# Length of Atlantic salmon smolt and their subsequent marine survival

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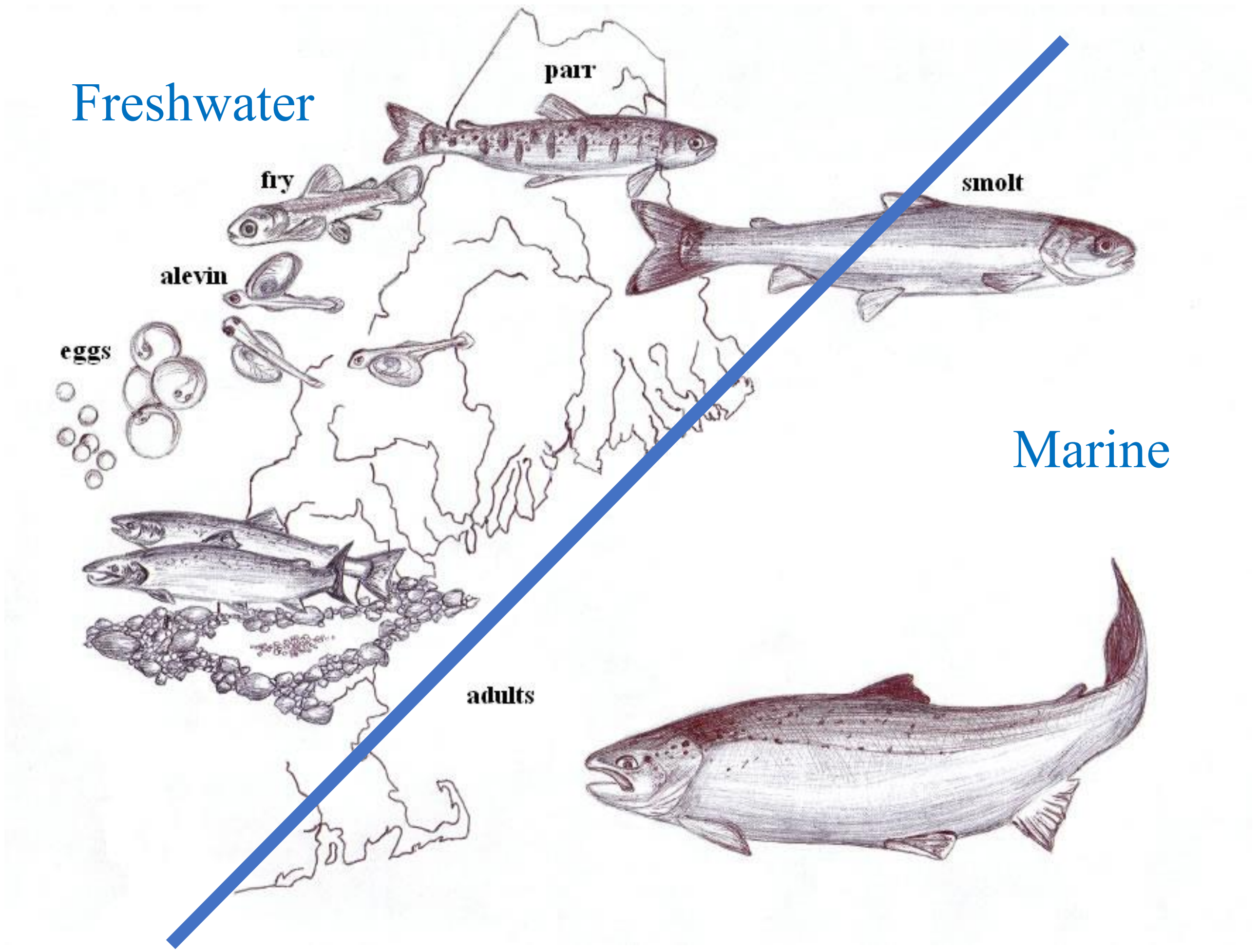
# Atlantic salmon life cycle

- Anadromous
  - Freshwater
  - Marine

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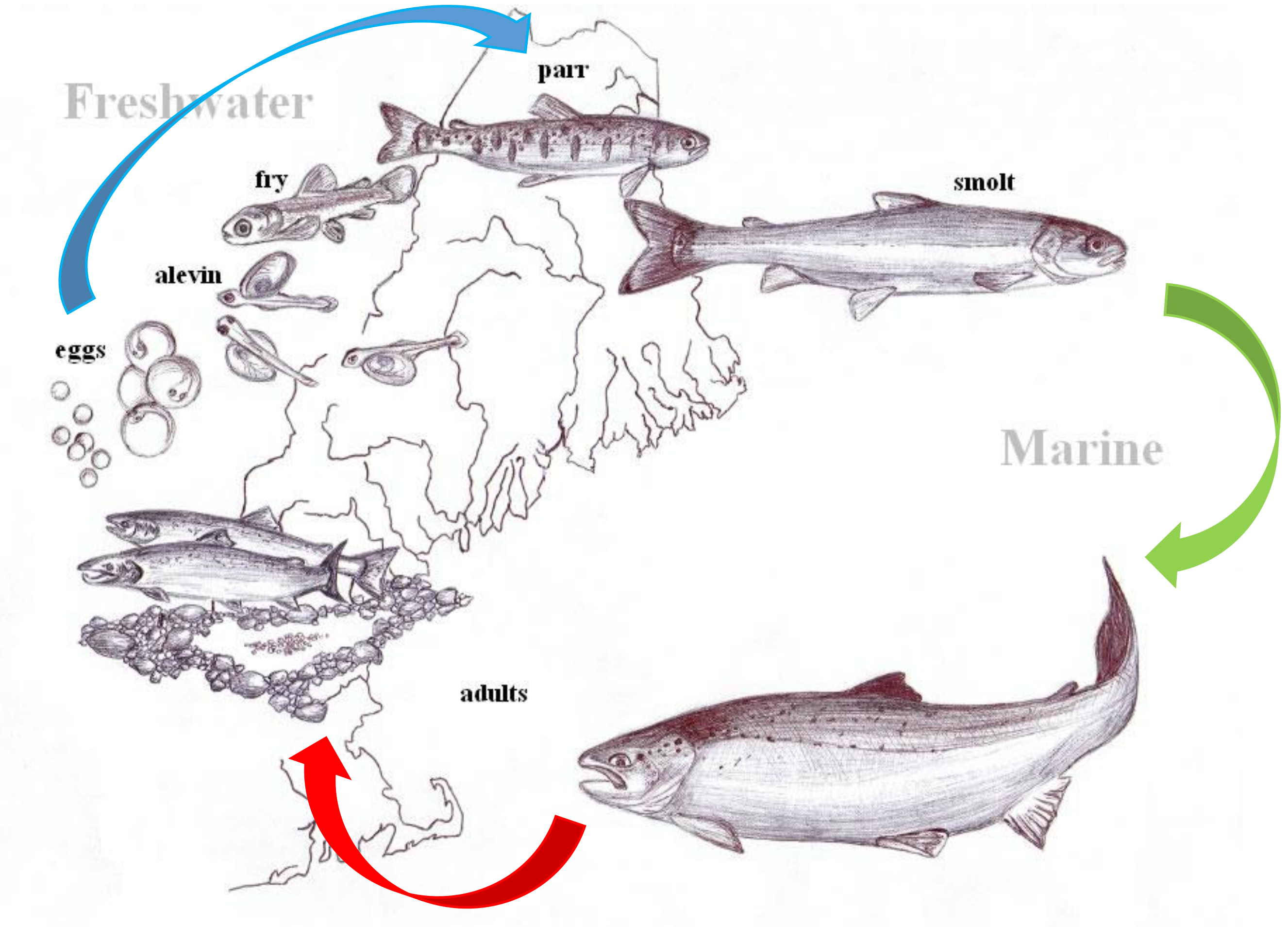
# Atlantic salmon life cycle

- Anadromous
  - Freshwater
  - Marine

- Three major transitions
  - Egg > Smolt (freshwater survival)
  - Smolt > Adult (marine survival)
  - Adult > Spawner (fishing mortality)

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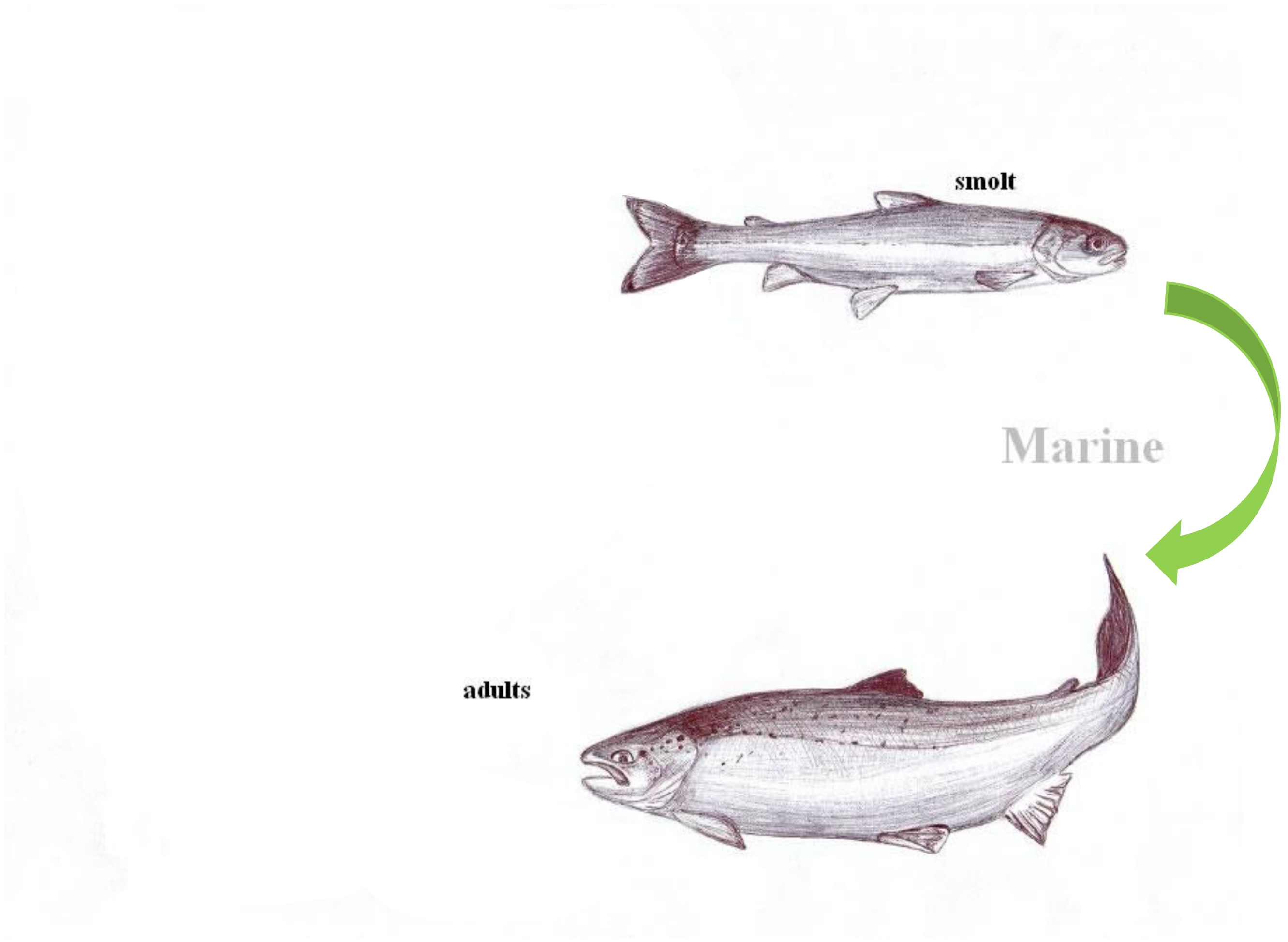
# Atlantic salmon life cycle

