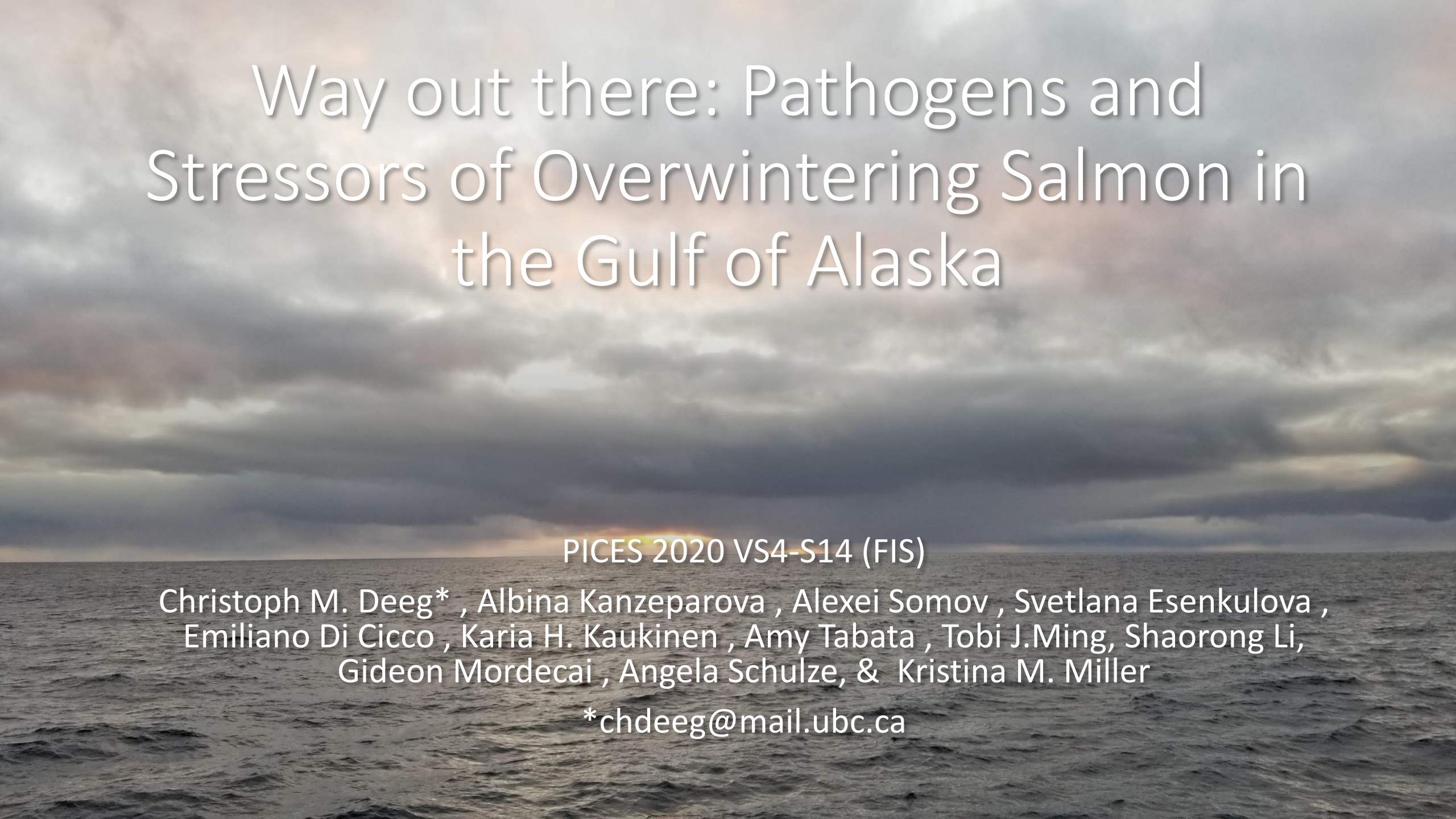
Way out there: Pathogens and Stressors of Overwintering Salmon in the Gulf of Alaska



PICES 2020 VS4-S14 (FIS)

