# Length of Atlantic salmon smolt and their subsequent marine survival

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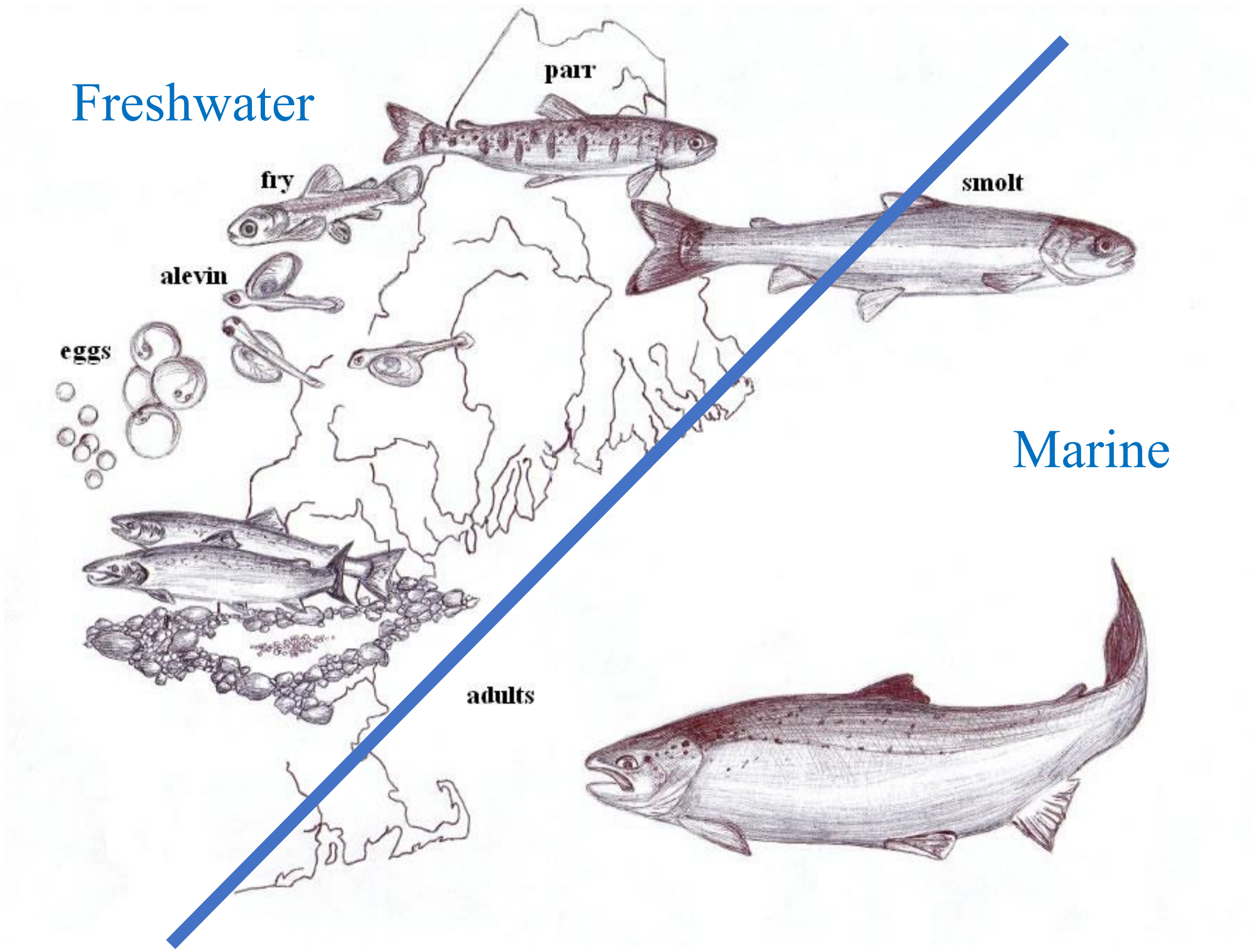
# Atlantic salmon life cycle

