



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

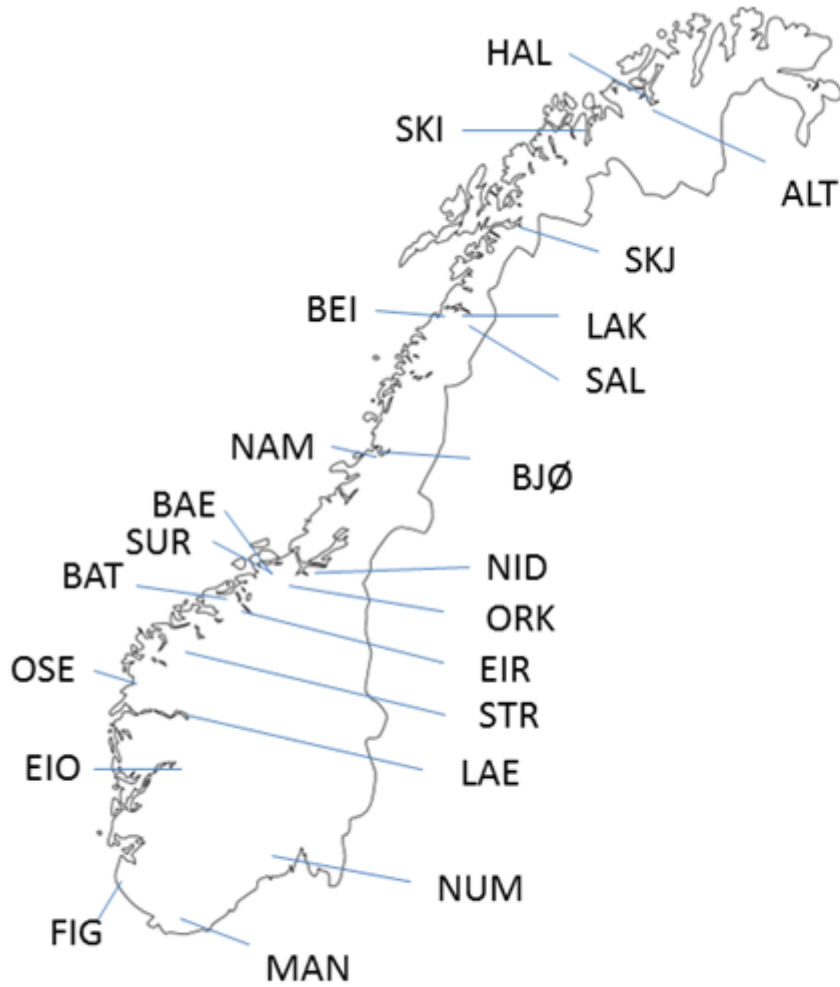
Temporally: Samples from 2 rivers spanning from 1990 to 2010

