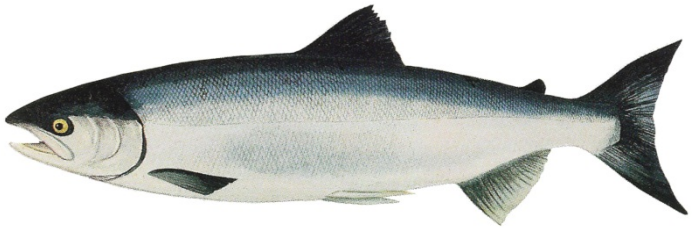
Virus interaction of wild and farmed fish populations

Kyle Garver

Pacific Biological Station



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ACRDP: Aquaculture Collaborative Research and Development program

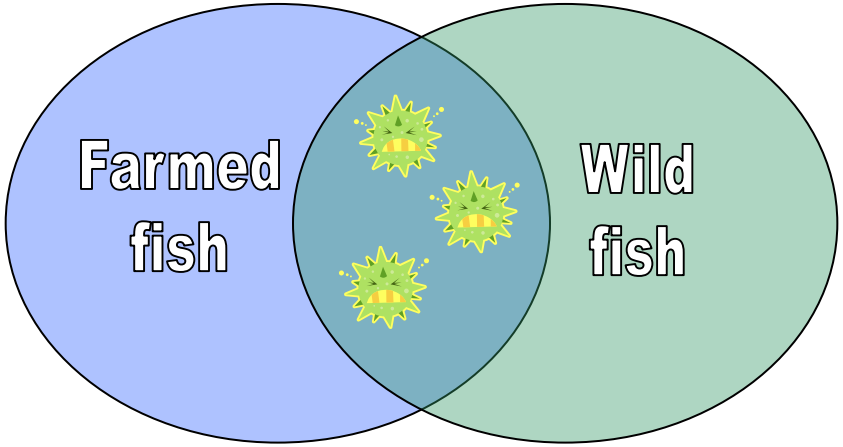
PARR: Program for Aquaculture Regulatory Research

GRDI: Genomics Research and Development Initiative

NSERC: Natural Sciences and Engineering Research Council

Issue

Sharing the environment → **Sharing the microbes**



- **Viral spillover…can it be predicted?**

Does virus spill-back occur?

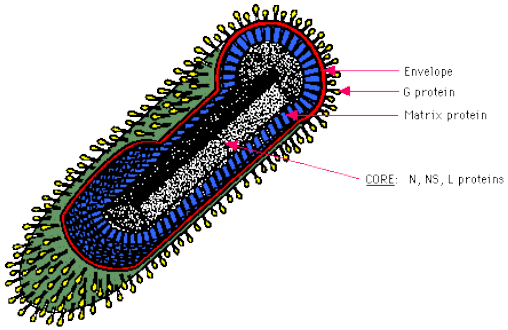
Key questions concerning virus dispersal from farms

1. How much virus is produced from an infected farm?
    - Viral shedding rates of Atlantic salmon

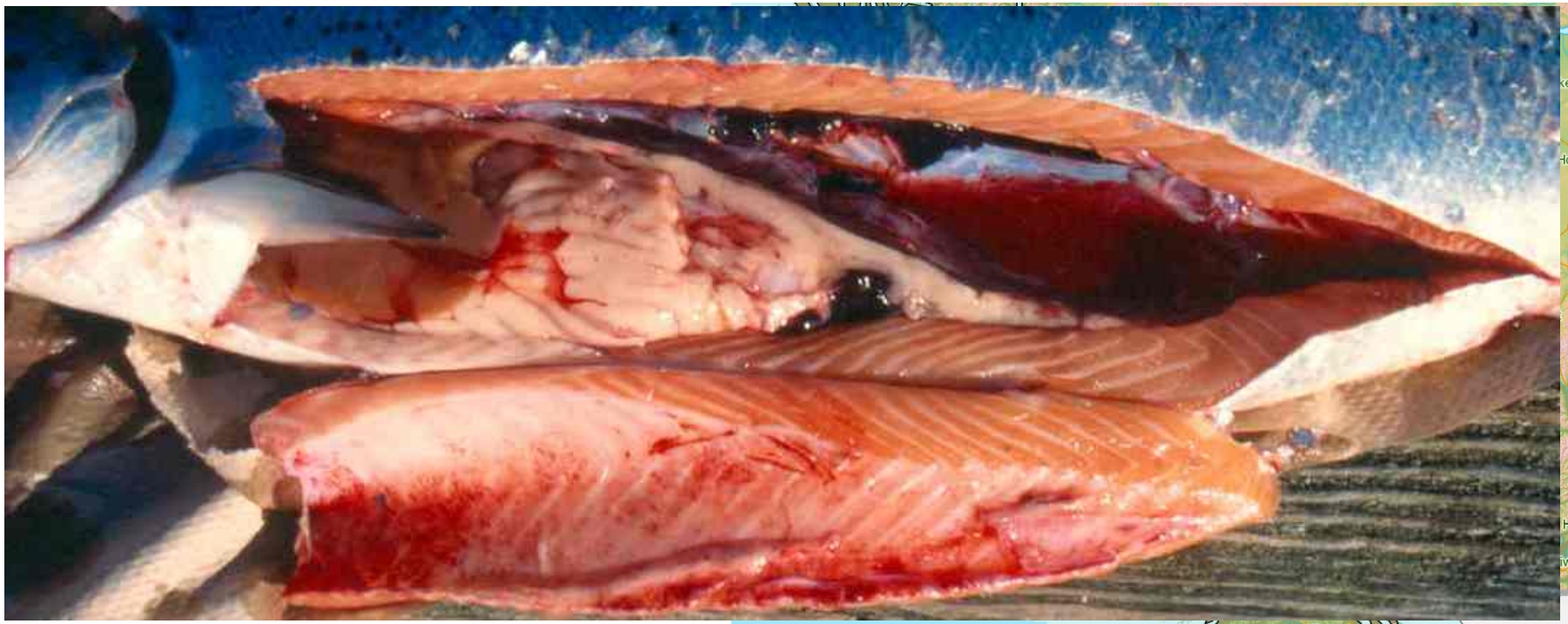
2. How long can the virus last outside of its host?
    - Virus decay in seawater

3. How much free virus is needed to infect a naïve farm?
    - Minimum infectious dose

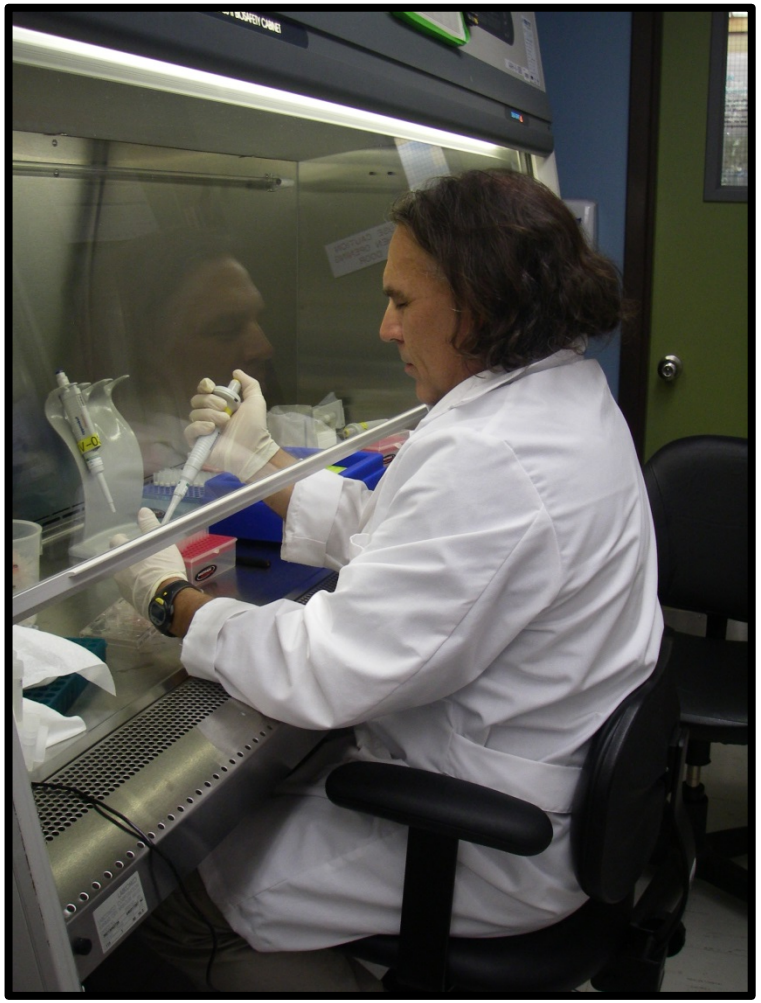
Infectious Hematopoietic Necrosis Virus (IHNV)



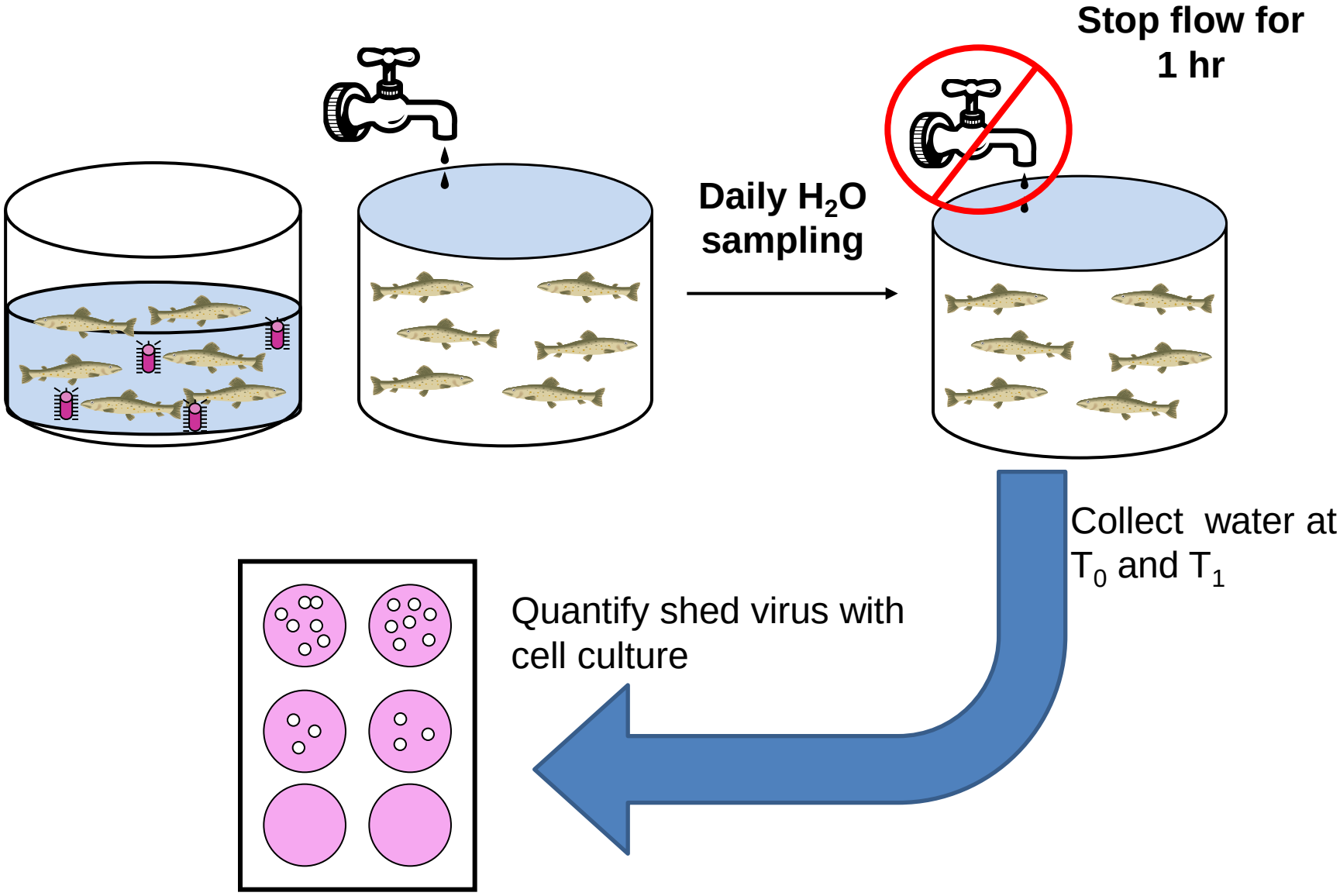
- In BC, IHNV is primarily associated with Sockeye salmon
- Can cause large-scale mortality events