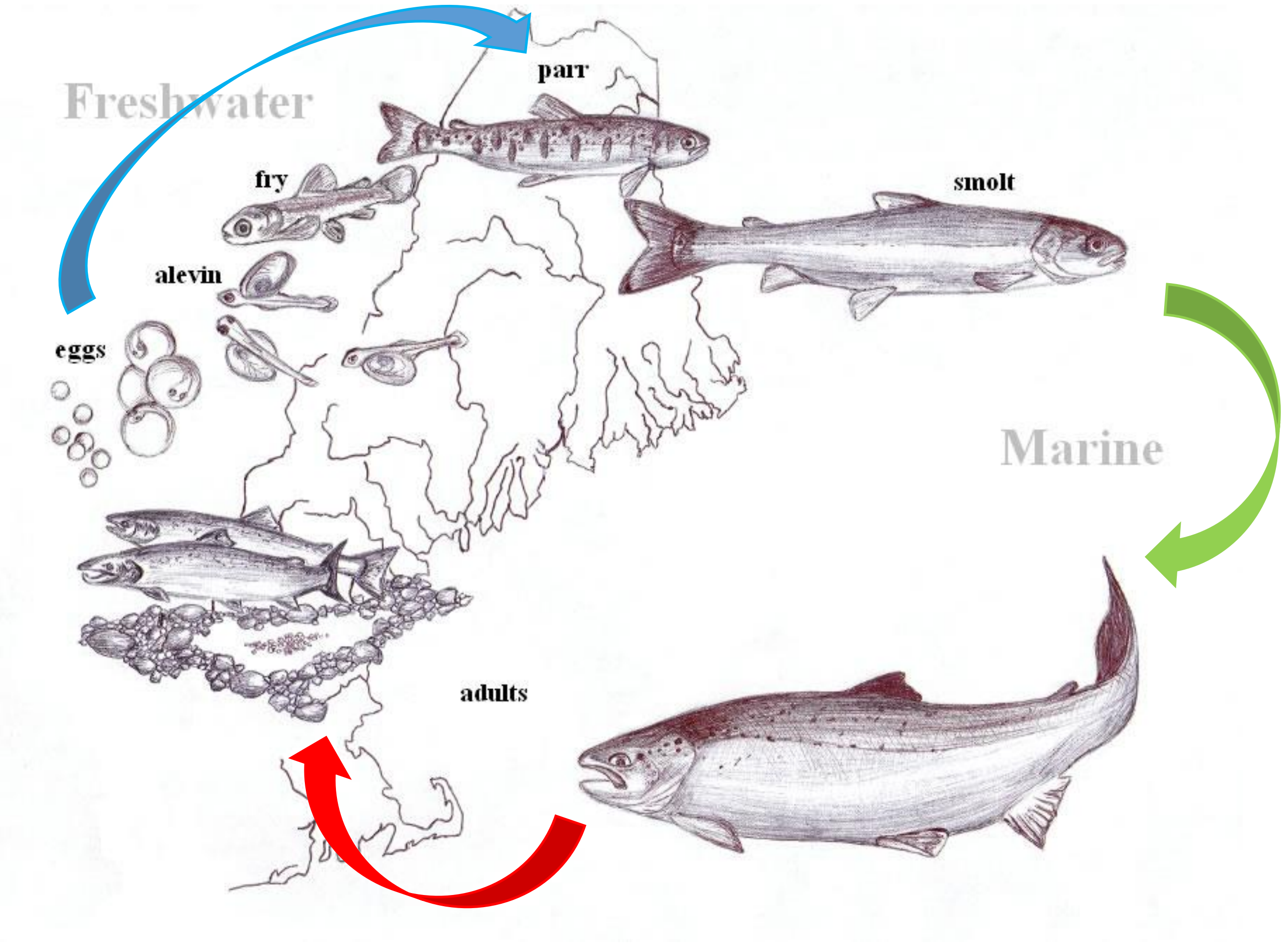
- Anadromous
  - Freshwater
  - Marine



# 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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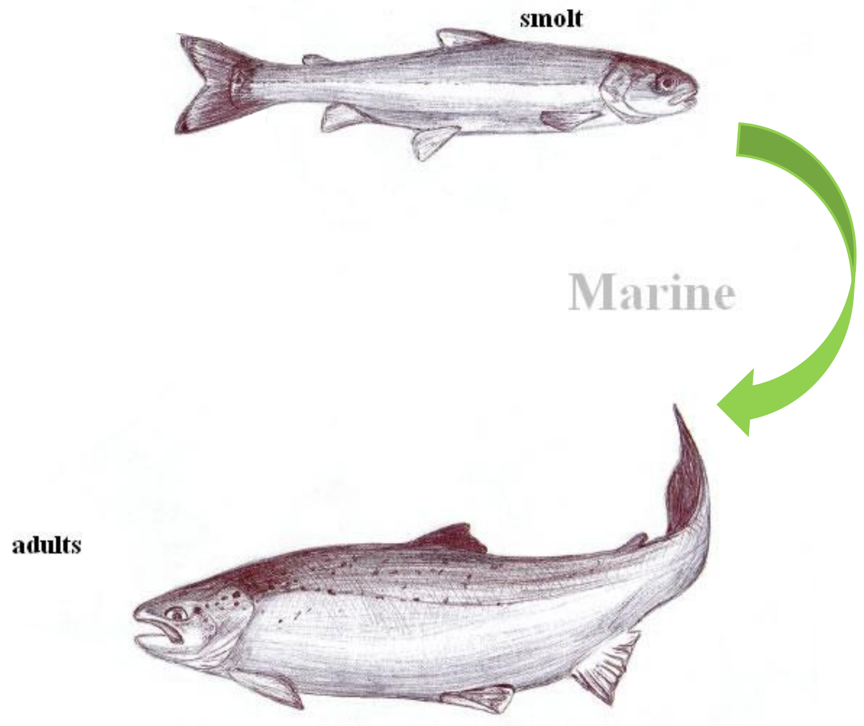
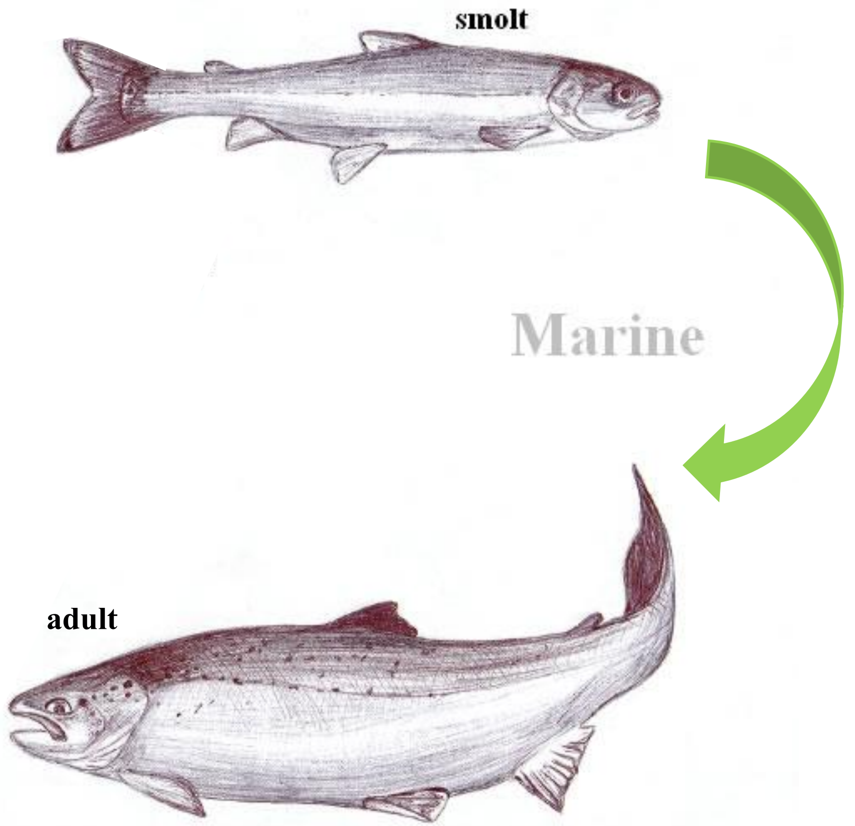
# Atlantic salmon life cycle