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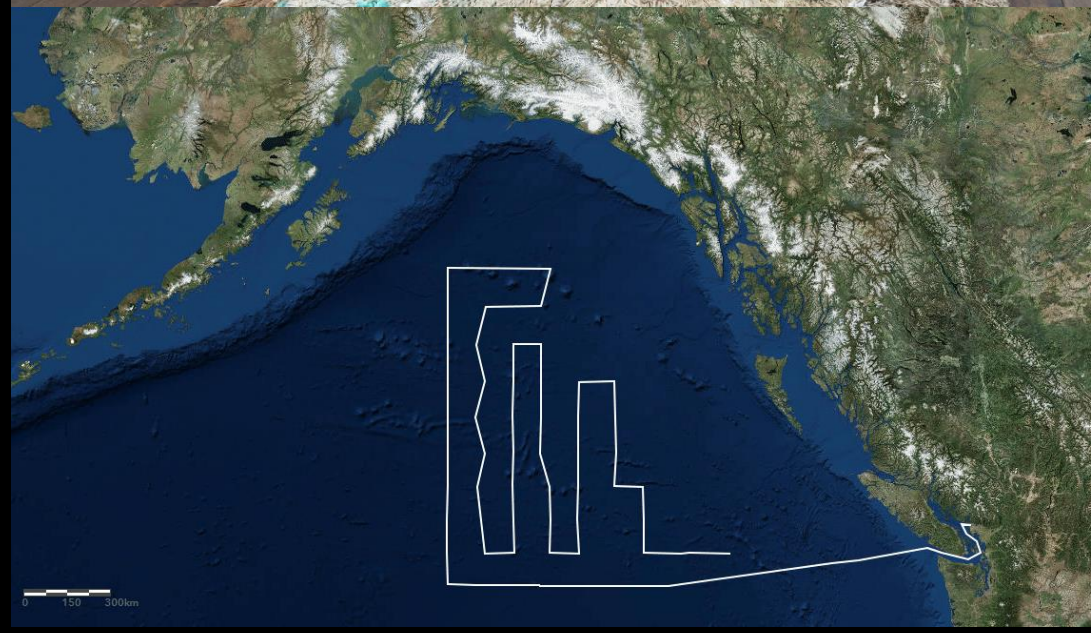
International Year of the Salmon Gulf of Alaska Expedition 2019

- GoA is key salmon overwintering ground
- Factors limiting ocean survival largely unknown
- Winter critical period?



IYS-GoA 2019: Salmon Health

Objective:

- Assess health and condition of overwintering salmon
  - Pathogens
  - Stressors

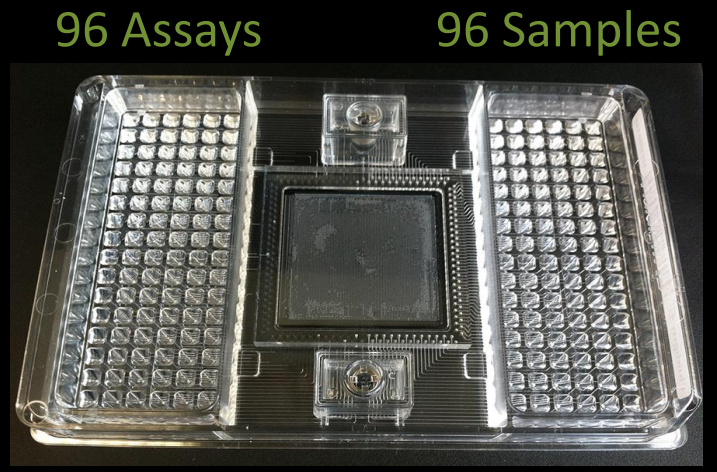
Methods:

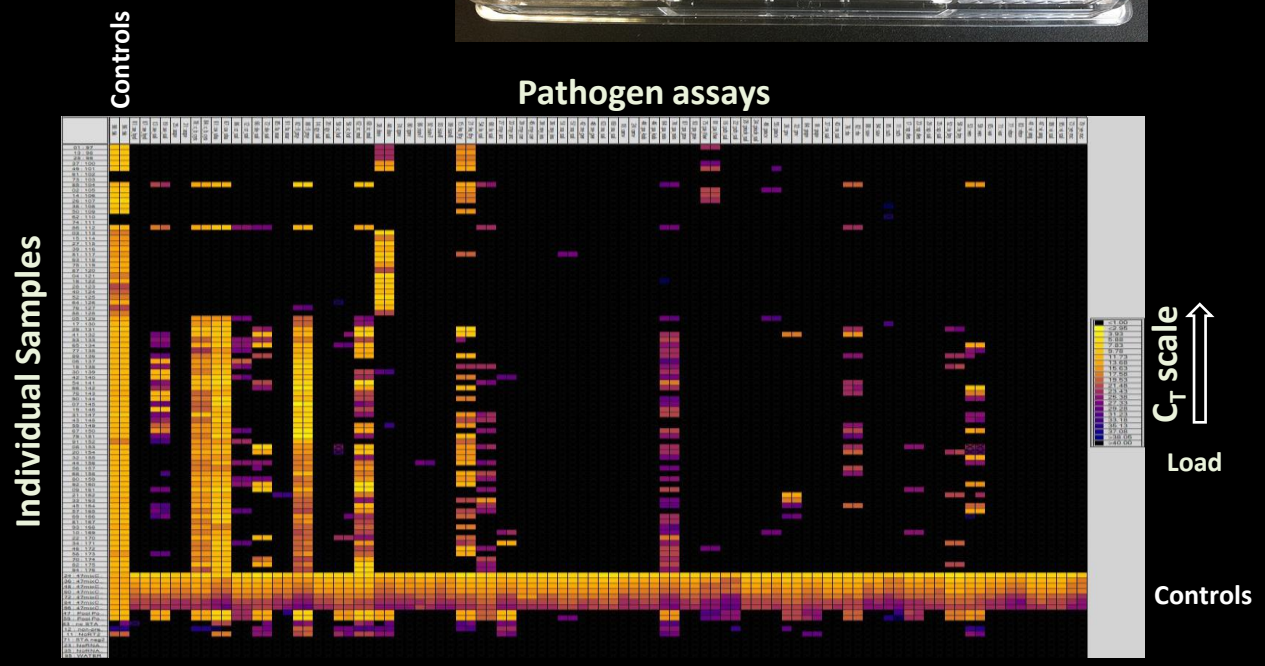
- Collect tissues

IYS-GoA 2019: Salmon Health

Methods (cont.):

- Fluidigm screen
  - qPCR: Pathogen screen
  - qRT-PCR: Fitchip
    - Host gene expression -> Stress response
- Histology





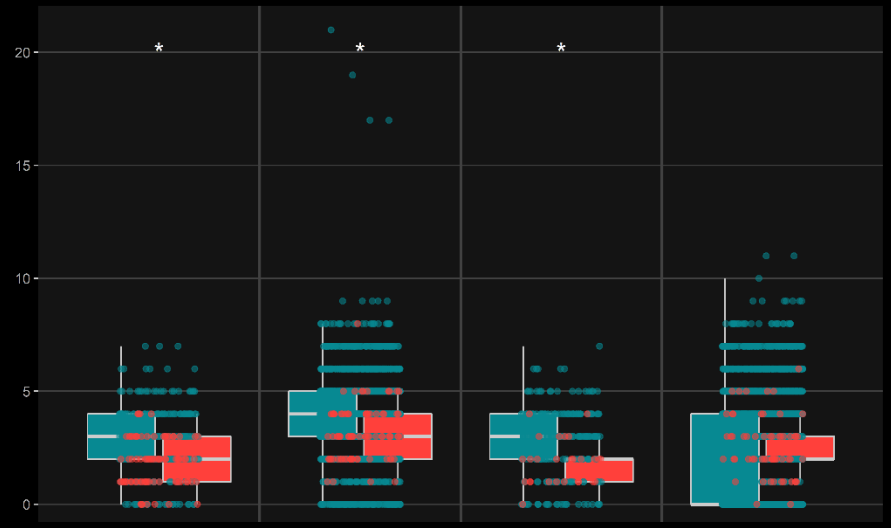
Aeromonas salmonicida	Dermocystidium salmonis	***Parvicapsula pseudobranchicola***	Rainbow trout orthomyxovirus
Candidatus Branchiomonas cysticola	***Ichthyophonus hoferi***	Paranucleospora theridion	***Putative -picorna virus***
Piscichlamydia salmonis	***Ichthyophthirius multifiliis***	***Sphaerothecum destruens***	***Piscine orthoreovirus-1 ****
Piscirickettsia salmonis	***Ichthyobodo sp.***	Tetracapsuloides bryosalmonae	***Pacific salmon parvovirus***
Renibacterium salmoninarum	***Kudoa thyrsites***	Salmon pescarenavirus-1	Putative Qin-like virus[KS2]
Rickettsia-like organism (RLO)	***Loma salmonae***	Salmon pescarenavirus-2	Chinook aquareovirus
Candidatus Syngnamydia salmonis	Myxobolus arcticus	Putative bafini virus	***Putative rhabdo[KS3] virus***
Tenacibaculum maritimum	***Myxobolus insidiosus***	Putative circo virus	***SalmovirusWFRC1[KS4]***
Vibrio anguillarum	***Nanophyetus salmincola***	Pacific salmon nidovirus	Putative RNA virus
Vibrio salmonicida	Neoparamoeba perurans	Cutthroat Trout Virus-2	***Erythrocytic necrosis virus***
Yersinia ruckeri	***Parvicapsula kabatai***	Putative hantavirus	***Viral encephalopathy and retinopathy virus***
Ceratanova shasta	***Parvicapsula minibicornis***	Pacific salmon nidovirus sequence variant	Viral hemorrhagic septicemia virus

