Modelling Coinfection: The Impact of Sea Lice Infestation on progression of PRV -1 (*Piscine orthoreovirus*) and PMCV (*Piscine myocarditis virus*) infection in Atlantic salmon

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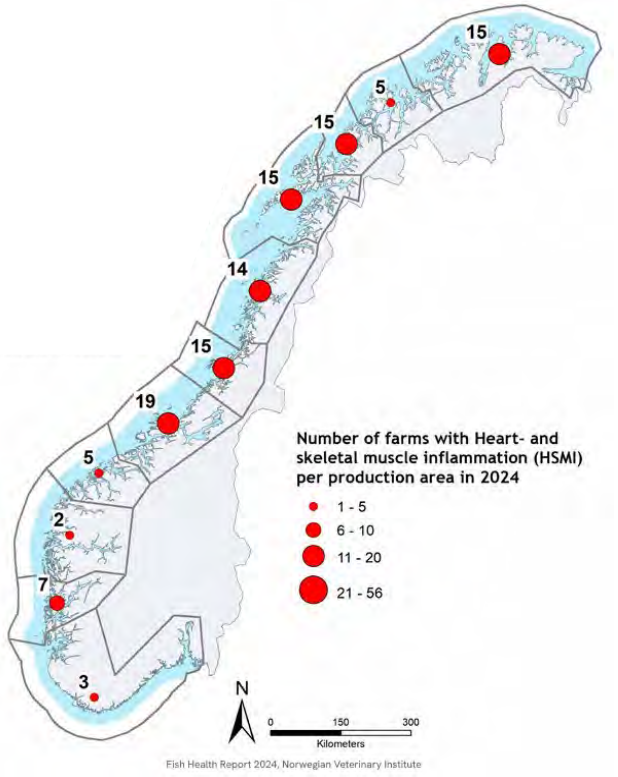
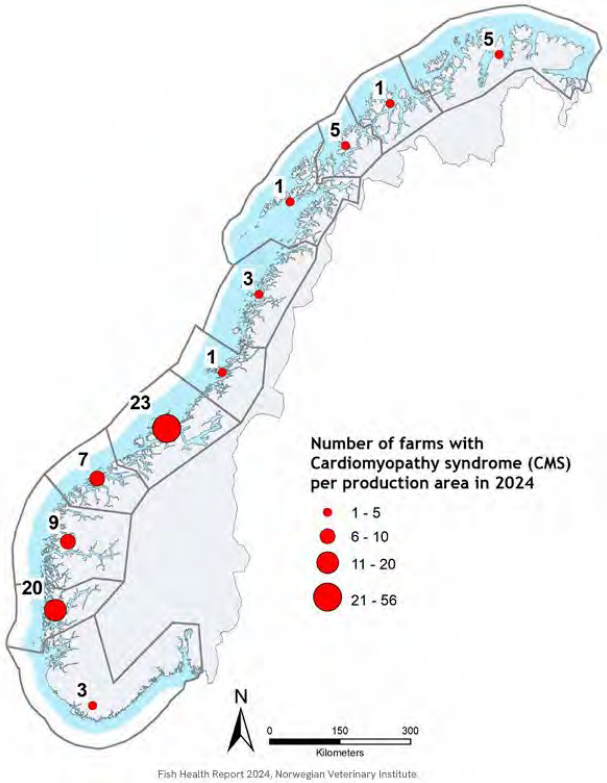
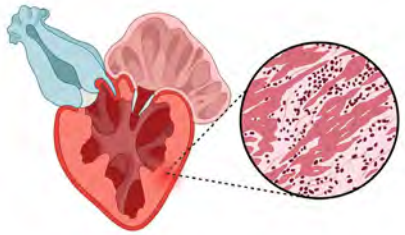
Background: The current state of CMS (PMCV) and HSMI (PRV) in Norway



- Among infectious diseases, **heart and muscle-related diseases** remain prominent.
- Both **heart and skeletal muscle inflammation (HSMI)** and **cardiomyopathy syndrome (CMS)** were detected at more locations in 2025 than in 2024.
- Among fish health personnel, **HSMI** ranked **third and CMS fifth** among the most important health challenges in the **seawater phase.**



PRV-1 is found in **almost 90 %** of farmed salmon in the sea phase in Norway

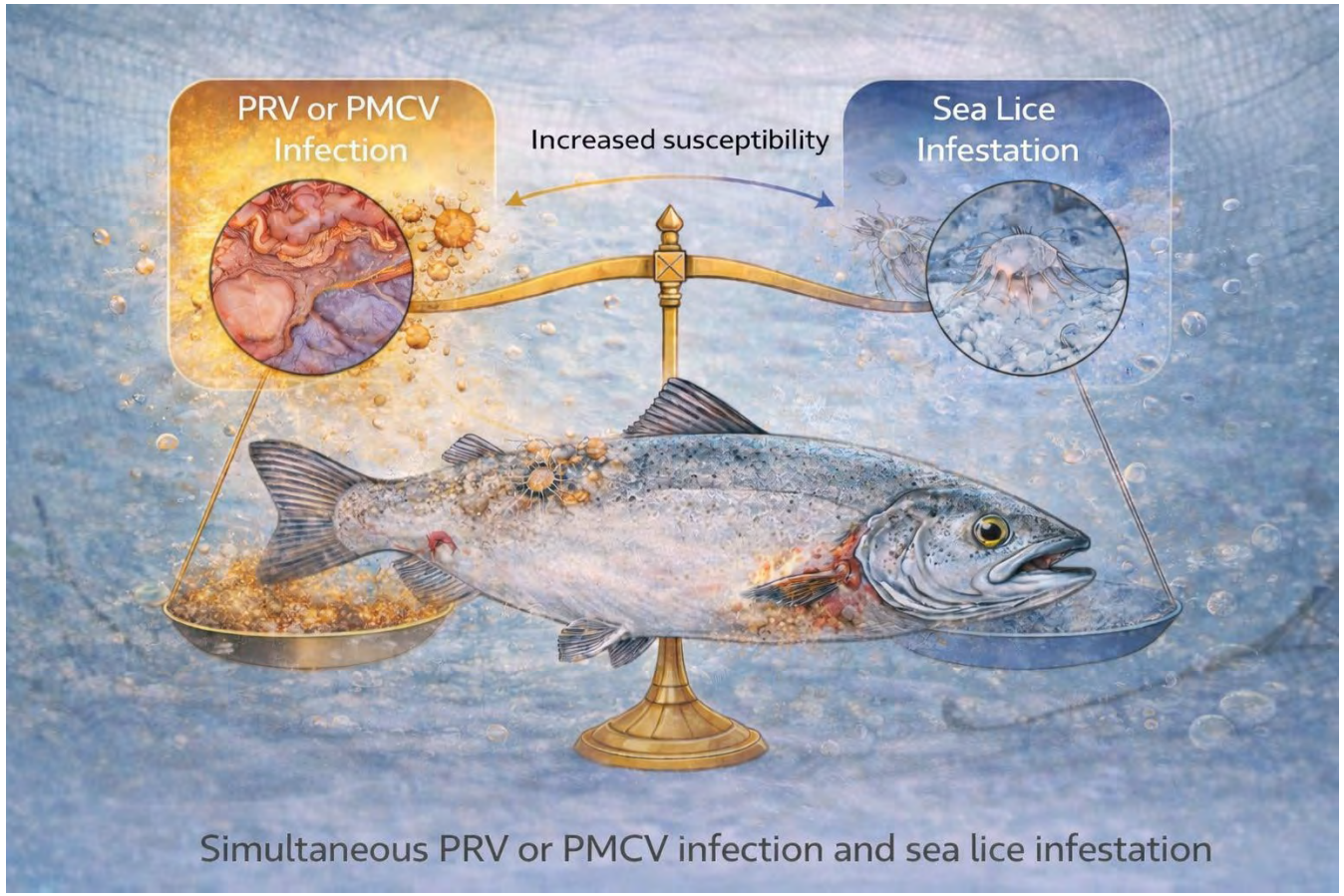


Both diseases are characterized by inflammation that develops in distinct layers of the heart

Background: Sea Lice (*Lepeoptheirus salmonis*) + Delousing

- Largest parasitic challenge in salmon aquaculture
- In 2025, the industry recorded 3,918 treatment weeks, approximately 700 more than in 2024
- Delousing and sea lice increase susceptibility to secondary infections (Skin-associated diseases)

Most common industry - relevant coinfection?



