Genetic variation for thermal sensitivity in growth and lice tolerance of Atlantic salmon
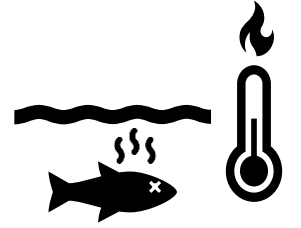
EAAP 2019, GHENT

26TH TO 30TH AUGUST

Hooi Ling Khaw[1], Solomon Antwi Boison[2], Lill-Heidi Johansen[1], Mette W. Breiland[1], Panya Sae-Lim[3]
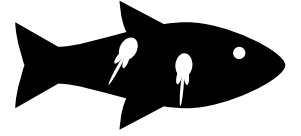
Background

- Climate change

  - major global concerns with no exception to aquaculture

- Growth of Atlantic salmon

  - depending on ambient temperature

  - Thermal stress leading to growth reduction

  - outside the optimum range of 11°C - 14°C

Background

- Sea lice infection

  - Industry spends more than € 500 mil on controlling sea lice

  - The spatial distribution of sea lice outbreak

  - Temperature ↑, sea lice life cycle ↓

- Possibility for selective breeding on environmental sensitivity?

- **Objective**: to quantify the heritable variation for thermal sensitivity in growth and lice tolerance of Atlantic salmon
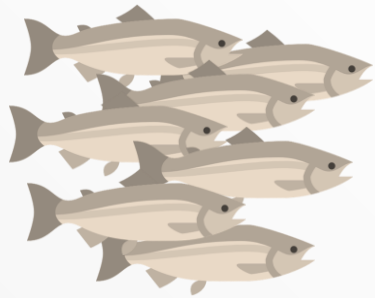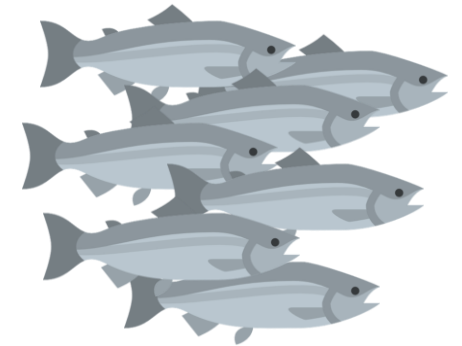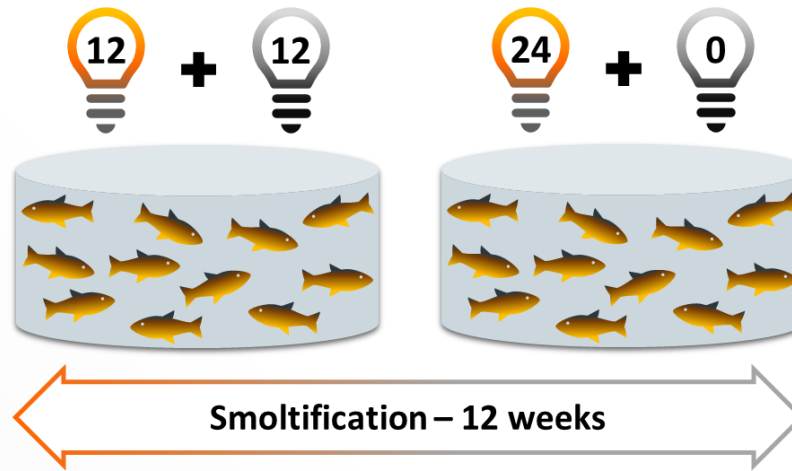
Photograph: Bengt Finstad

