A Holistic Modelling Approach to Predict Silver (Ag) Toxicity on Rainbow Trout Populations

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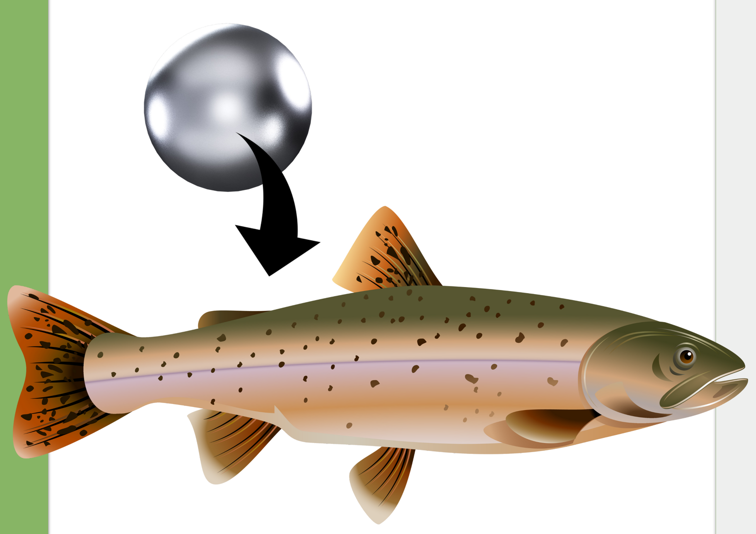
Introduction



Toxic effects of silver (Ag) to freshwater fish depend on water physico-chemical parameters:

- Biotic ligand models (BLM) allow to calculate interactions between water chemistry and metal toxicity
- For juvenile and adult fish, such as rainbow trout (*Onchorhynchus mykiss*), Ag accumulation at the gill decreases sodium (Na) uptake, leading to mortality

Sodium Balance Model (SBM) by Paquin et al. (2002):

- SBM describes effects of Ag on the internal Na-balance in rainbow trout
- SBM predicts the median survival time (ET50) of the population for a specific Ag accumulation in the gills (i.e., the biotic ligand [BL]).

SBM and the ET50 have clear limitations:

- SBM only applicable to juvenile and adult rainbow trout
- No extrapolation to other effects levels or exposure durations

Objectives:

- Refine the SBM model of Paquin et al. (2002)
- Use the SBM to compare effects of Ag across different water chemistries and between different rainbow trout life stages

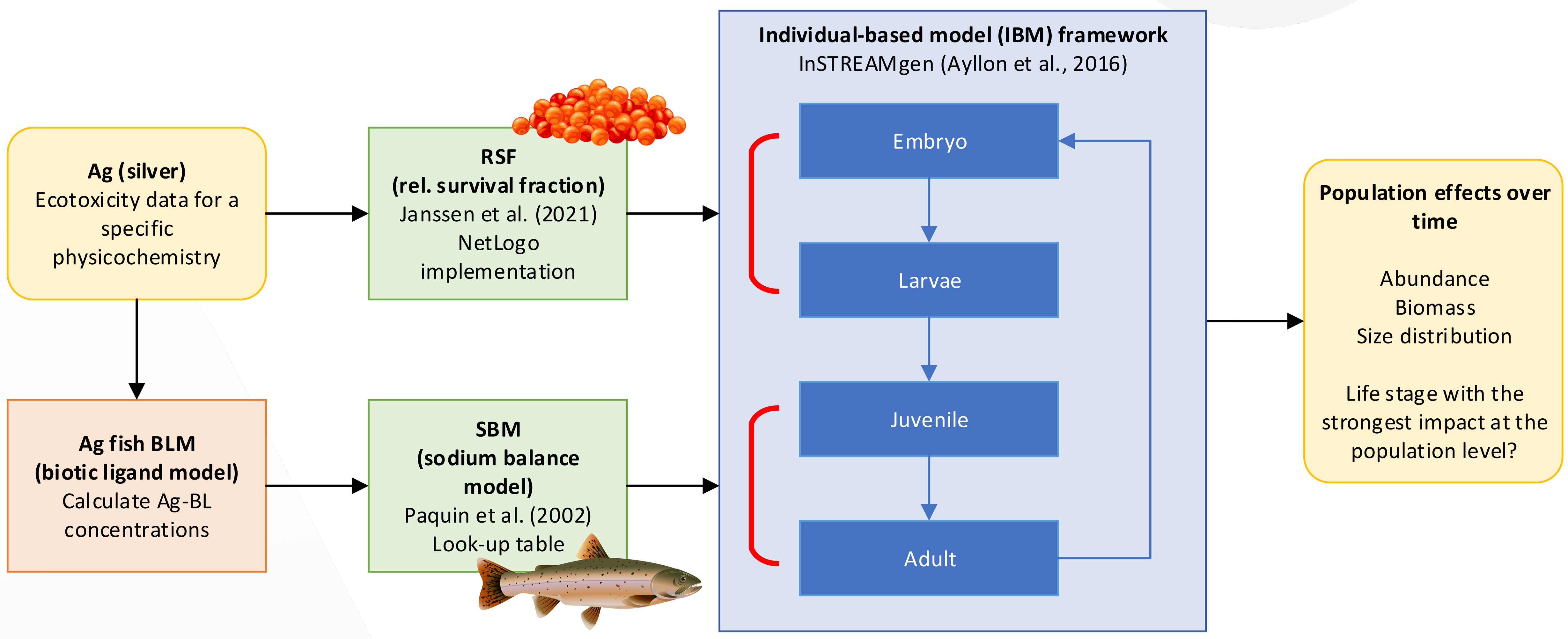
➜ Goal:

Assess which is the most sensitive life stage towards Ag toxicity, and which is most determining for rainbow trout population effects

Methods

Modular design:

BLM – calculate Ag accumulation at BL
+
SBM – predict adult/juvenile mortality
+
RSF – estimate embryo/larval mortality
+
IBM – predict population-level effects



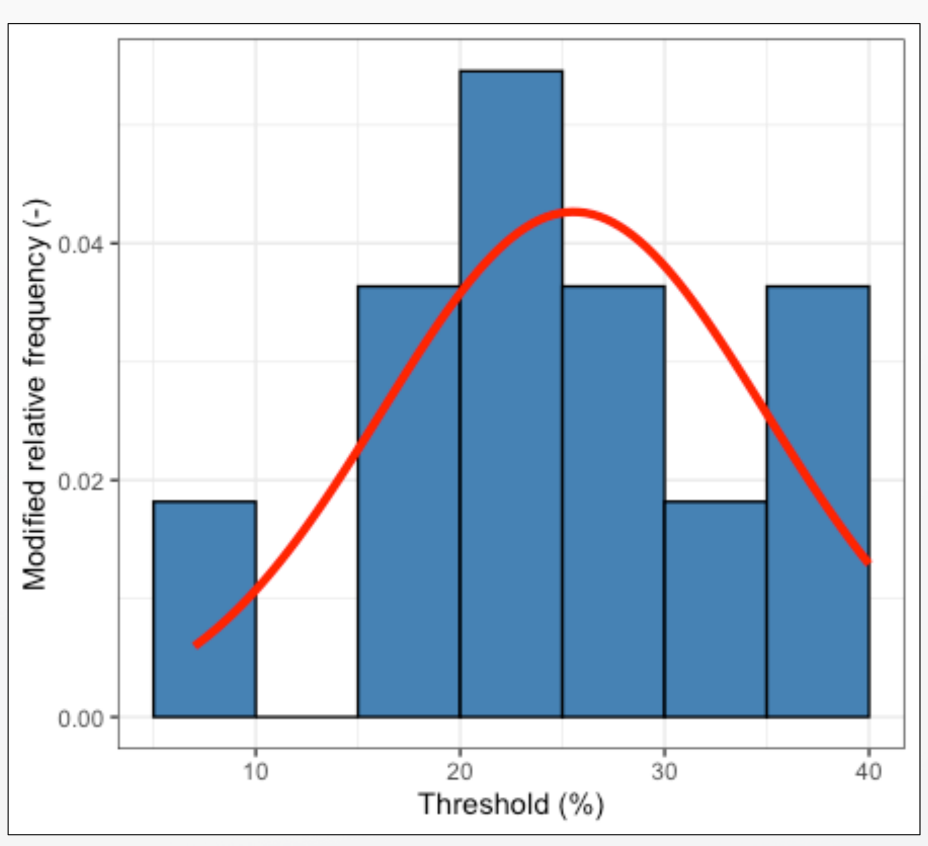
Results

1 Refinement of the SBM

Main assumption of the SBM from Paquin et al. (2002)
= decrease of 30% in plasma Na is lethal

Based on ionoregulation data:
there is a distribution on the lethal % threshold!

Use parallel measurements of plasma Na and mortality:

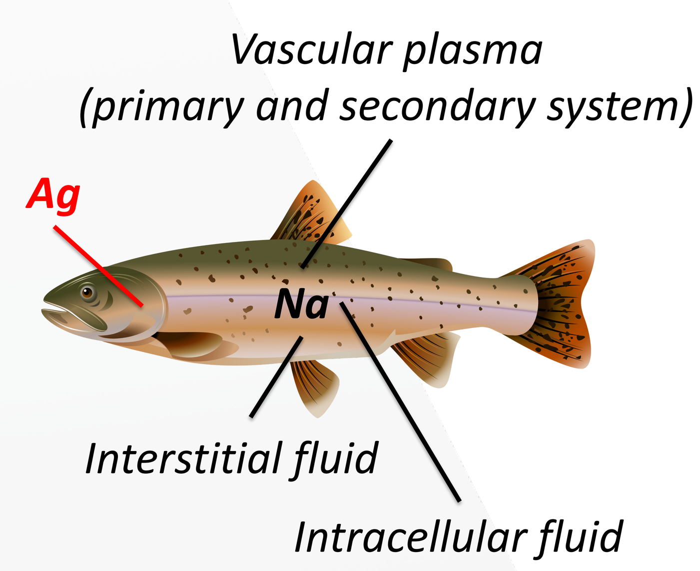


Better prediction of **intra-specific variation** of mortality that is observed when a rainbow trout population is exposed to Ag

