%	**100%**	0%	0%	0%	0%
10	25	3%	0%	21%	0%	0%	0%	3%
1	2.5	0%	0%	0%	3%	0%	0%	0%

Conclusions

- Concentration of marker important

Conclusions

- Concentration of marker important

- **^{137}Ba** and **^{135}Ba** 100% mark uptake at a concentration of **100 µg. L^{-1}**

Conclusions

- Concentration of marker important
- ^{137}**Ba** and ^{135}**Ba** 100% mark uptake at a concentration of **100 µg. L^{-1}**
- ^{136}**Ba** 100% mark uptake at a concentration of **1000 µg. L^{-1}**

Conclusions

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- **^{137}Ba** and **^{135}Ba** 100% mark uptake at a concentration of **100 µg. L^{-1}**
- **^{136}Ba** 100% mark uptake at a concentration of **1000 µg. L^{-1}**
- Length of immersion time requires further investigation

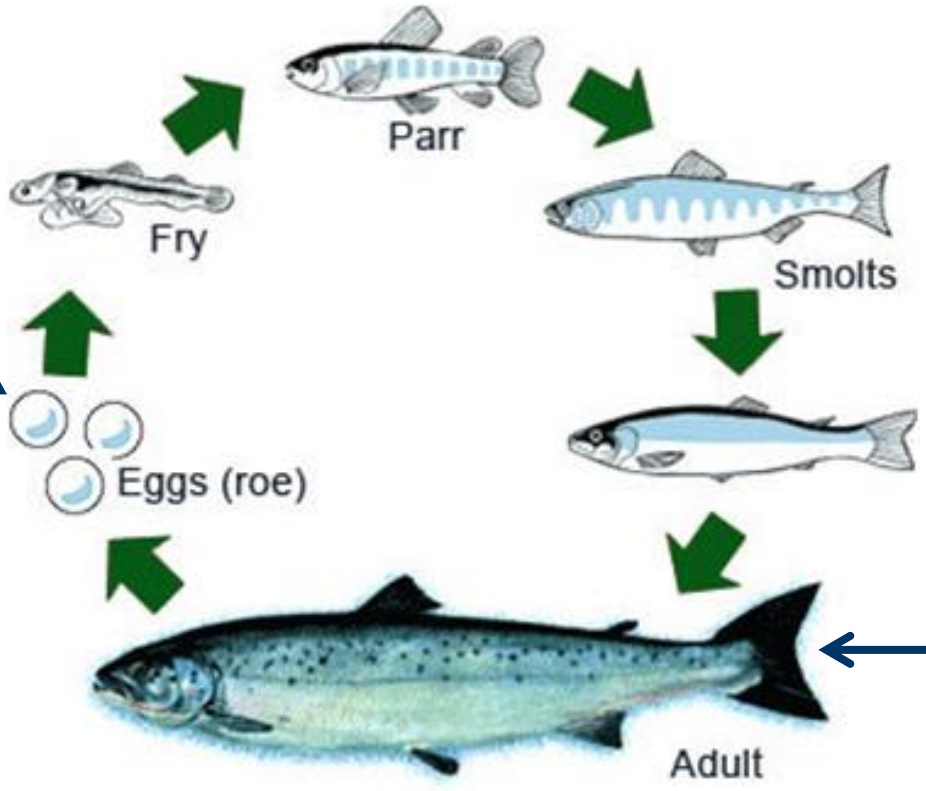
Summary

- All three techniques could be used for mass marking Atlantic salmon with 100% mark success
- Vaccination: 63 codes, Maternal Transfer: 63 codes, Egg immersion: 7 codes
- 100% mark uptake is easiest to achieve using Ba markers
- 100% mark uptake with Sr markers is possible at higher concentrations compared to Ba markers

Mark application points

Vaccination

Egg immersion



Maternal Transfer

Fish Health

Monitoring of mortality and growth between tagged and control fish is being undertaken for all three marking techniques

Monitoring of production parameters

	Spawning	Fertilsation	Hatch success	First feeding	Vaccination	Smoltifaction	Sea Transfer	Production Size
Vaccination Mortality Growth					No difference	No difference	No difference	
Egg immersion Mortality Growth		No difference	No difference	No difference	No difference			
Maternal Transfer Mortality Growth	No difference	No difference	No difference	No difference	No difference			

Cost projections

Scenario 1: Marking 100% of production with 1 marker

(achievable)