Experimental Design

Experimental fish

6,000 Atlantic salmon parrs

50 families
120 per family

Smoltification – 12 weeks
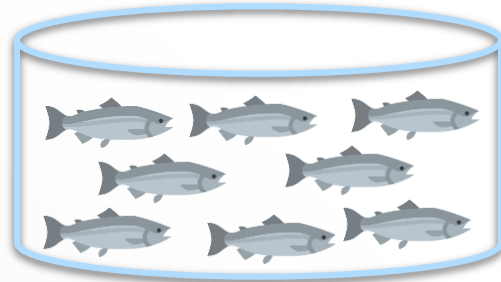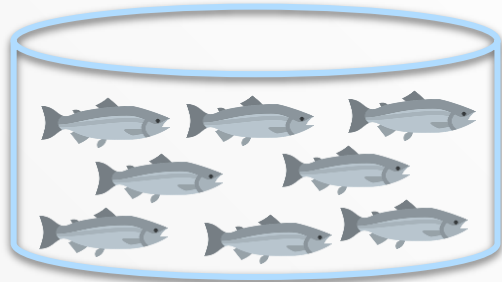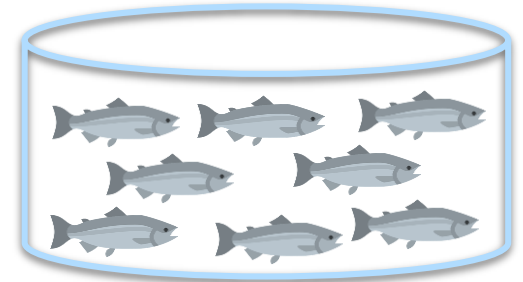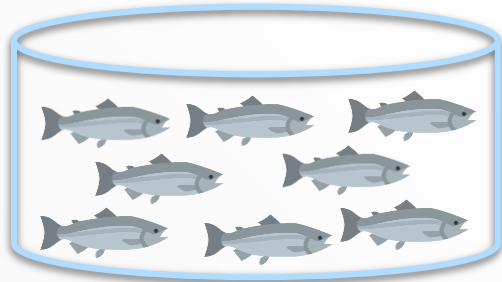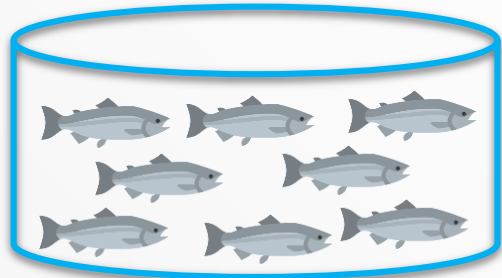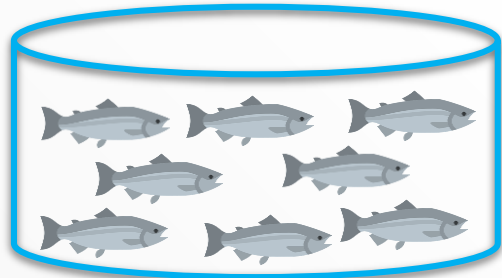
Post-smolts

Challenge test

450 fish per treatment tank
Average initial weight of 102g

6 treatment tanks

Nofima
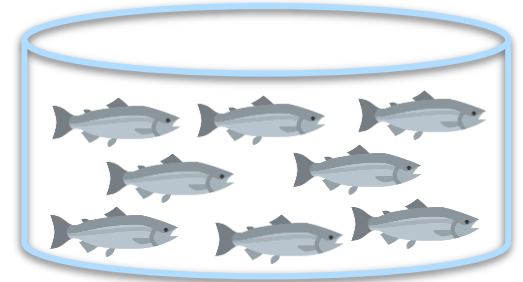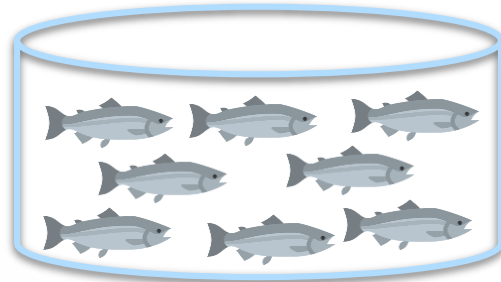
Challenge test

Adjust to treatment temperature
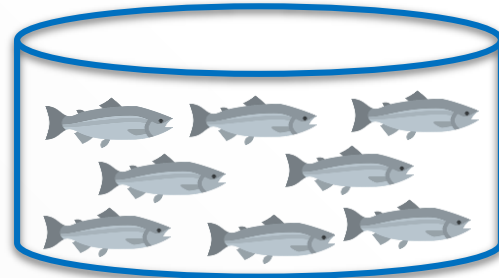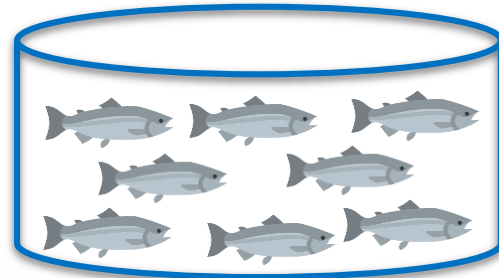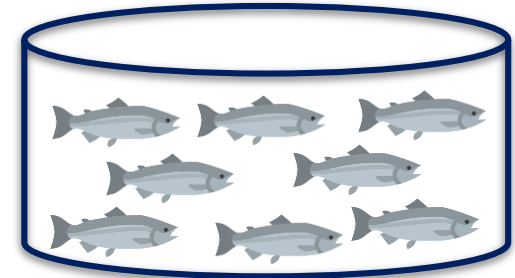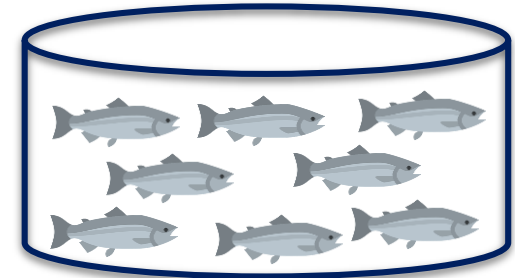
5°C treatment   10°C treatment   17°C treatment