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



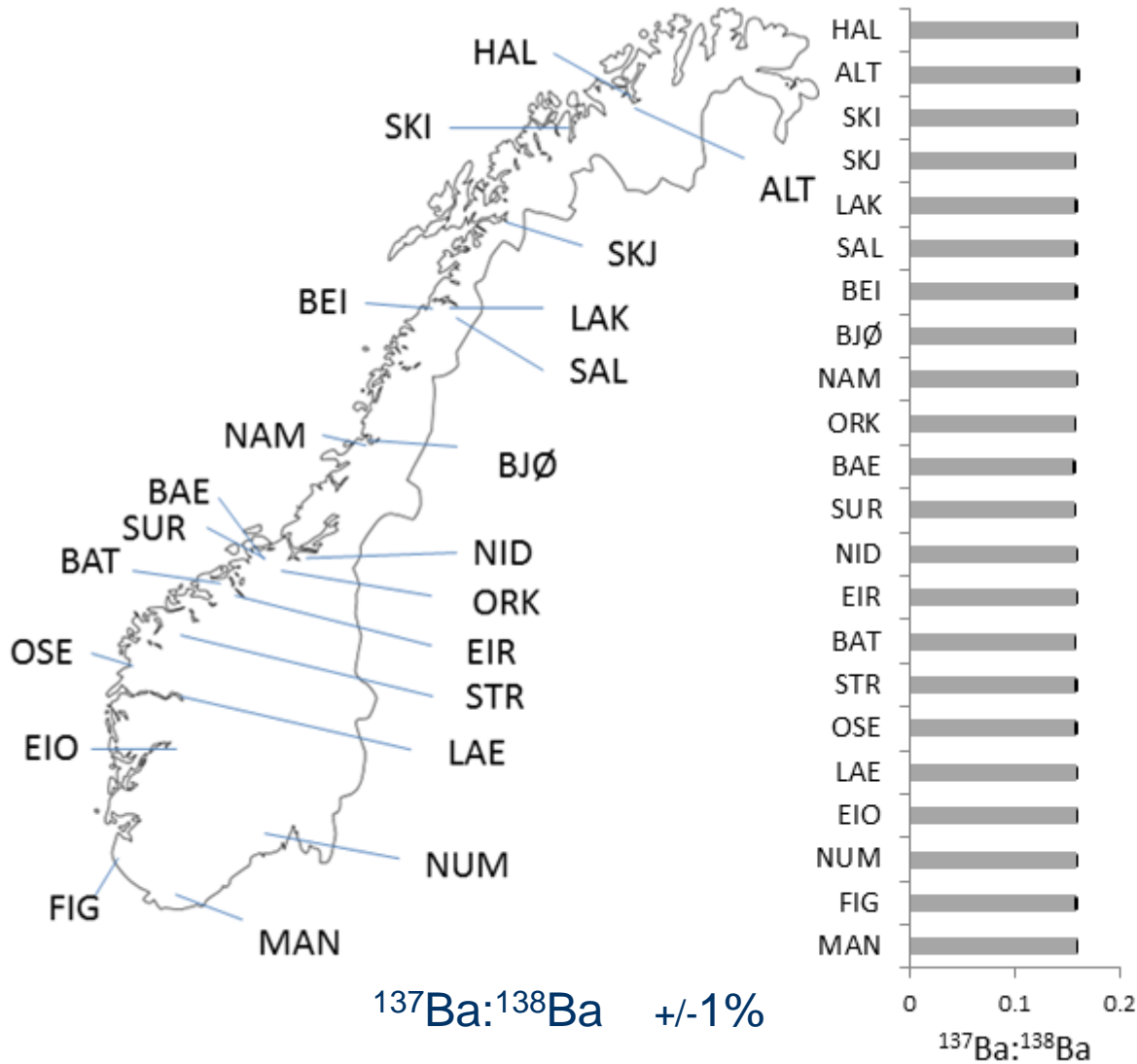


Background ratios



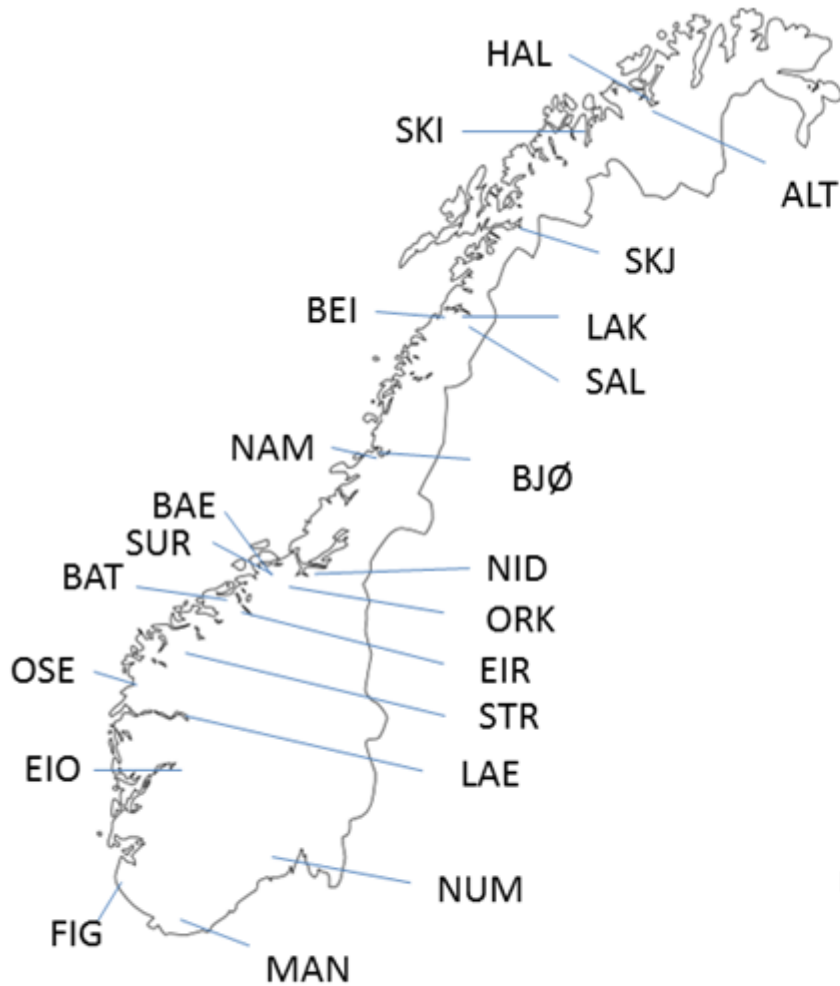


Background ratios

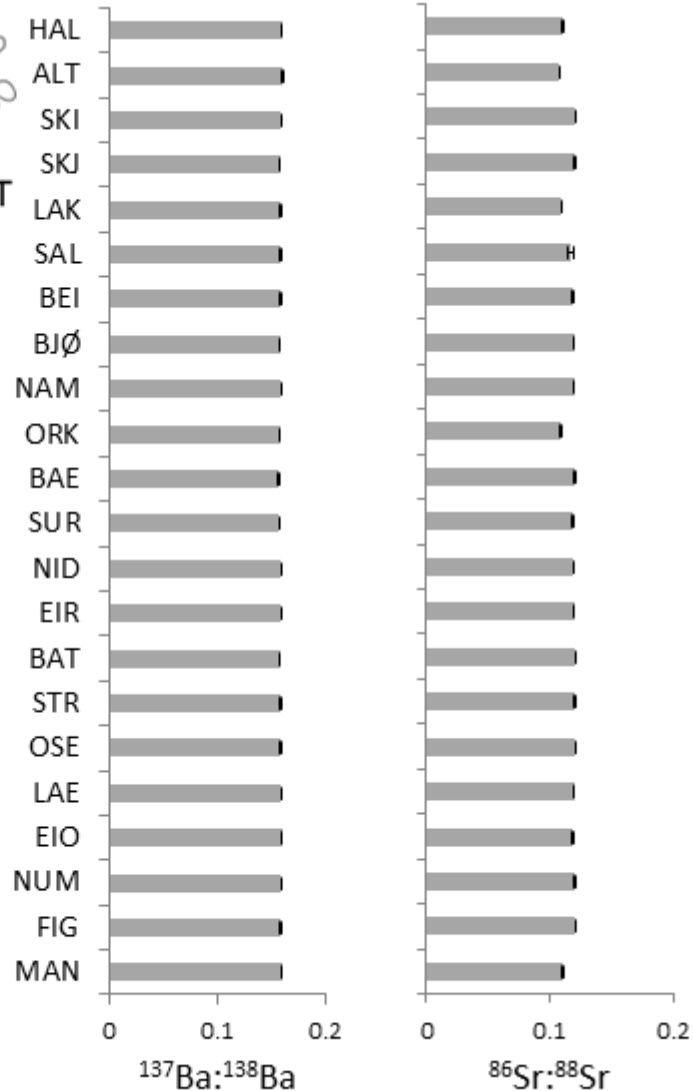




Background ratios

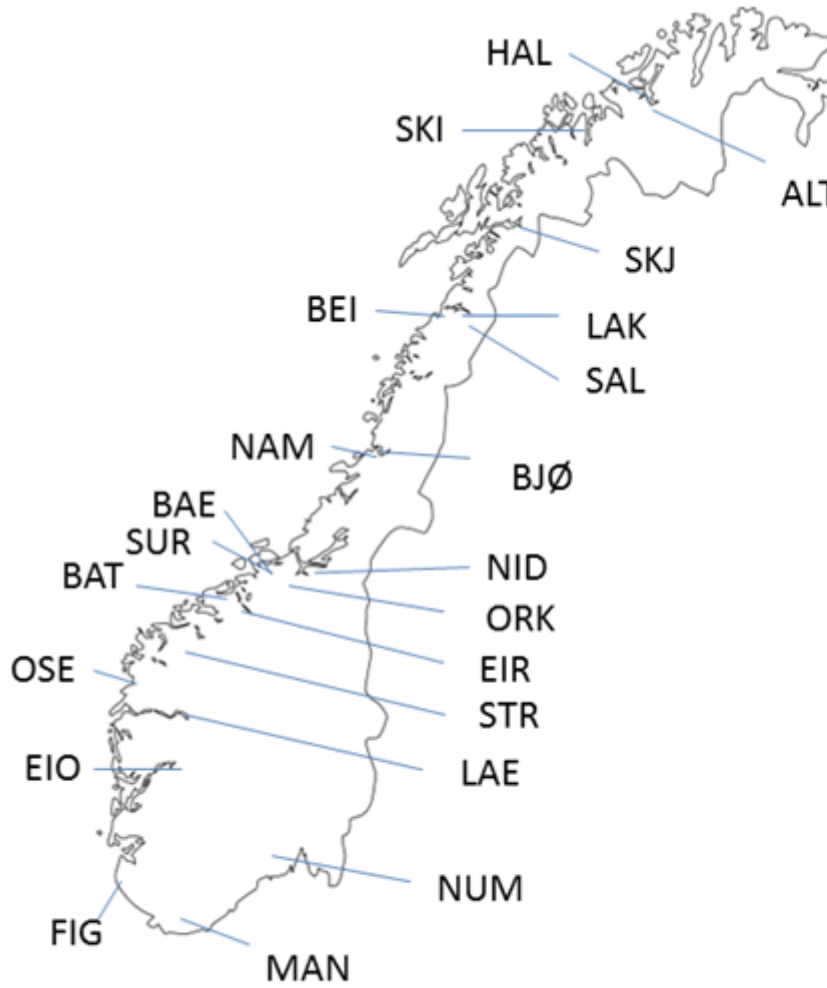


$^{137}\text{Ba}:^{138}\text{Ba}$ $\pm 1\%$
 $^{86}\text{Sr}:^{88}\text{Sr}$ $\pm 5\%$