– Smolt > Adult (marine survival)



# 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.

# 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

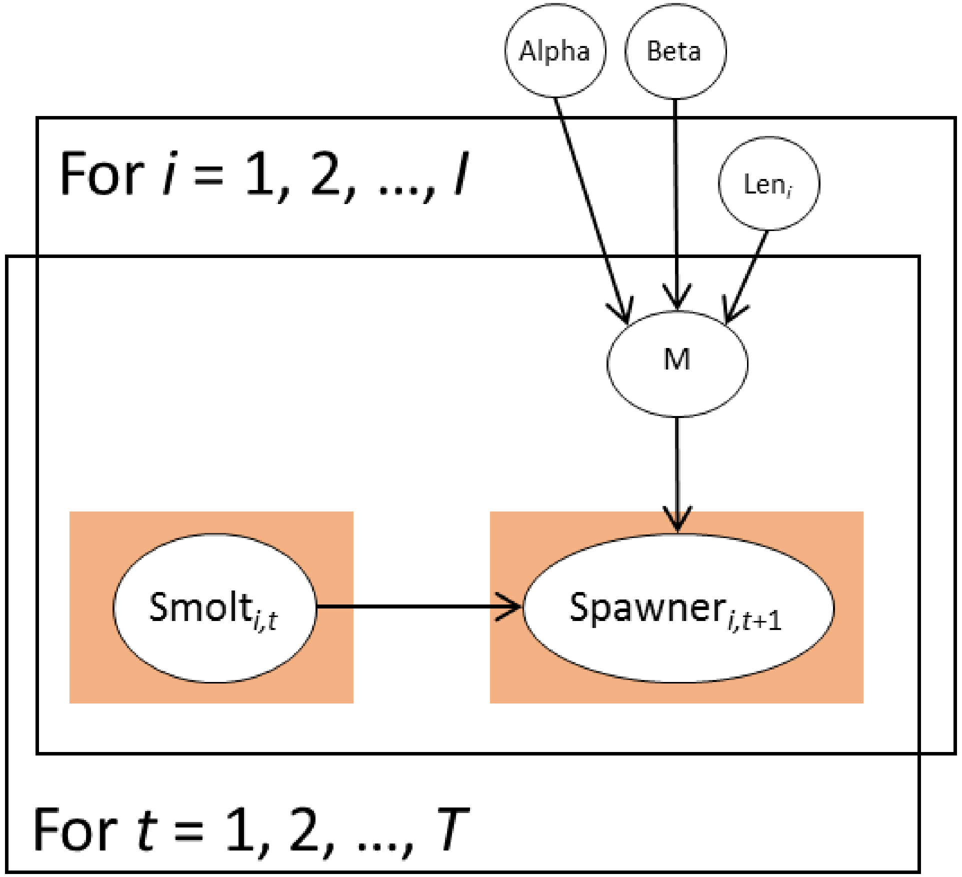
State matrix of individual $i$ $\quad z_i = [A, ?, B, ?]$
Space matrix of individual $i$ $\quad w_i = [1, 0, 1, 0]$

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 $t = 4$.

# Method

## 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



# Method

JAGS

1) Estimate marine survival from Bayesian State-Space model

– Estimates joint probability of transition ($\phi$) and detection ($p$) probabilities by MCMC

$$\pi(\phi, p|z, w) \propto \pi(z, w|\phi, p)\ \pi(\phi)\ \pi(p)$$

where:

$\pi(\phi, p \mid z, w)$ = posterior parameter probabilities

$\pi(z, w \mid \phi, p)$ = product of the likelihood of the data given the parameters