Quantify Virus Transmission Parameters through Controlled Laboratory Studies

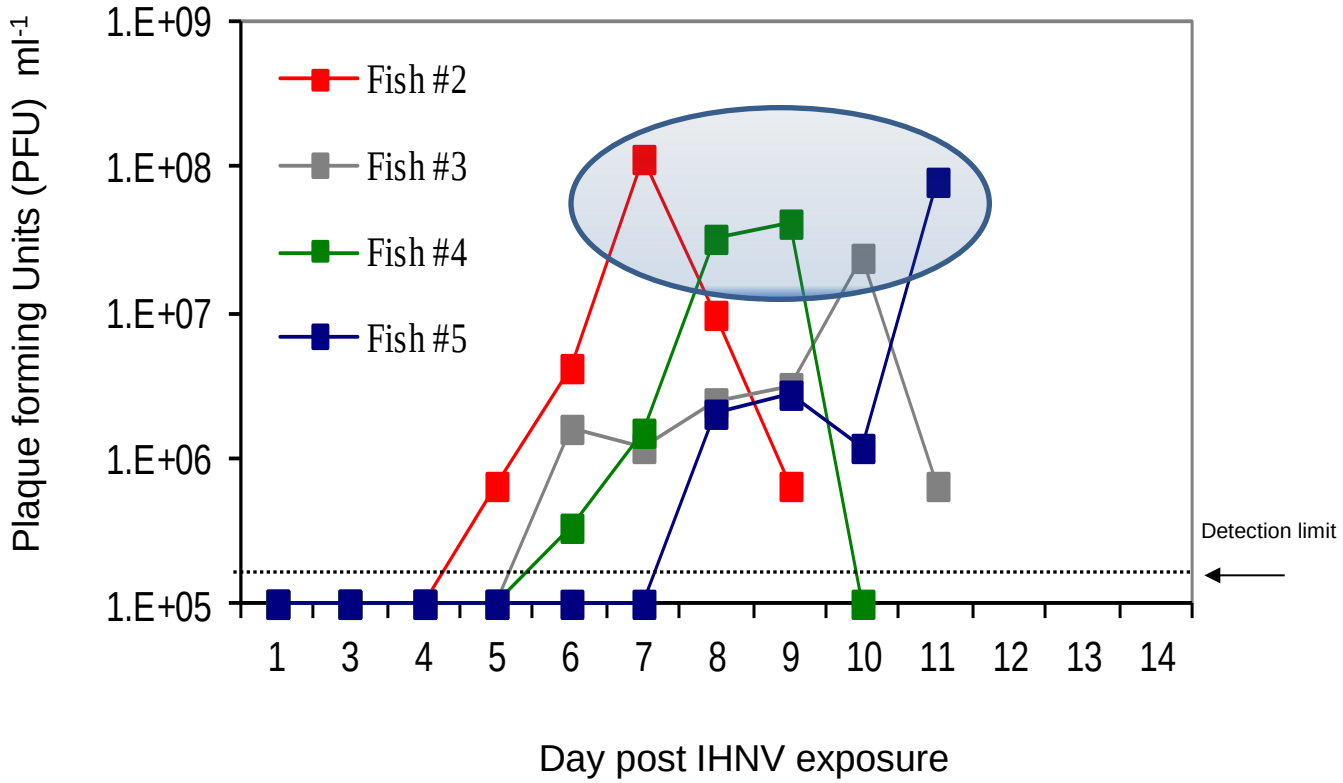


IHNV shedding set-up



IHNV shedding in Atlantic salmon

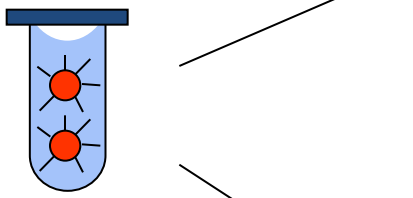
Peak shedding rate = 3.2 x 10^7 PFU $fish^{-1}$ $hour^{-1}$



Virus decay in seawater

- Challenge – Finding appropriate laboratory condition to simulate ocean environment

Multiple environmental conditions



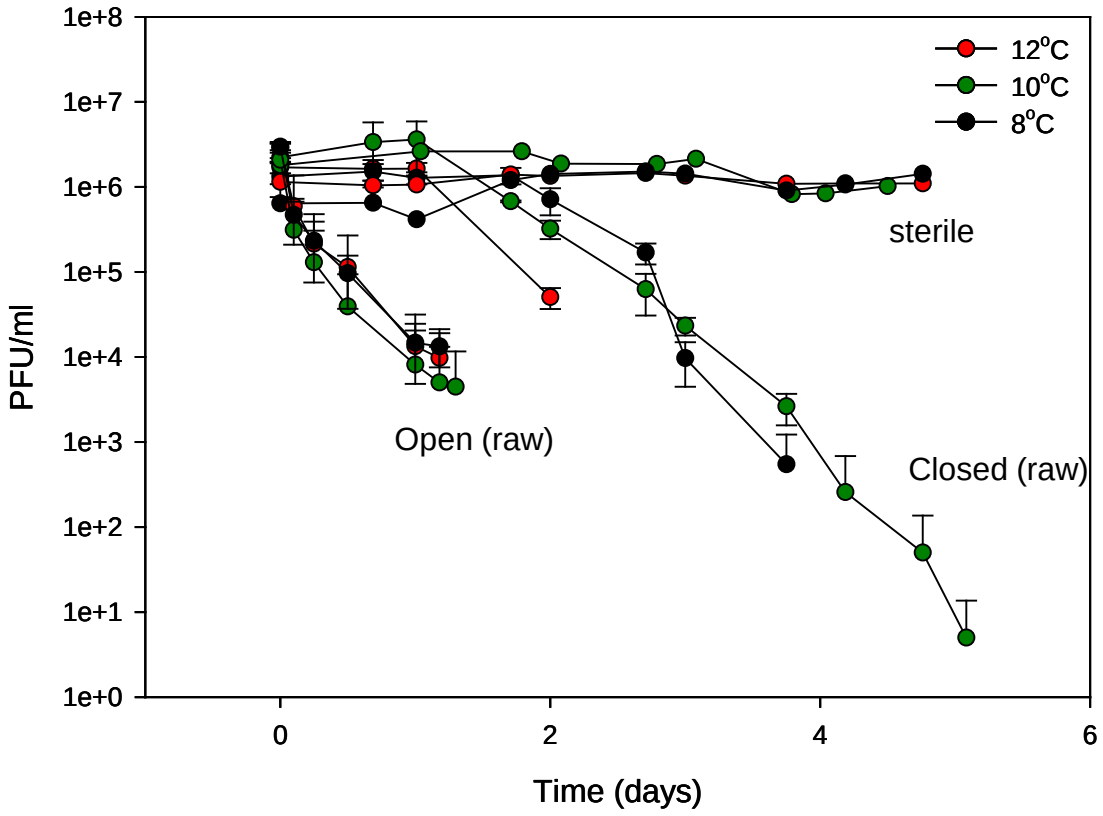
Water Temperature

8, 10 and 12^{o}C

Water aeration

Open vs Closed system

IHNV decay in seawater



- **Virus decay is biologically mediated**
- **decay rate constant (open system)**