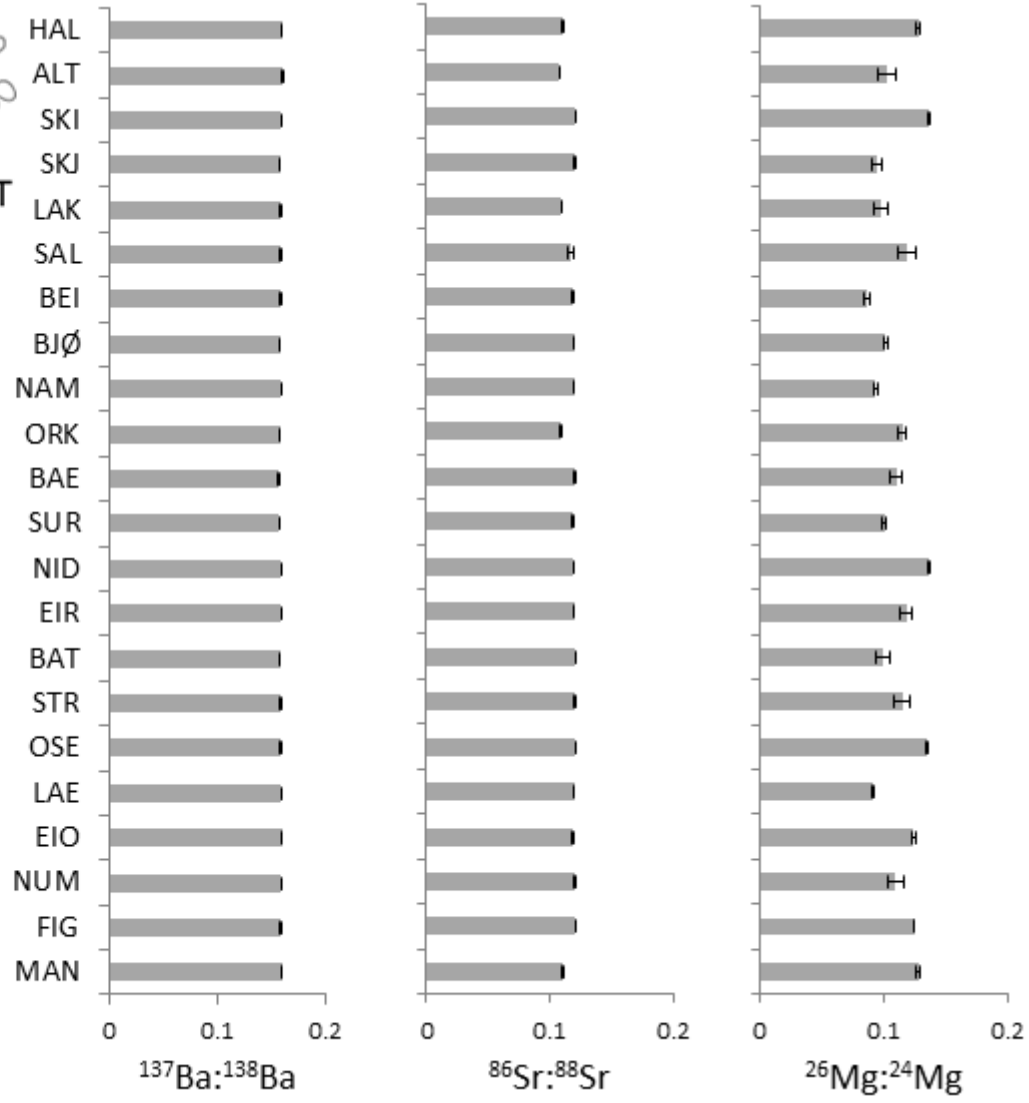




Background ratios

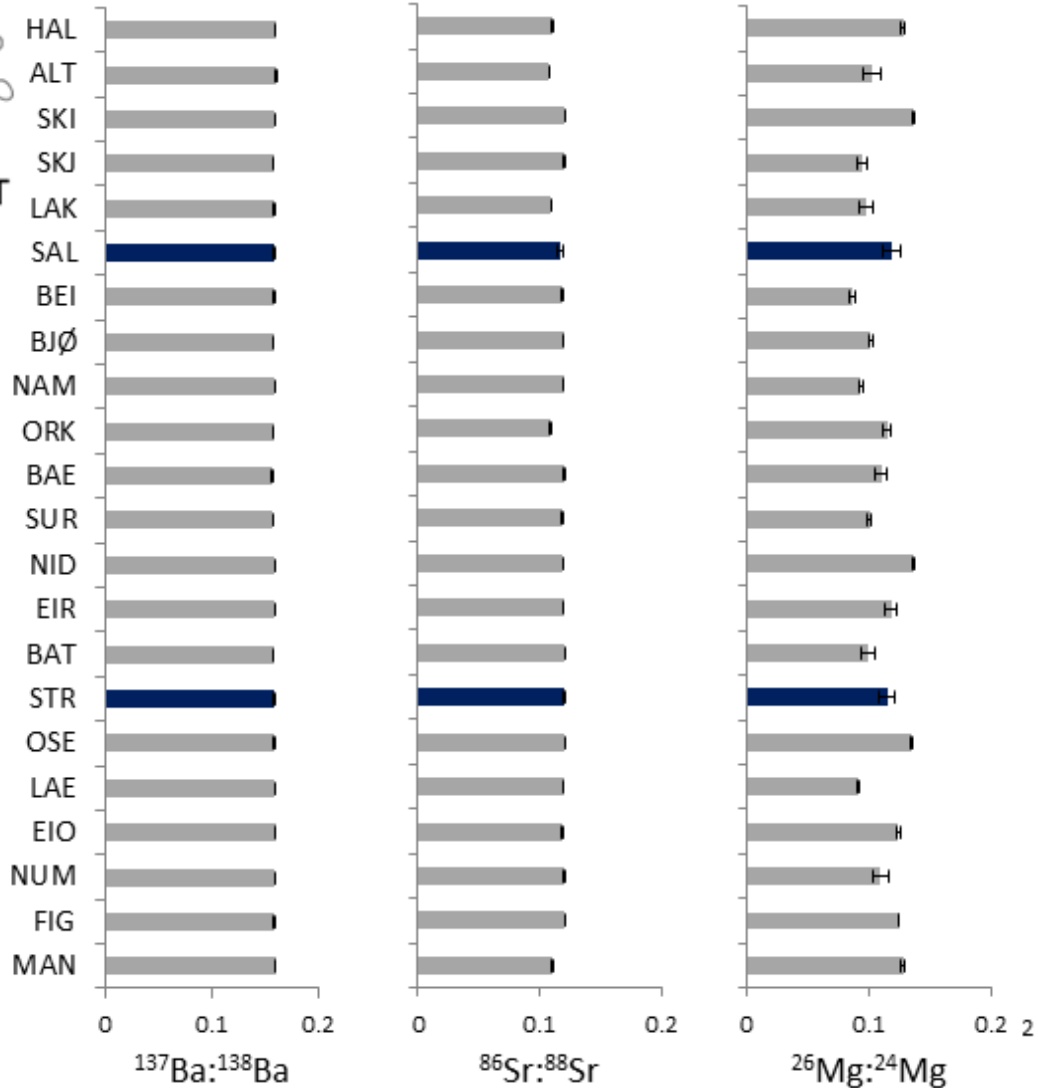
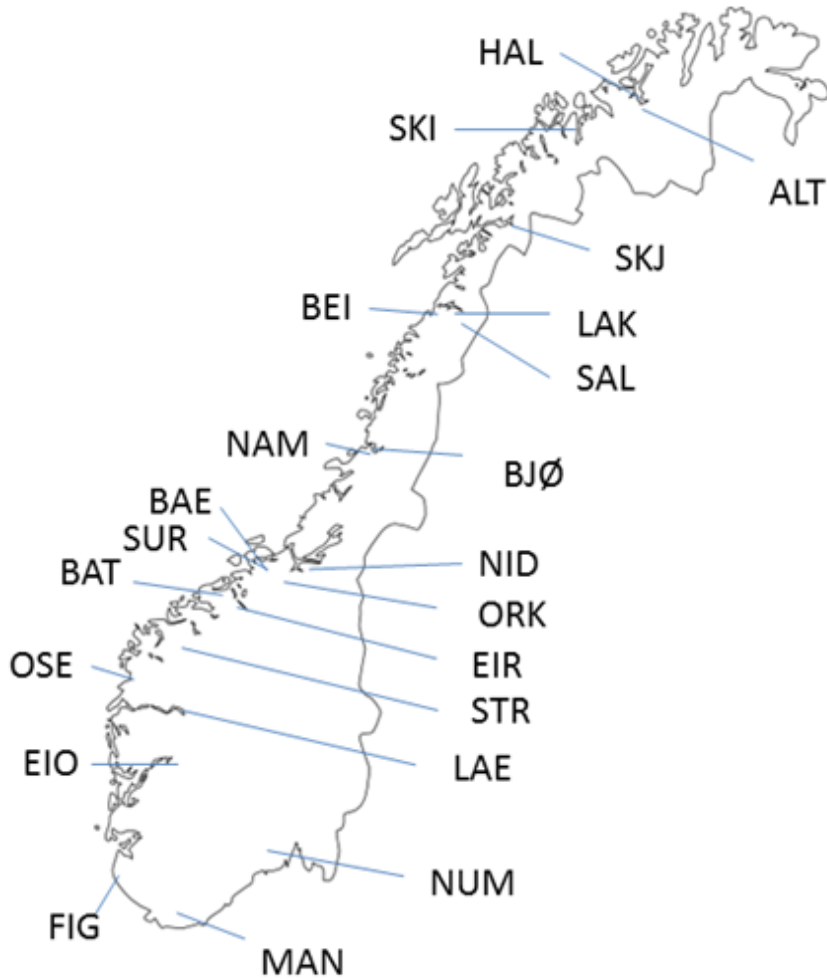


$^{137}\text{Ba}:^{138}\text{Ba}$ +/- 1%
 $^{86}\text{Sr}:^{88}\text{Sr}$ +/- 5%
 $^{26}\text{Mg}:^{24}\text{Mg}$ +/- 15%