– Smolt > Adult (marine survival)

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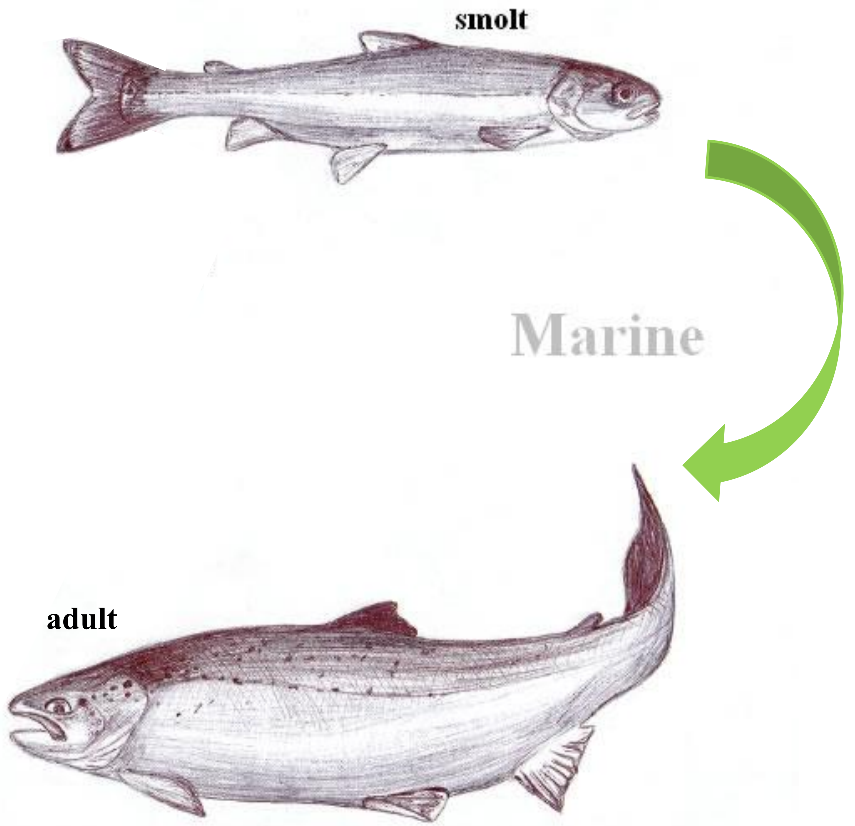
# Atlantic salmon marine survival

- Risks
  - Physiological stress of F/W -> S/W
    - Temperature, salinity, etc.
  - Novel, abundant predators
  - Distant-water fisheries
    - Highly regulated since 1990

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# Previous research & hypotheses

- Marine survival might be related to:
  - Smolt length
    - Larger smolt better survive
  - Origin
    - Wild (vs hatchery) smolts better survive
  - Environmental conditions
    - Better growth conveys better survival

Potter, E. C. E., Maoileidigh, N. O. & Chaput, G. *(Eds.)* 2003. Marine mortality of Atlantic salmon, *Salmo salar* L: methods and measures. DFO Canadian Science Advisory Secretariat - Research Document 2003/101

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# Question & prediction

- Question:

  Does marine survival increase with increasing smolt length?

- Prediction:

  Estimated marine survival will increase with smolt length

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# Method

1) Estimate marine survival from Bayesian State-Space model

2) Adapt BSSM to estimate effect of individual smolt length

3) Consider alternative hypotheses: model comparison [Todo]

# Method

1) Estimate marine survival from Bayesian State-Space model

State matrix of individual $i$ $\qquad z_i = [A, ?, B, ?]$

Space matrix of individual $i$ $\qquad w_i = [1, 0, 1, 0]$

Individual $i$ observed in state $k = A$ at time $t = 1$, was unobserved at $t = 2$, was observed in $k = B$ at $t = 3$ and was unobserved at $t = 4$.

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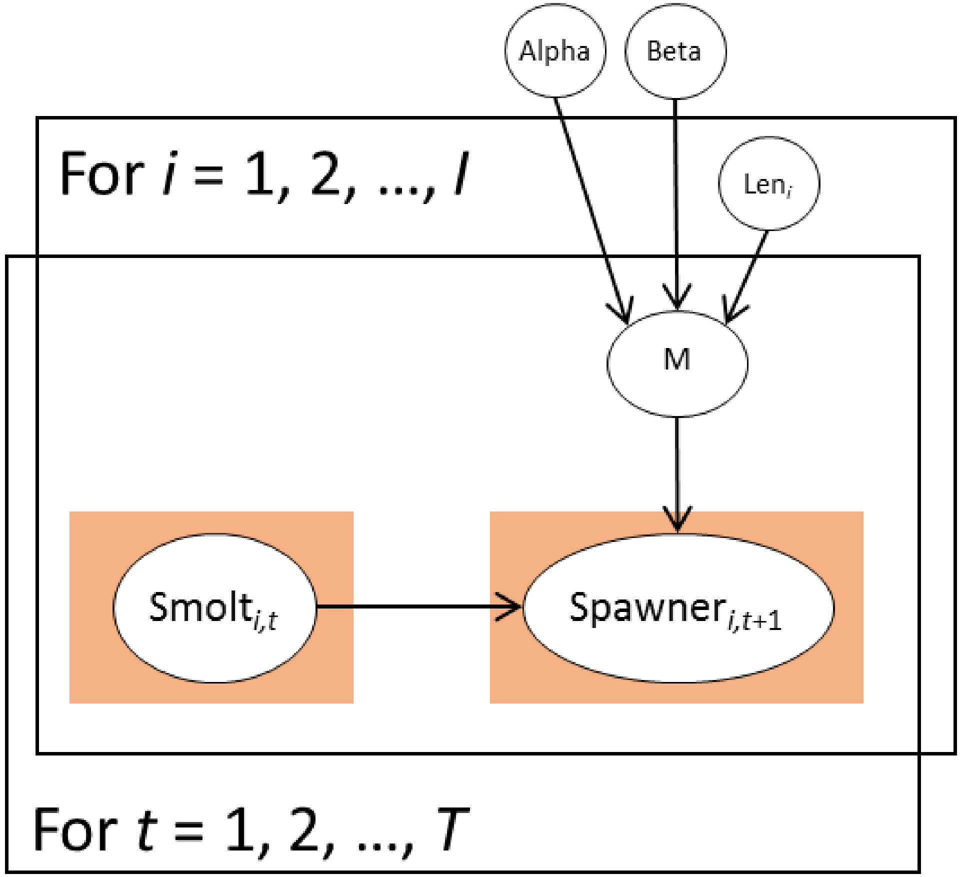
# Method

JAGS

1) Estimate marine survival from Bayesian State-Space model

- Individual-based BSSM:
  - admits individual smolt lengths
- Assimilates information to stock level:
  - admits population-level covariates



# Testing: no covariates

- Generate data & estimate parameters from same model
- Generating parameters:

| Parameter | Abbreviation | High Ms case | Low Ms case |
|---|---|---|---|
| Mean individual marine survival | Ms | 0.70 | 0.05 |
| Individual detection at release | release | 1.00 | 1.00 |
| Individual detection at first detection station | pES | 0.85 | 0.85 |
| Survival between detection stations | ESBins | 1.00 | 1.00 |