Challenge test – On challenge day

Lice density: 30 cops per fish
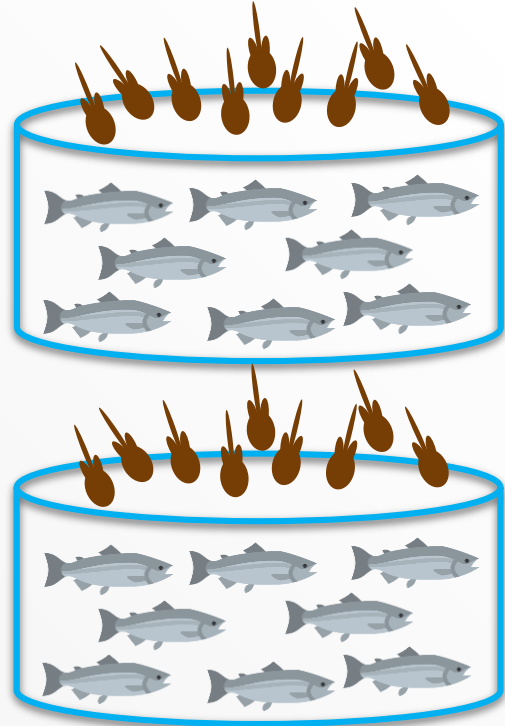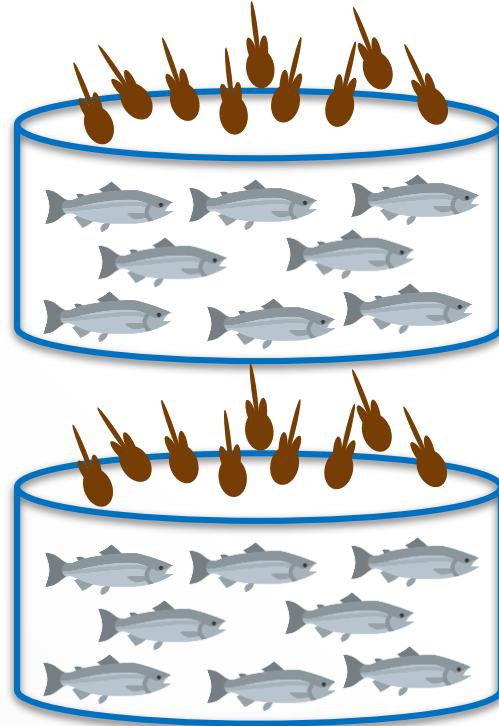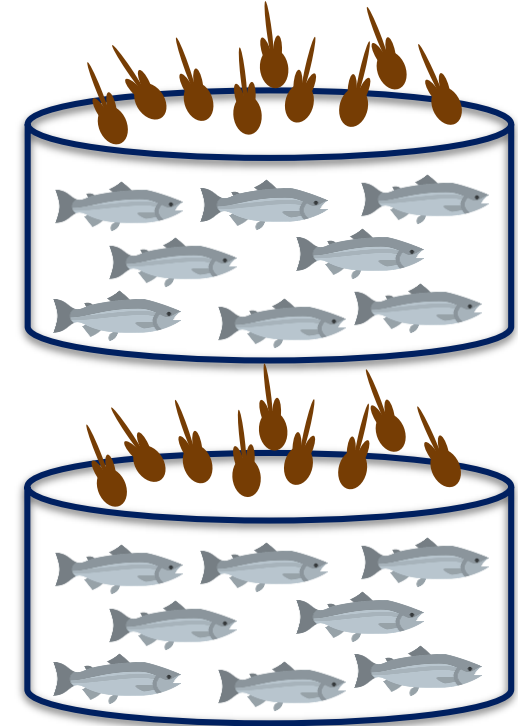
5°C treatment   10°C treatment   17°C treatment

Challenge test - Duration

175 to 180 day-degree
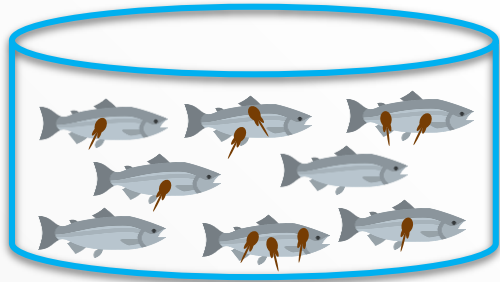
150 to 160 day-degree
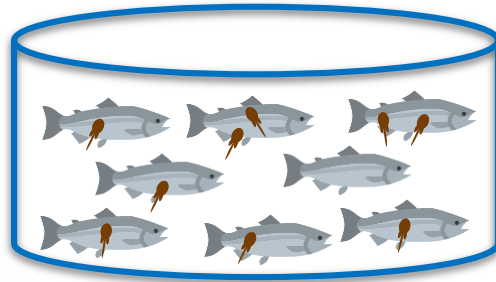
119 to 136 day-degree
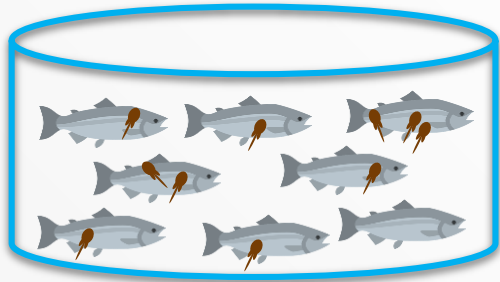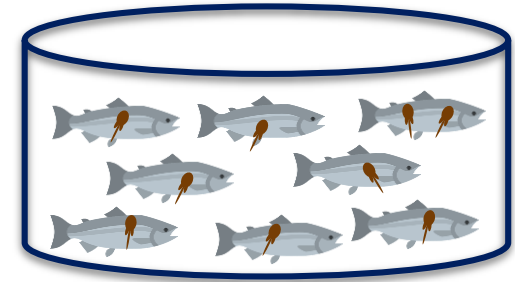
5°C treatment
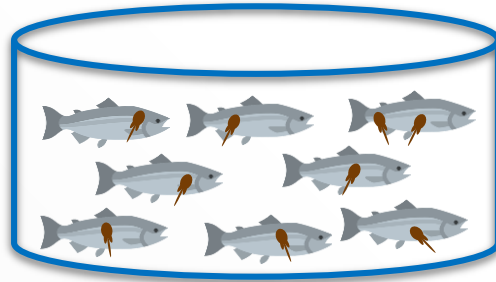
10°C treatment
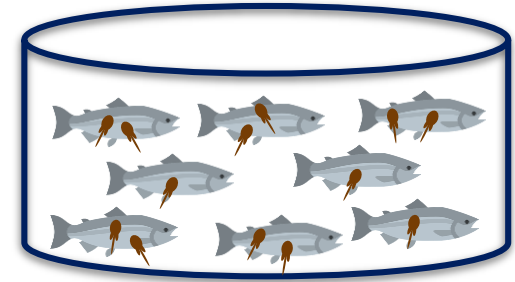
17°C treatment