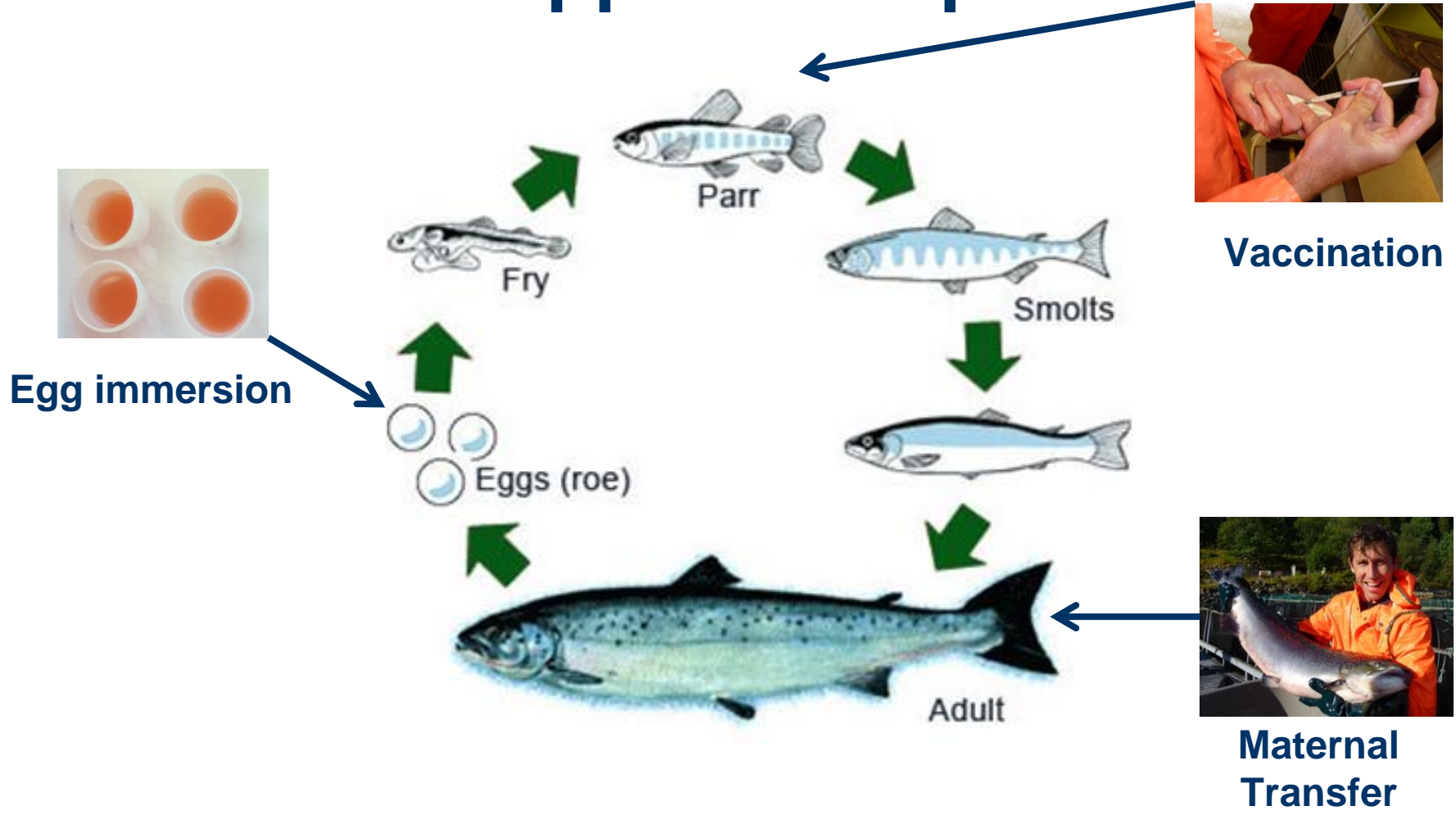
Background ratios



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

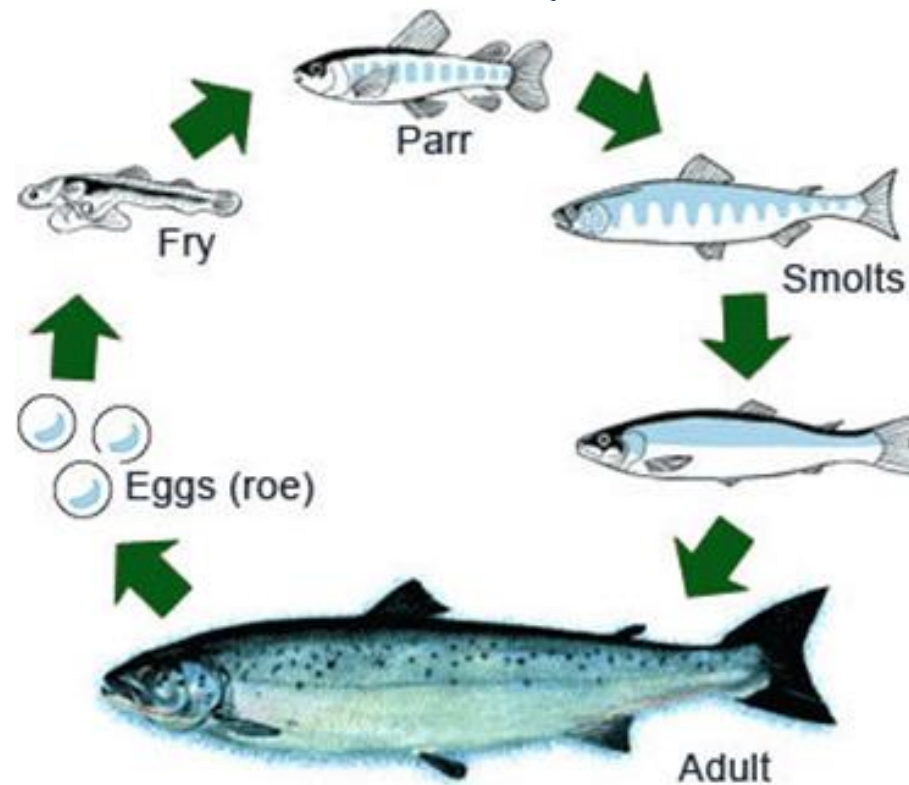


Mark application points





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

(2) Injection sites

Intra-peritoneal cavity

Muscle

(3) Solutions

Water

Vaccine

Emulsion

Water

Vaccine

Emulsion

(2) Tag/Control

T

C

T

C

T

C

T

C

T

C

T

C

Replicate fish

12

12

12

12

12

12

12

12

12

12

12

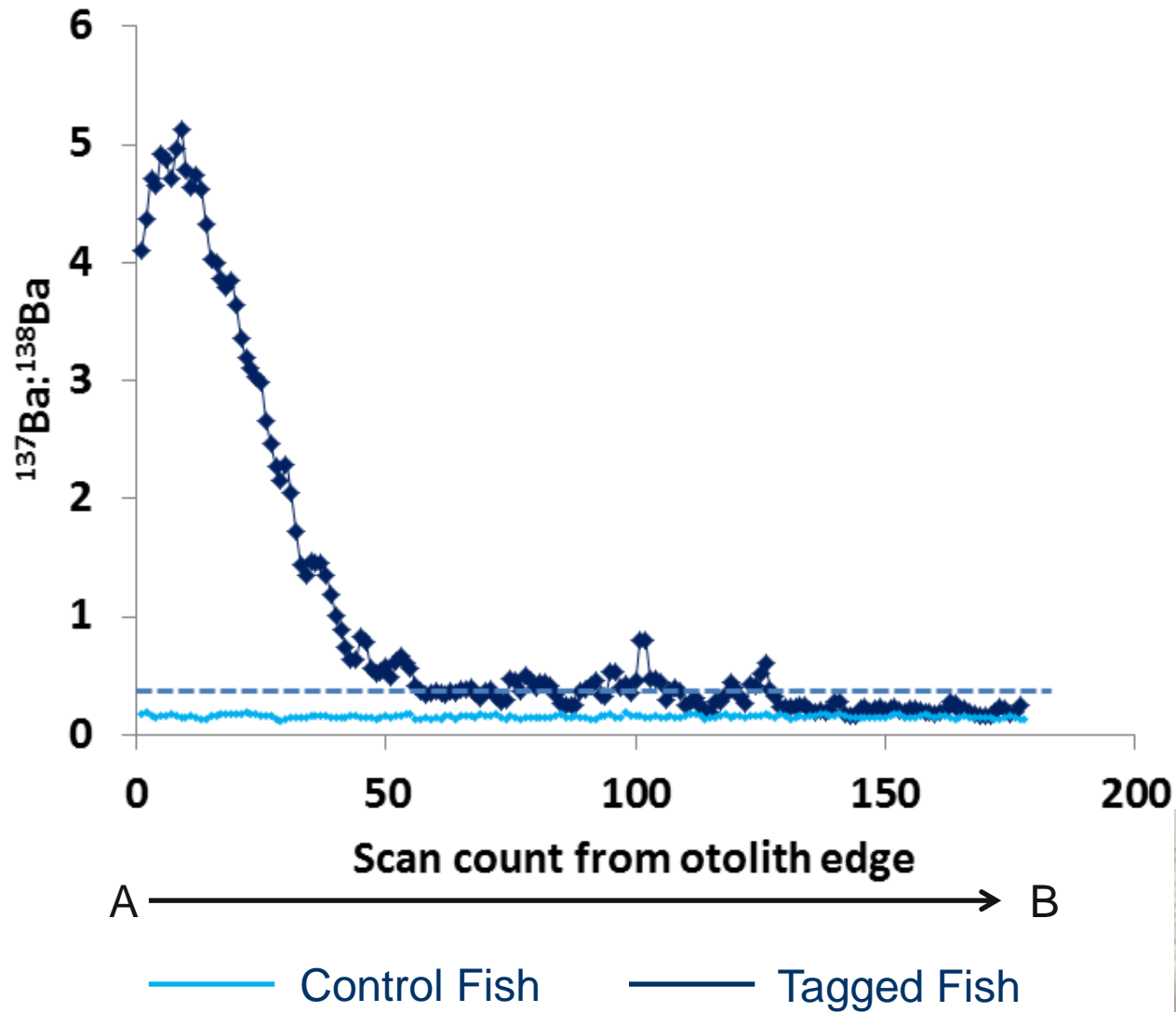
12

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



Results