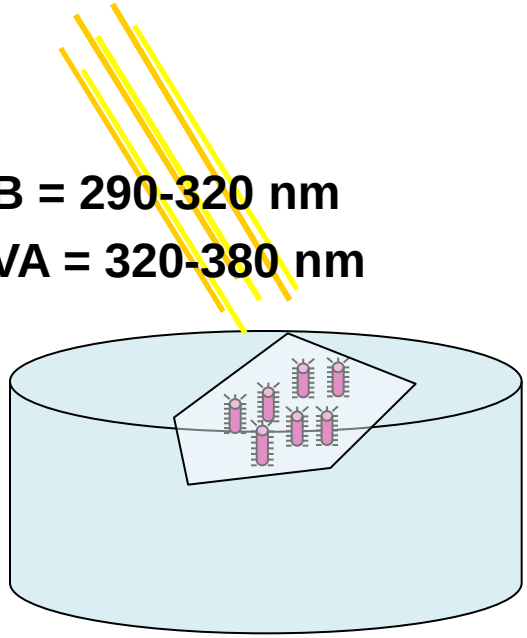
$k = 4.11\ (d^{-1})$

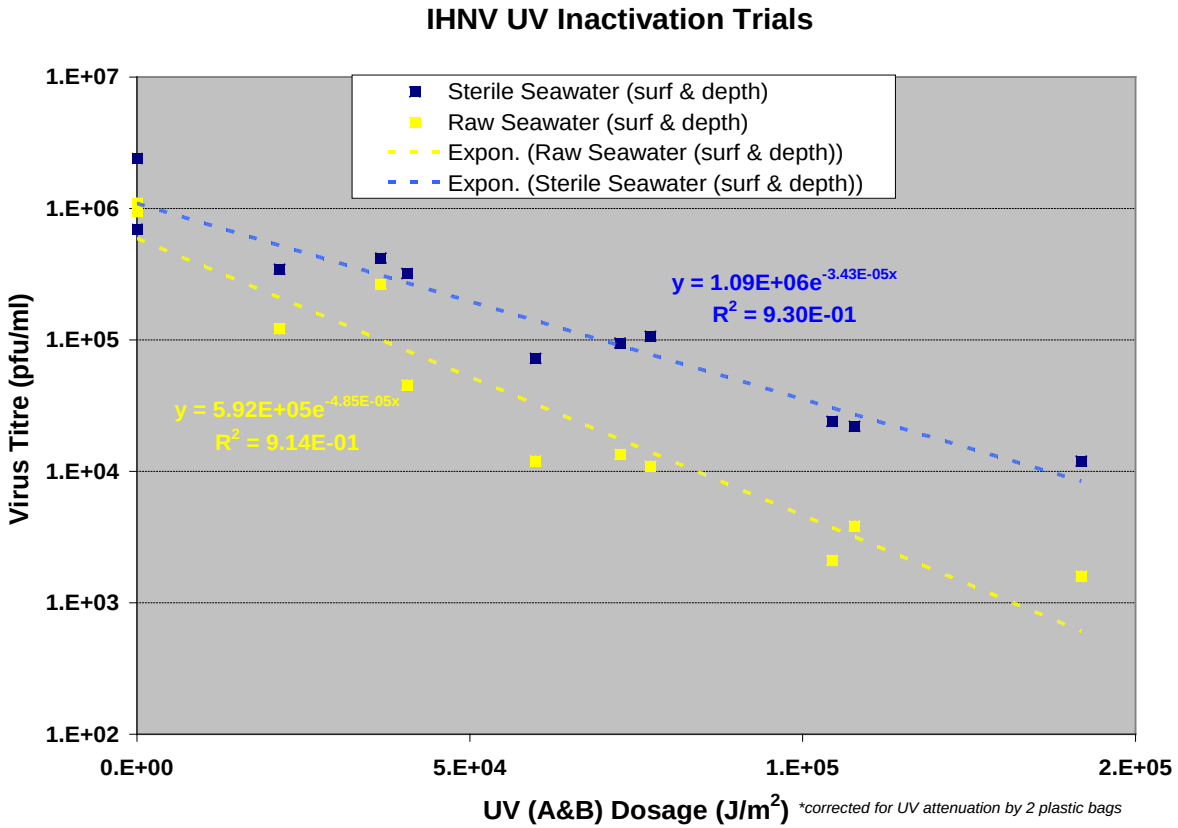
Virus decay by sunlight

- UV radiation from the sun is the primary germicide in the environment

UVB = 290-320 nm

UVA = 320-380 nm



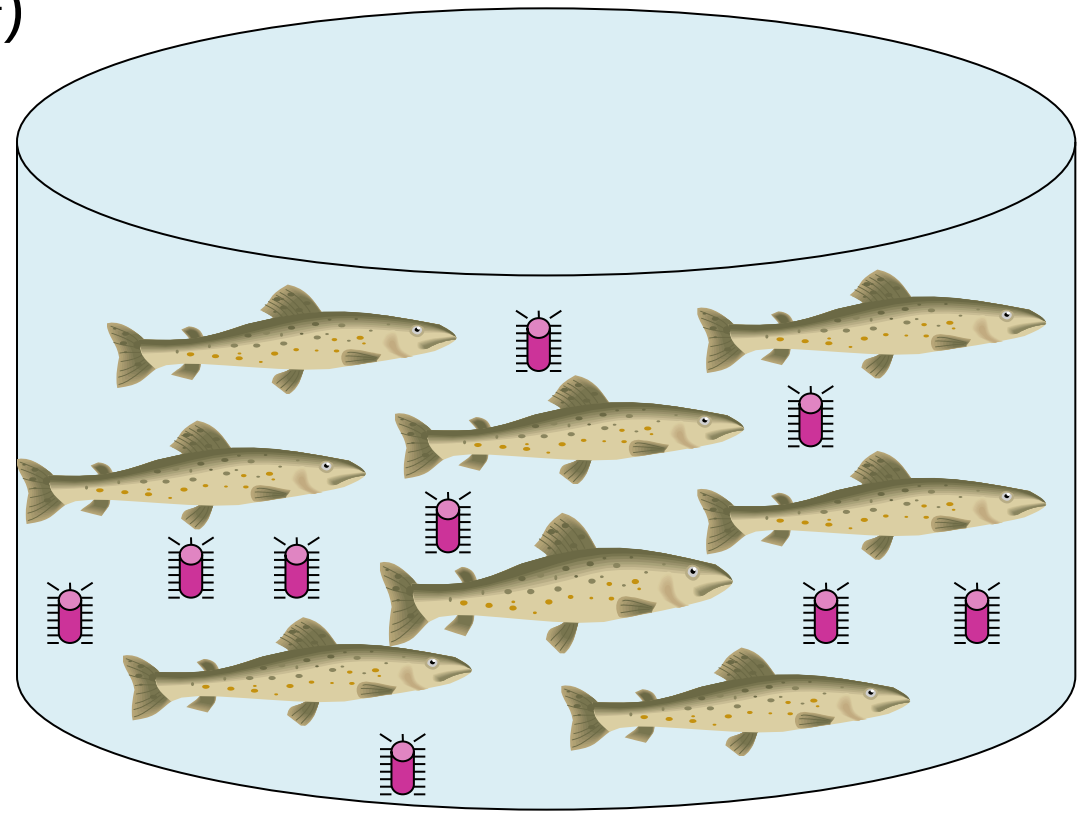


Minimum Infectious Dose (MID)

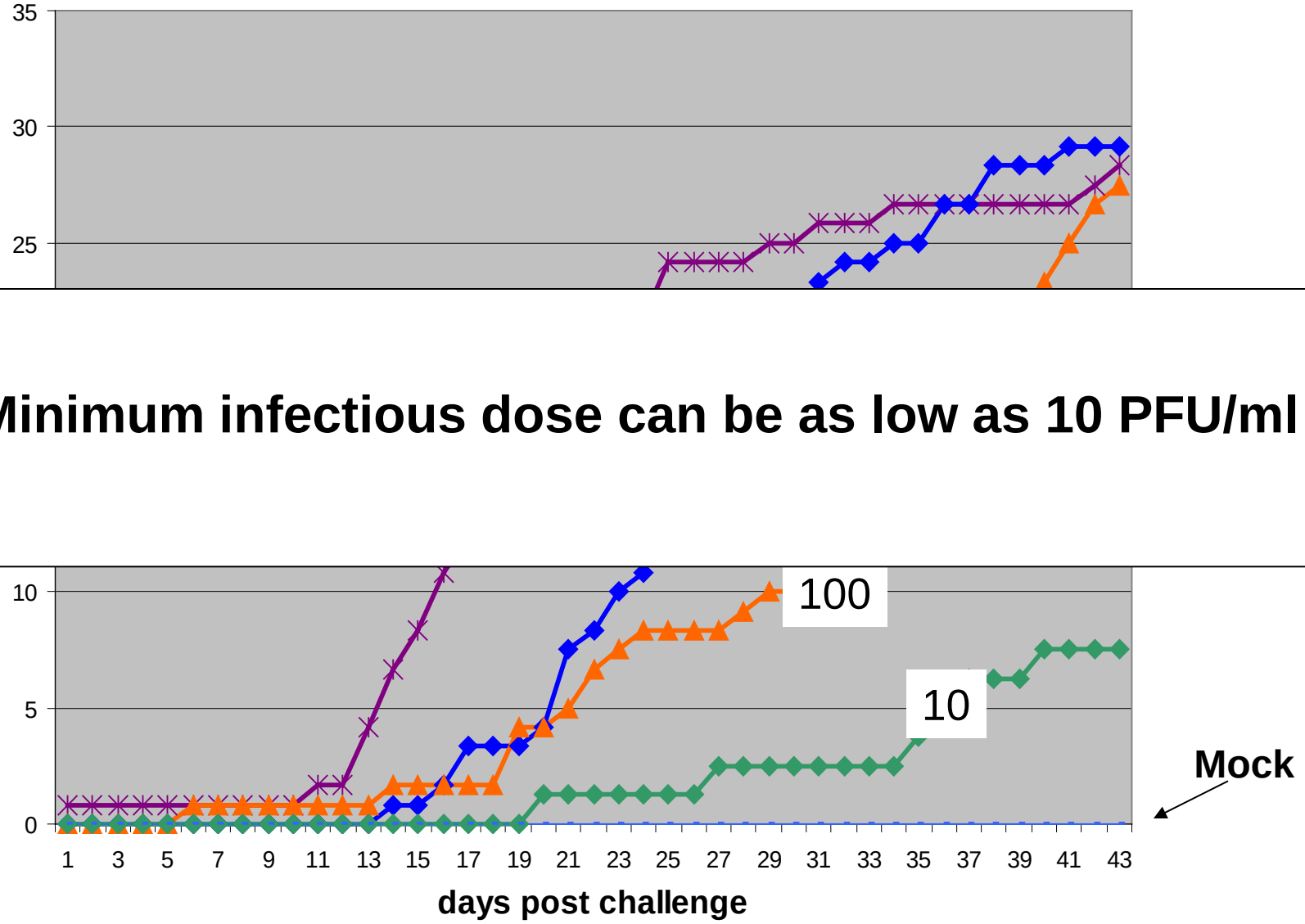
- Waterborne exposure of Atlantic Salmon to IHNV
  - 1 hour static immersion challenge