Challenge test – At termination

Count individual lice

Body length

Body weight

Phenotypes

Picture source: https://nifes.hi.no/en/research-topics/aqua-culture/farmed-fish/atlantic-salmon-farmed/
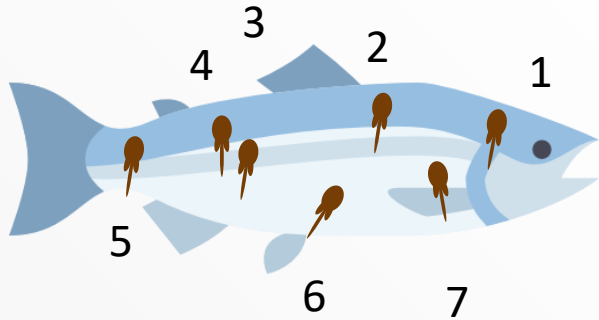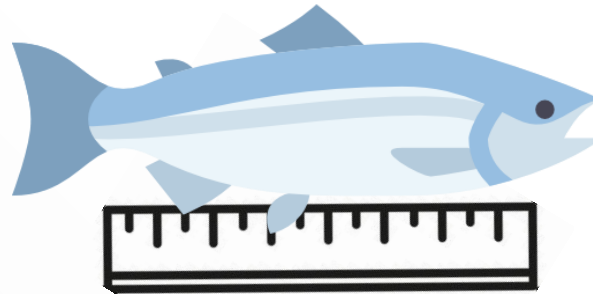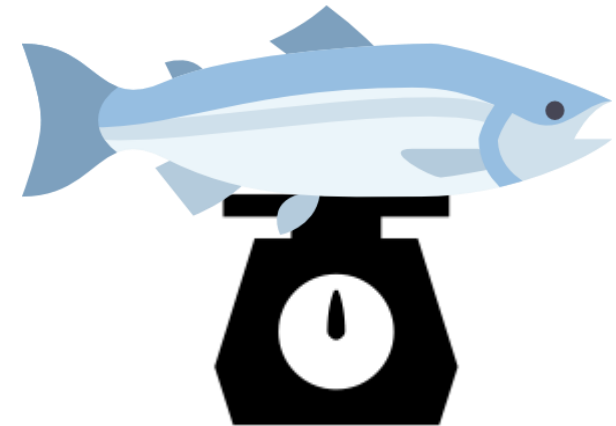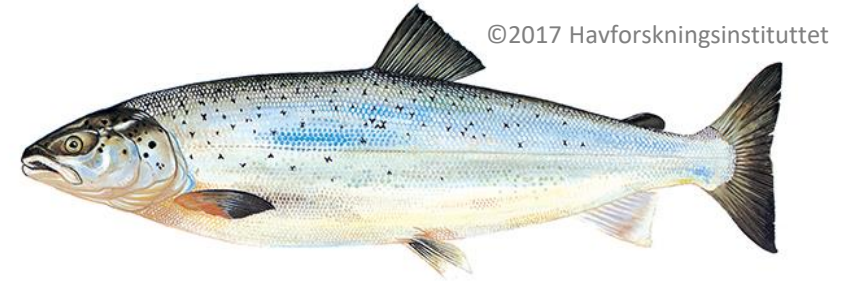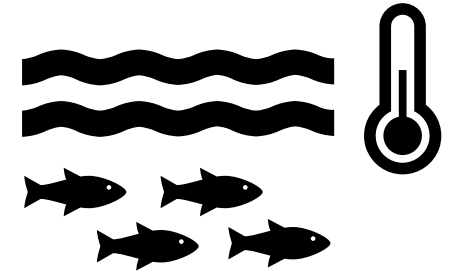
Growth