- On sites with PRV -1 and PMCV, delousing treatments can trigger mortality and morbidity
- Gap in our understanding (literature) of how the dynamics work
- What effect do Sea Lice have on viral infection and the development of clinical disease (CMS and HSMI) and vice-versa?

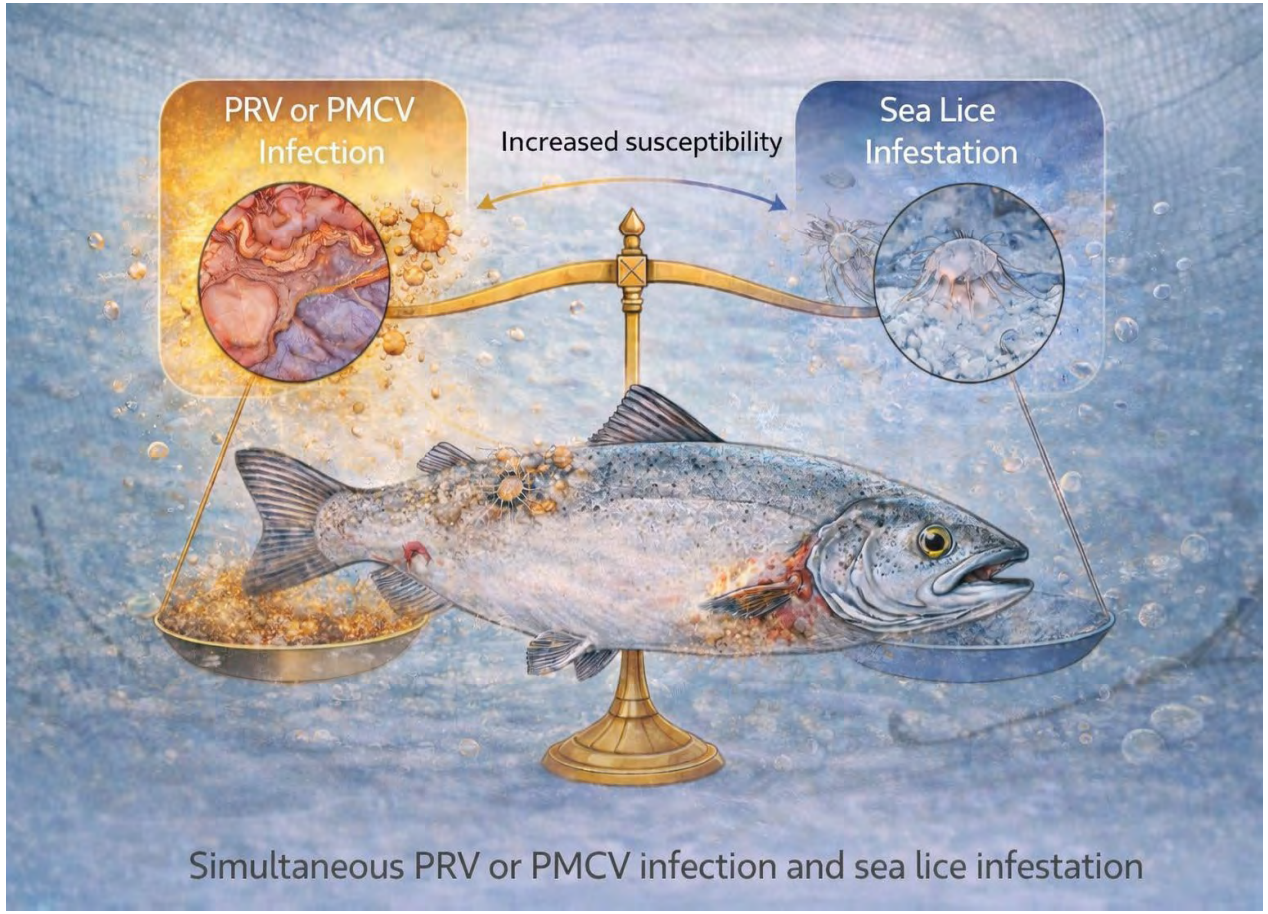
Research Objectives:

Evaluate how coinfection with PRV-1 or PMCV, and sea lice influences…

1) The **severity of HSMI, CMS** , and **sea lice infestation**

and

2) The **host immune response (dynamics)** at the **molecular** and **protein level**



Experimental Design: Modelling Coinfection

60 fish/tank
(N = 120/infection group)
1320 fish, 90-110 g

Control – No infection
PMCV
PRV-1a
PRV-1b
PMCV + SL
PRV-1a + SL
PRV-1b + SL
Sea Lice (#2)

Sea lice challenge *(immersion)* *8 tanks*

SL + PRV-1a
SL + PRV-1b
Sea Lice (#1)

Sea lice challenge *(immersion)* *6 tanks*

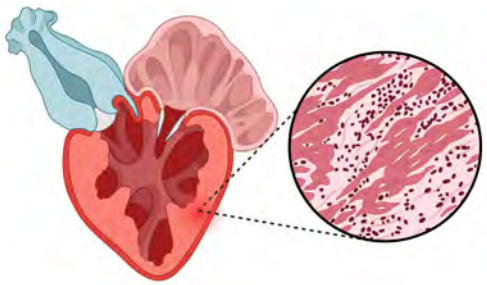
Enrollment/ Challenge
Second PRV challenge
Post-challenge monitoring and sampling

Smoltification – 4 weeks
0 days Study start
7 days (1 week)
48 days (Week 6)
98-105 days (14-15 weeks)

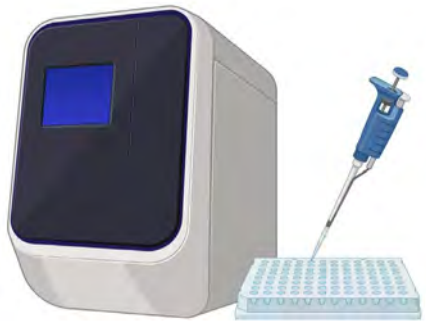
Freshwater 0 ± 5 ppt, 12 ± 2°C
24-hour light photoperiod

Saltwater 32 ± 3 ppt, 12 ± 2°C
12:12 light photoperiod

Methods: Disease Severity and Lice Infection



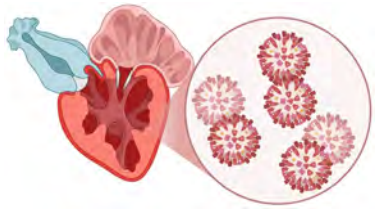
	Tissue Assessed	Variable of Interest
Histology	Heart	Score inflammation in heart compartments (Fritsvold et al., 2009)



RT-qPCR	Red blood cells and Heart	PRV-1 L1, and PMCV ORF3 CT value (i.e., viral load)

Lice Counts	Whole fish	Sea lice burden (i.e., number of lice per fish)