- Challenge dose (PFU ml^{-1})
  - 10^4 ,10^3, 10^2, 10^1

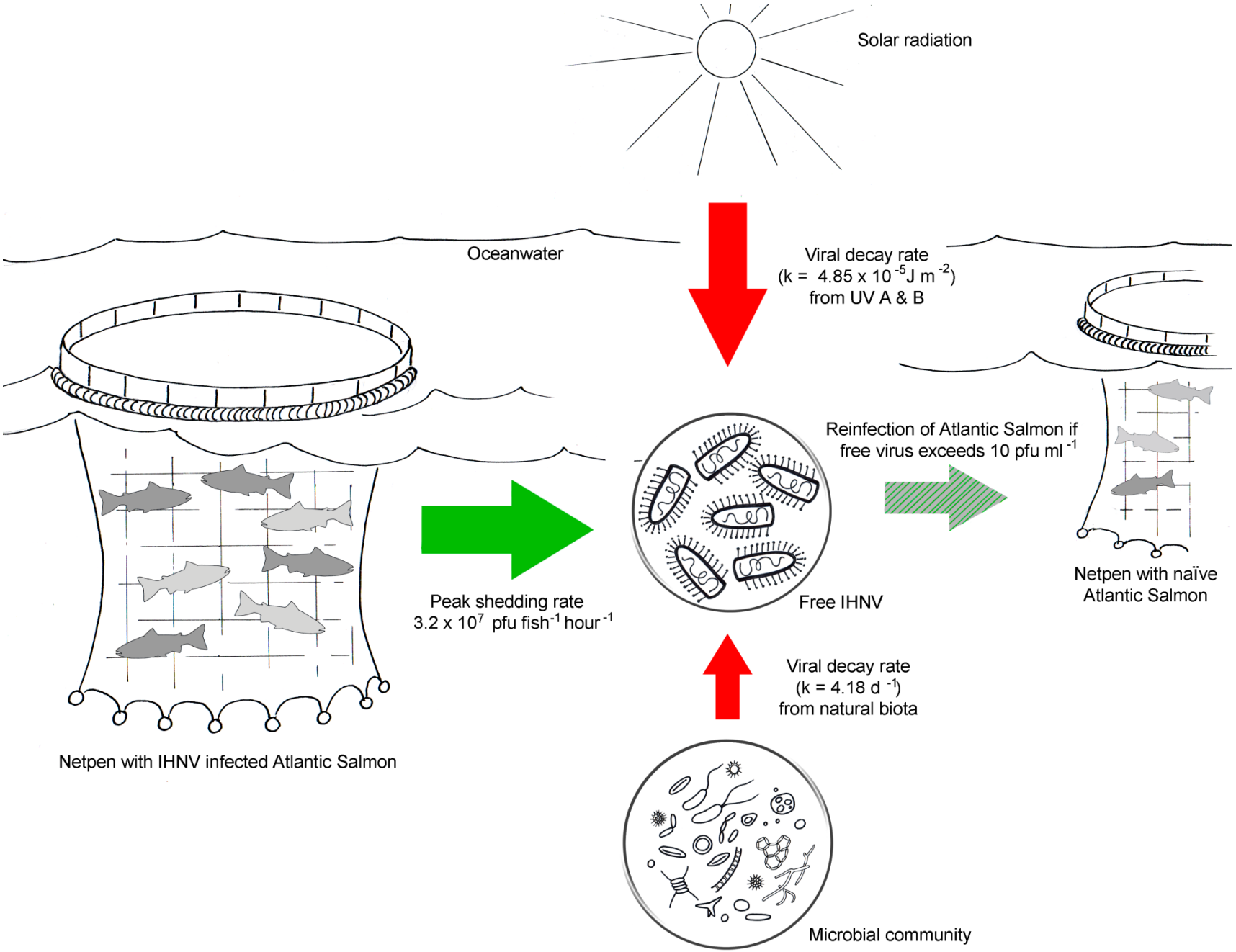
- Monitor for mortality and assay for virus



Minimum infectious Dose



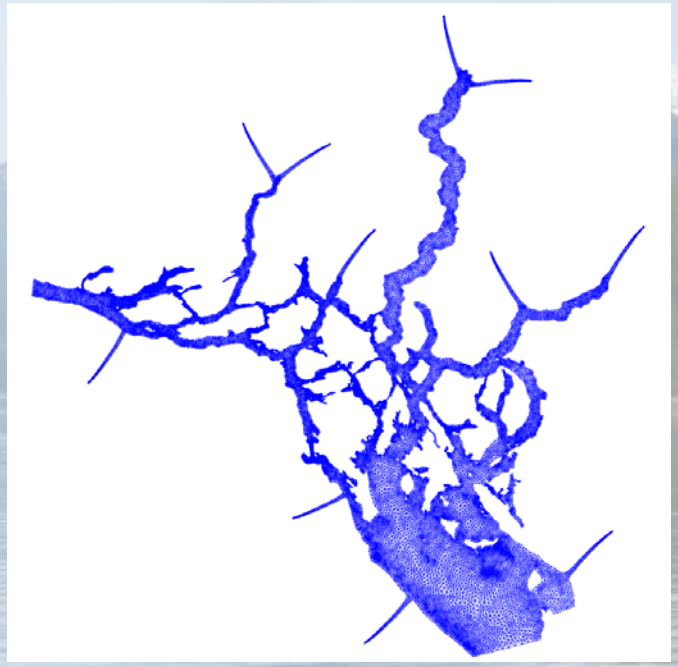
Minimum infectious dose can be as low as 10 PFU/ml

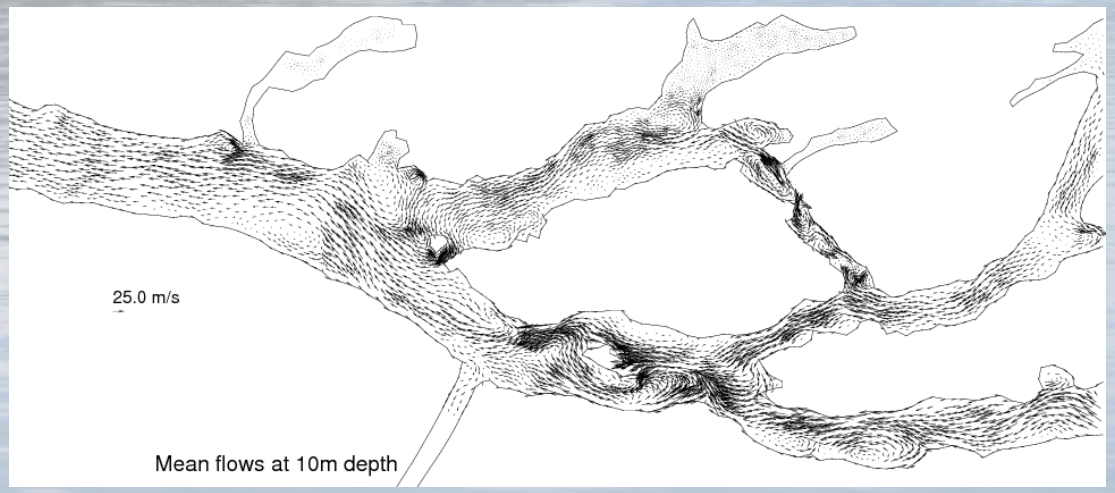

Solar radiation
Oceanwater
Viral decay rate
(k = 4.85 x 10 -5 J m -2)
from UV A & B
Reinfection of Atlantic Salmon if
free virus exceeds 10 pfu ml -1
Netpen with naïve
Atlantic Salmon
Peak shedding rate
3.2 x 10 7 pfu fish -1 hour -1
Free IHNV
Netpen with IHNV infected Atlantic Salmon
Viral decay rate
(k = 4.18 d -1)
from natural biota
Microbial community

Water circulation model for the Discovery Islands

Finite Volume Coastal Ocean Model (FVCOM)

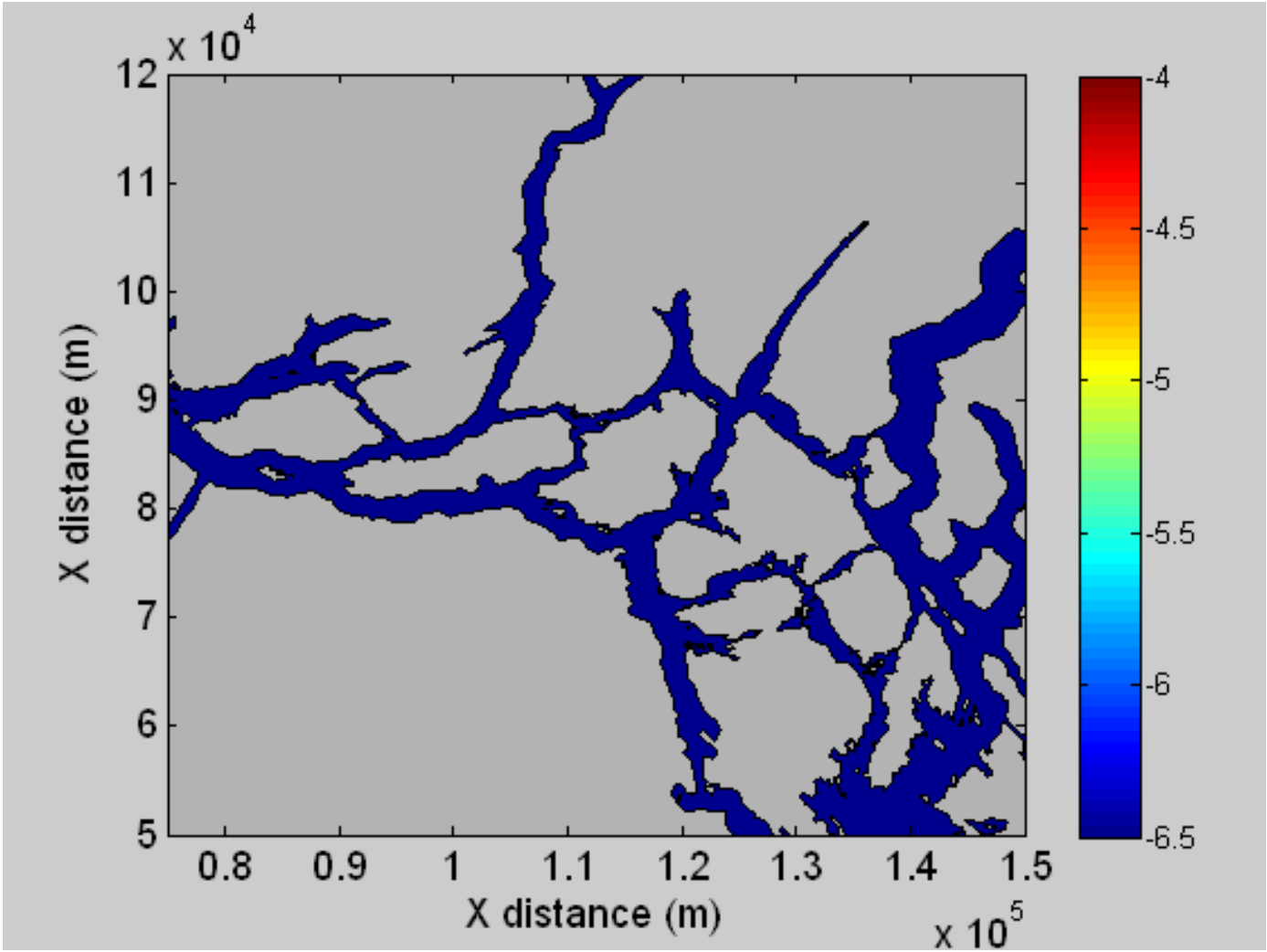
Foreman et al. Atmosphere-Ocean 2012, Vol 50:3 pp.301-316