- Growth of salmonid is depending on water temperature

- Growth trait – thermal growth coefficient

$$\frac{\sqrt[3]{WT_E} - \sqrt[3]{WT_I}}{Day * degree} \times 1000$$

[Jobling, 2003]

- WT_I - initial weight

- WT_E - end weight

- Day*degree   - $\left((Date_T - Date_I) \times 10°C\right) + \left((Date_E - Date_T) \times T_t\right)$

Jobling, M., 2003. Aquaculture Research 34: 581-584

Nofima

Lice tolerance
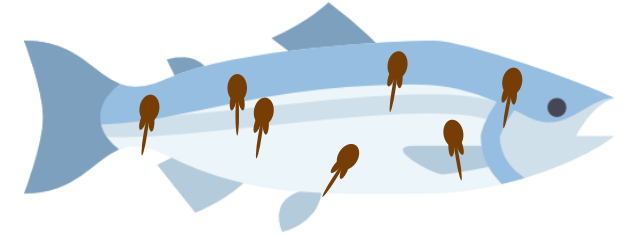
- Lice count took at the termination point was transformed with log1p:

$$\ln(1 + lice\ count)$$
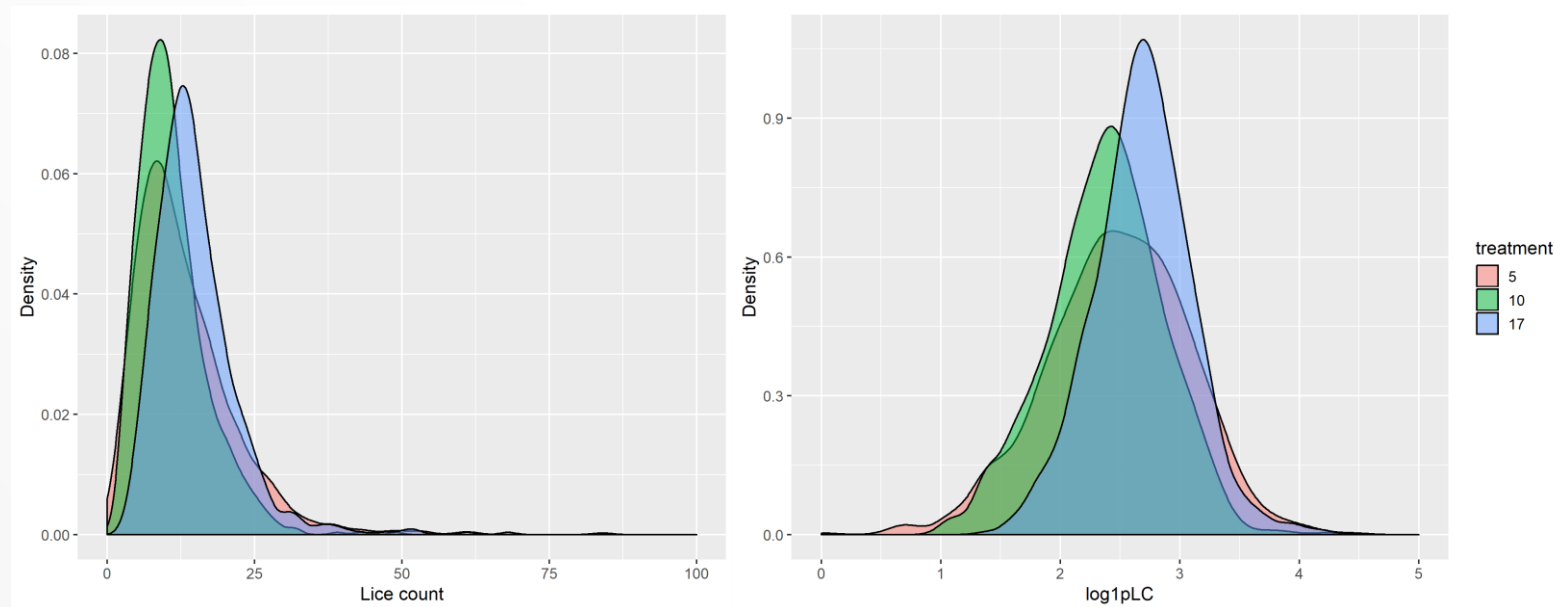
Statistical analysis