$\pi(\phi)$ = prior probabilities of transition

$\pi(p)$ = prior probabilities of detection

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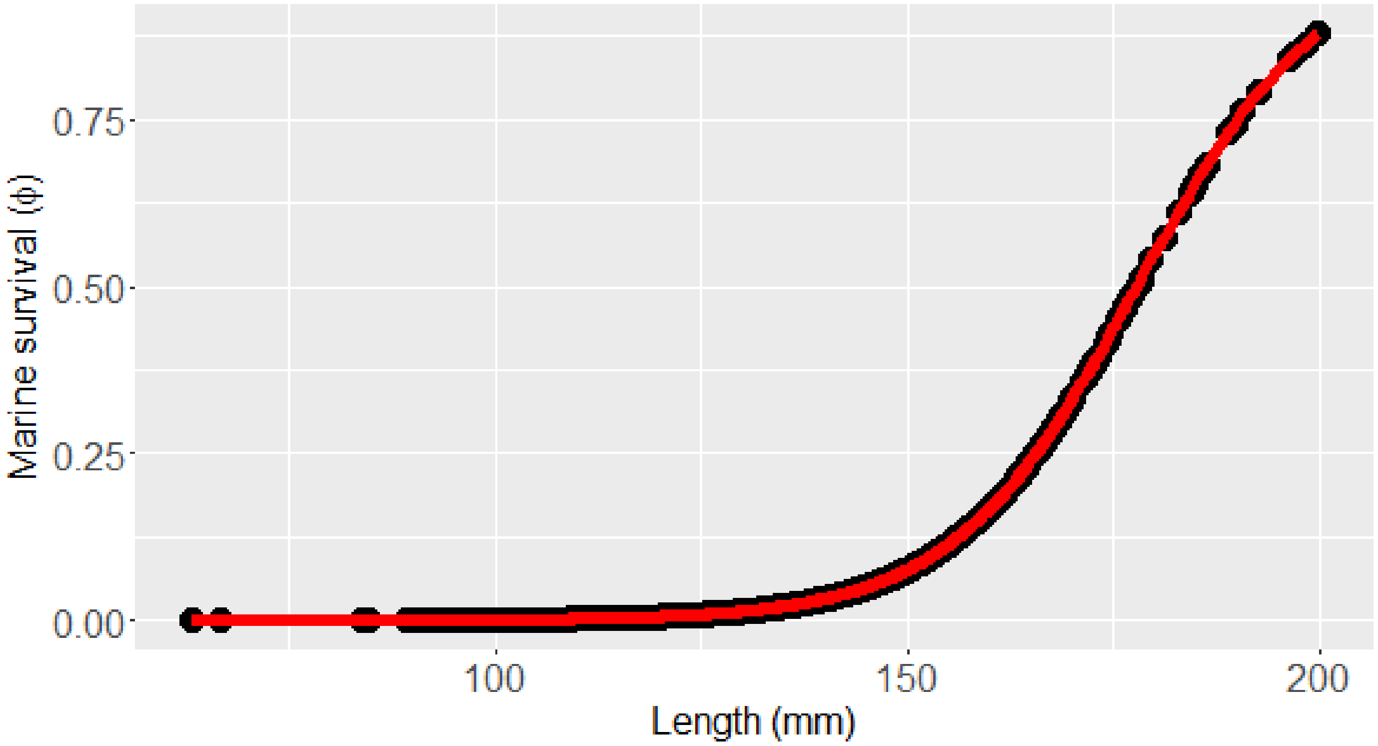
# Method

## 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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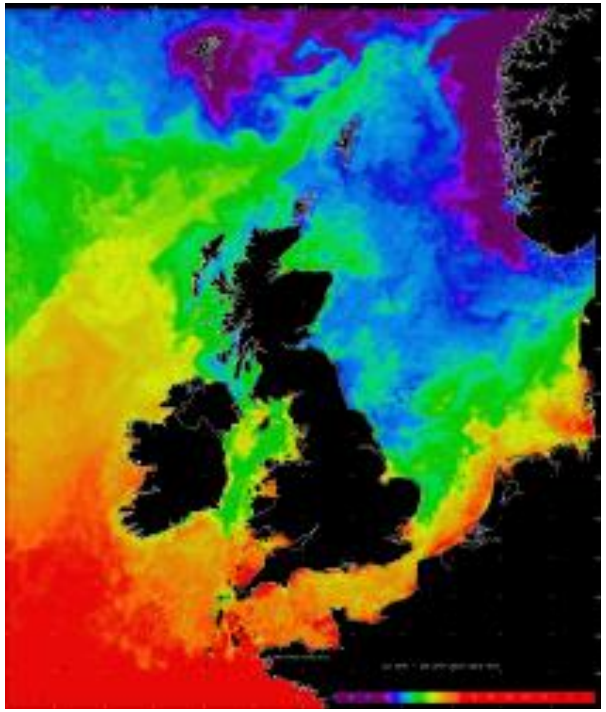
# Method

3) Consider alternative hypotheses: model comparison [Todo]

Additional variables to explain marine survival:

- Sea surface temperature ~ growth conditions
- Other…



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# Testing the BSSM

- Generate data & estimate parameters from same model

- Generating parameters:

| Parameter | Abbreviation | Value |
|---|---|---|
| Mean individual marine survival | Ms | 0.09 |
| Individual detection at release | release | 1.00 |
| Individual detection probabilities at PIT readers | pES, pBn | 0.85, 0.85 |
| Survival between PIT readers | ESBins | 1.00 |
| Length-Survival logistic regression coefficients | a, b | -16, 0.09 |