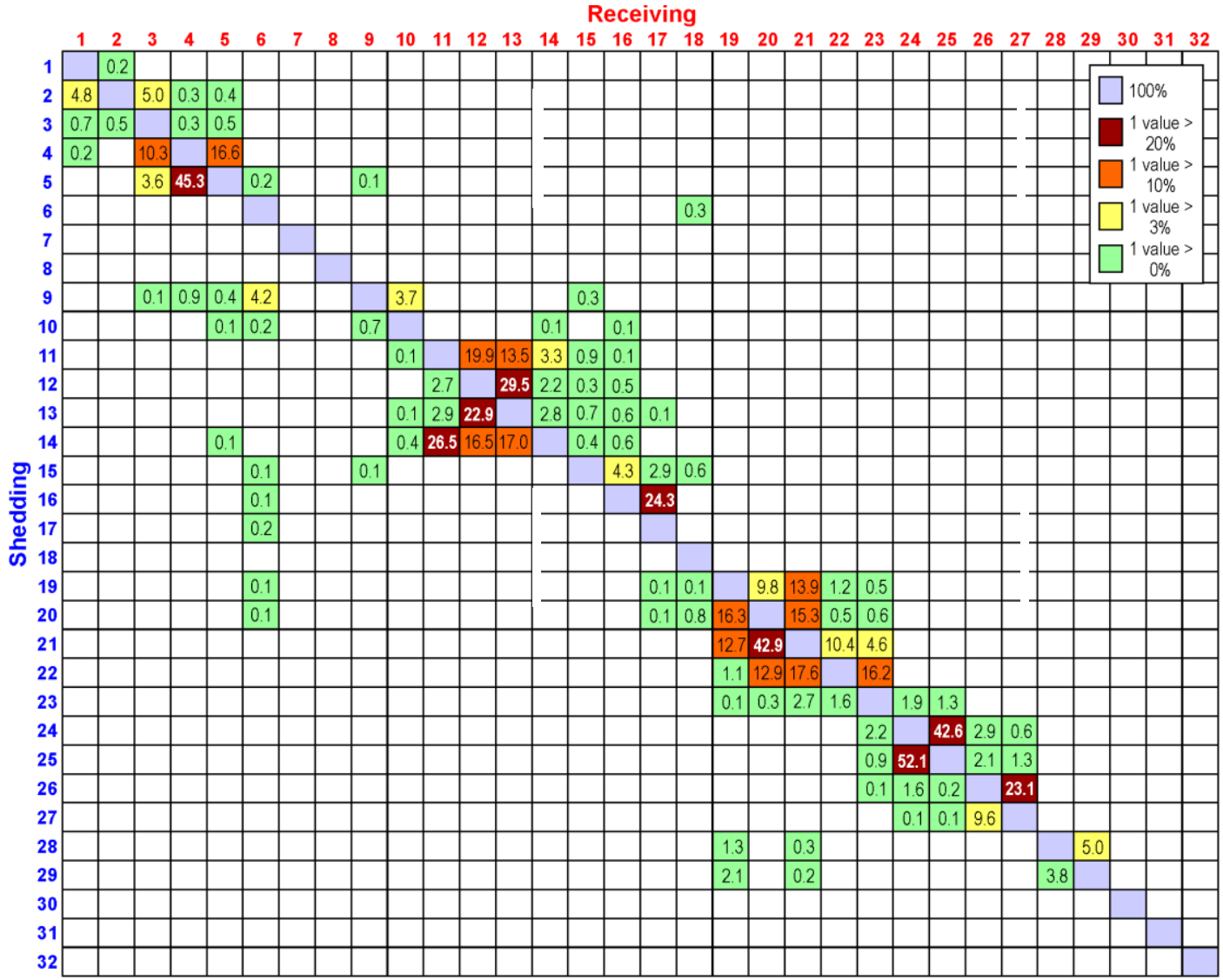


Virus dispersion model

- Coupling IHNV transmission parameters to physical oceanographic water circulation model



Connectivity Tables



How can the model be used?

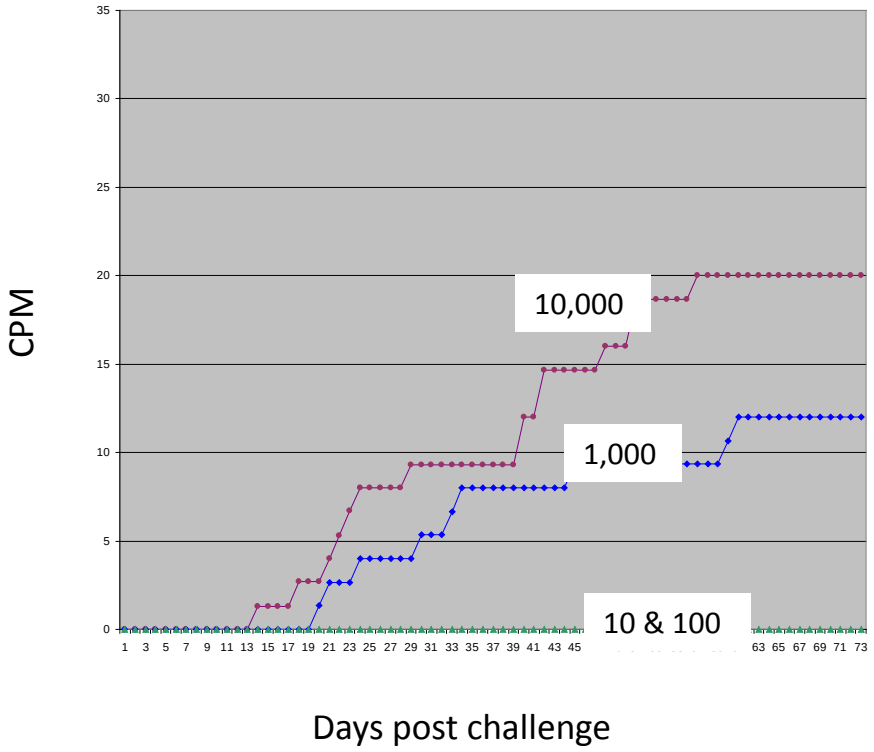
Established a tool to provide accurate geospatial predictions of risk of IHNV spillback

- Refine management zones based on connectivity
- Evaluate effect of disease management strategies (i.e. vaccination)
- Risk to sockeye salmon (requires knowledge of infectious dose)

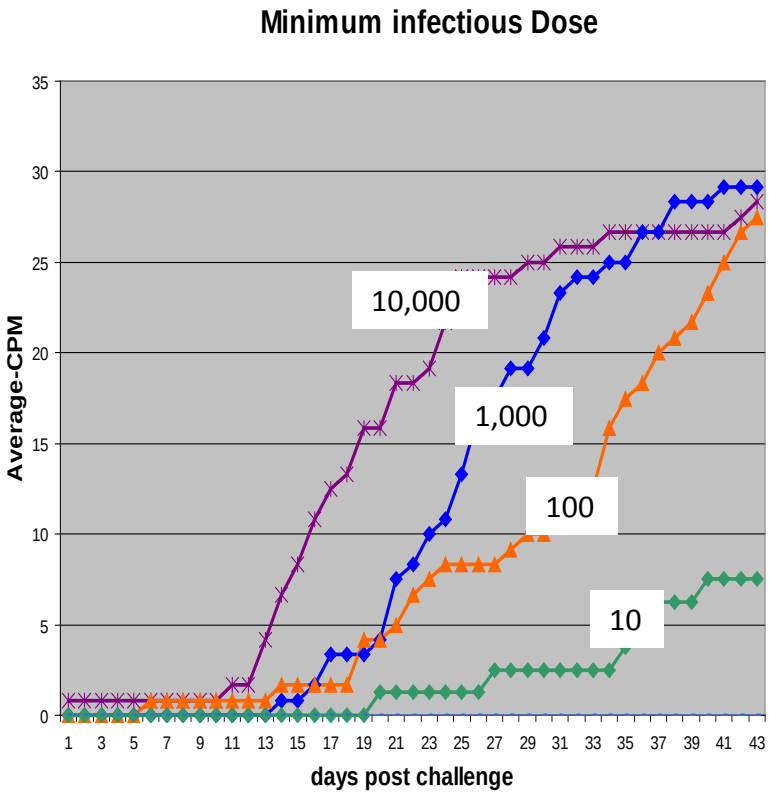
Sockeye Smolt Susceptibility?

Sockeye smolts

IHNV minimum infectious dose



Atlantics



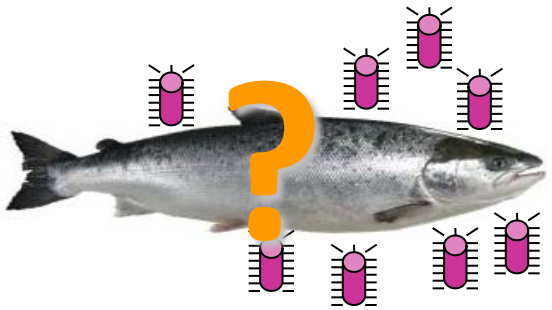
Sockeye smolts are 100X less susceptible than Atlantic salmon smolts

Use of APEX-IHN® and effect on virus spread?

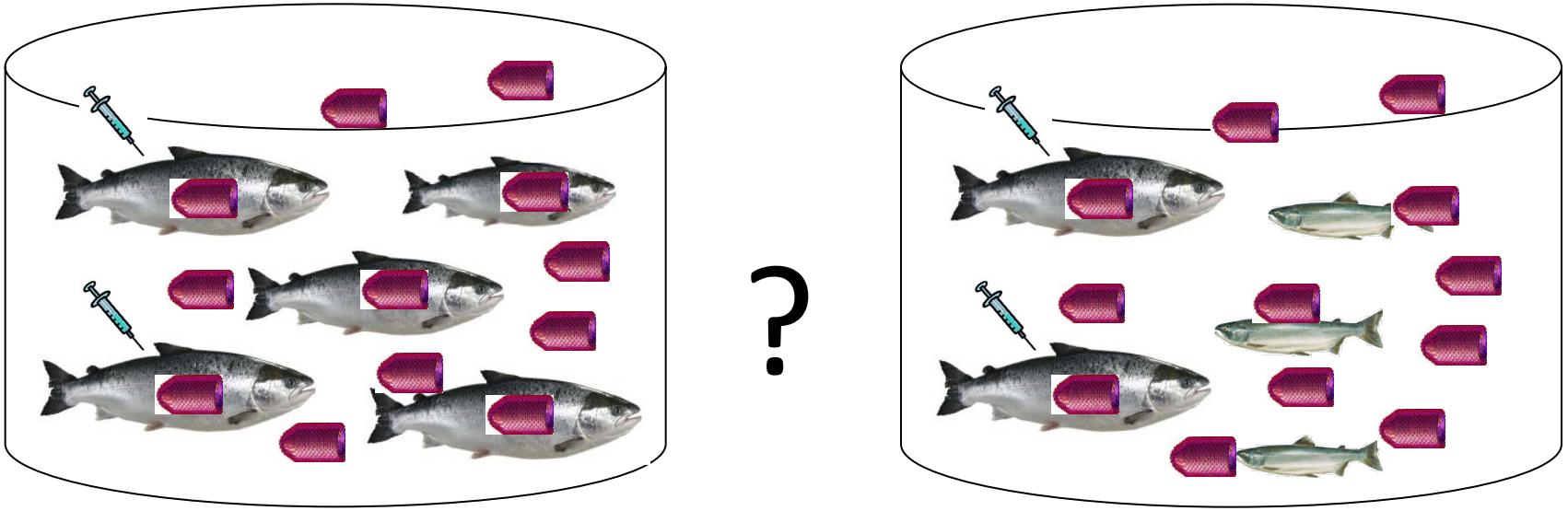
- Since licensing, >60 million doses of the vaccine have been administered

- What is the risk of virus dispersion from a Atlantic salmon net-pen that has been APEX-IHN vaccinated?