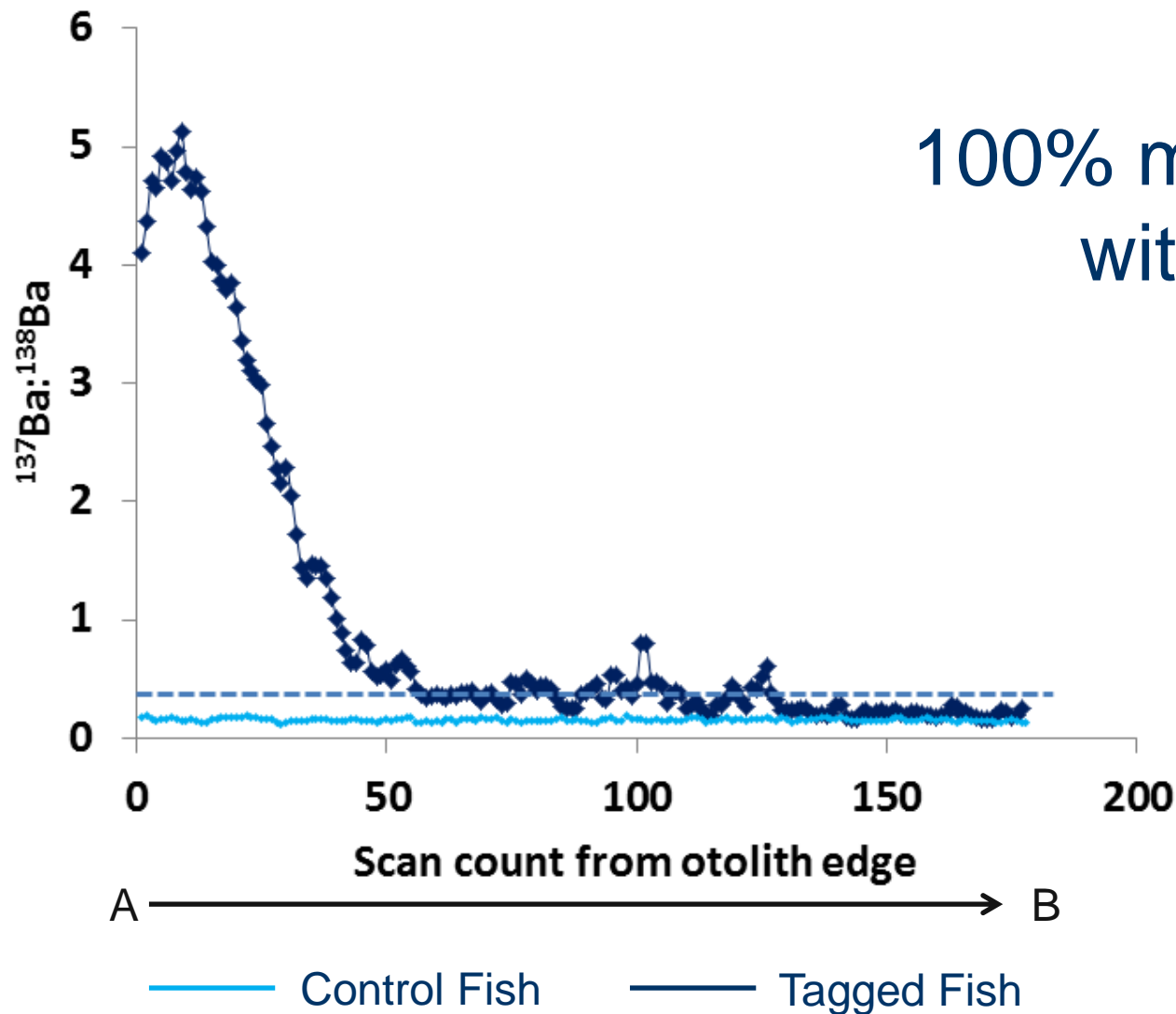
$^{137}\text{Ba} : ^{138}\text{Ba}$



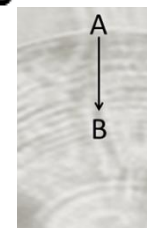


Mark Success

$^{137}\text{Ba}:^{138}\text{Ba}$



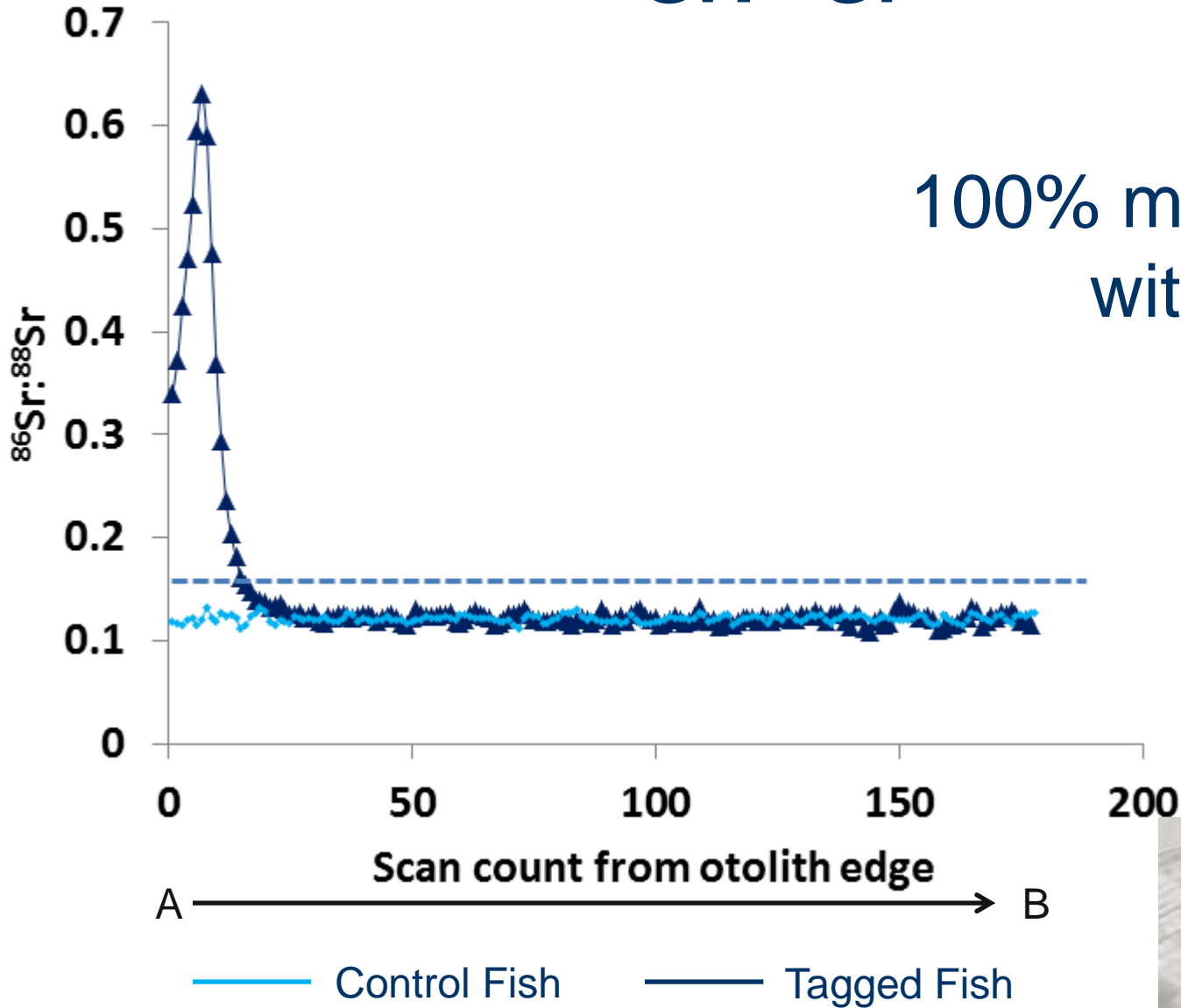
100% mark uptake
with ^{137}Ba



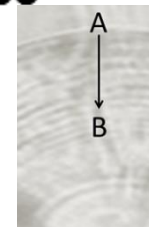


Mark Success

$^{86}\text{Sr}:^{88}\text{Sr}$



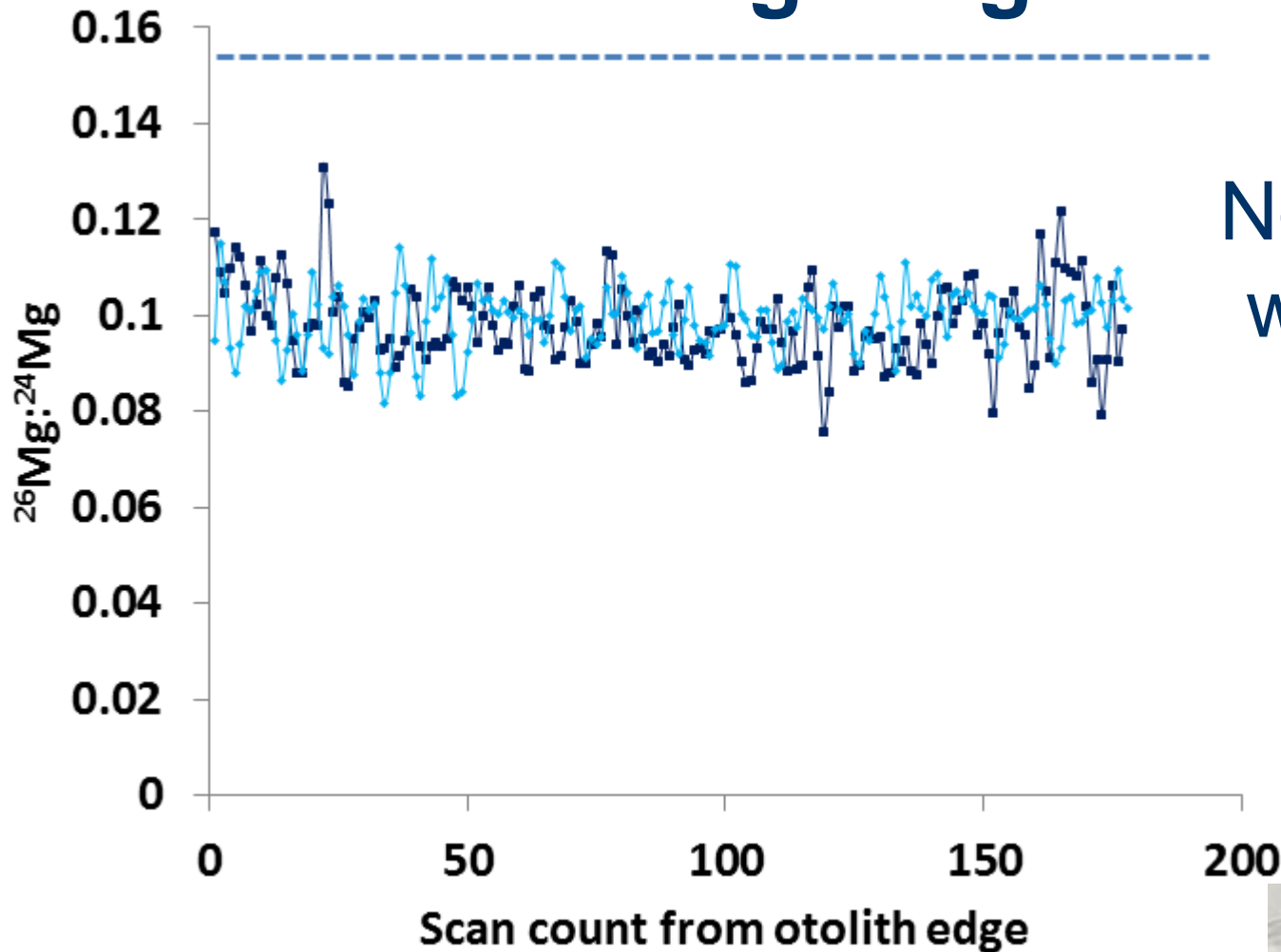
100% mark uptake
with ^{86}Sr





Mark Success

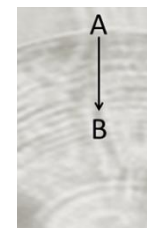
$^{26}\text{Mg} : ^{24}\text{Mg}$



No uptake
with ^{26}Mg

A → B

— Control Fish — Tagged Fish





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:

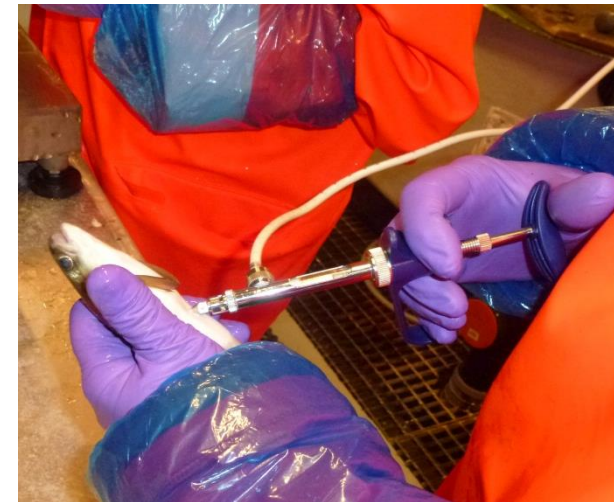
- **1** : ^{137}Ba
- **4** : ^{137}Ba , ^{135}Ba , ^{136}Ba , ^{86}Sr
- **7** : ^{137}Ba , ^{136}Ba , ^{135}Ba , ^{134}Ba , ^{87}Sr , ^{86}Sr & ^{26}Mg

Concentrations:

($\mu\text{g. g}^{-1}$ fish weight)

(Average weight 102 +/- 0.6 g)

1 μg
0.1 μg
0.01 μg
0.001 μg





Experimental design

(3) Combinations

Single

Four

Seven

(4) Concentrations

1, 0.1, 0.01, 0.001

1, 0.1, 0.01, 0.001

1, 0.1, 0.01, 0.001

($\mu\text{g. g}^{-1}$ fish weight)

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 ($\mu\text{g. g}^{-1}$ fish)	^{137}Ba						
1	1							
	0.1							
	0.01							
	0.001							



Results

Number of Markers	Concentration ($\mu\text{g. g}^{-1}$ fish)	Mark uptake						
		^{137}Ba						
1	1	100%						
	0.1	100%						
	0.01	100%						
	0.001	100%						



Results

Number of Markers	Concentration ($\mu\text{g. g}^{-1}$ 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

Number of Markers	Concentration ($\mu\text{g. g}^{-1}$ 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	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 ($\mu\text{g. g}^{-1}$ 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 ($\mu\text{g. g}^{-1}$ 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 **$0.001 \mu\text{g}$** per gram of fish



Conclusions

- ^{137}Ba as a single marker can be used at concentrations as low as $0.001 \mu\text{g}$ per gram of fish
- Combinations of ^{134}Ba , ^{135}Ba , ^{136}Ba and ^{137}Ba can be used at concentrations as low as $0.01 \mu\text{g}$ 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.

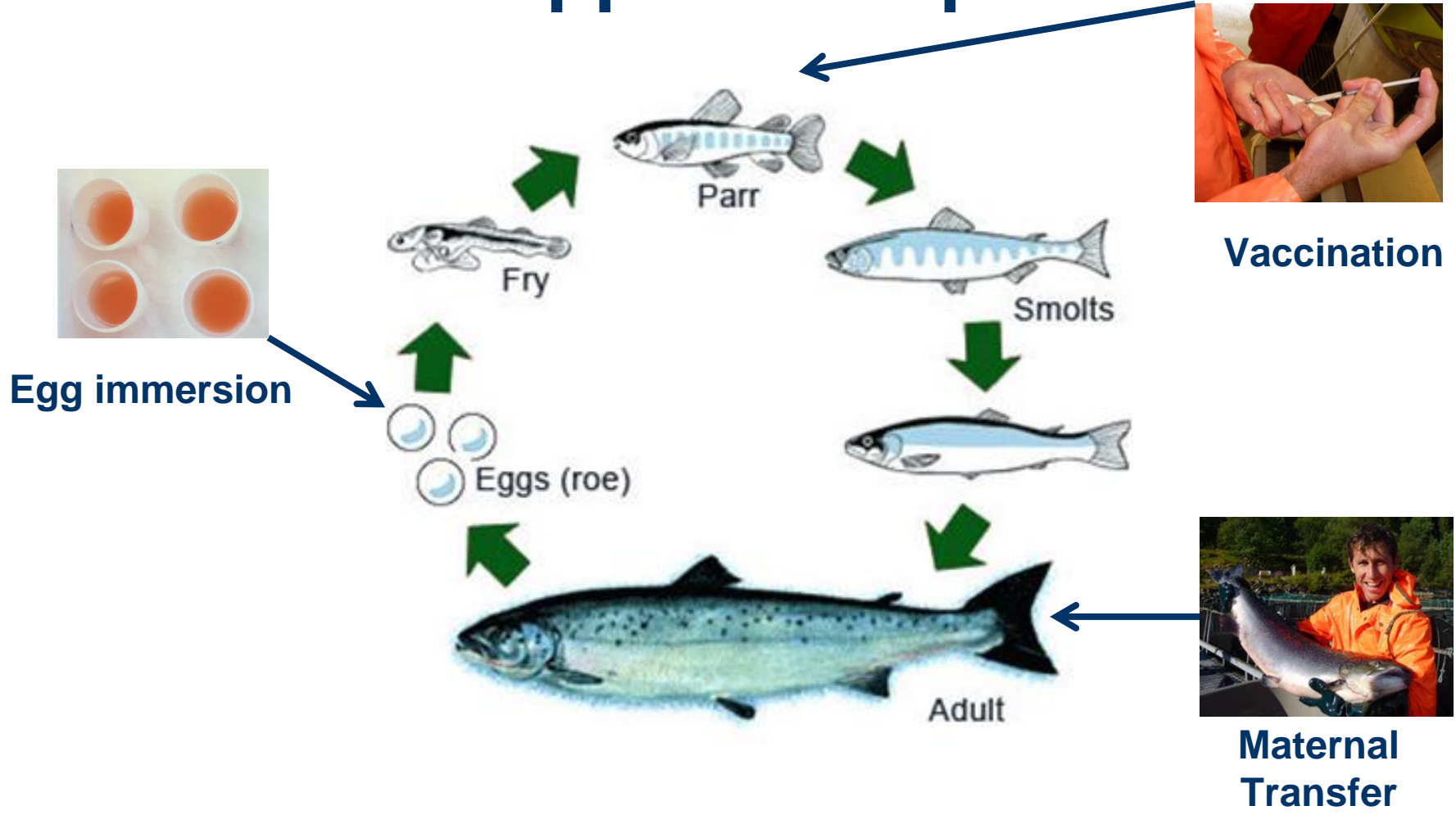


Mass Marking Via Maternal Transfer



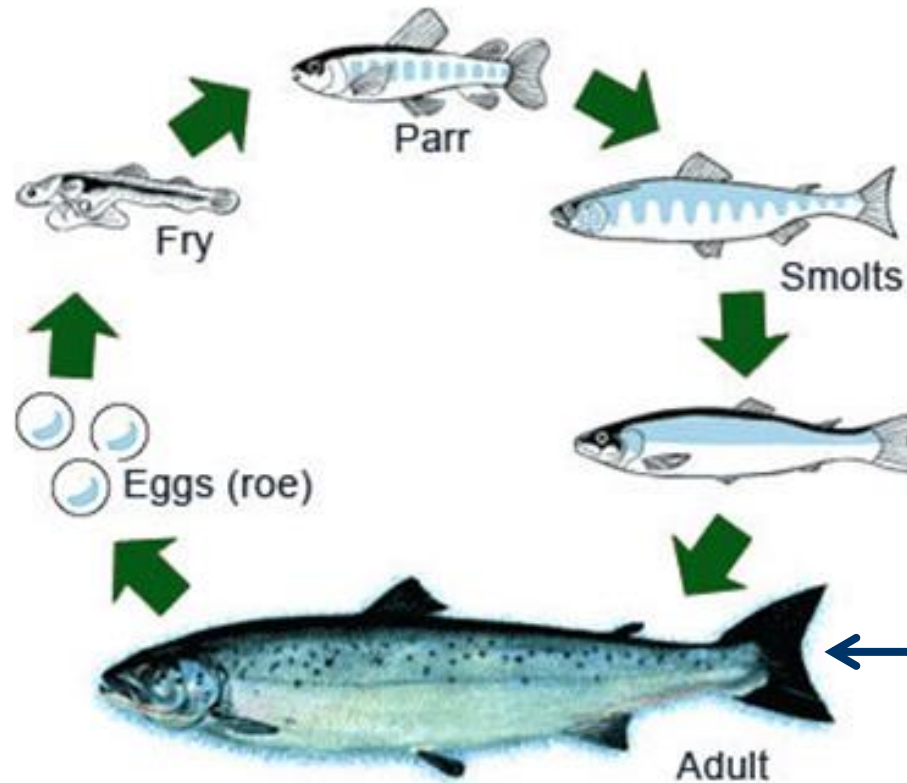


Mark application points





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

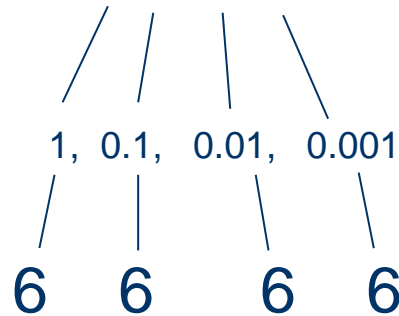
(1) Combination

Seven markers

(4) Concentrations

(μg isotope per g brood fish weight)