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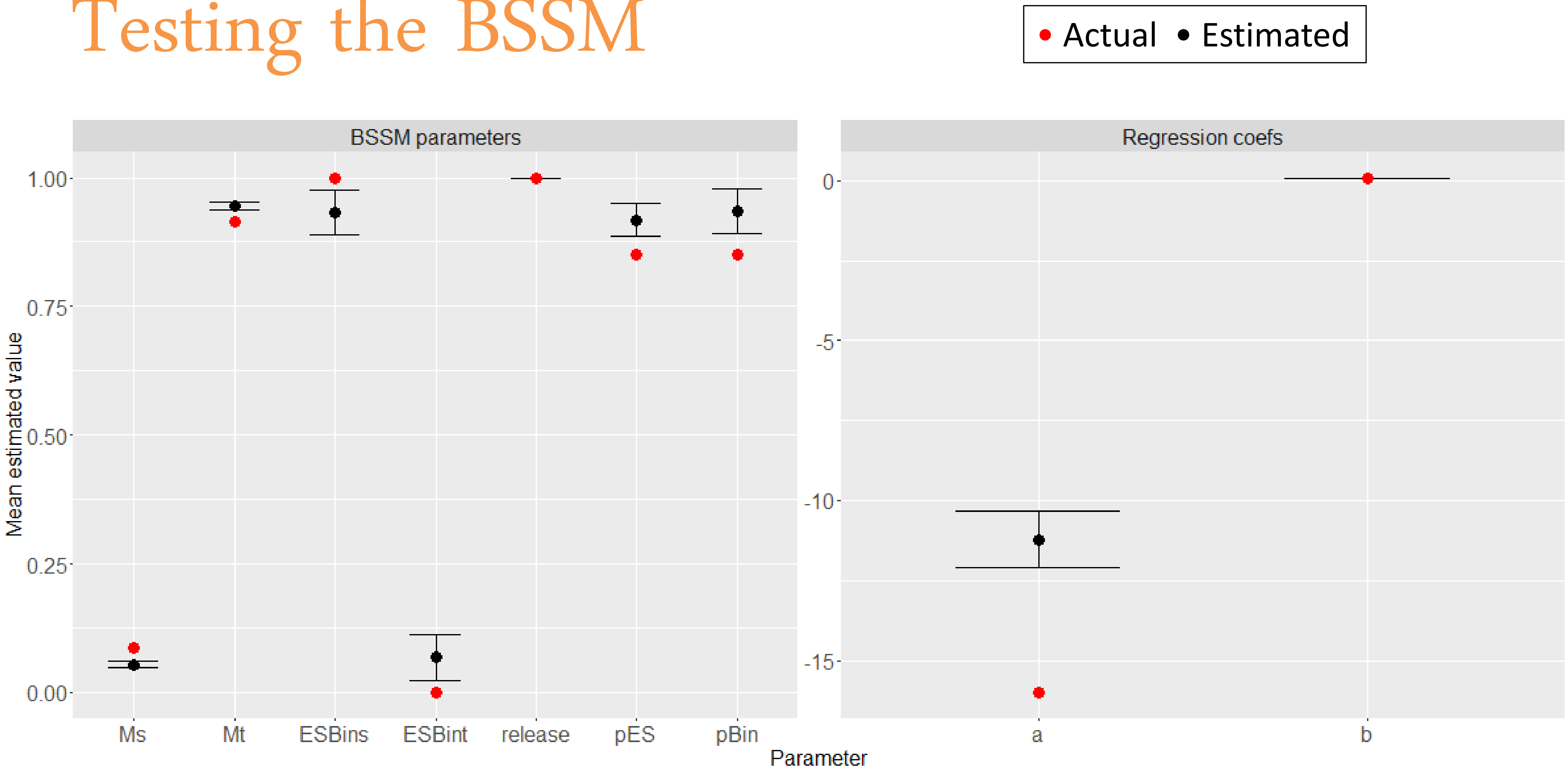
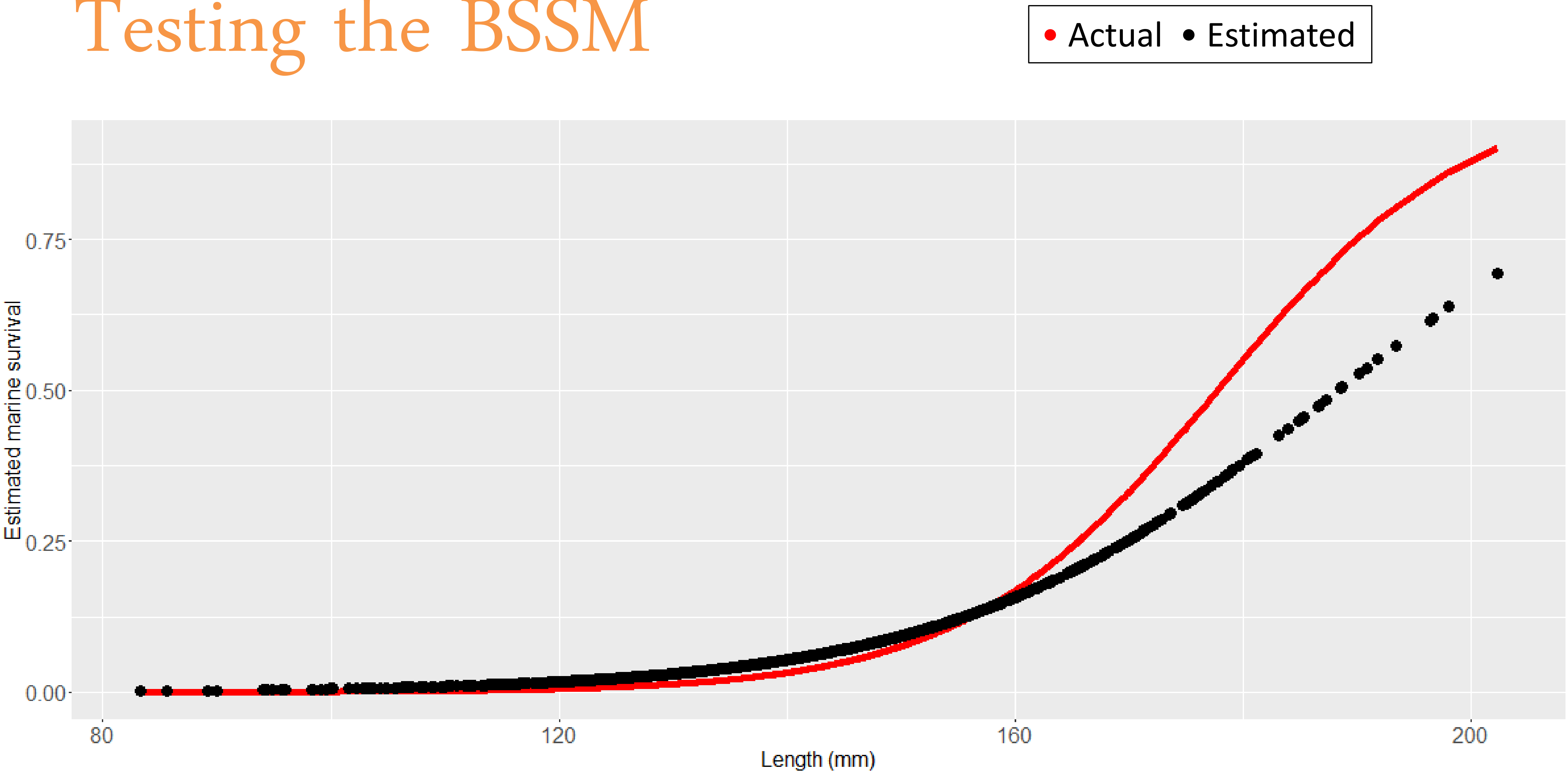
# Testing the BSSM