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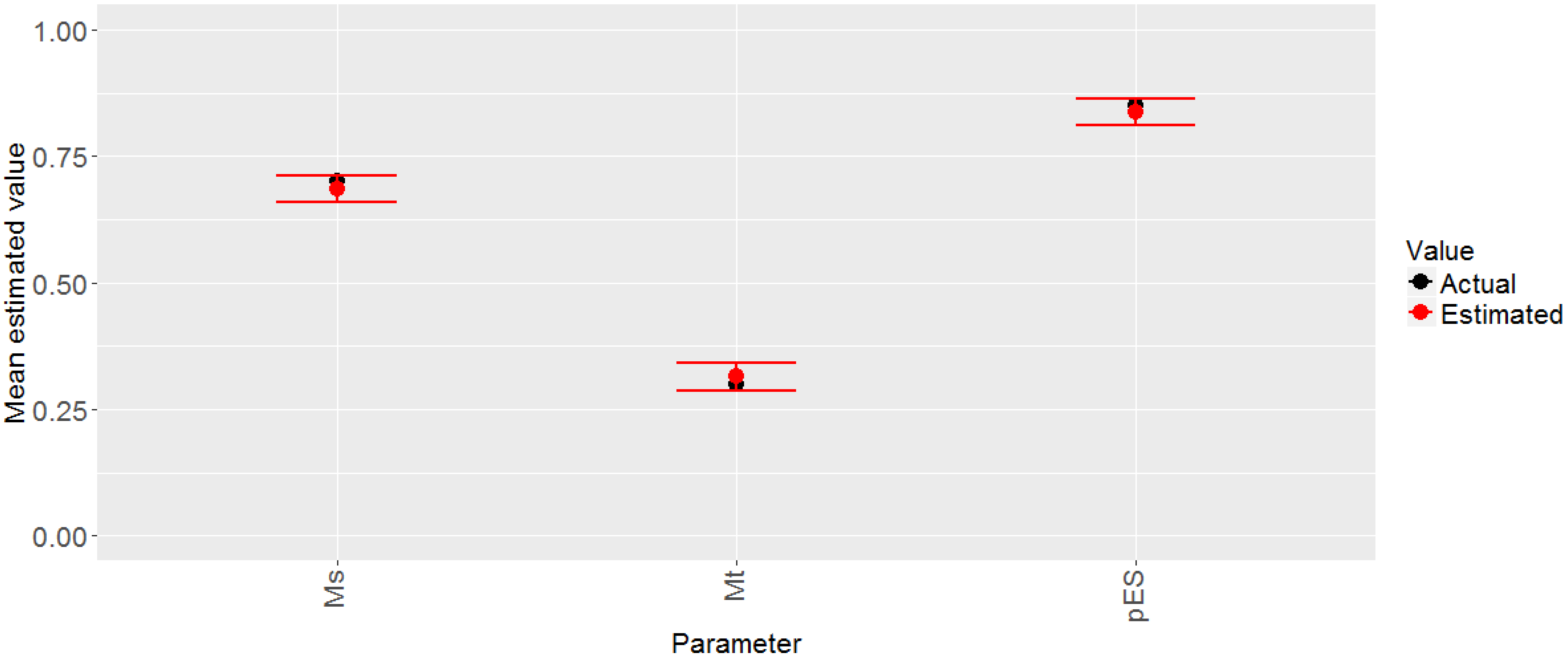
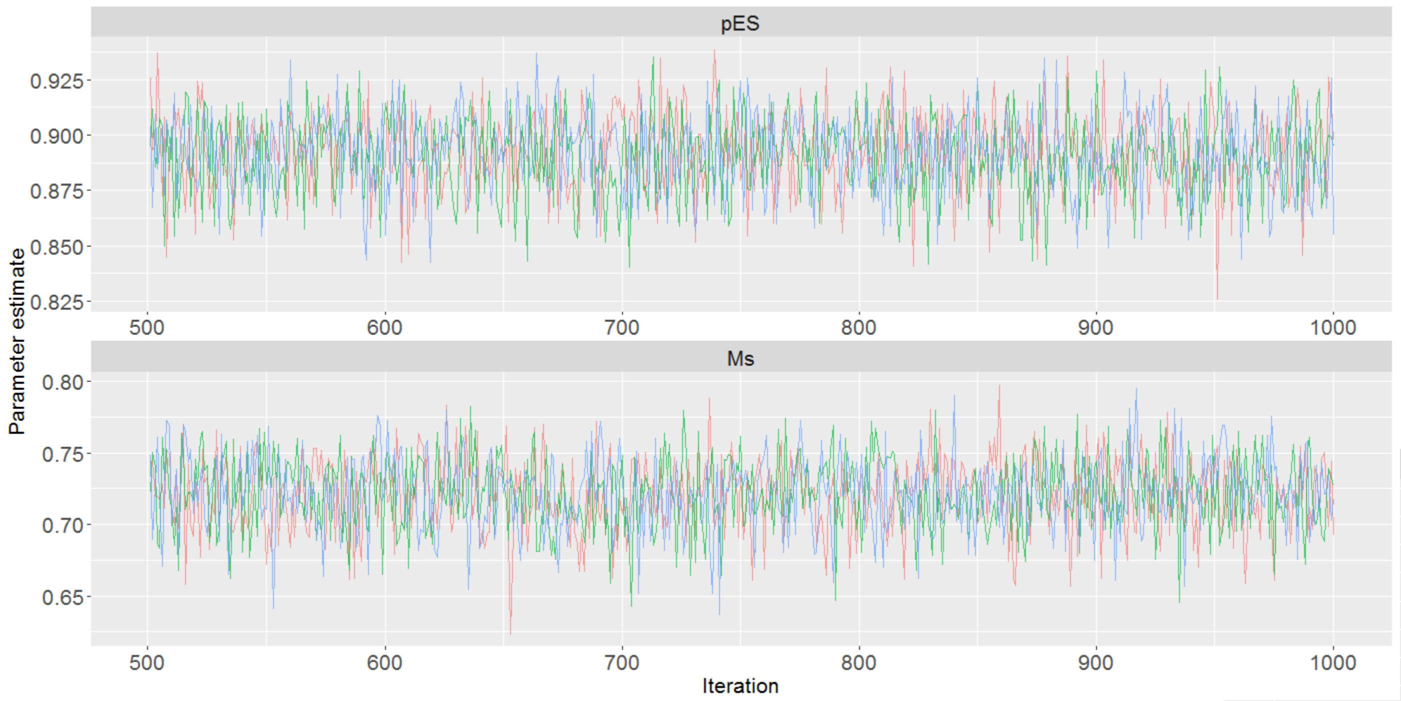
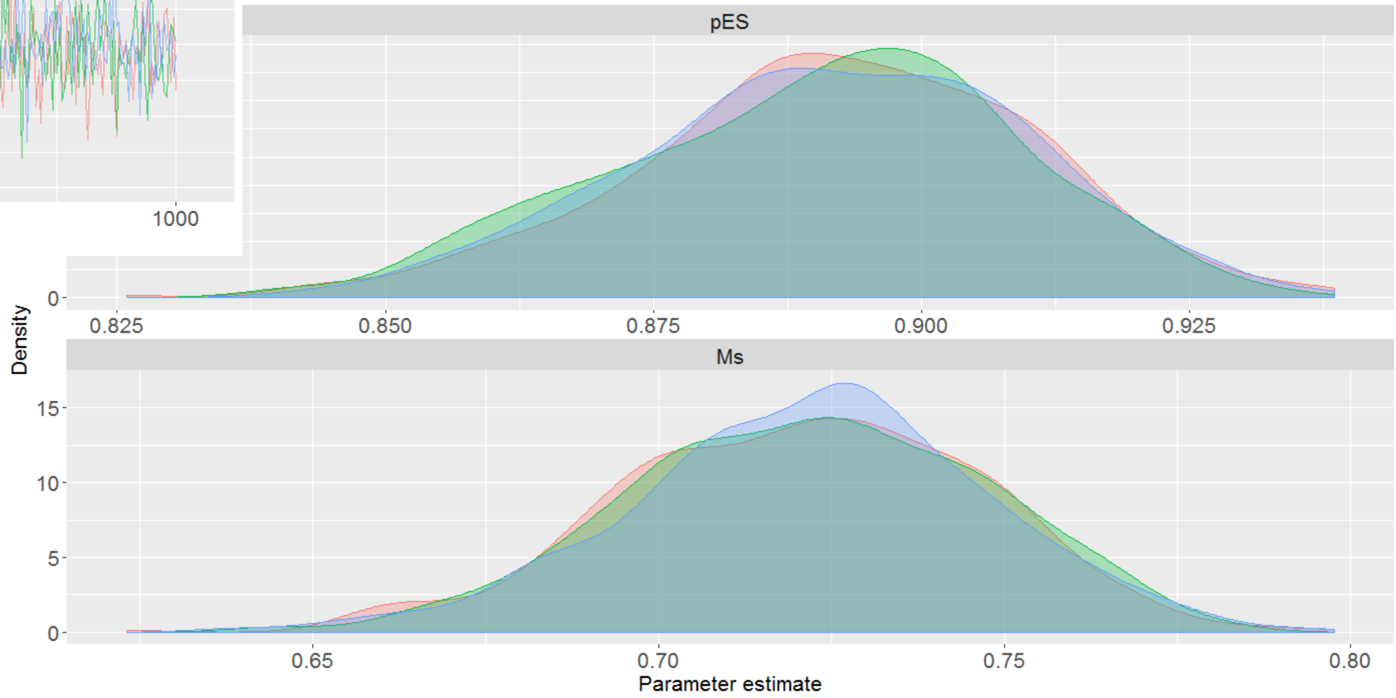
# Testing: high Ms case



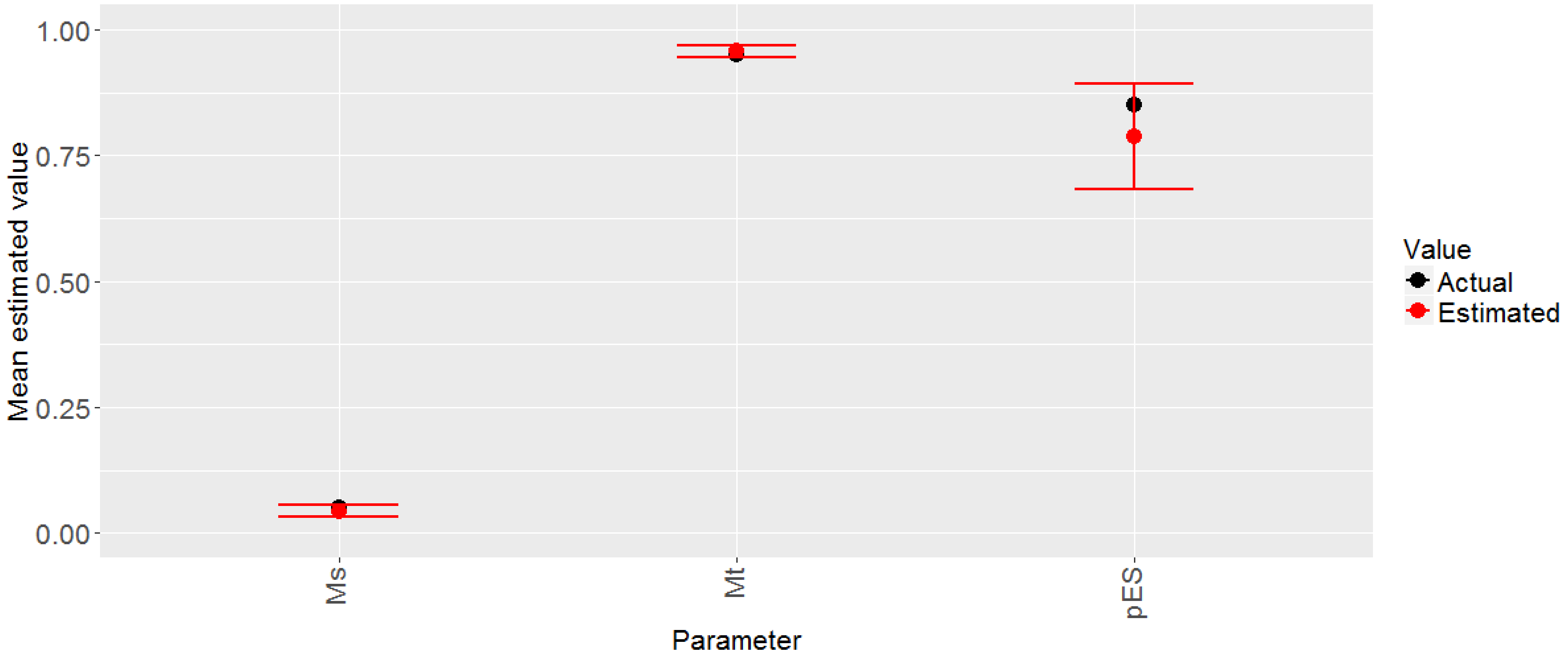
# Testing: high Ms case




```
> gelman.diag(ab)
Potential scale reduction factors:

     Point est. Upper C.I.
a_mu          1       1.00
b_mu          1       1.01

Multivariate psrf

1
```