- Multivariate model in WOMBAT

  - Phenotypes, TGC and log1pLC, at each temperature as different trait

  - Genomic relationship matrix was used in the estimation

Fixed effect - tank **Random genetic effect**

$$
\begin{bmatrix} \mathbf{y}_1 \\ \mathbf{y}_2 \\ \mathbf{y}_3 \\ \mathbf{y}_4 \\ \mathbf{y}_5 \\ \mathbf{y}_6 \end{bmatrix} = \begin{bmatrix} \mathbf{X}_1 & 0 & 0 & 0 & 0 & 0 \\ 0 & \mathbf{X}_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & \mathbf{X}_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & \mathbf{X}_4 & 0 & 0 \\ 0 & 0 & 0 & 0 & \mathbf{X}_5 & 0 \\ 0 & 0 & 0 & 0 & 0 & \mathbf{X}_6 \end{bmatrix} \begin{bmatrix} \mathbf{b}_1 \\ \mathbf{b}_2 \\ \mathbf{b}_3 \\ \mathbf{b}_4 \\ \mathbf{b}_5 \\ \mathbf{b}_6 \end{bmatrix} + \begin{bmatrix} \mathbf{Z}_{1_A} & 0 & 0 & 0 & 0 & 0 \\ 0 & \mathbf{Z}_{2_A} & 0 & 0 & 0 & 0 \\ 0 & 0 & \mathbf{Z}_{3_A} & 0 & 0 & 0 \\ 0 & 0 & 0 & \mathbf{Z}_{4_A} & 0 & 0 \\ 0 & 0 & 0 & 0 & \mathbf{Z}_{5_A} & 0 \\ 0 & 0 & 0 & 0 & 0 & \mathbf{Z}_{6_A} \end{bmatrix} \begin{bmatrix} \mathbf{a}_1 \\ \mathbf{a}_2 \\ \mathbf{a}_3 \\ \mathbf{a}_4 \\ \mathbf{a}_5 \\ \mathbf{a}_6 \end{bmatrix} + \begin{bmatrix} \mathbf{e}_1 \\ \mathbf{e}_2 \\ \mathbf{e}_3 \\ \mathbf{e}_4 \\ \mathbf{e}_5 \\ \mathbf{e}_6 \end{bmatrix}
$$

Nofima

Results

Descriptive statistics – Mean by Tank

Bar represents standard deviation

End Body Weight
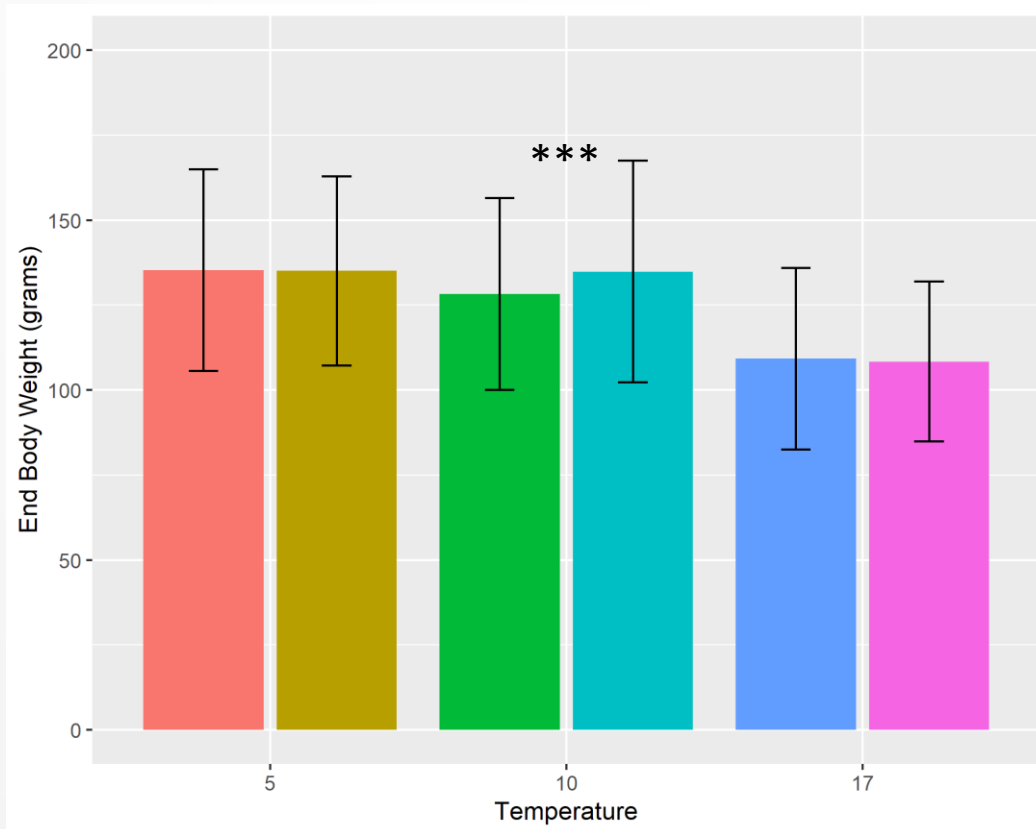
Thermal Growth Coefficient
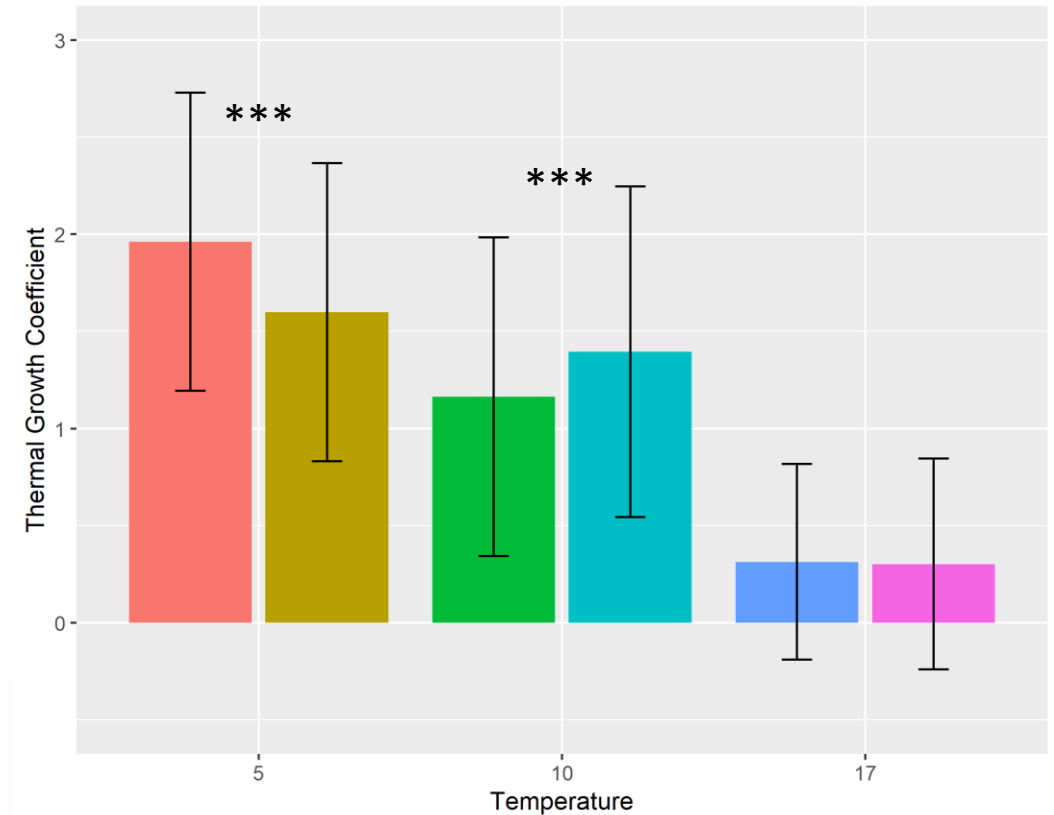
Descriptive statistics – Mean by Tank