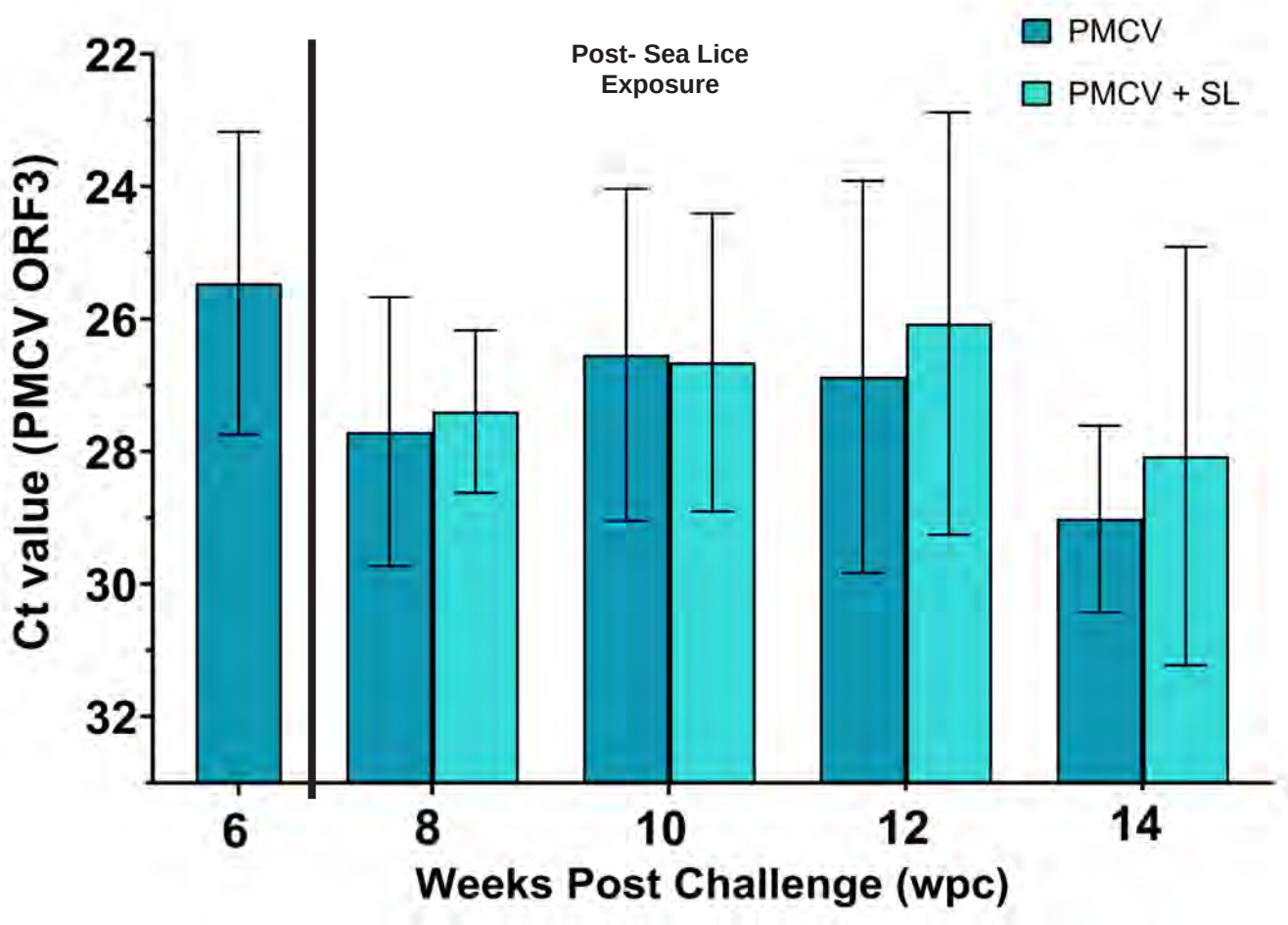
PMCV → Sea lice: Does sea lice infestation impact PMCV load in the heart?



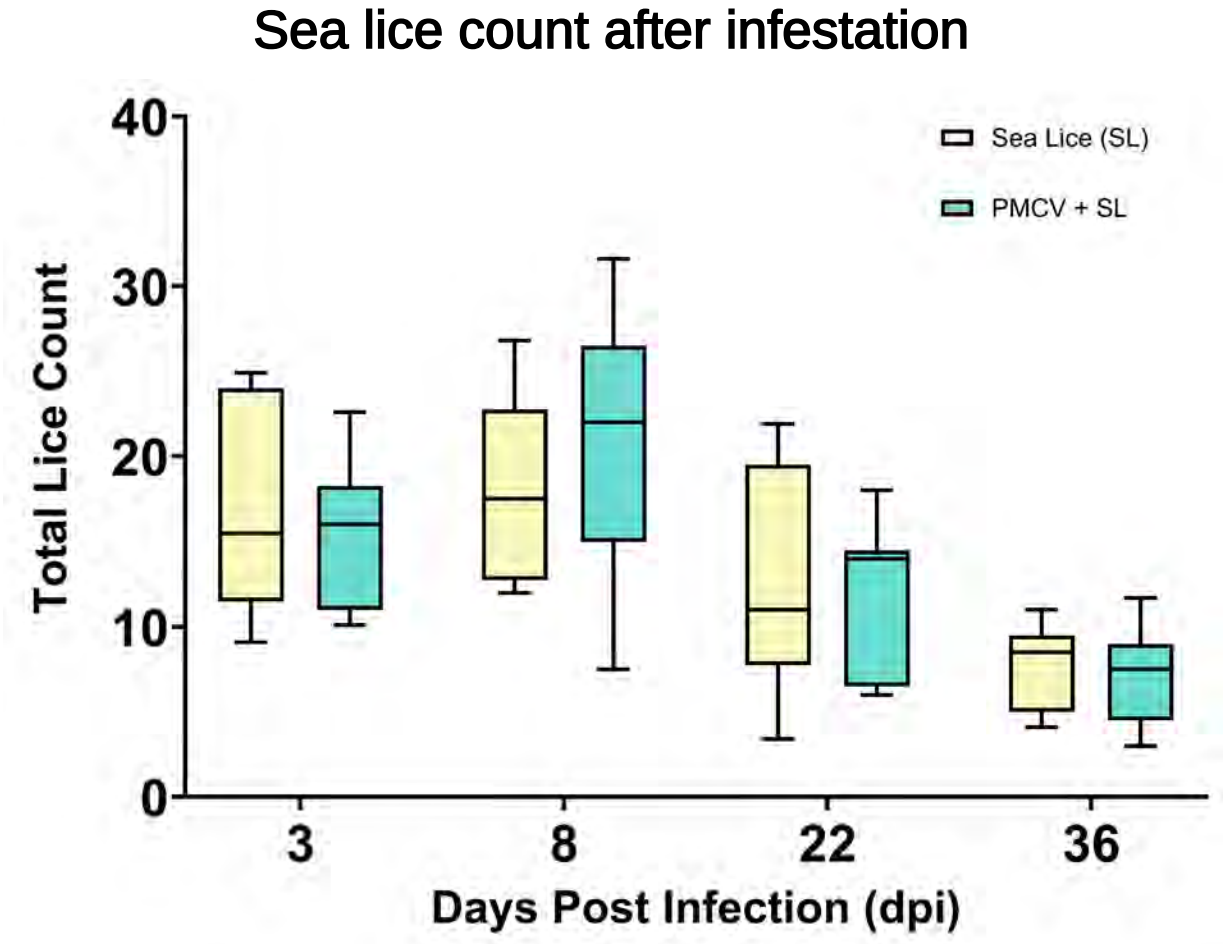
Total RNA
from Heart

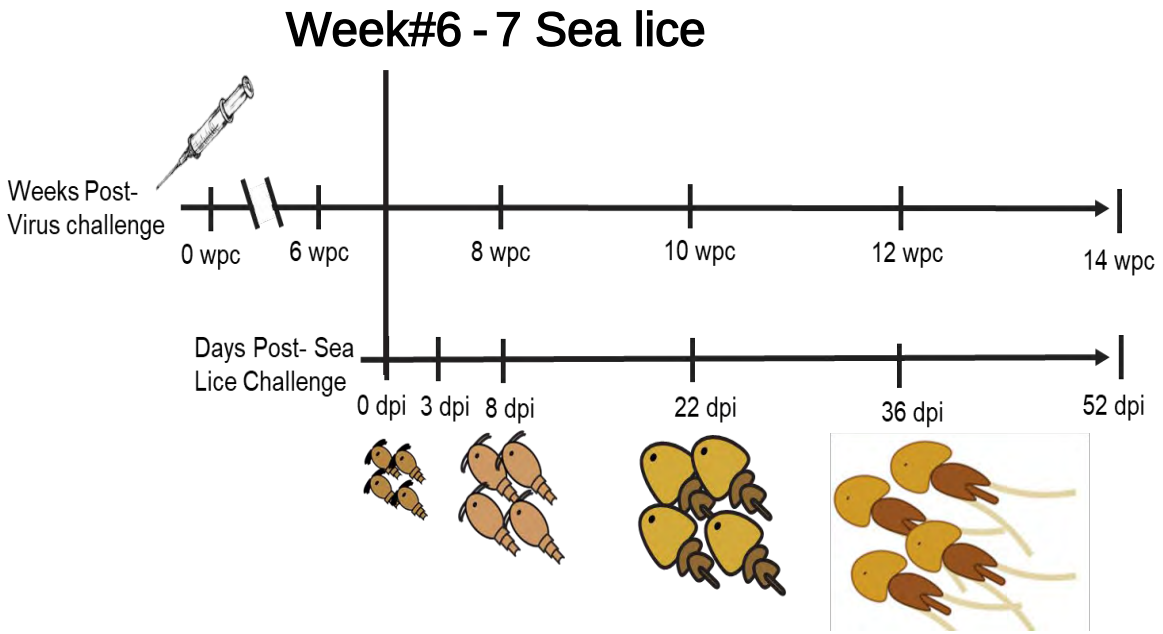
Sea lice do not affect PMCV viral load in the heart

Week#6 - 7 Sea lice



PMCV → Sea lice: Does PMCV infection impact sea lice count and development in salmon?