GoA Pathogen survey

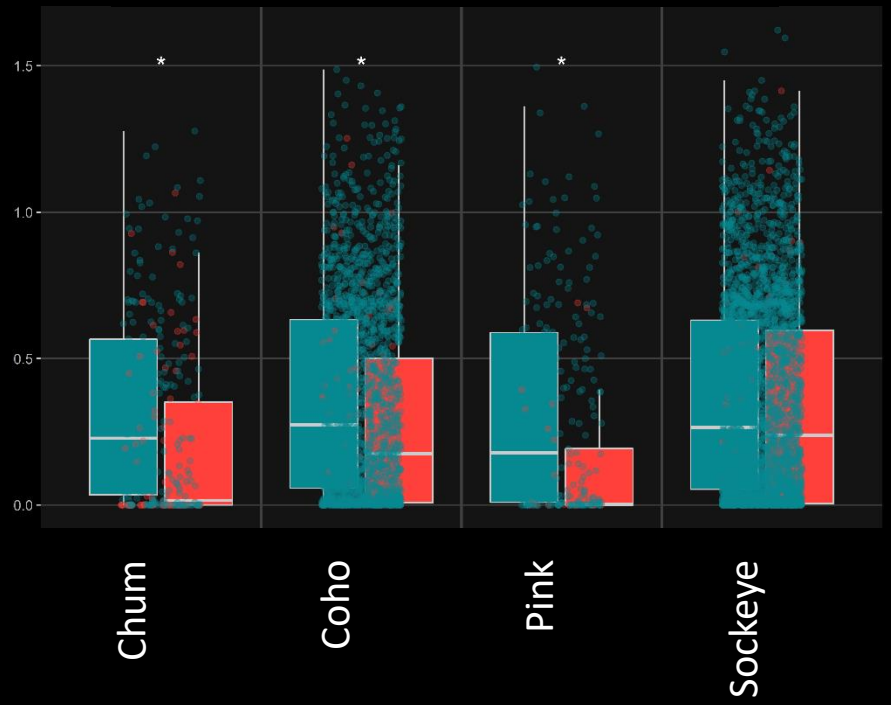
- 253 Salmon
  - 84 Chum
  - 80 Coho
  - 61 Sockeye
  - 27 Pink
- Fluidigm qPCR surveyed for 48 pathogens
  - 11 Bacteria
  - 17 Parasites
  - 20 Viruses
  - ***21 Detections***