Bar represents standard deviation

Lice Count
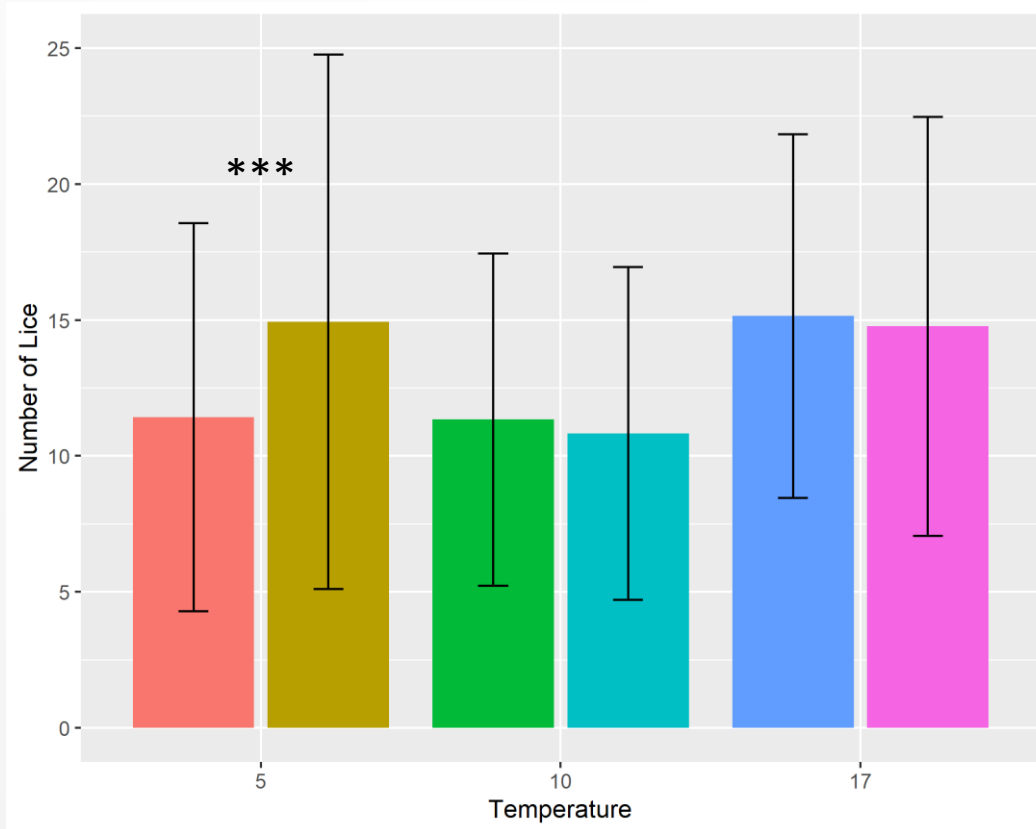
log1pLC
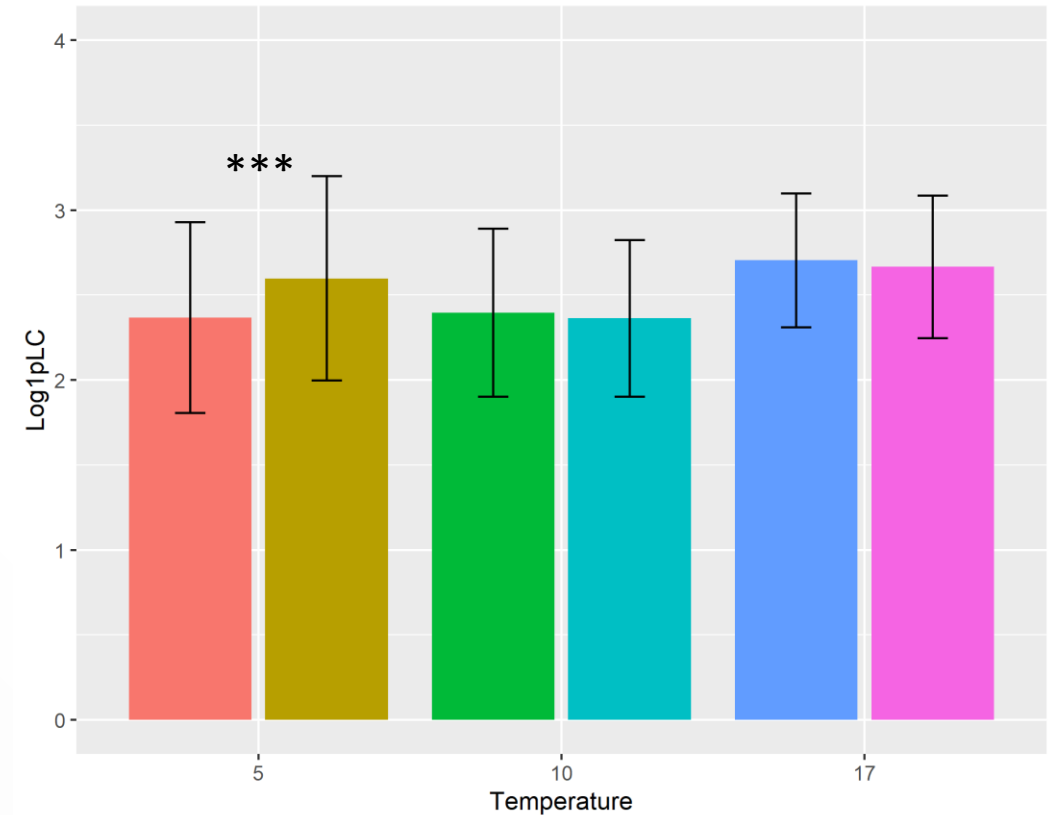
Genetic correlation and heritability

Traits	Estimate ± standard error		
	log1pLC5	log1pLC10	log1pLC17
log1pLC5	0.30 ± 0.05		
log1pLC10	0.66 ± 0.14	0.19 ± 0.05	
log1pLC17	0.40 ± 0.16	0.61 ± 0.17	0.20 ± 0.05
	TGC5	TGC10	TGC17
TGC5	0.33 ± 0.05		
TGC10	0.72 ± 0.12	0.21 ± 0.05	
TGC17	0.57 ± 0.12	0.79 ± 0.11	0.37 ± 0.06

Nofima

Concluding remarks

Moderate re-ranking for growth

Strong re-ranking for lice tolerance

Genetic variation
in thermal sensitivity

Selective breeding on thermal sensitivity for growth and lice tolerance in Atlantic salmon

Nofima

FutureFish

Thank you !

Nofima   MOWI

Hooi Ling Khaw
Researcher

✉ hooi.ling.khaw@nofima.no

🌐 https://nofima.no/

Lice density

- Lice density (LD) = lice count/EWT^2/3

- Phenotypic correlation between EWT and LD by different temperature:

  - EWT5 vs LD5:   -0.49

  - EWT10 vs LD10:   -0.54

  - EWT17 vs LD17:   -0.52

Genetic correlation and heritability

Traits	Estimate ± standard error		
	Lice_count5	Lice_count10	Lice_count17
Lice_count5	0.29 ± 0.06		
Lice_count10	0.76 ± 0.12	0.20 ± 0.04	
Lice_count17	0.34 ± 0.16	0.65 ± 0.15	0.23 ± 0.05

Nofima

Genetic correlation and heritability (pedigree)

Traits	Estimate ± standard error		
	log1pLC5	log1pLC10	log1pLC17
log1pLC5	0.38 ± 0.08		
log1pLC10	0.76 ± 0.11	0.30 ± 0.07	
log1pLC17	0.46 ± 0.19	0.63 ± 0.18	0.18 ± 0.06
	TGC5	TGC10	TGC17
TGC5	0.32 ± 0.07		
TGC10	0.67 ± 0.14	0.24 ± 0.06	
TGC17	0.49 ± 0.16	0.79 ± 0.12	0.42 ± 0.09

Nofima