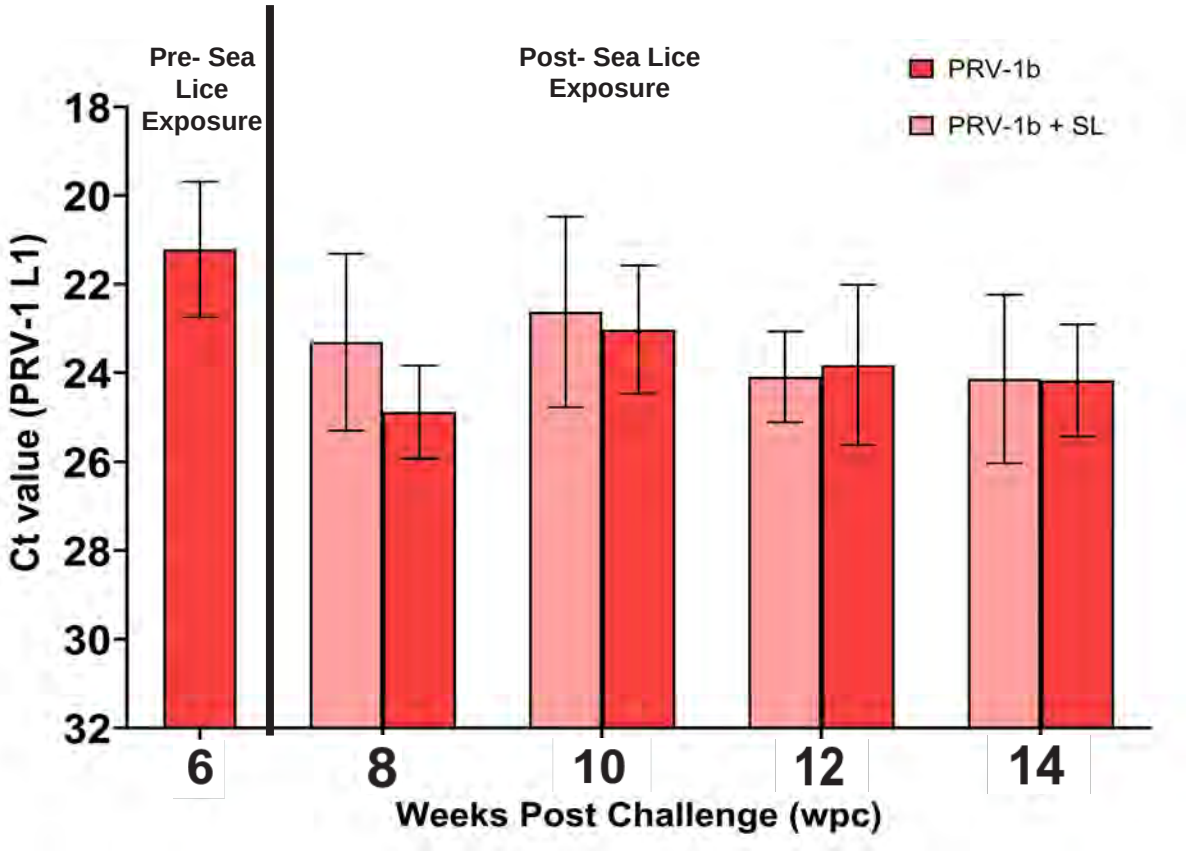




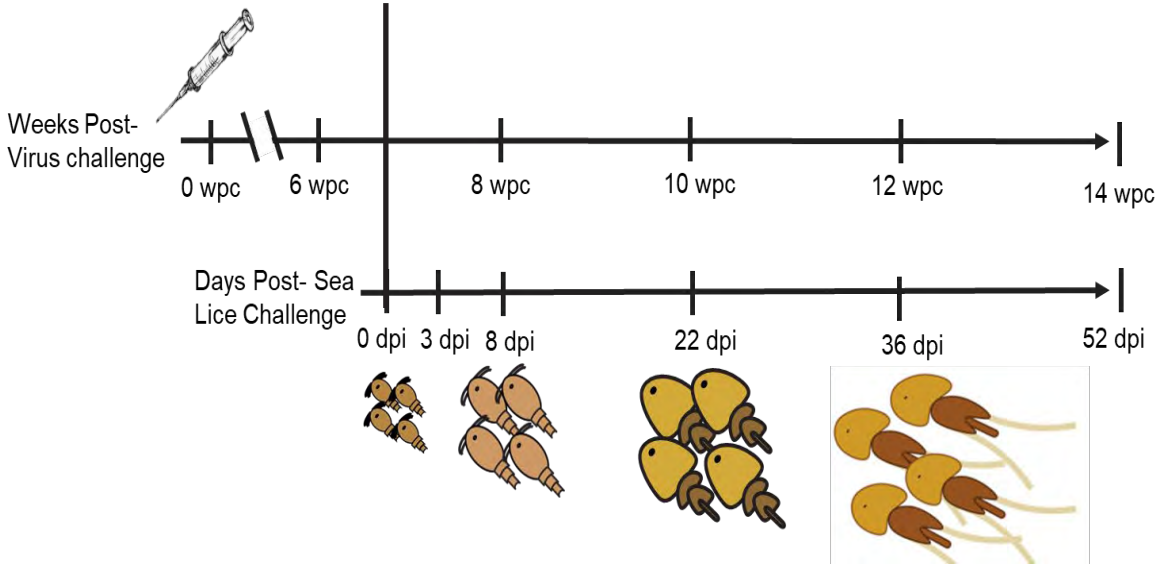
PMCV infection does not influence sea lice count and development in Atlantic salmon

PRV-1 → Sea lice: Does sea lice infestation after PRV infection aggravate viral load in RBC?