  - Do vaccinated fish shed an infectious dose of virus?



IHNV Transmission potential of **APEX vaccinated Atlantics**



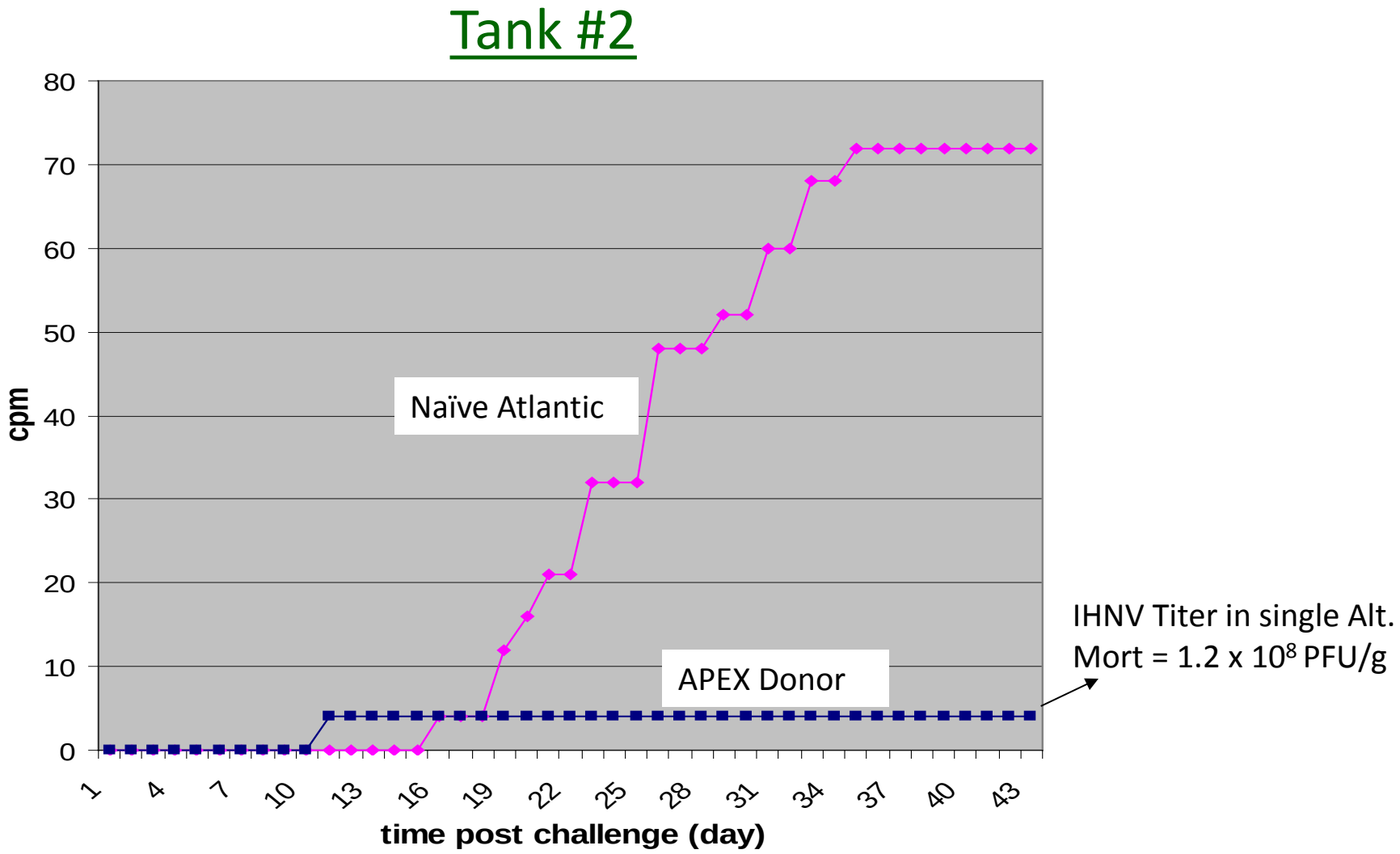
25 IHNV (ip injected) **APEX** Atlantic = **Donor**
25 Naïve Atlantic smolts