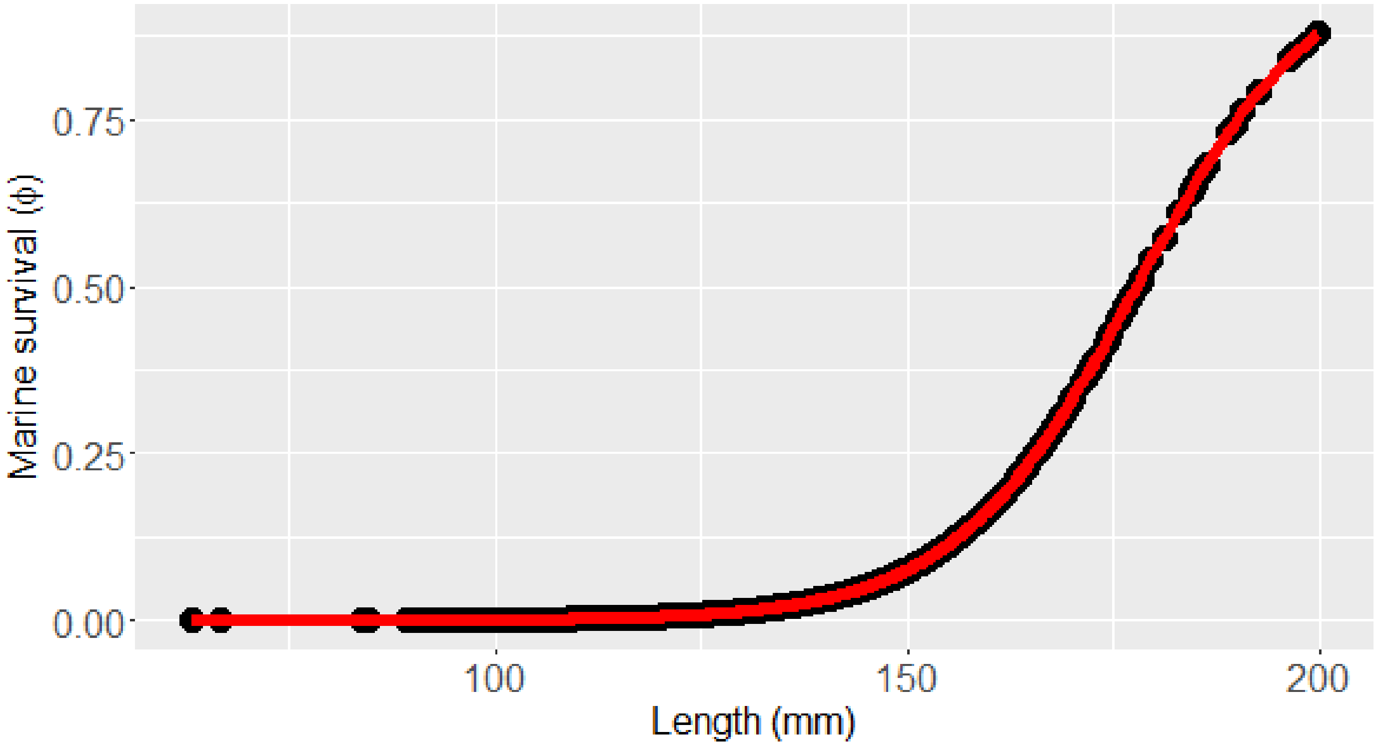


# Testing: low Ms case



# Method

## 2) Adapt BSSM to estimate effect of individual smolt length




$$\phi = \frac{1}{1 + \exp(-lp)}$$

$$lp \sim \alpha + \beta \text{Length}$$

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# Testing: length covariate

- Generate data & estimate parameters from same model
- Generating parameters:

| Parameter | Abbreviation | High Ms case | Low Ms case |
|---|---|---|---|
| Mean individual marine survival | Ms | 0.70 | 0.05 |
| Individual detection at release | release | 1.00 | 1.00 |
| Individual detection at first detection station | pES | 0.85 | 0.85 |
| Survival between detection stations | ESBins | 1.00 | 1.00 |
| Length-Survival logistic regression coefficients | a_mu, b_mu | -5, 5 | -5, 5 |

# Testing: high Ms case

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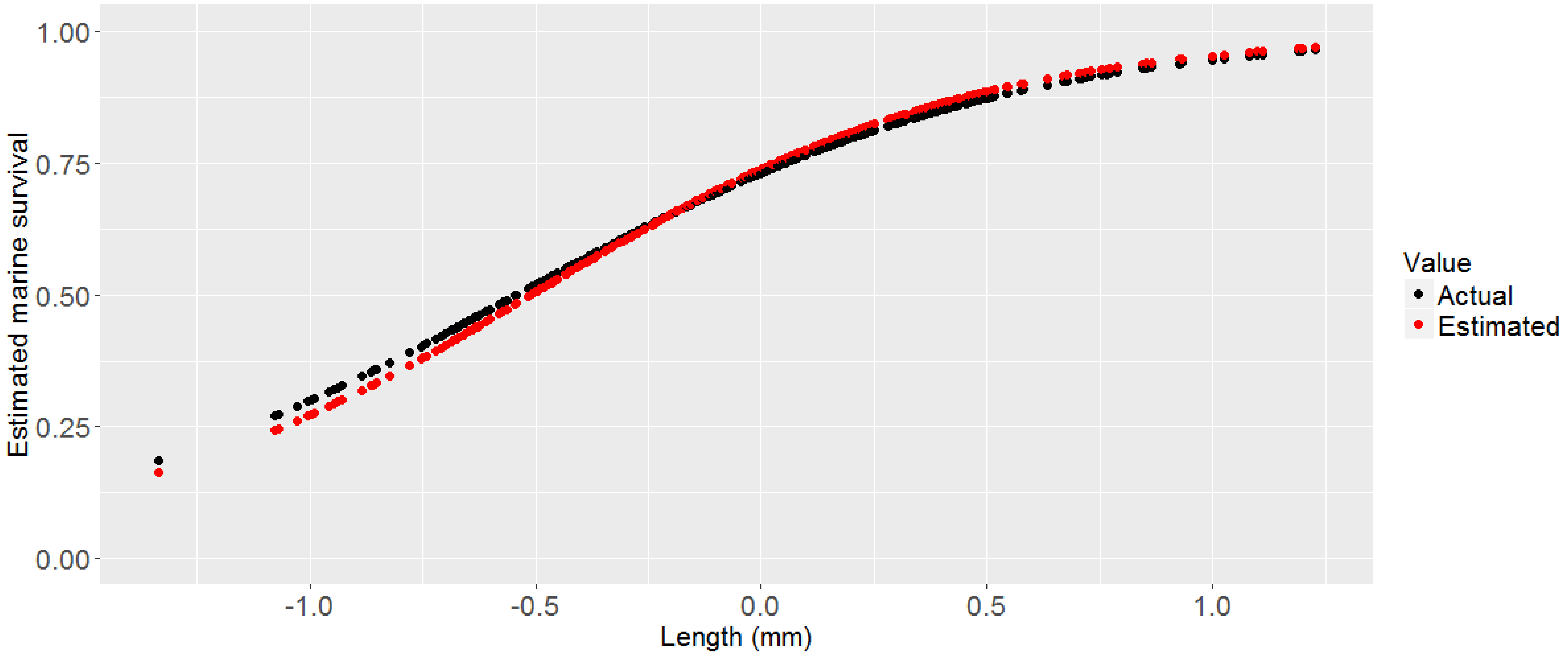

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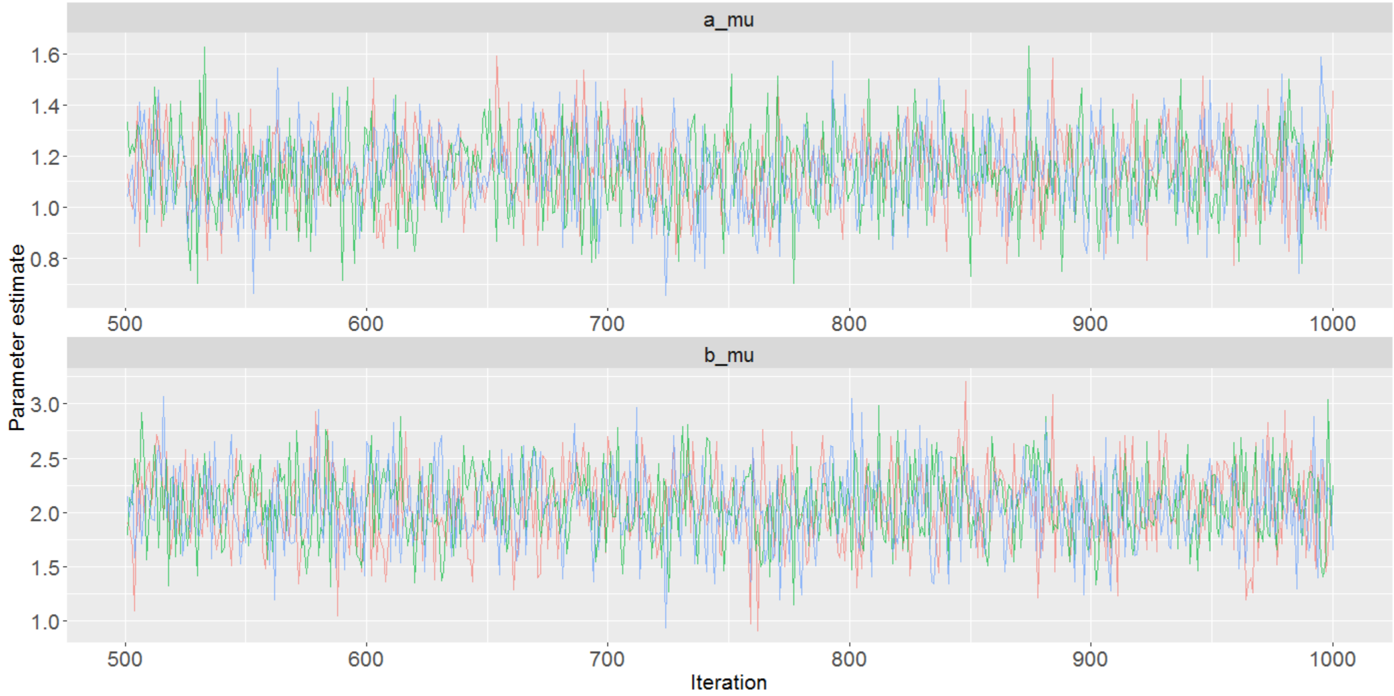