GoA vs BC Coast

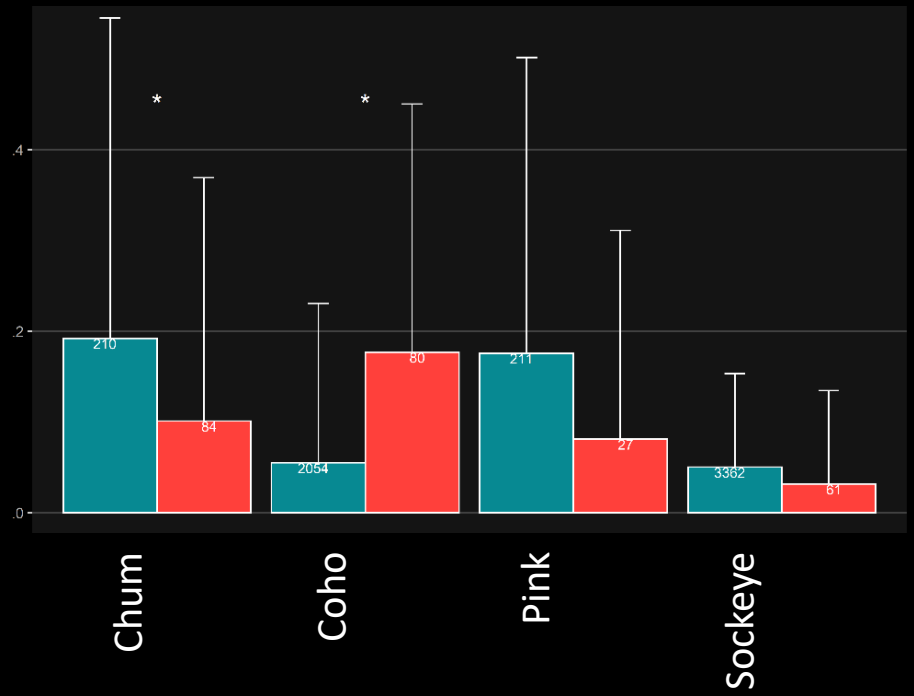
Number of Pathogens



Shannon Diversity of Pathogens



Relative Infection Burden (RIB)