Replicate fish



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 $\mu\text{g} \cdot \text{g}^{-1}$ 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 $\mu\text{g. g}^{-1}$ 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 $\mu\text{g. g}^{-1}$ 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 $\mu\text{g} \cdot \text{g}^{-1}$ 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 $0.02 \mu\text{g} \cdot \text{g}^{-1}$ 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 $\mu\text{g. g}^{-1}$** brood stock
- Combinations using ^{136}Ba and ^{134}Ba can be created at a concentrations as low as of **0.2 $\mu\text{g. g}^{-1}$** brood stock

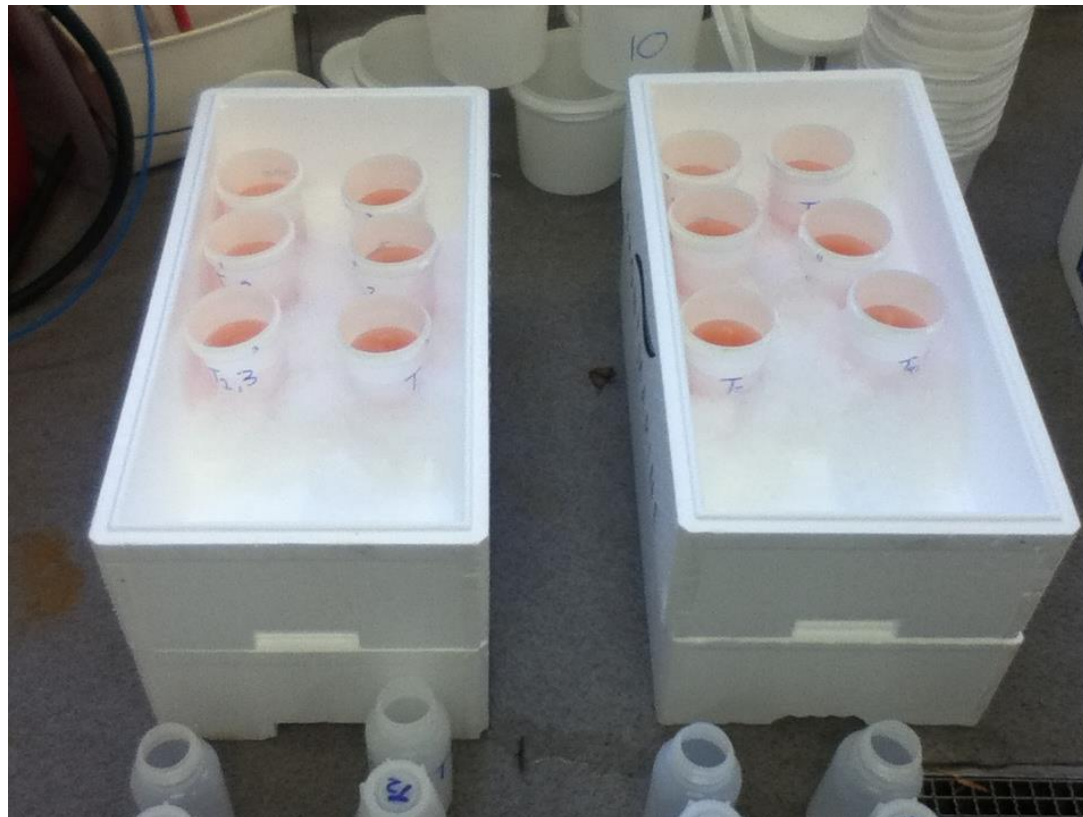


Conclusions

- 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 $\mu\text{g. g}^{-1}$** brood stock
- Combinations using ^{136}Ba and ^{134}Ba can be created at a concentrations as low as of **0.2 $\mu\text{g. g}^{-1}$** brood stock
- Combinations using ^{87}Sr and ^{86}Sr can be created at a concentration as low as **2 $\mu\text{g. g}^{-1}$** brood stock