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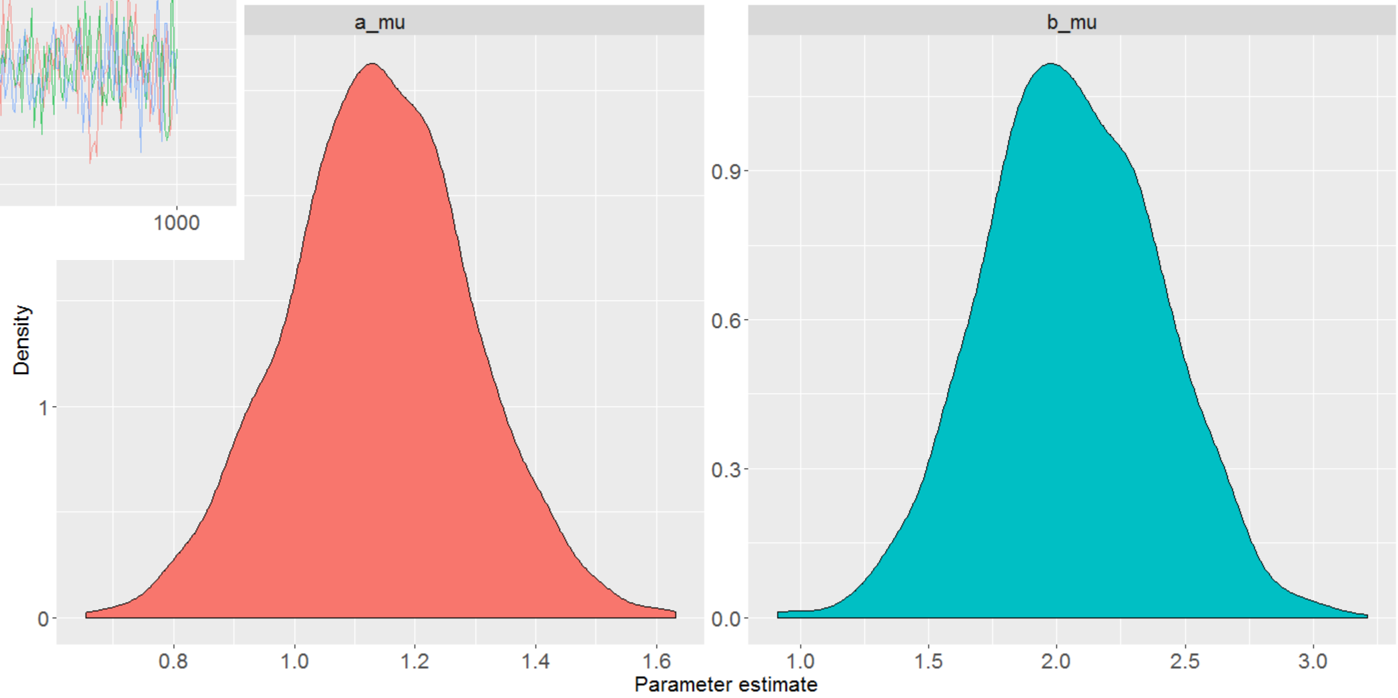

# Testing: low Ms case

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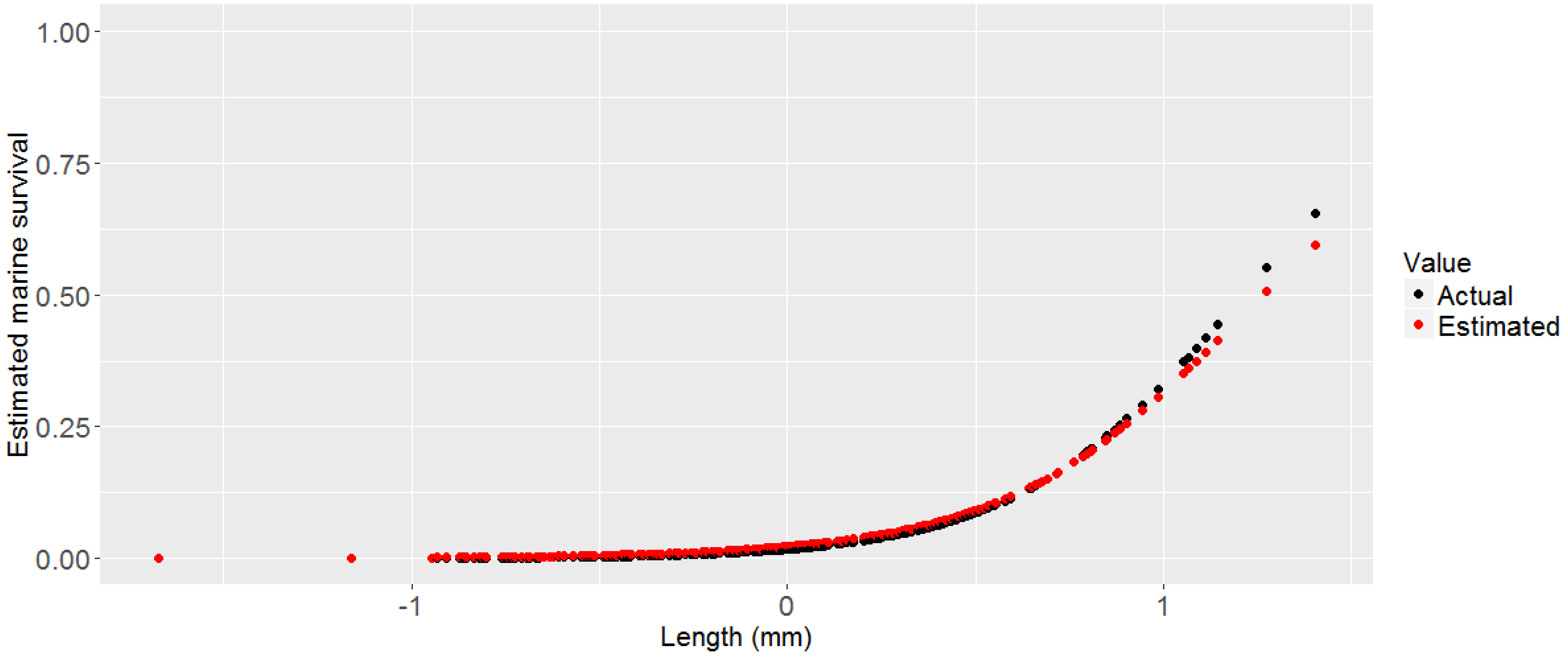

# Testing: Next steps

- Better specification of $\alpha$ and $\beta$ (logistic regression) priors?
- $\alpha$ as a random variable: account for individual variation?
- More testing…

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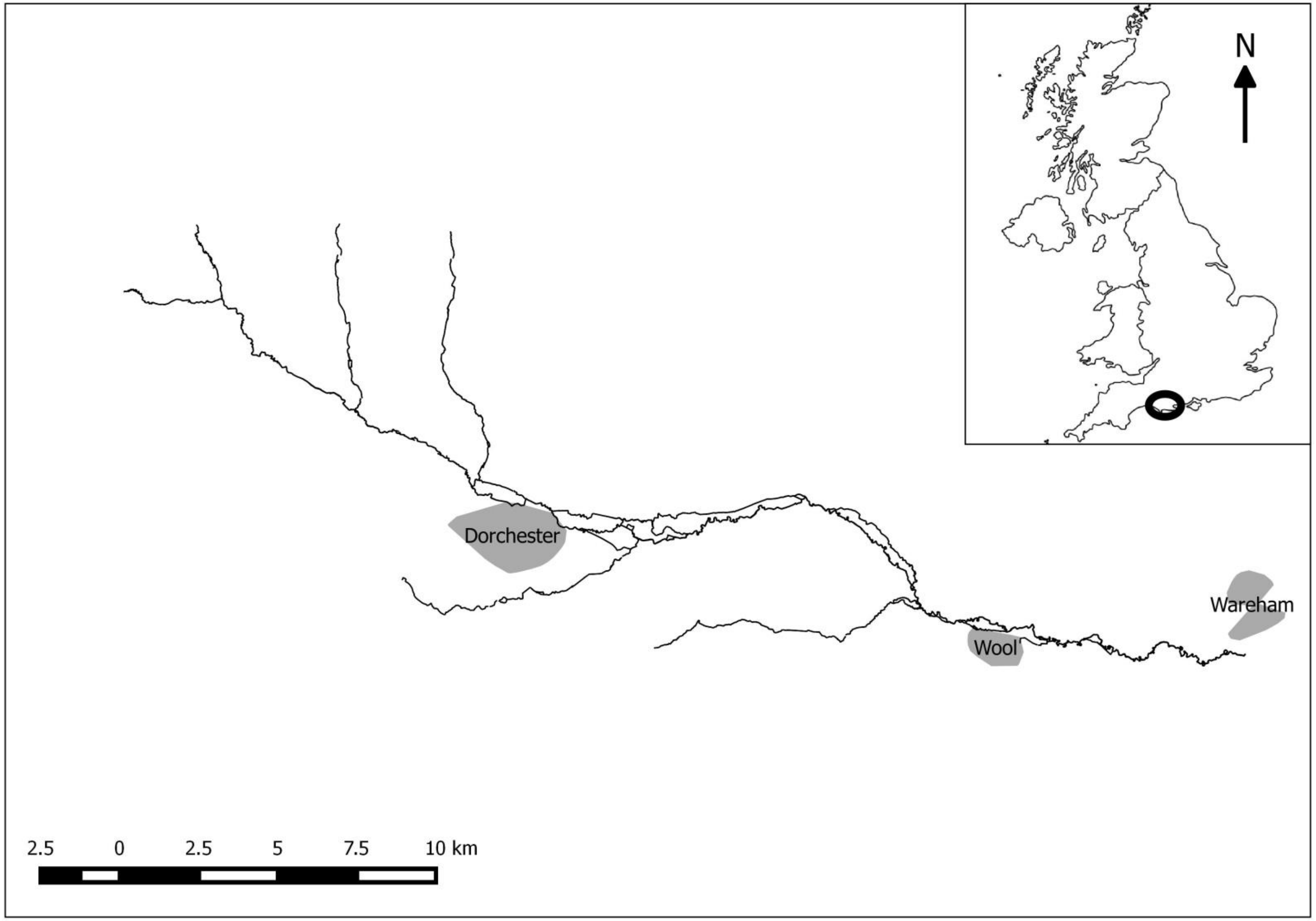
# Example: Frome salmon