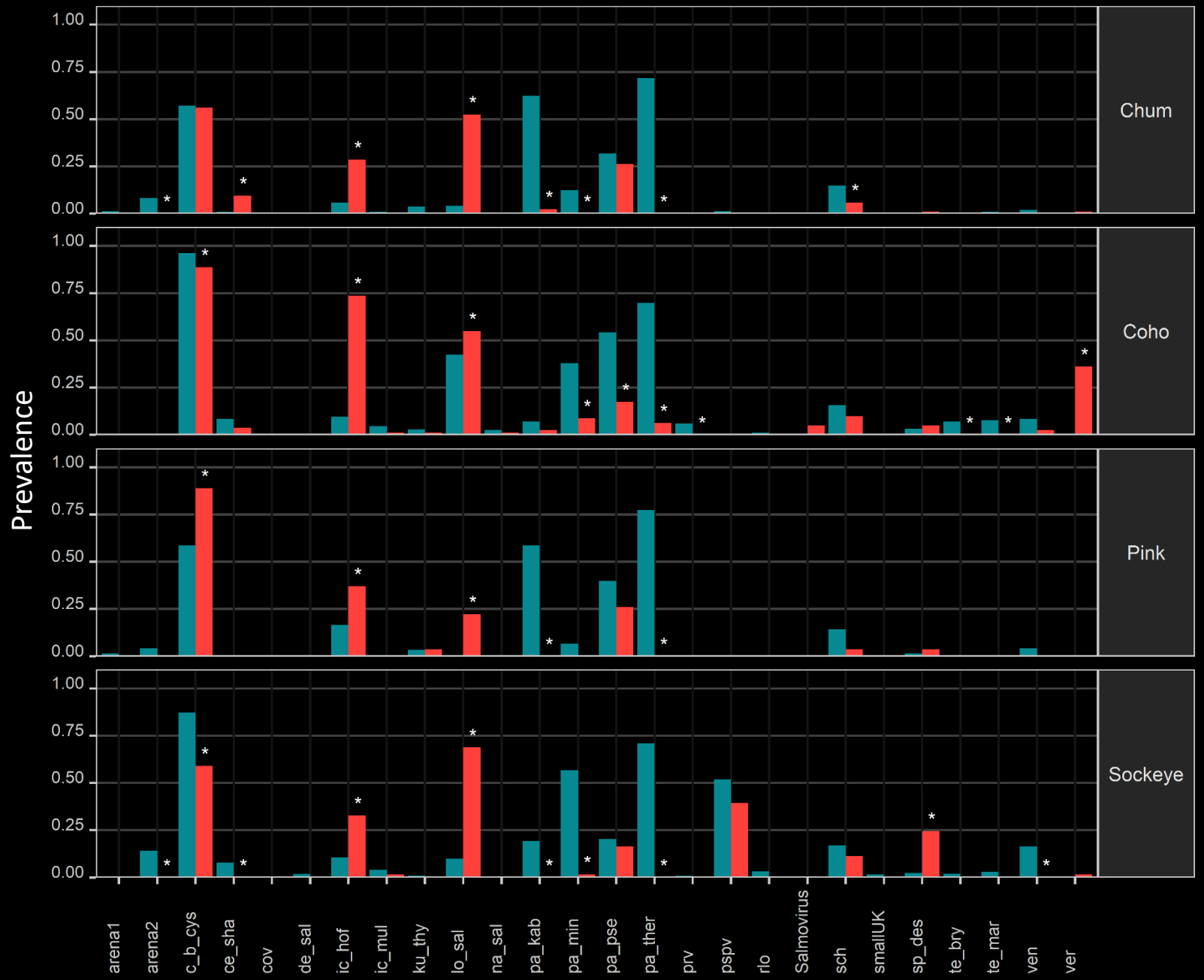


BC coast

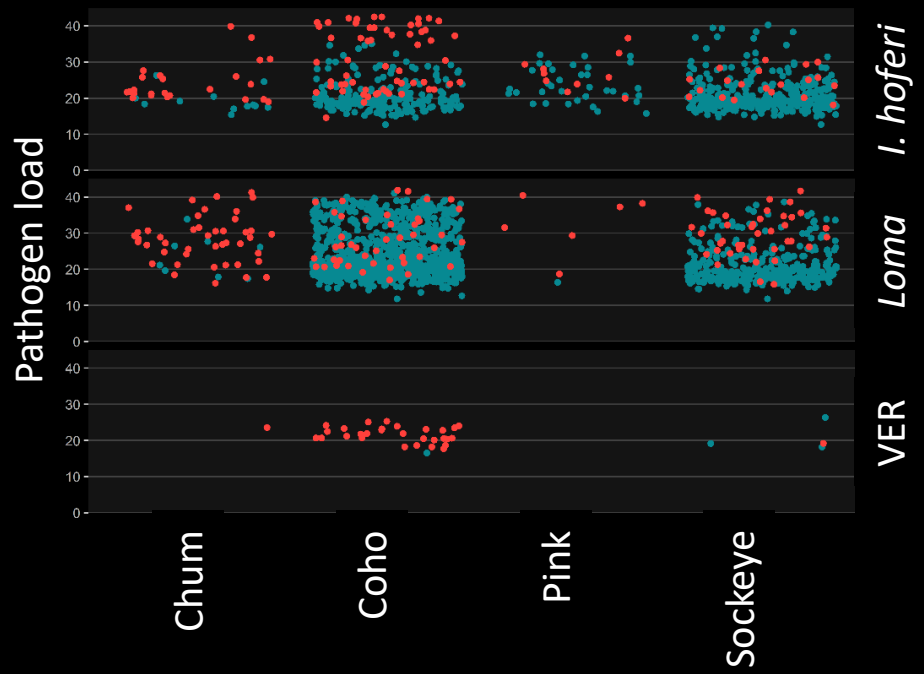
GoA

*: $p < 0.05$ (t-test)