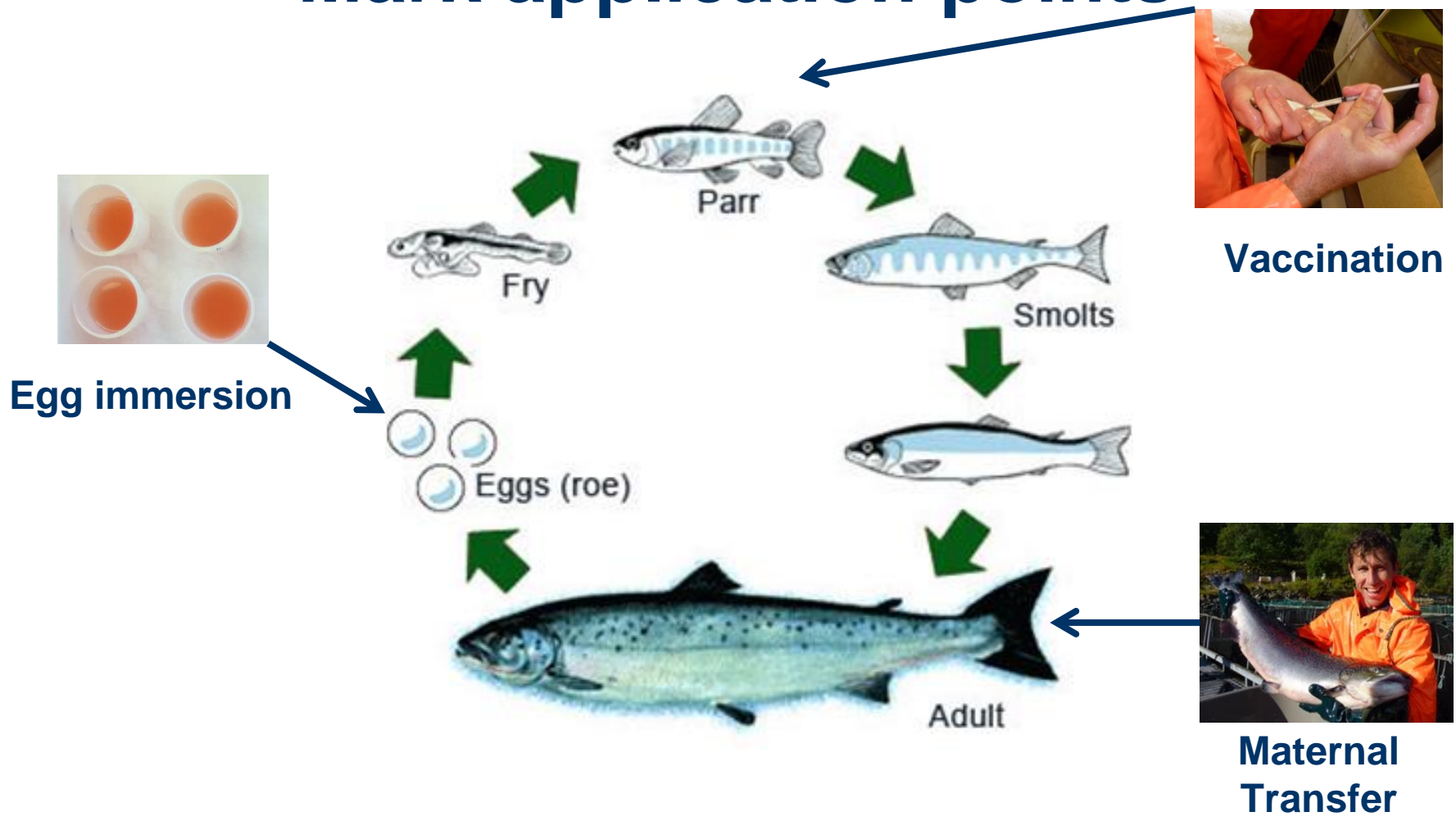


Mass Marking Via Egg Immersion



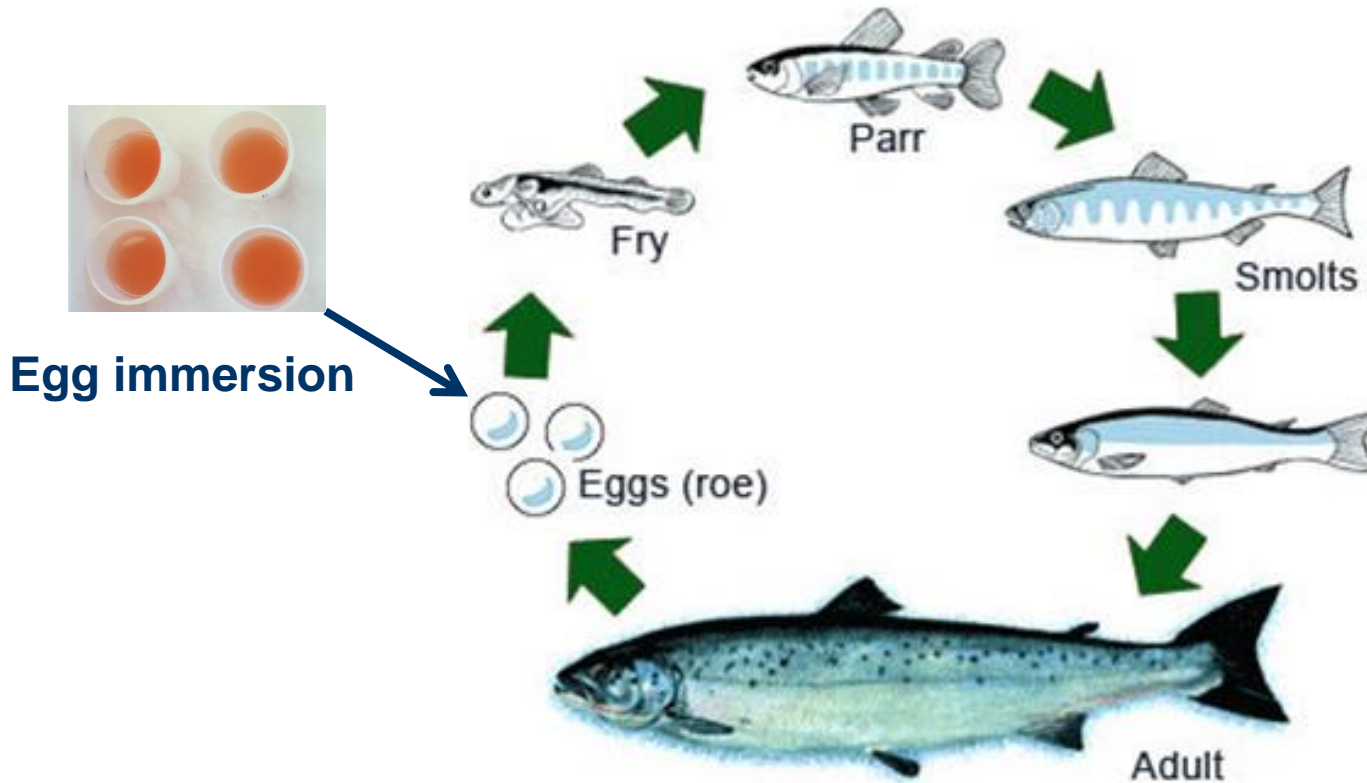


Mark application points





Mark application points





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



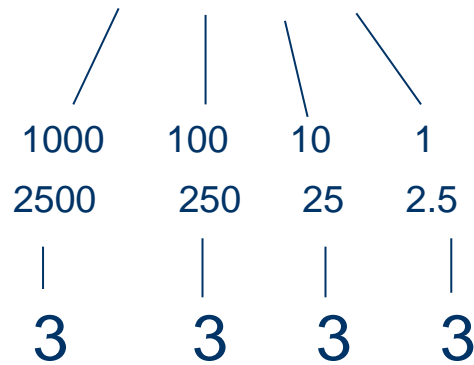


Experimental design

(1) Combination

Seven markers

(4) Concentrations Ba
(μg per litre water) Mg & Sr



Replicate batches

Plus 3 control batches immersed in pure water

Each batch contained ~1000 fertilised eggs

First otolith samples taken before first feeding





Results

Marker Concentrations ($\mu\text{g. L}^{-1}$)		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 ($\mu\text{g. L}^{-1}$)		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

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- ^{137}Ba and ^{135}Ba 100% mark uptake at a concentration of $100 \mu\text{g. L}^{-1}$



Conclusions

- Concentration of marker important
- ^{137}Ba and ^{135}Ba 100% mark uptake at a concentration of $100 \mu\text{g. L}^{-1}$
- ^{136}Ba 100% mark uptake at a concentration of $1000 \mu\text{g. L}^{-1}$



Conclusions

- Concentration of marker important
- ^{137}Ba and ^{135}Ba 100% mark uptake at a concentration of $100 \mu\text{g. L}^{-1}$
- ^{136}Ba 100% mark uptake at a concentration of $1000 \mu\text{g. L}^{-1}$
- Length of immersion time requires further investigation

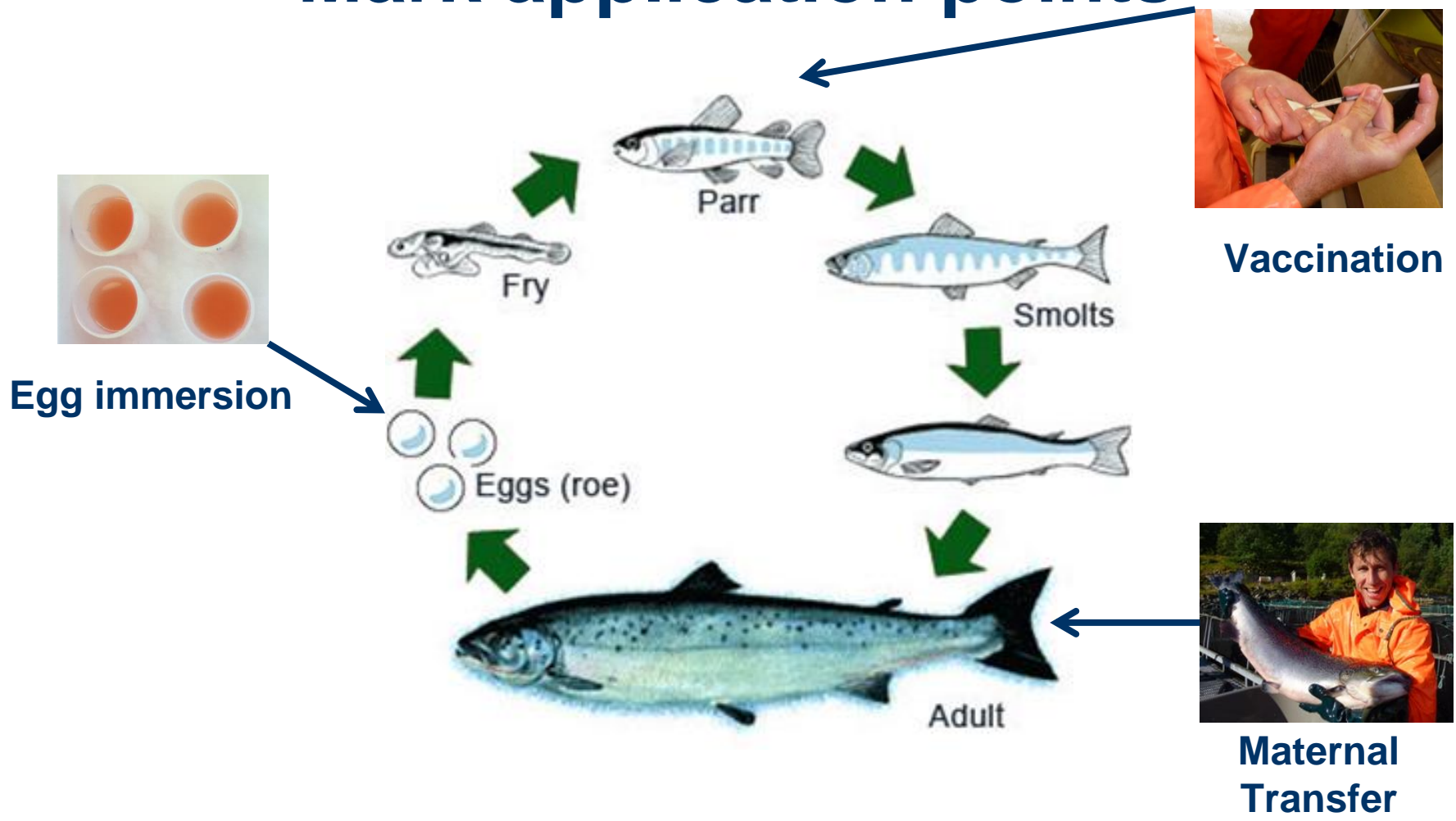


Summary

- 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







Cost projections

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



Cost projections

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Scenario 2: Marking 80% of production (24 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)



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 $\mu\text{g. g}^{-1}$ fish weight (15 g for 300 million parr)	\$4.36 per mg (~ \$0.0006 per parr)	\$65400



Cost projections

Scenario 1

Marking 300 million farmed Atlantic salmon with 1 Ba code

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Egg immersion (2000 eggs L ⁻¹)	Material Cost (\$US)	Total
^{137}Ba @ 100 $\mu\text{g. L}^{-1}$ (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 $\mu\text{g. g}^{-1}$ 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 $\mu\text{g. L}^{-1}$ (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 $\mu\text{g. g}^{-1}$ 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
				\$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
Leroy	13%	39000000	1V	\$0.0002	\$8,502
Salmar	9%	27000000	3V	\$0.0003	\$8,910
Cermaq	5%	15000000	1V2MT	\$0.0004	\$5,886
Grier	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