- Chalk stream
- Wild salmon
- 98% smolts age 1
- PIT tags



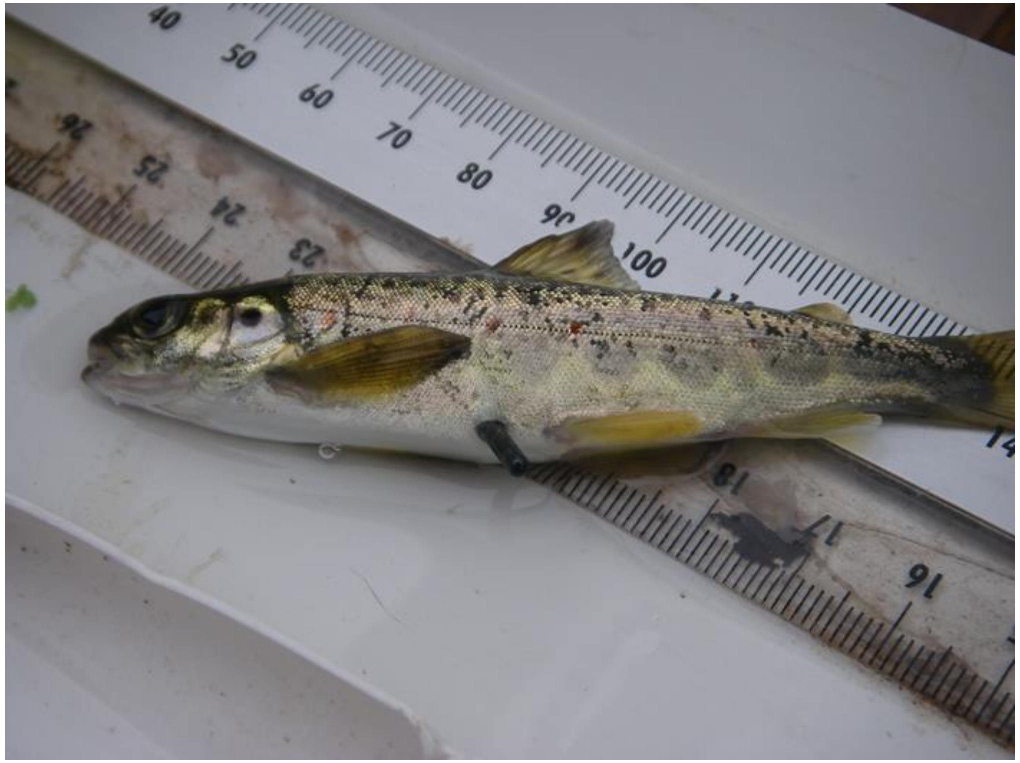
# Example: Frome salmon

<u>PIT tagging programme</u>

- Annual from 2003 – present
- Cover entire Frome catchment
- Aim to distribute 10,000 PIT tags
- PIT readers throughout catchment

<u>Sample size for analysis</u>

- 8423 PIT tagged smolts
- 191 PIT tagged adult returns



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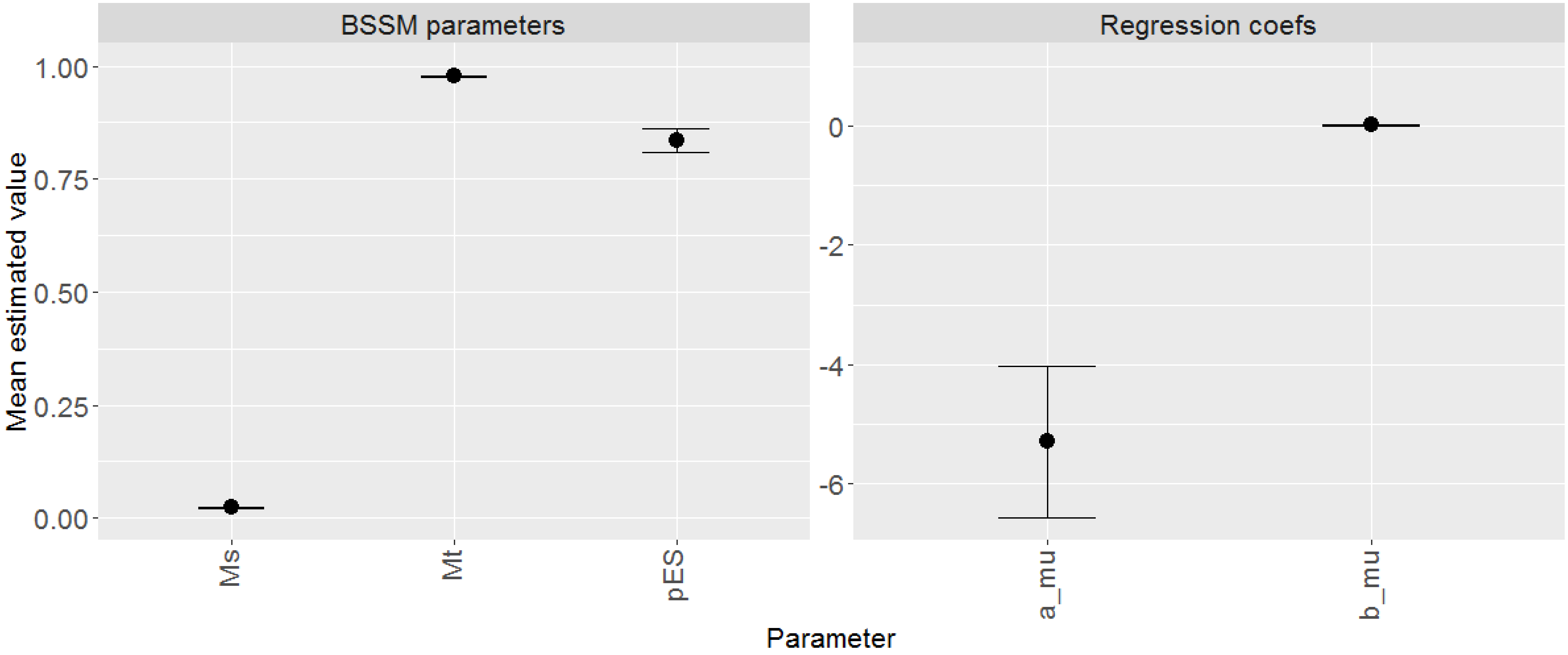
# Example: Frome salmon



# Example: Frome salmon

- Frome A. salmon marine survival estimate:
  - Chapman model = 1.8–2.5%
  - This BSSM = 2.3%

- PIT reader detection probability estimate:
  - Chapman model = 0.85
  - This BSSM = 0.84

- Chapman ≈ BSSM

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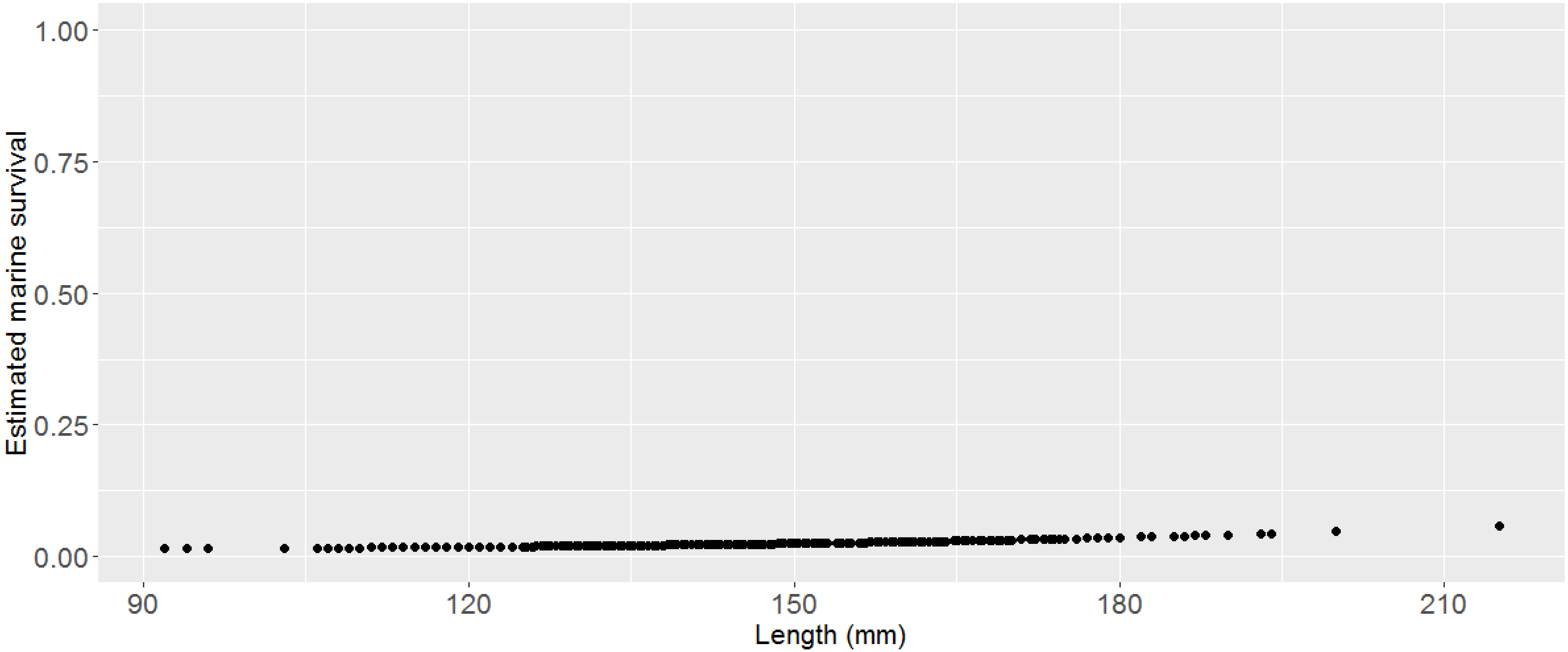
# Example: Frome salmon