# Testing the BSSM



# Testing the BSSM

- Further tests reveal that reduced $pES$ and $pBn$ introduce bias in parameter and coefficient estimates.

- Marine survival estimates largely unaffected by bias.

- Could be improved by informative priors or model re-specification.

- Further work needed.

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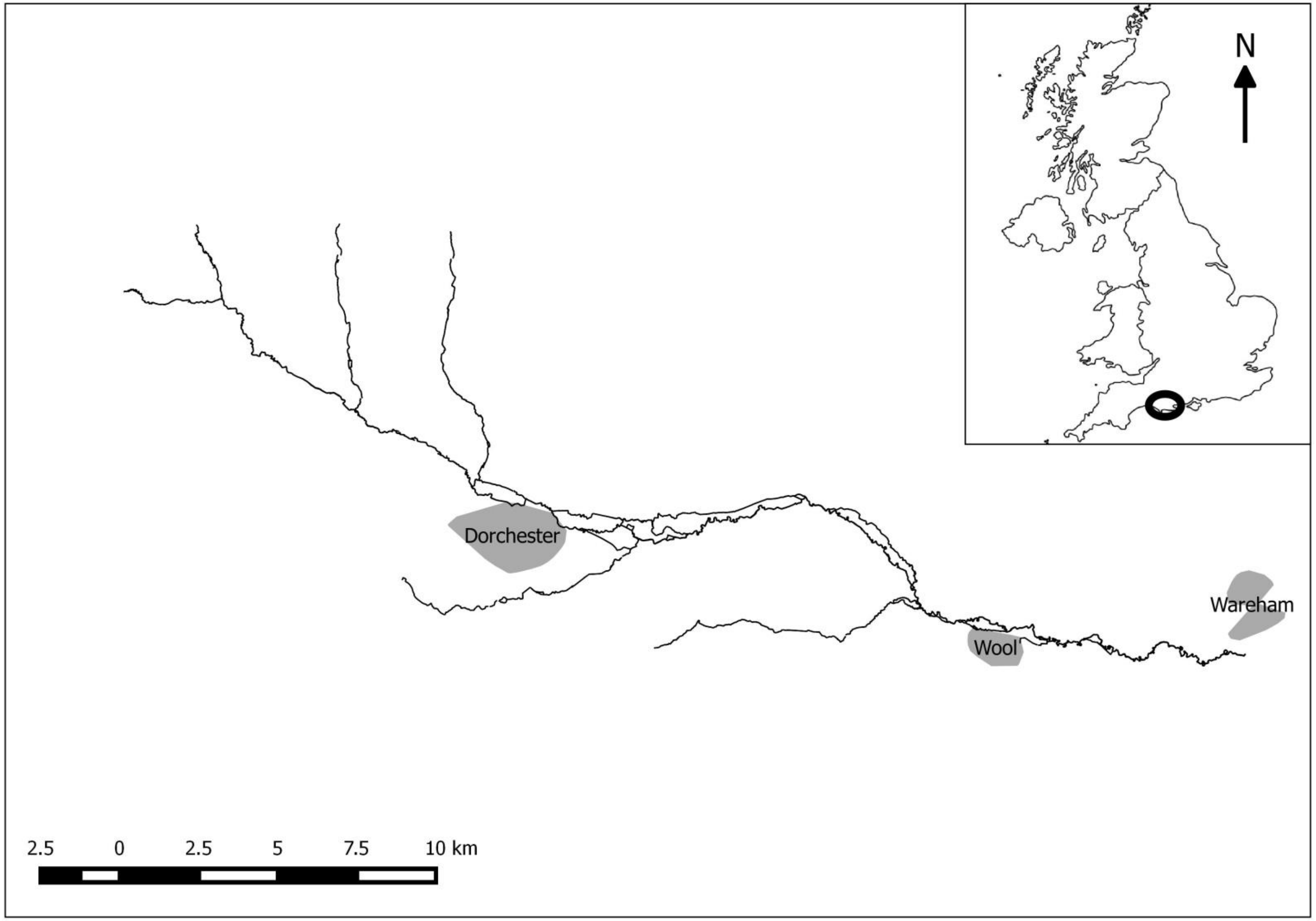
# Example: A. salmon in the Frome, Dorset