Week#6 - 7 – Sea lice

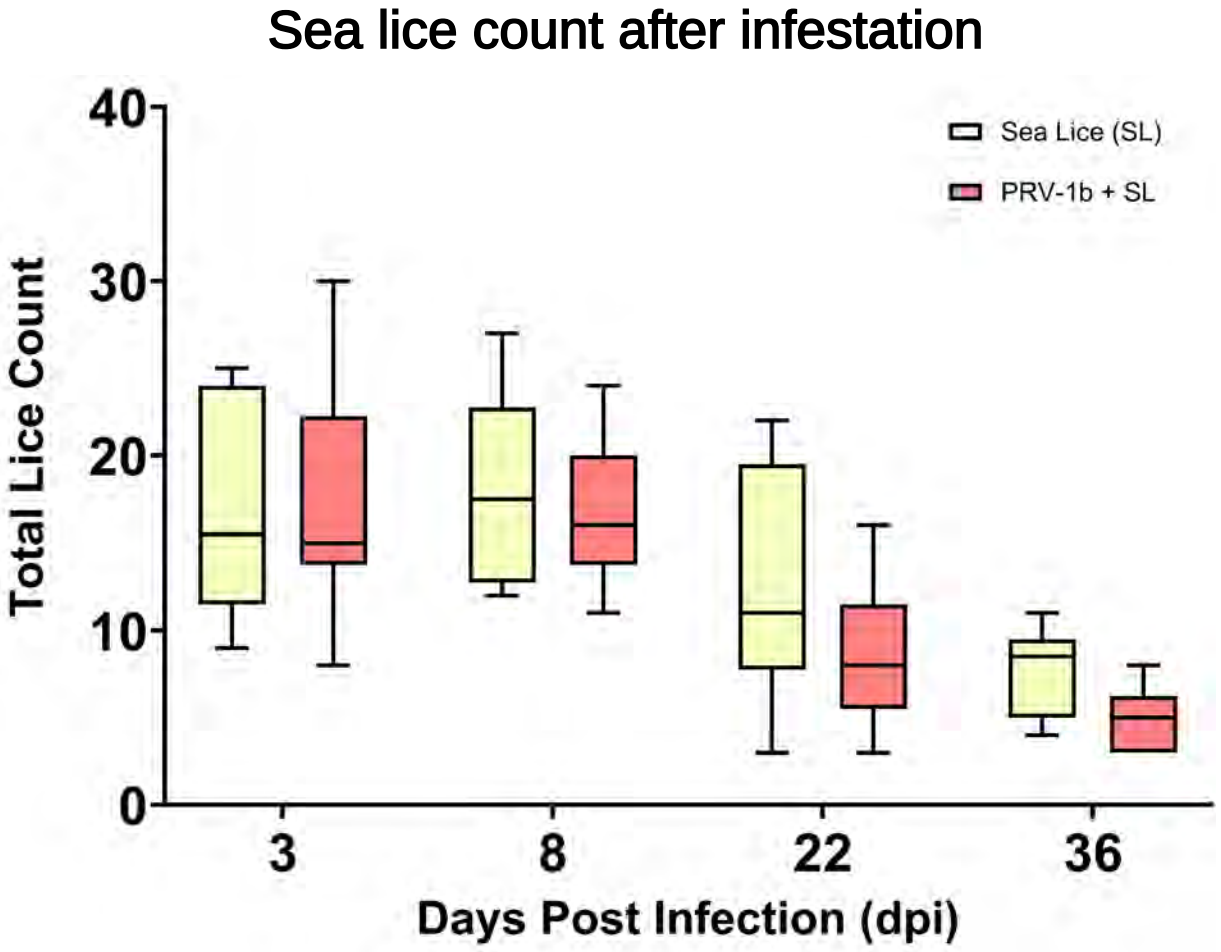


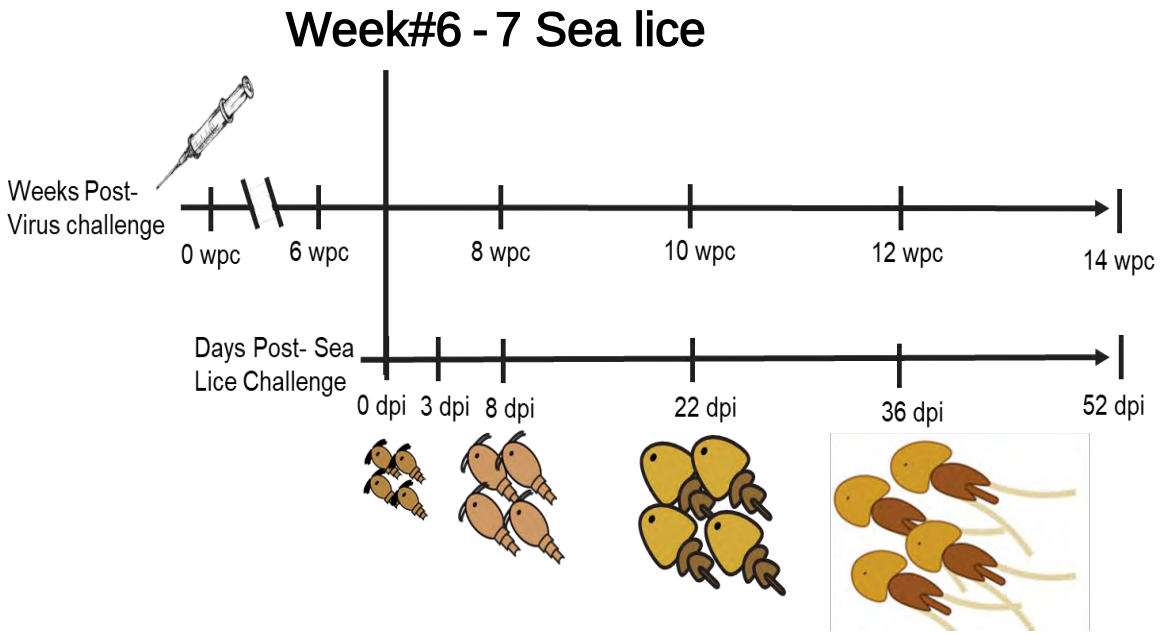
Week#6 - 7 Sea lice



Sea lice do not affect PRV - 1b viral load in RBC

PRV-1 → Sea lice: Does PRV1-b infection impact sea lice count and development in salmon?



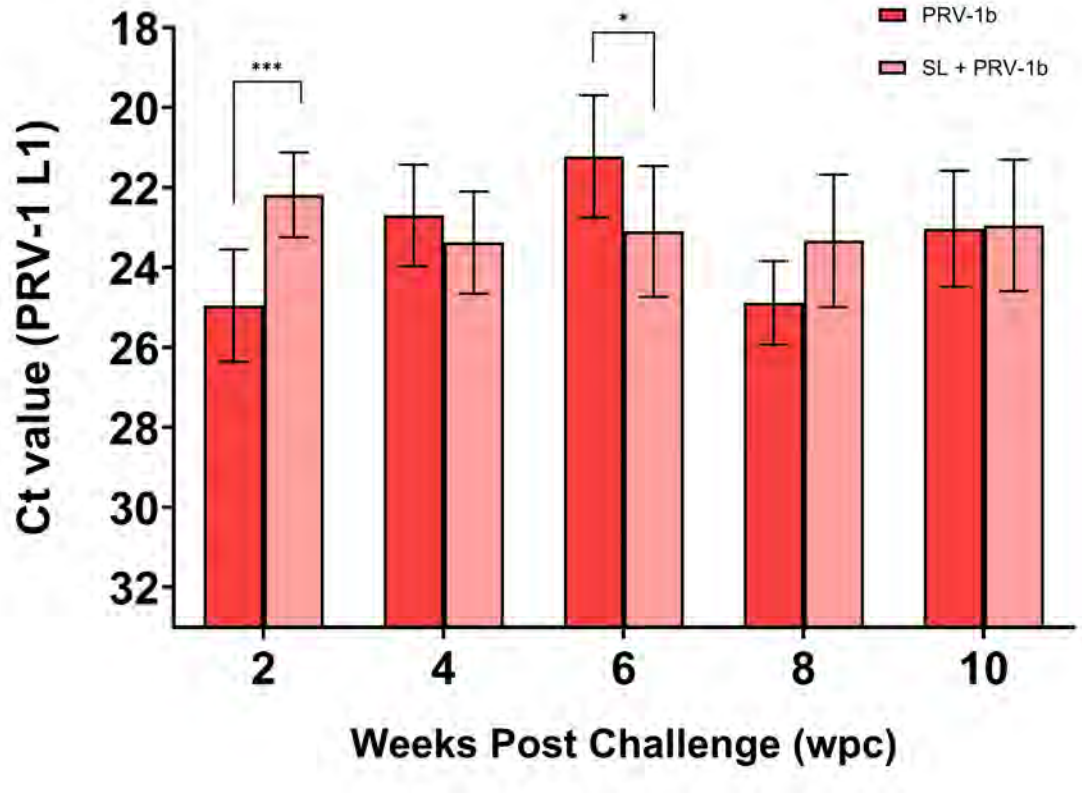


PRV-1b infection does not influence sea lice count and development in Atlantic salmon

Sea lice → PRV-1: Does sea lice infestation impact PRV -1b load in RBC?