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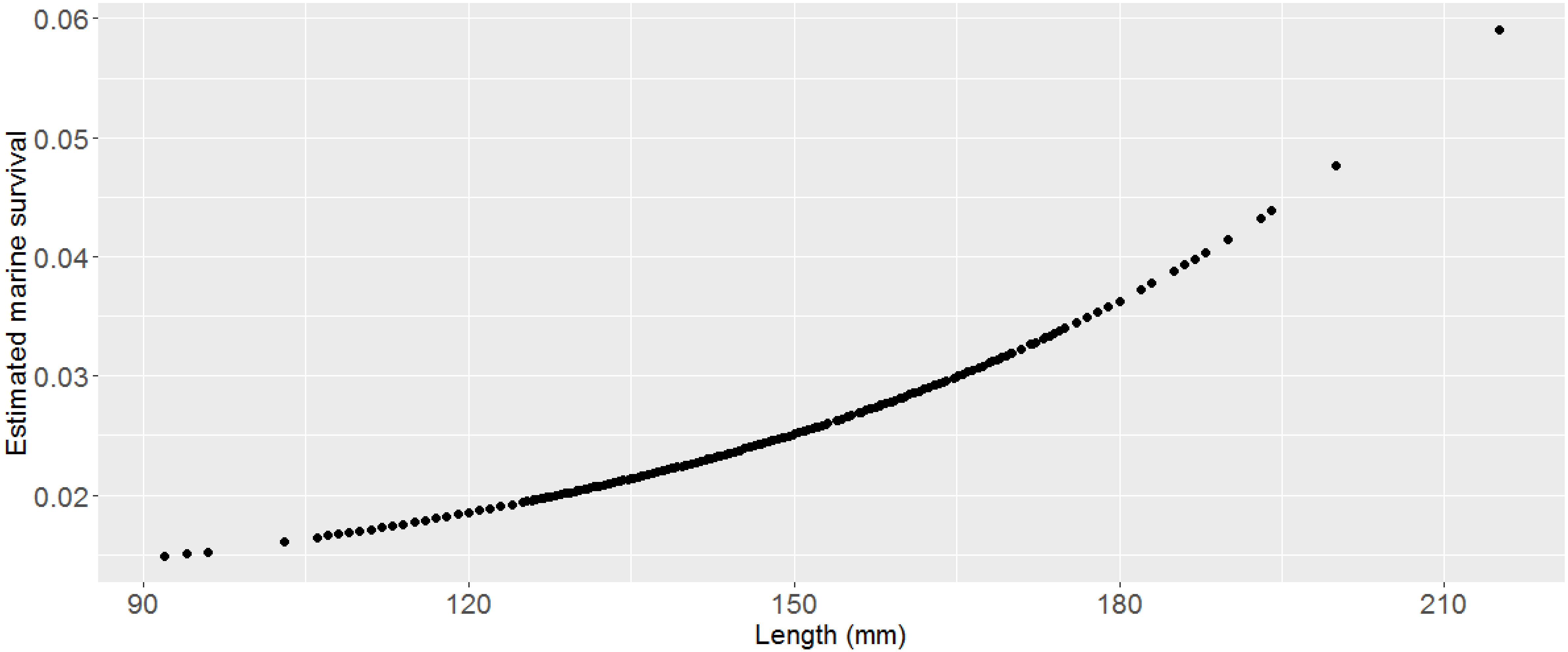

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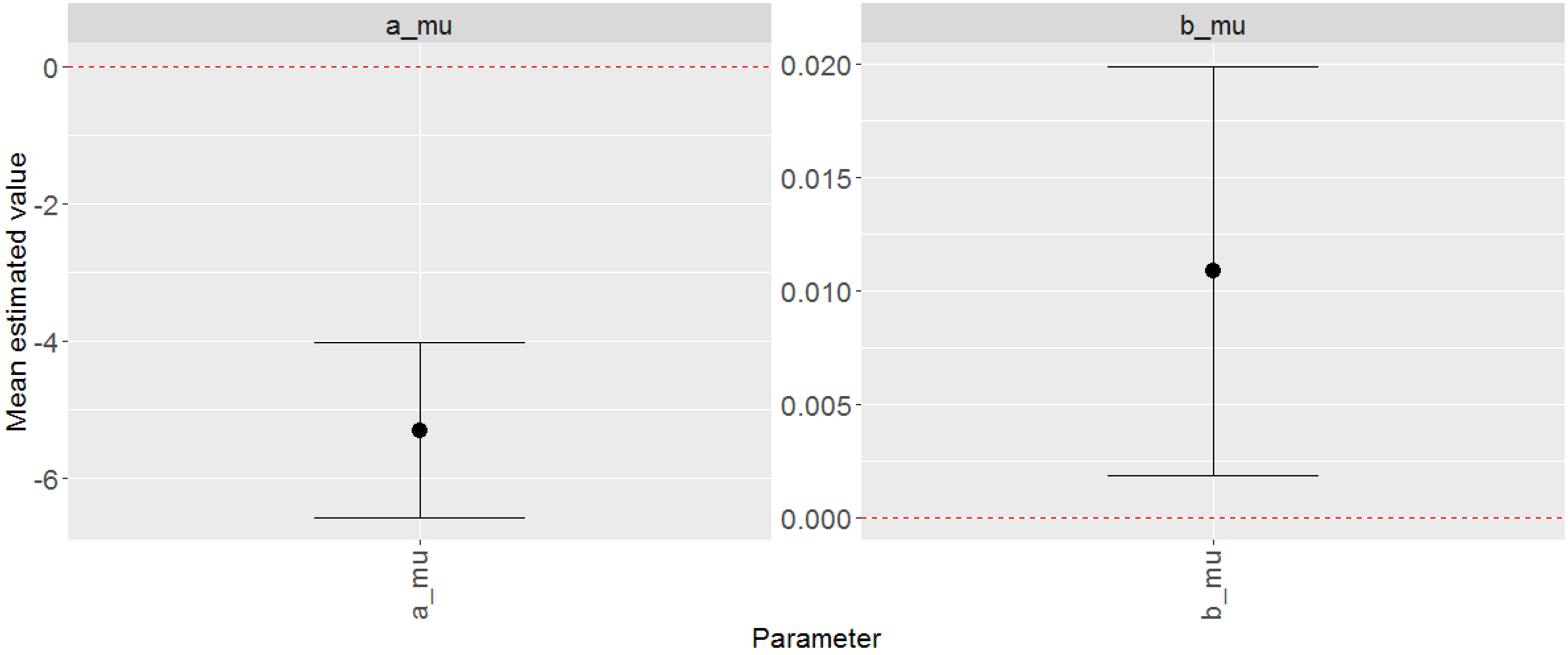

# Conclusions

PRELIMINARY

- BSSM estimates marine survival accounting for imperfect detection
- Admits individual, e.g., length, and other covariates, e.g., SST, etc.
- Frome salmon smolt marine survival related to their length…

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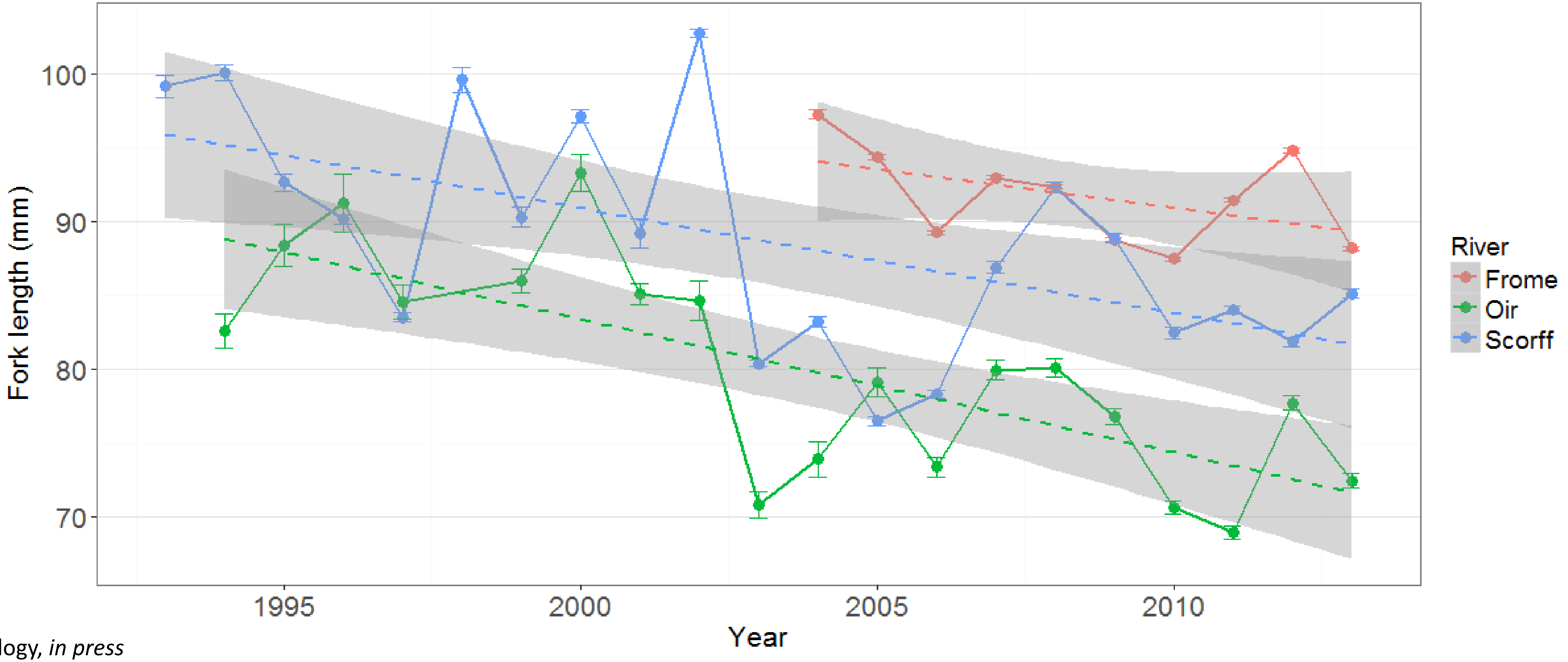
# Implications