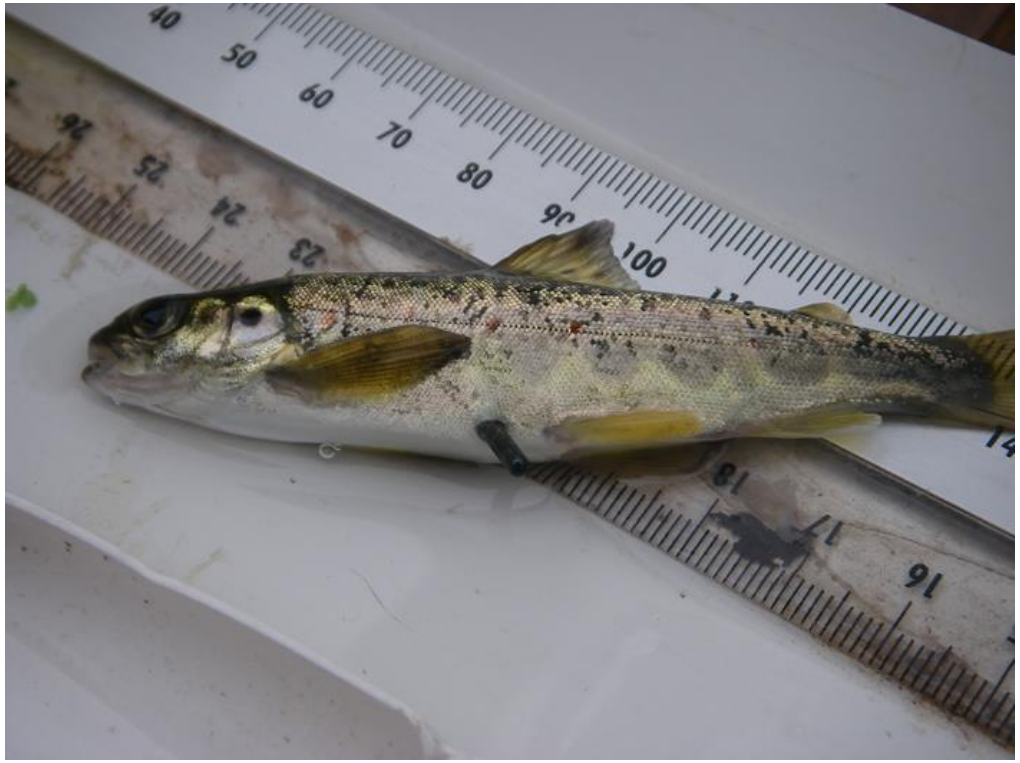
- Chalk stream
- Wild salmon
- 98% smolts age 1
- PIT tags



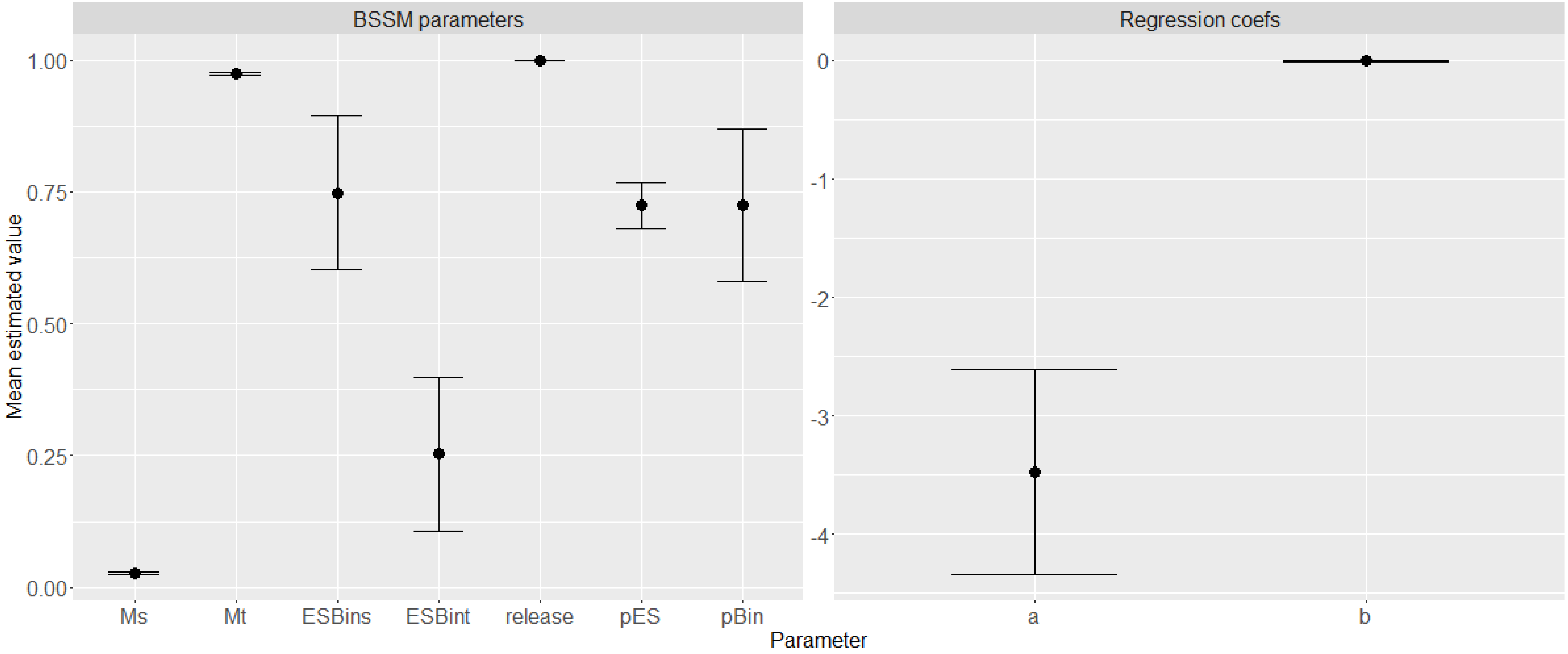
# Example: A. salmon in the Frome, Dorset