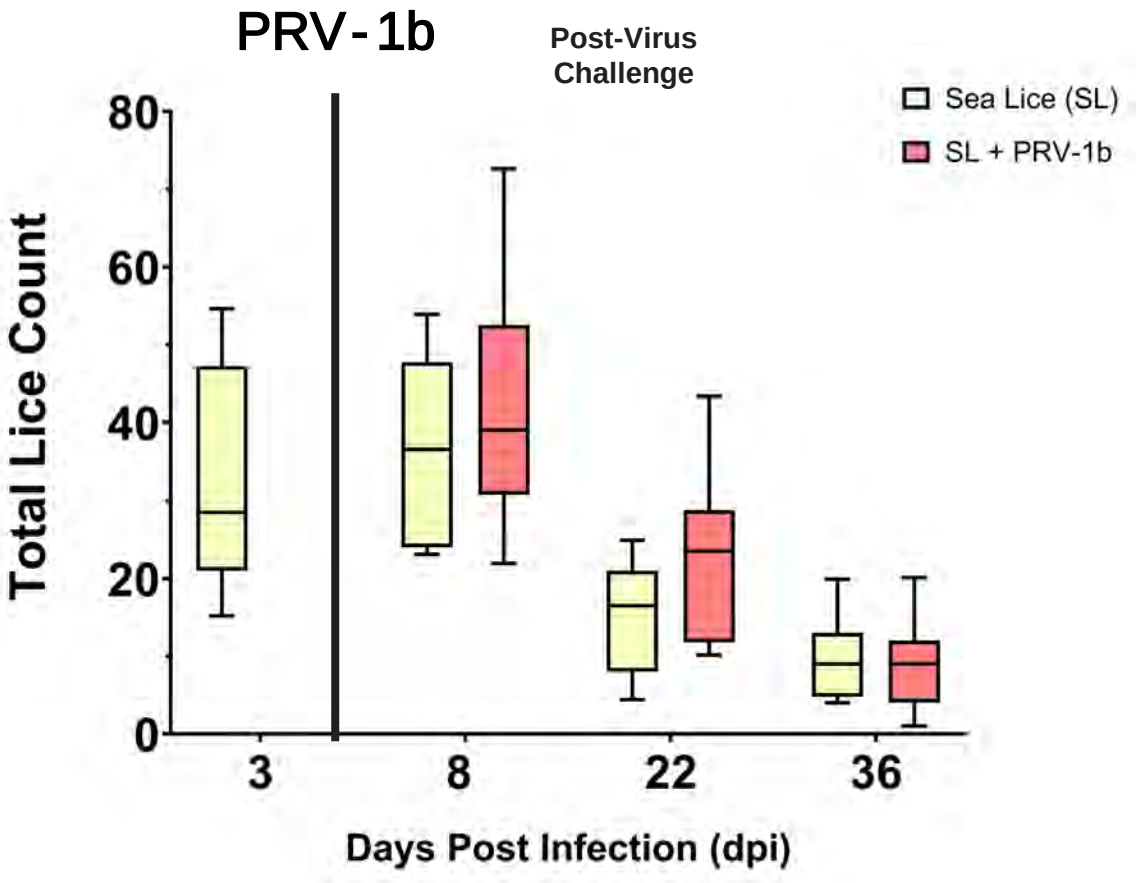
Total RNA from
Red Blood Cells

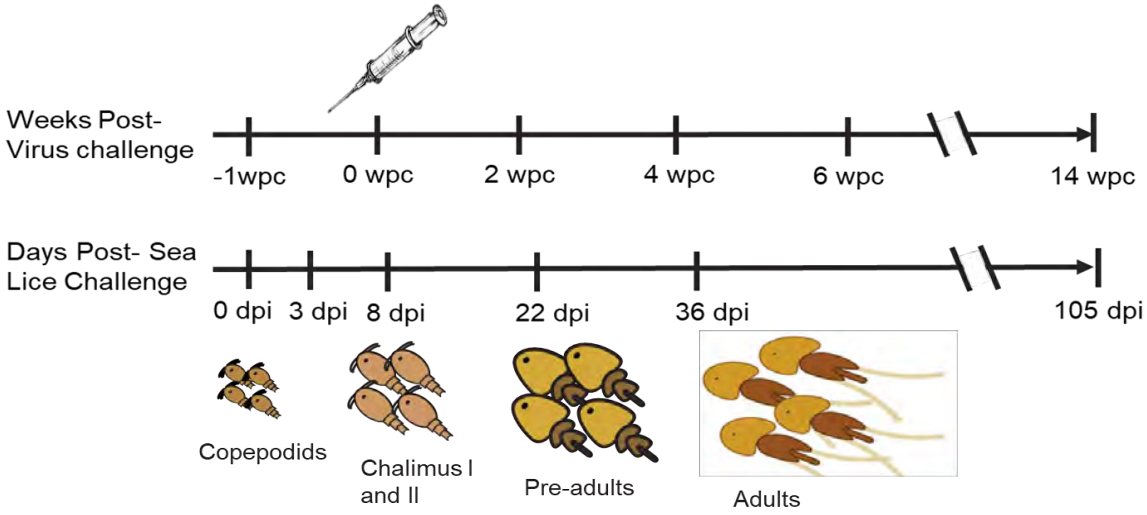
Sea lice and after 7 days PRV



- Coinfected group (Sea lice) showed significantly higher viral load at 2wpc
- Viral load peaked in the PRV-1b group at 6wpc, and significantly higher than PRV-1b
- **PRV-1b load in RBC peaked earlier in the group coinfected with sea lice**

Sea lice → PRV-1: Does viral infection impact Sea lice count and development in salmon?

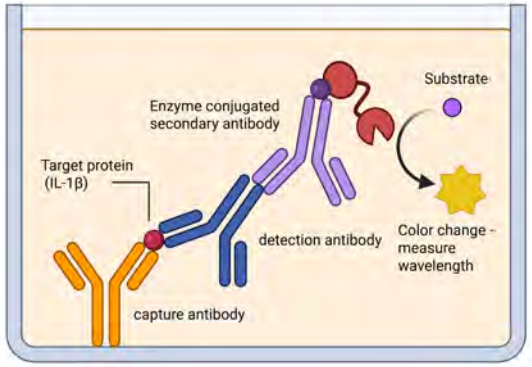


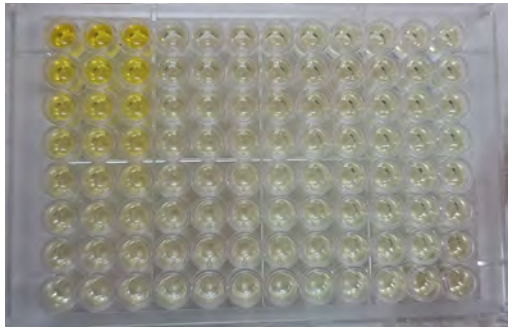


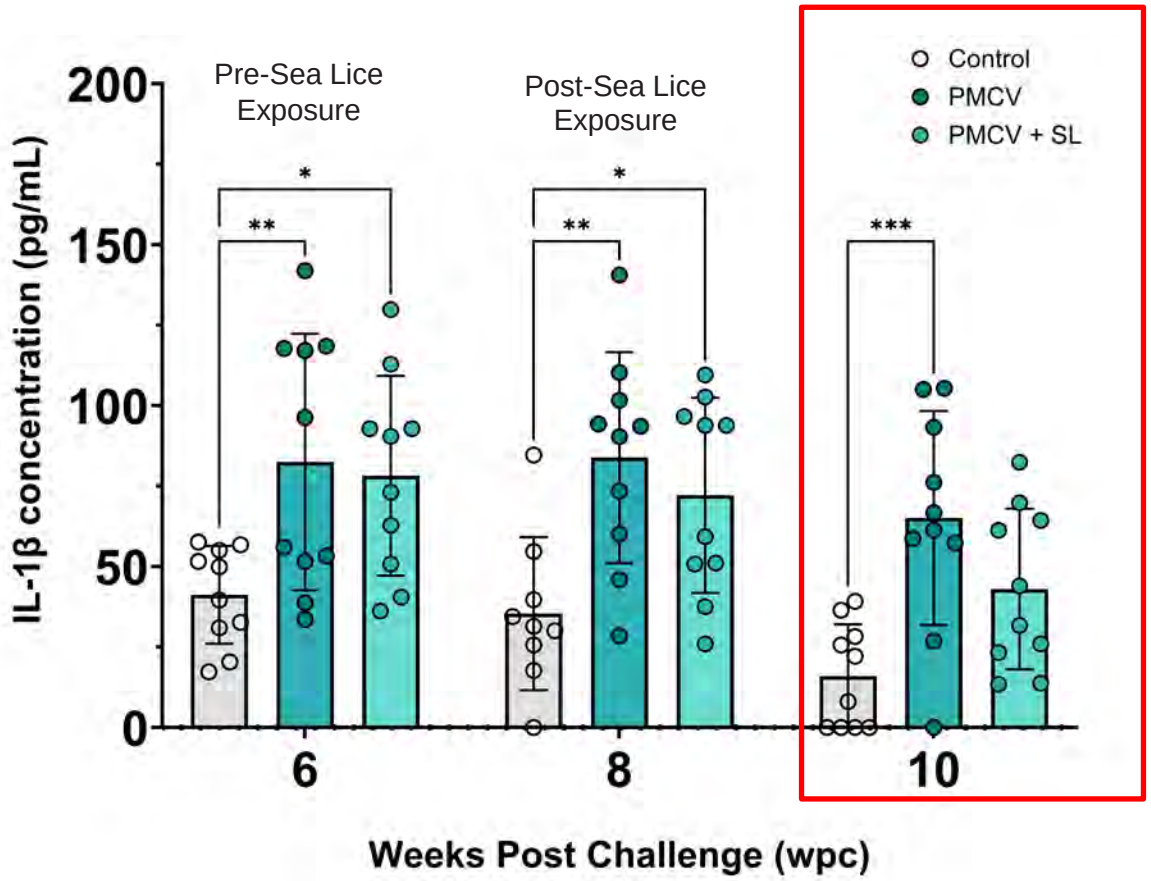
PRV-1b does not impact the count and development of sea lice

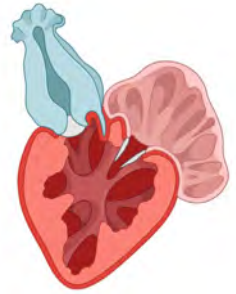
PMCV Coinfection: Does Sea lice impact pro -inflammatory cytokines in the heart?