Cost projections

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(achievable)

Scenario 2: Marking 80% of production (24 company's)
(achievable)

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(achievable)

Scenario 3: Marking 100% of production (54 company's)
(achievable)

Cost projections

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

Scenario 2: Marking 80% of production (24 company's)
(achievable)

Scenario 3: Marking 100% of production (54 company's)
(achievable)

Scenario 4: Marking all farm locations (500-1000 sites)
(Individual codes possible, but currently restrained by cost, and would require further optimisation of techniques)

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 (15 g for 300 million parr)	$4.36 per mg (~ $0.0006 per parr)	**$65400**

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

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 (15 g for 300 million parr)	$4.36 per mg (~ $0.0006 per parr)	$65400

Egg immersion (2000 eggs L^{-1})	Material Cost ($US)	Total
^{137}Ba @ 100 µg. L^{-1} (150,000 L for 300 million eggs)	$4.36 per mg (~ $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 (60000 brood fish for 300 million eggs)	$4.36 per mg (~ $0.872 per brood fish)	**$52320**

Cost projections Scenario 2

Marking 80% of production (24 largest companies, 24 codes)

Method: Marking fish once via vaccination or once via maternal transfer with Ba codes

Vaccination: Marks the region of the otolith developing at the parr/pre-smolt stage

Maternal Transfer: Marks the core of the otolith developing at the eyed egg stage

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.

Data is sourced from:
http://marineharvest.com/PageFiles/1296/2013%20Salmon%20Handbook%2027-04-13.pdf

Cost projections Scenario 2

Marking 80% of production (24 biggest companies, 24 codes)

Company	Production (%)	Production (n fish)	Code number	Marker cost per fish	Cost per company
Marine Harvest	22%	66000000	2MT	0.0002	11510
Lerøy Seafoods	13%	39000000	1V	0.0002	8502
Salmar	9%	27000000	3V	0.0003	8910
Cermaq	5%	15000000	4MT	0.0005	7746
Grieg Seafoods	4%	12000000	5V	0.0006	7746
6	1.42%	4263158	16MT	0.0007	2945
7	1.42%	4263158	7V	0.0010	4272
8	1.42%	4263158	6MT	0.0026	11255
9	1.42%	4263158	15MT	0.0028	11998
10	1.42%	4263158	18MT	0.0032	13456
11	1.42%	4263158	26MT	0.0033	14200
12	1.42%	4263158	9V	0.0055	23362
13	1.42%	4263158	8MT	0.0080	34173
14	1.42%	4263158	17MT	0.0082	34917
15	1.42%	4263158	20MT	0.0085	36375
16	1.42%	4263158	10V	0.0086	36812
17	1.42%	4263158	28MT	0.0087	37118
18	1.42%	4263158	12V	0.0098	41587
19	1.42%	4263158	19MT	0.0107	45428
20	1.42%	4263158	29MT	0.0108	46172
21	1.42%	4263158	27MT	0.0112	47630
22	1.42%	4263158	30MT	0.0113	48373
23	1.42%	4263158	21V	0.0119	50881
24	1.42%	4263158	11V	0.0122	52011
			Average cost	**$0.0059**	$26557
			Total cost for marking 80% of production		**$663937**

Cost projections Scenario 3

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 3

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

Company Number	Company (% 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%	2000000	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%	2000000	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%	2000000	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	$17,414

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

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

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

In total 54 companies (100% of production)
Average cost of $0.0017 per fish to tag.

Total material cost: **$500,000**

Analysis costs Scenario 1

Monitoring program sampling 10000 fish per year

Analysis of 10000 samples per year	Days required	Equipment cost per Day	Labour cost	Totals
Sample preparation (50 per day)	200		200 Days	?
Laser ablation (50 per day)	200	$2400	200 Days	$480000 + L
Data analysis (50 per day)	200		200 Days	?
			Total Estimated Cost	?

Sample analysis costs based on standard processing costs

Analysis costs Scenario 2

Rapid response to an escape event

Analysis of 50 samples	Days required	Equipment cost	Labour cost	Totals
Sample preparation	2		2 Days	?
Laser ablation	1	$2400	1 Day	$2400 + L
Data analysis and report	2		2 Days	?
			Total Estimated Cost	?

Sample analysis and report can be completed in 1 week from the day otoliths are delivered to the laboratory

Conclusion

Sample analysis and report can be completed in 1 week from the day otoliths are delivered to the laboratory