25 **Donor**
40 Naïve sockeye smolts

Note: each challenge done in duplicate tanks

Results

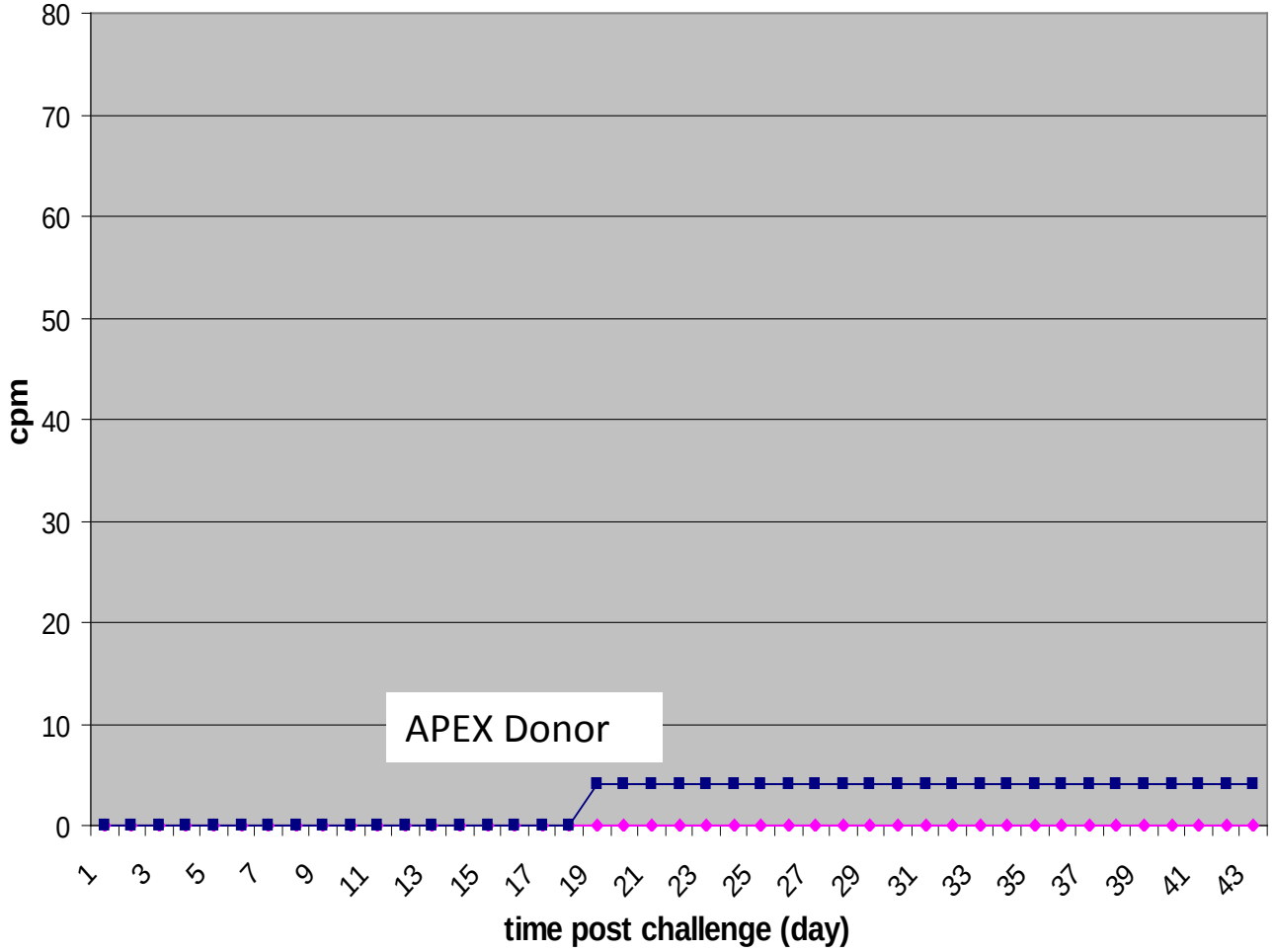
APEX Atlantic : Atlantic



Results

APEX Atlantic : Sockeye

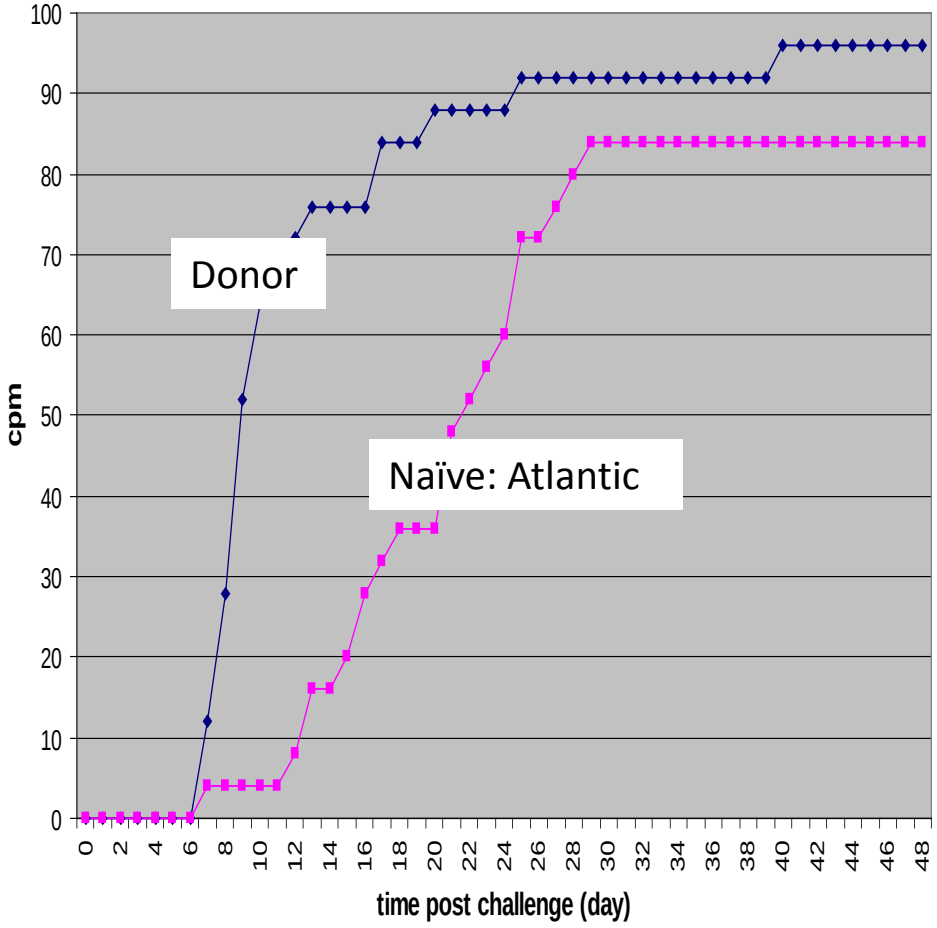
Tank #2



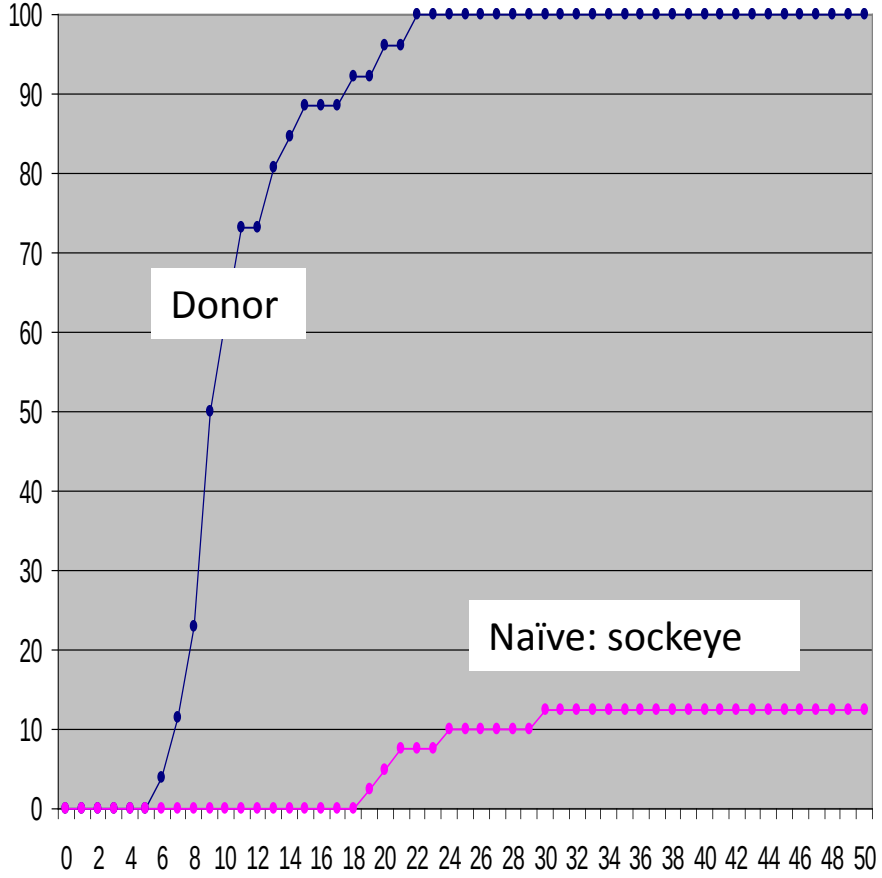
IHNV Titer in single Atl. mort = 2 x 10^7 PFU/g

Results

Atlantic : Atlantic



Atlantic : Sockeye



Summary

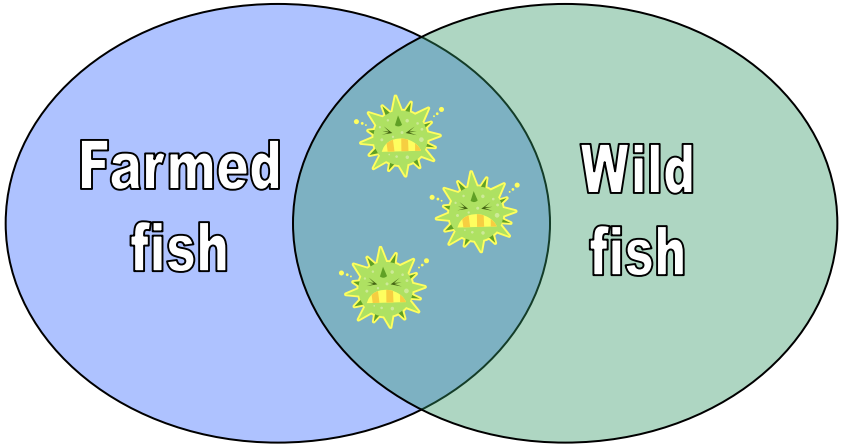
- APEX-IHN® vaccinated Atlantic salmon are highly protected against IHN disease when exposed to a lethal dose virus.

- APEX-IHN® vaccinated Atlantic salmon greatly reduce the viral transmission potential to wild and farmed salmon.

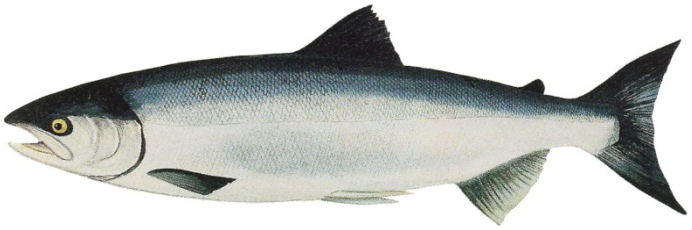
- Model simulations incorporating vaccine usage can now be run to evaluate impact on farm connectivity

Issue

Sharing the environment → **Sharing the microbes**



- **Viral occurrence in wild fish?**

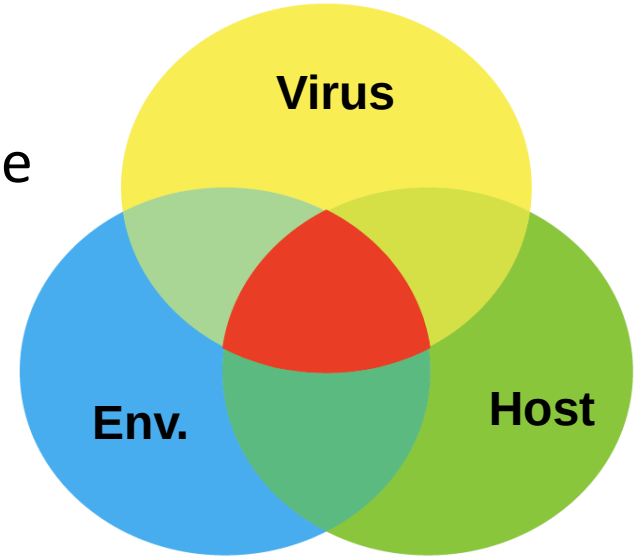


What drives IHNV prevalence in a population?

Epidemiological Approach:

Study patterns to identify risk factors for disease

- Is there a correlation between the density (escapement) of sockeye with pathogen prevalence
- Is pathogen prevalence dependent upon fish size and/or age?
- Does the presence/intensity of one pathogen impact infection of others?

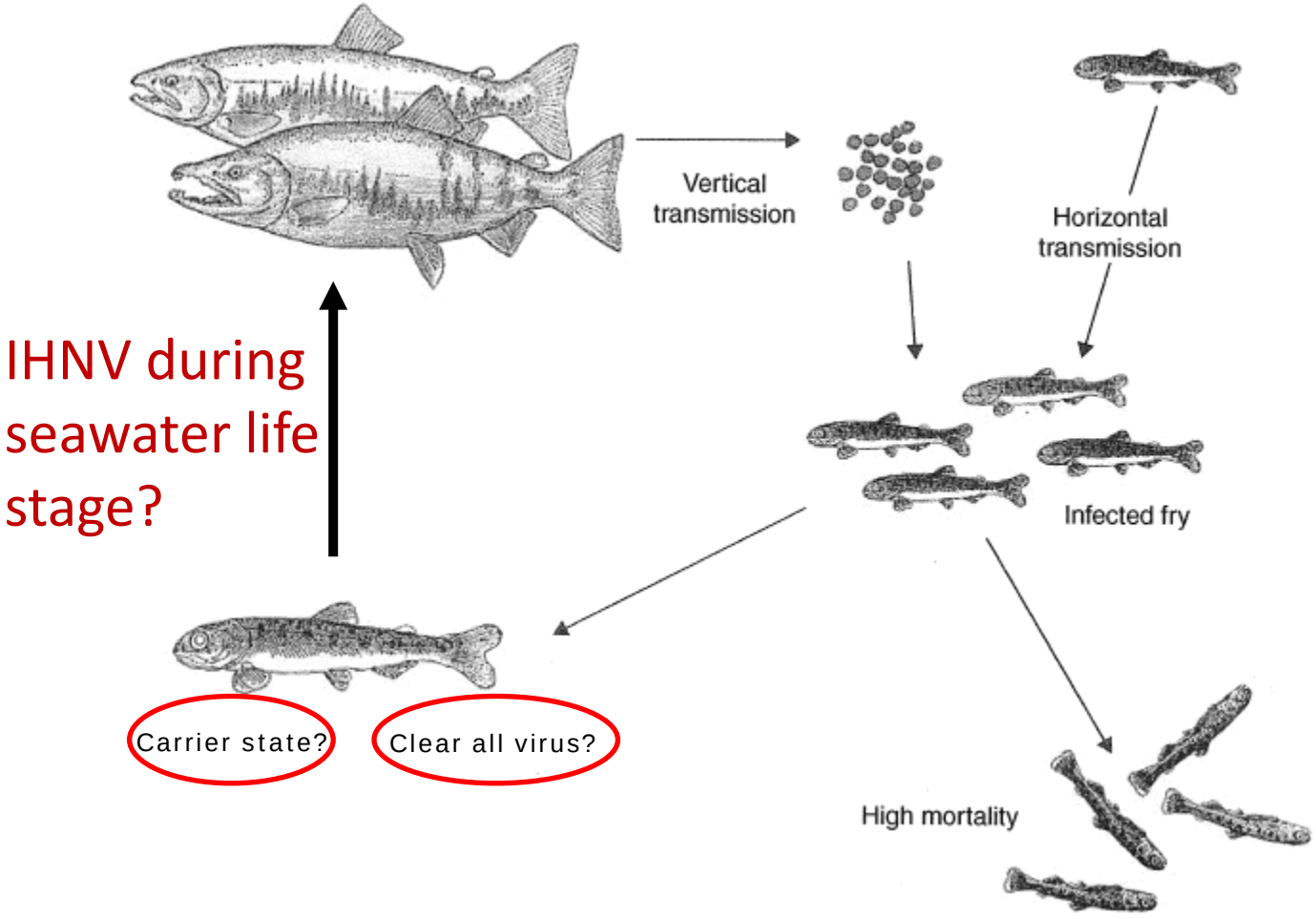


2015 Project initiated involving Okanagan Nation Alliance (ONA) and Centre for Coastal Health (CCH)

IHNV Basic Biology: filling in knowledge gaps

- Life cycle of IHNV

IHNV Disease Ecology: Knowledge Gaps



Modified from Bootland, L.M. and Leong, J.C. 1999: Fish Diseases and Disorders , Volume 3

Health Assessment of Sockeye Smolts:
Sampling 2010 - 2011 - 2012

Stock ID, Sea Lice enumeration, Histology sampling, and Pathogen Screening (**IHNV**)

IHNV detected in marine phase sockeye salmon

Year	# of Sockeye smolts	% IHNV Positive
2010	169	0.59
2011	775	4.8
2012	478	0
All	1479	2.6

- First evidence of IHNV in Sockeye smolts, suggests IHNV carrier state.