IL-1β Sandwich ELISA







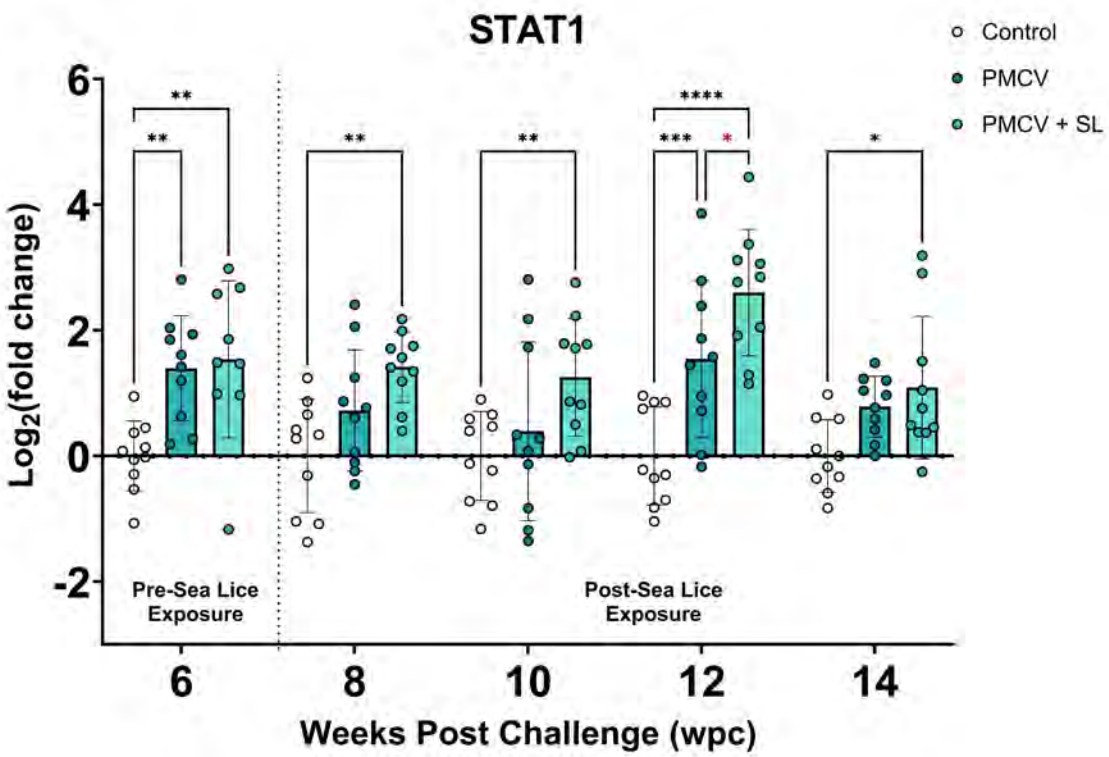


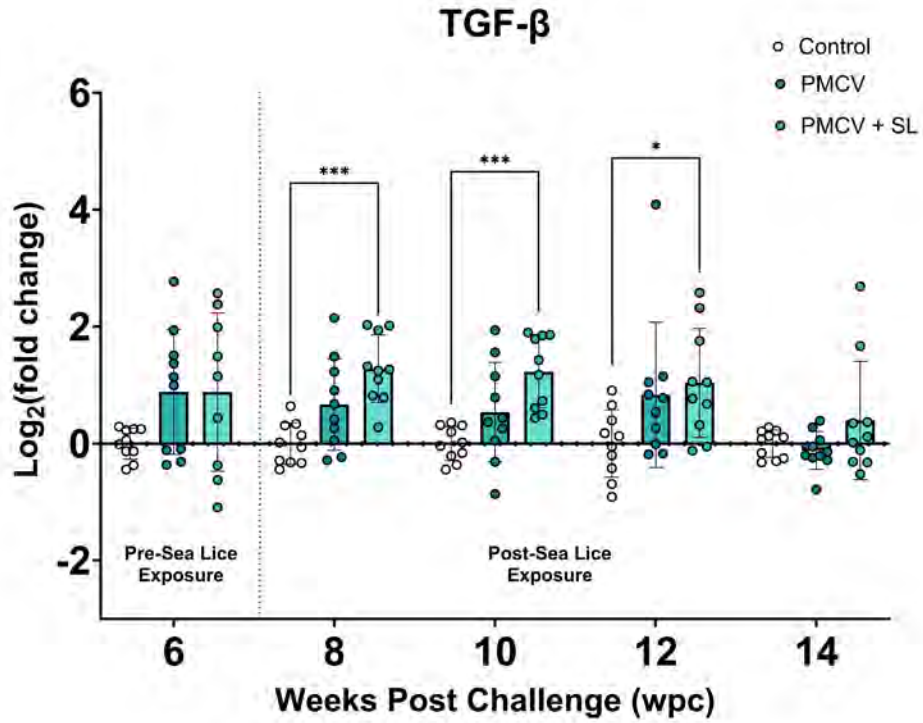
Total Heart Protein

Sea lice infestation affected the ability of salmon to maintain higher [IL-1β] in the heart

PMCV → Sea lice: Does Sea lice impact inflammation dynamics in the heart?

Heart RNA





Pro-inflammatory sign related to interferon signaling
The sea lice group had higher expression in heart tissue

Anti-inflammatory cytokine
The sea lice group had higher expression in heart tissue

Methods: Respiratory Performance

Infection Groups Sampled:

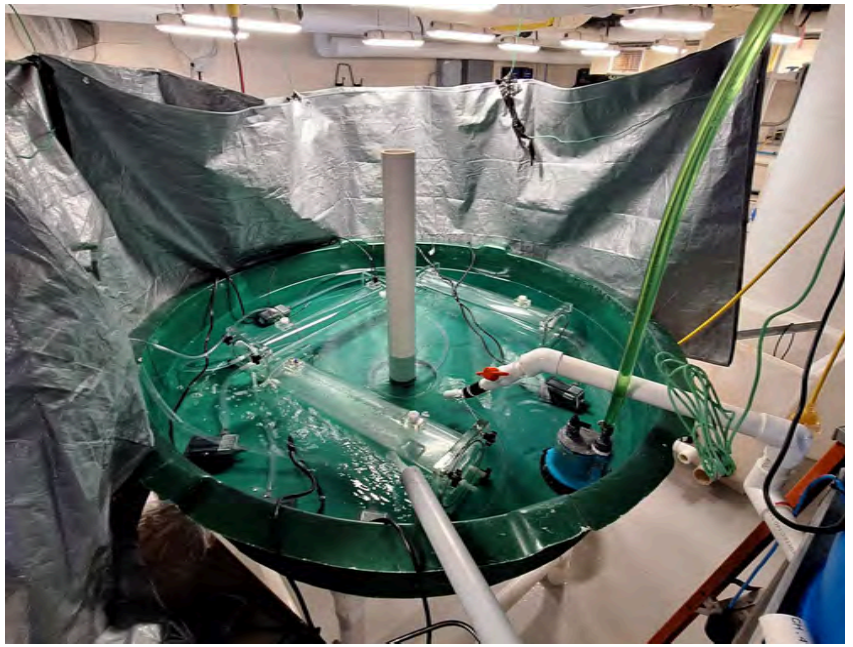
1) Control (no infection)

2) PRV-1b (virulent)