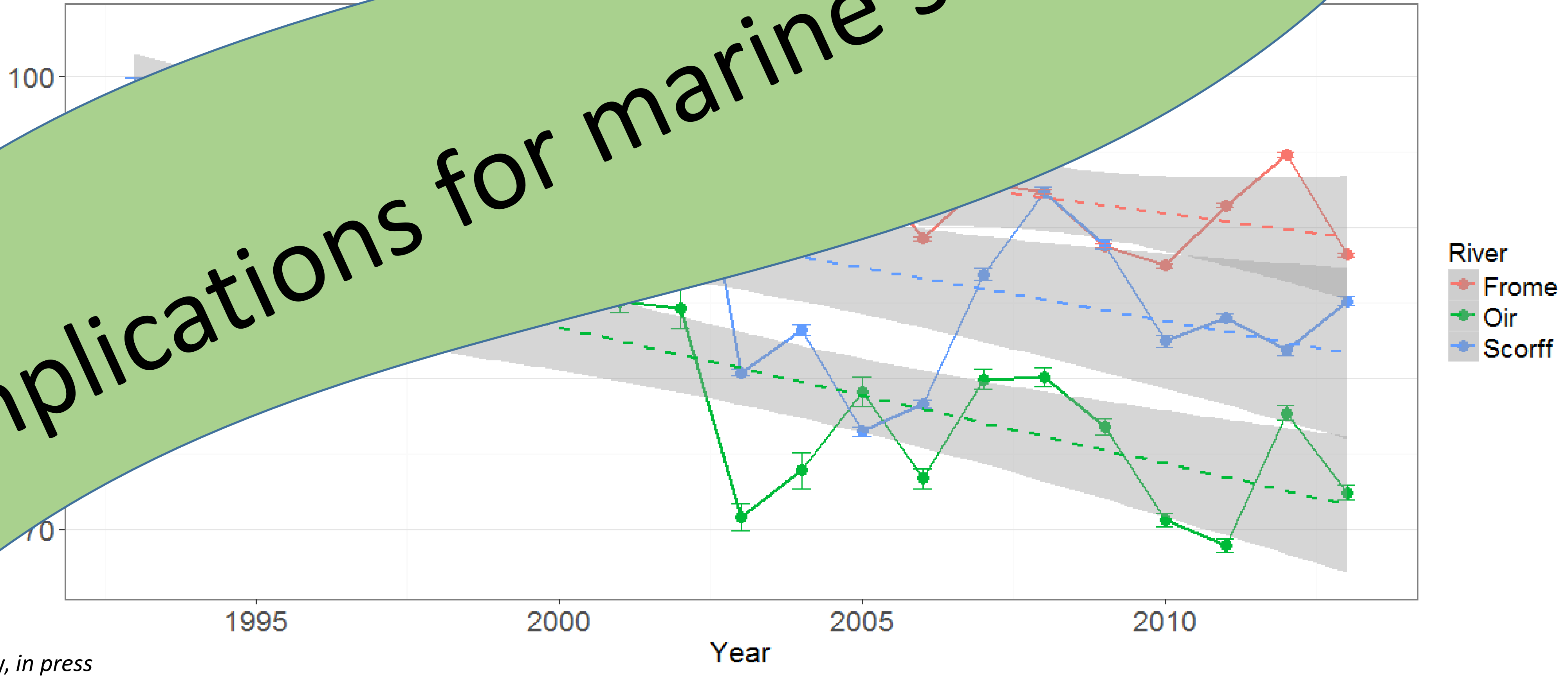
- Salmon parr are shrinking: Frome (UK), Oir & Scorff (France)




Gregory *et al.*, Freshwater Biology, *in press*

# Implications

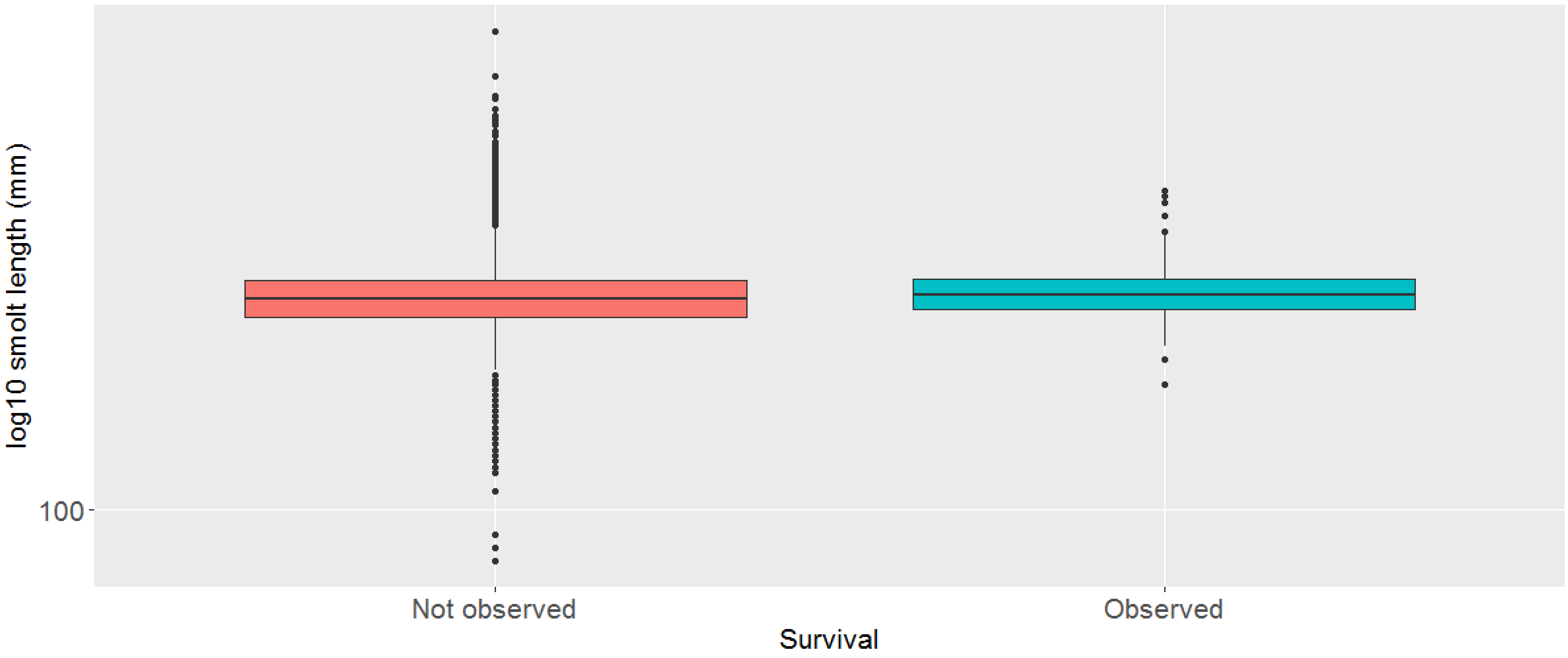
• Salmon parr are shrinking: From [...] )



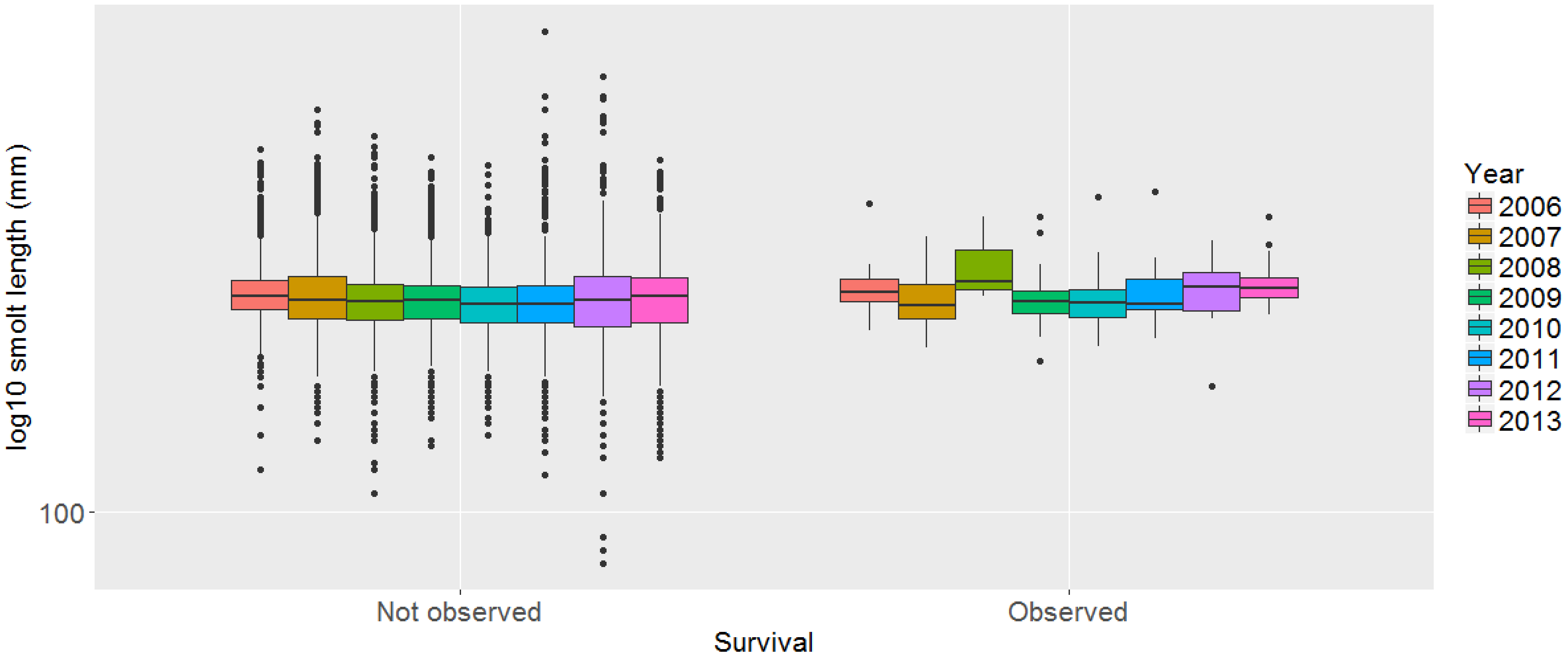

Implications for marine survival?

Gregory *et al.*, Freshwater Biology, *in press*

# Example: exploratory plots

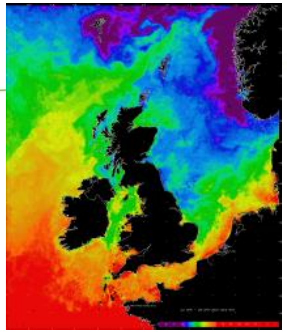


# Example: exploratory plots



# Next steps

- Extend model to estimate marine survival for separate years
- Extend model to estimate 1SW & MSW marine survival separately
- Compare models including additional explanatory variables…



# Method

3) Consider alternative hypotheses: model comparison [Todo]

Additional variables to explain marine survival:

- Sea surface temperature ~ growth conditions
- Other…

$$\phi = \frac{1}{1 + \exp(-lp_i)}$$

$$lp_i \sim \alpha_i + \beta_1 \mathrm{Length_i} + \beta_2 SST + \ \ldots + \beta_k$$

# Thanks for listening

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