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

Sample size for analysis
- 8423 PIT tagged smolts
- 191 PIT tagged adult returns



# Example: A. salmon in the Frome, Dorset



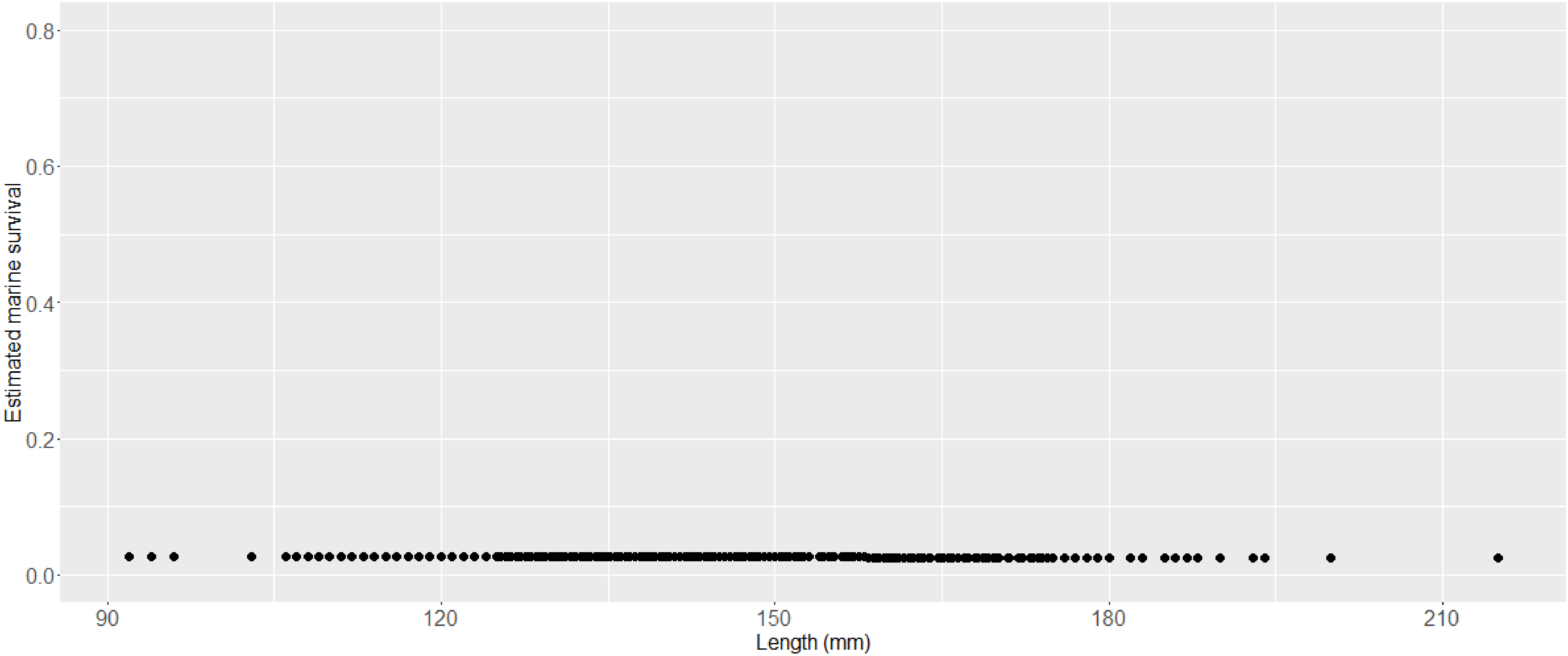
# Example: A. salmon in the Frome, Dorset

- Frome A. salmon marine survival estimates:
  - Chapman model = 1.8 – 2.5%
  - This BSSM = 2.6%

- PIT reader detection probability estimates:
  - Chapman model = 0.85
  - This BSSM = 0.73

- Transition between PIT readers appears low: 0.75

# Example: A. salmon in the Frome, Dorset



# Preliminary conclusions

- BSSM can estimate 1SW marine survival accounting for detection uncertainty.

- Admits individual covariates, e.g., length, environmental conditions, …

- Individual length appears unrelated to marine survival for Frome Atlantic salmon smolts. But this requires more work.

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# Next steps

- Improve model to reduce bias from low detection probabilities.
- Alternative equations to include covariates, e.g., linear…
- Extend the model to estimate 1SW and MSW survival separately.
- Compare models including additional explanatory variables.

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# Thanks for listening

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