The Smoking Gun?

Virus strain typing

IHNV from Sockeye smolts grouped into 2 sequence

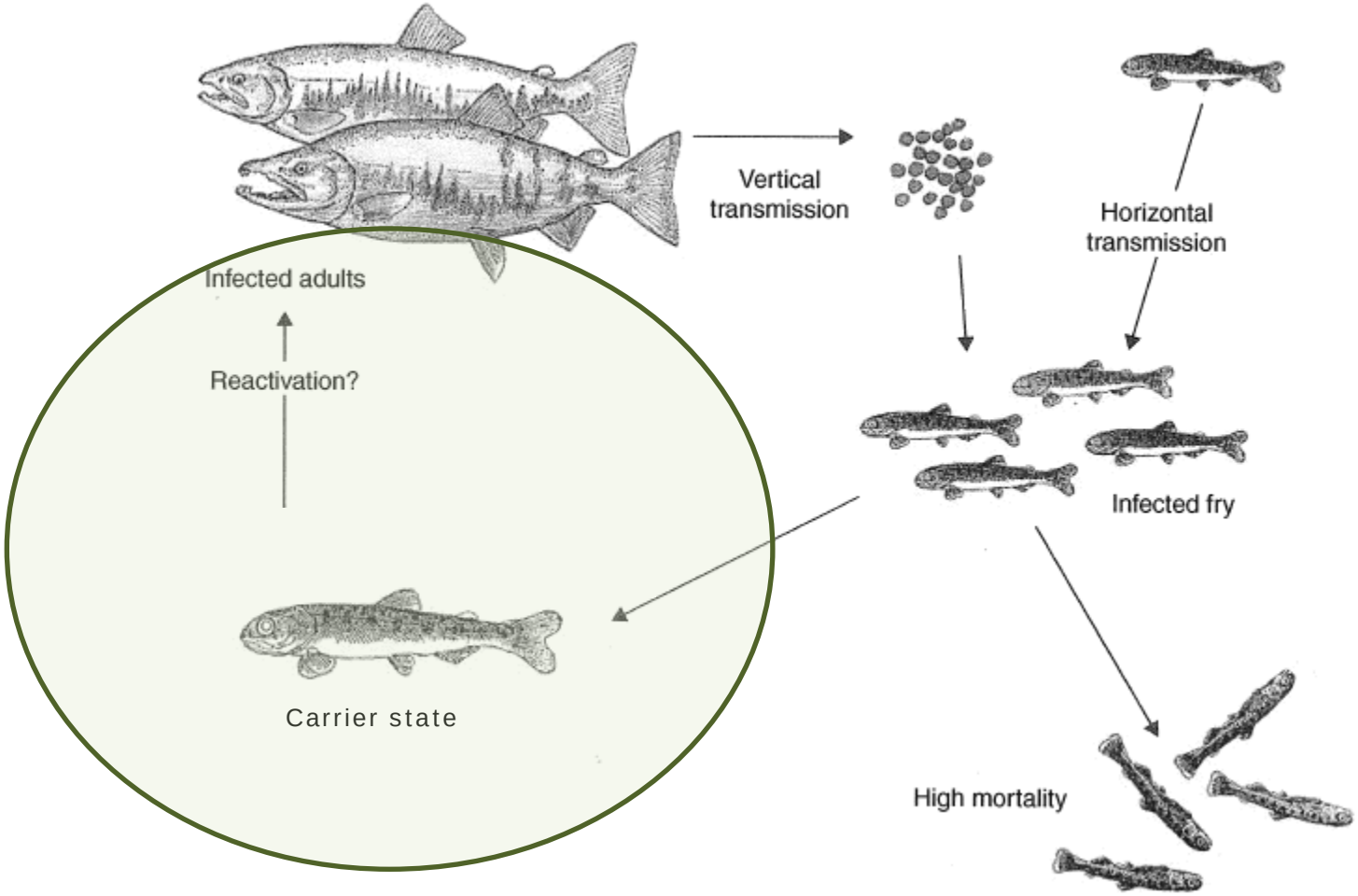
Type #1 = mG050**U**

Type #2 = mG251**U**

Type #1 (mG050**U**) = IHNV farmed Atlantic salmon

Sockeye carriers are likely source of virus to marine farmed Atlantic salmon.

What's next?


Vertical transmission
Horizontal transmission
Infected adults
Reactivation?
Infected fry
Carrier state
High mortality

Laboratory Challenges: IHNV in Sockeye salmon

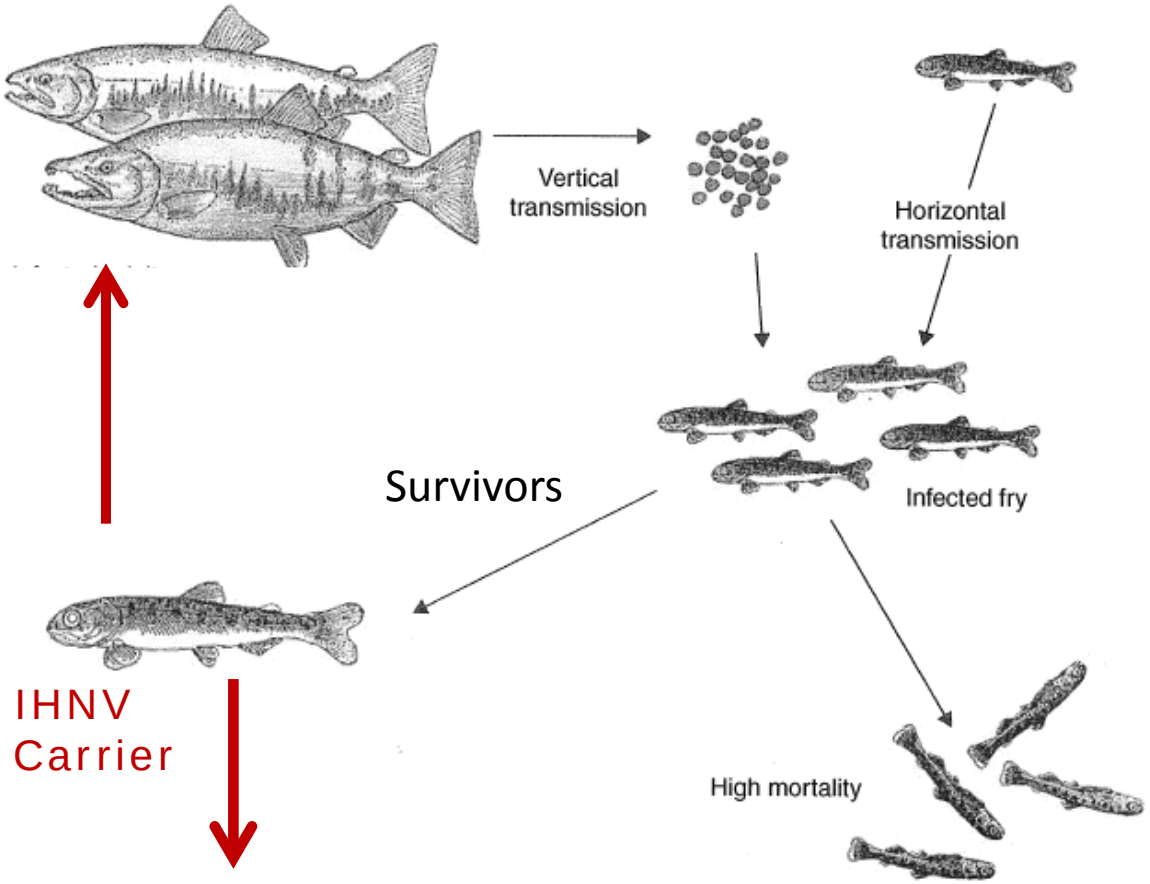
Successfully generated IHNV carriers in the laboratory

<u>Current Investigations:</u>

Host response and physiological consequence of being a carrier & potential for reactivation

Epidemiological Consequences

Is this how IHNV is maintained in a salmon population?



IHNV source to Naïve hosts?

References

Müller, A., Sutherland, B.J.G., Koop, B.F., Johnson, S.C., Garver, K.A. (2015) Infectious hematopoietic necrosis virus (IHNV) persistence in Sockeye Salmon: effect on brain transcriptome and response to the viral mimic poly(I:C). BMC Genomics 2015, 16:634 doi:10.1186/s12864-015-1759-y.

Foreman, M.G.G., Guo, M., Garver, K.A., Stucchi, D., Chandler, P., Wan, D., Morrison, J., Tuele, D. (2015) Modelling infectious hematopoietic necrosis virus dispersion from marine salmon farms in the Discovery Islands, British Columbia, Canada. PLoS ONE 10(6): e0130951. doi:10.1371/journal.pone.0130951

Garver, K.A., Mahony, A., Stucchi, D., Richard, J., Van Woensel, C., Foreman, M., (2013) Estimation of waterborne transmission parameters associated with IHNV infection in Atlantic salmon. PLoS ONE 8(12): e82296. doi:10.1371/journal.pone.0082296

Foreman, M.G.G, Stucchi, D.J., Garver, K.A., Tuele, D., Isaac, J., Grime, T., Guo, M. (2012) A Circulation Model for the Discovery Islands, British Columbia. Atmosphere-Ocean 50 (3), 301-316.


Thank you!