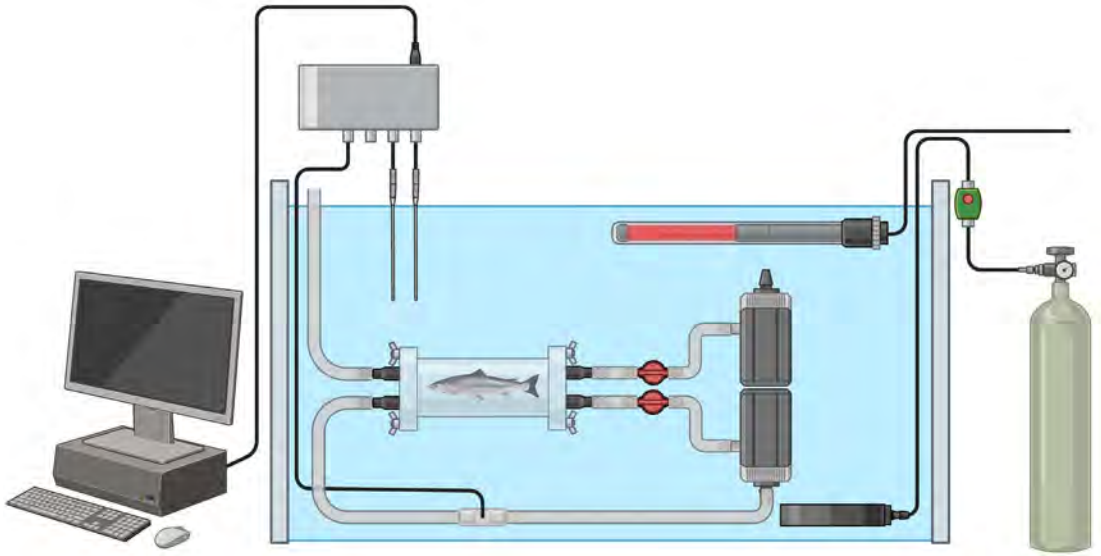
3) PMCV

Variables of Interest:

- Ctmax (3°C/h)
- Oxygen Consumption
- Relative ventricular mass (RVM)



- 15 fish tested per group across three weeks (8, 9, and 10 weeks post injection challenge)
- Timed to test at peak of lesion severity in heart



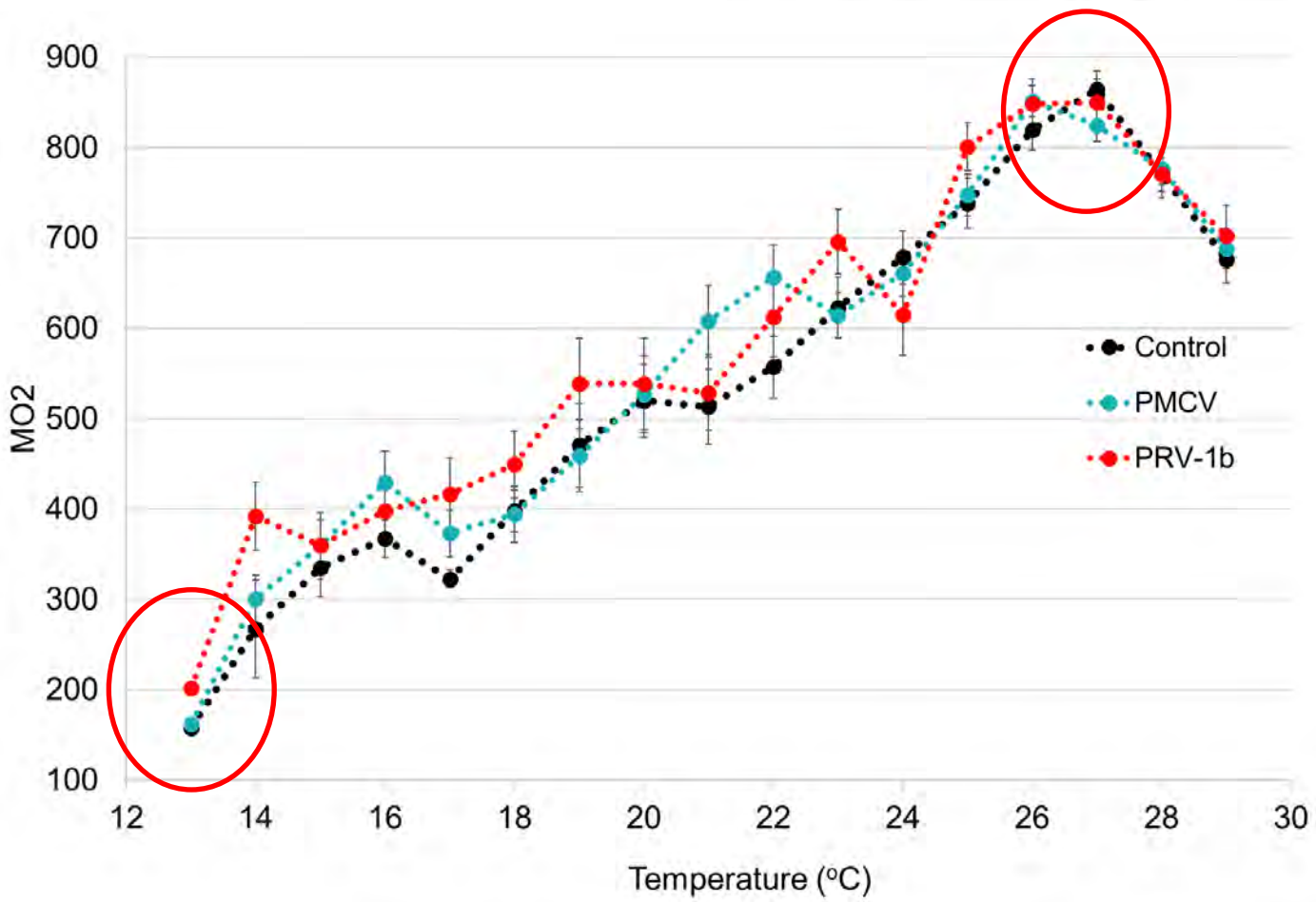
Respiratory Performance

Hypothesis:
HSMI/CMS reduces cardiac performance

MO_2 may:
- ↓ at max (impaired performance)
- ↑ at rest (chronic stress/inflammation)

PRV and PMCV infection do not impair thermal oxygen -use performance

$$\dot{M}O_2 = \frac{\text{Oxygen consumed}}{\text{time}}$$



Respiratory Performance

Group	Control	PRV-1b	PMCV
Weight (g) ± SD	215.0 ± 34.0	210.3 ± 40.1	217.9 ± 35.0
SMR ± SD	182.2 ± 27.3	194.4 ± 47.4	192.8 ± 36.0
MMR ± SD	915.1 ± 112.6	951.8 ±107.5	923.2 ± 75.1
RVM ± SD	0.1050 ± 0.009	0.1087 ± 0.017	**0.1265** ± 0.021
Welch's t-test P-value	-	0.3700	**<0.0001**

Ctmax (C°)			
Week	PRV-1b	PMCV	Control
8	28.75	28.93	29.20
9	29.00	28.83	28.89
10	29.15	29.12	28.98

1. Blood: spleen contraction, HGB, HTC
2. Ventilation Adjustments: rate and amplitude
3. Cardiovascular: Heart rate and stroke volume (cardiac output
4. Acid-Base regulation: carbonic anhydrase, Bohr & Root effect
5. Pathology was limited (results pending)

Conclusions

- Sea lice infestation (single) does not impact [PMCV] in the heart, but affects the peak of [PRV-1b] in RBC
- PMCV or PRV-1b infection does not affect the severity of (single) sea lice infestation
- Sea lice affect the dynamics of heart inflation induced by PMCV
- PRV-1b or PMCV infection does not alter oxygen consumption during acute warming (likely reflects compensatory mechanisms masking underlying cardiovascular limitations)

Caveats to extrapolate to the field: Single sea lice infestations vs continuous sea lice pressure and constant adverse conditions in the field, including multiple pathogens and delousing

Work in progress….

- Evaluated gene expression of cellular mediated immunity (CD8, MHC I, MHC II, Tbet, CD4-1, and STAT1), cytokines (IFNγ, TGF-β, IL-1β), and cytotoxic activity (GrmA) in heart and spleen tissue
- Measured IL-1β concentration in spleen tissue, and PRV-1 specific IgM in plasma
- Also looking at antiviral responses in the heart
- Histopathology

Thank you to the Dixon Research Group!

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