2 Mathematics of the refined SBM

SBM predicts plasma Na in 4 compartments:

$$\begin{cases} \frac{dC_{V1}}{dt} \\ \frac{dC_{V2}}{dt} \\ \frac{dC_{IS}}{dt} \\ \frac{dC_{IC}}{dt} \end{cases}$$



Each organism has its individual tolerance (t_i) towards decrease in plasma Na due to Ag exposure:

$$t_i \sim \mathcal{N}(\mu, \sigma^2)$$

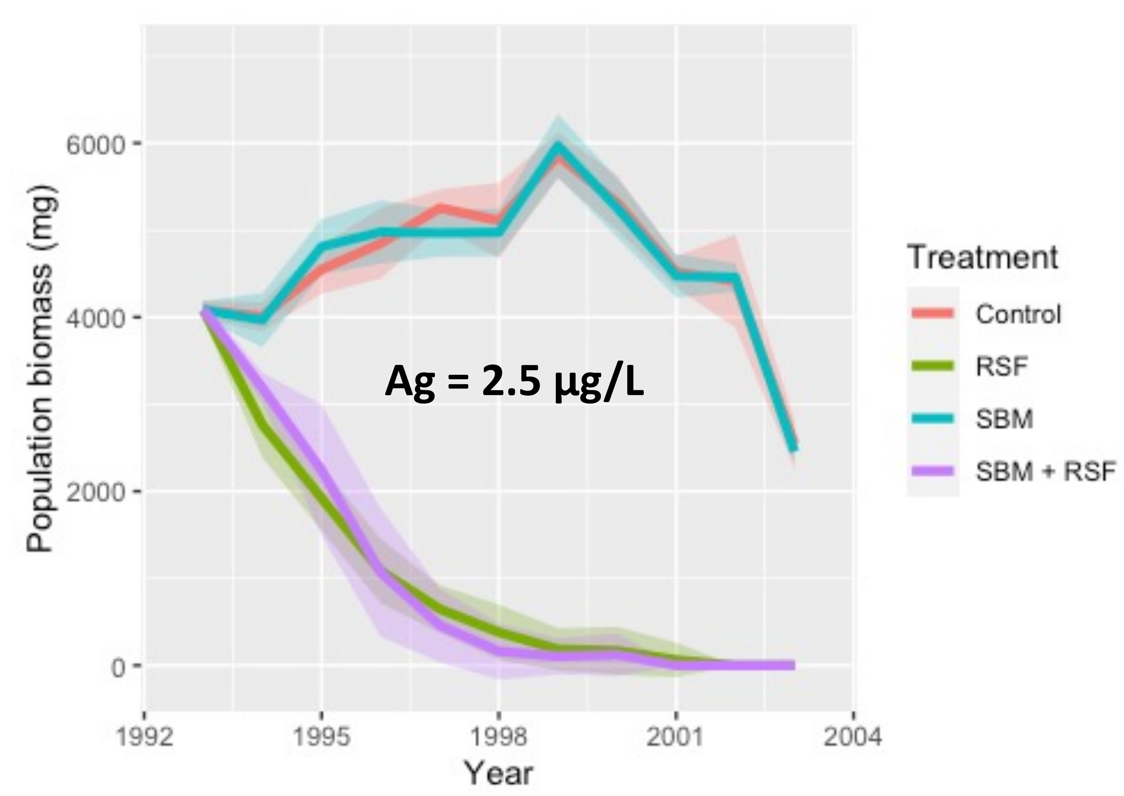
Individual threshold leads to an individual survival time at a specific Ag concentration (predicted with the SBM):

$$T_i = f([BL{:}Ag], t_i)$$

Individual survival time is implemented in the individual-based population model (InSTREAMGen)

$$\text{IF } (\tau_{exp} > T_i) \quad \text{THEN } [\, die? = TRUE \,]$$

3 Predictions using BLM-SBM-IBM



Dissolved Ag	Ind. level mortality (70d) implemented		Pop. effects on biomass (10y average) predicted	
	RSF	SBM	RSF only	SBM only
1.2 µg/L	36%	0%	0%	0%
2.5 µg/L	100%	2%	100%	0%
5 µg/L	100%	87%	100%	100%

Conclusion

Based on the predictions of the BLM-SBM-IBM:

- Refined SBM better predicts realistic variability in mortality that is observed when rainbow trout is exposed to Ag (results not shown)
- SBM considers an individual threshold approach, where an individual's survival depends on its tolerance towards a decrease in plasma Na
- Effects on embryo/larvae (with RSF) and juveniles/adults (with SBM) were extrapolated to populations using a toxicokinetic (TK) approach
- Effects on embryo/larvae (with RSF) occur at lower dissolved Ag concentrations than effects on juveniles/adults (with SBM)
- Based on the IBM predictions, effects on embryo/larvae due to Ag are more determining for population- level effects than effects on juveniles/adults

References: Paquin et al., *Comp. Biochem. Physiol. C*, 2002, 133.1-2:3-35
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