GoA vs BC Coast

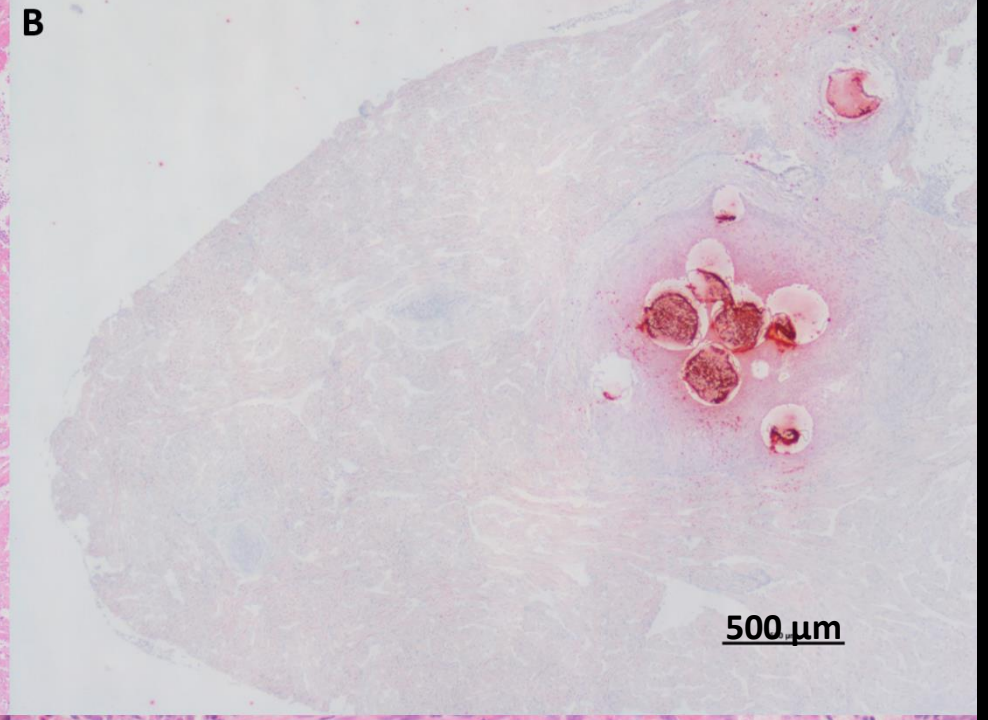


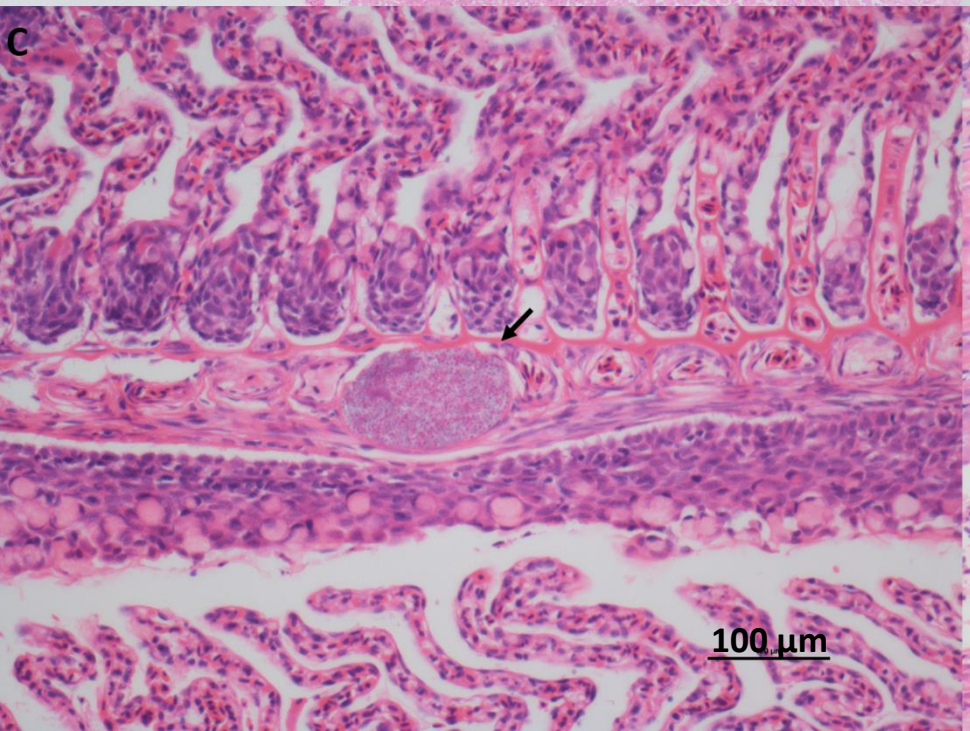
*: p<0.05 (Fisher's exact test)

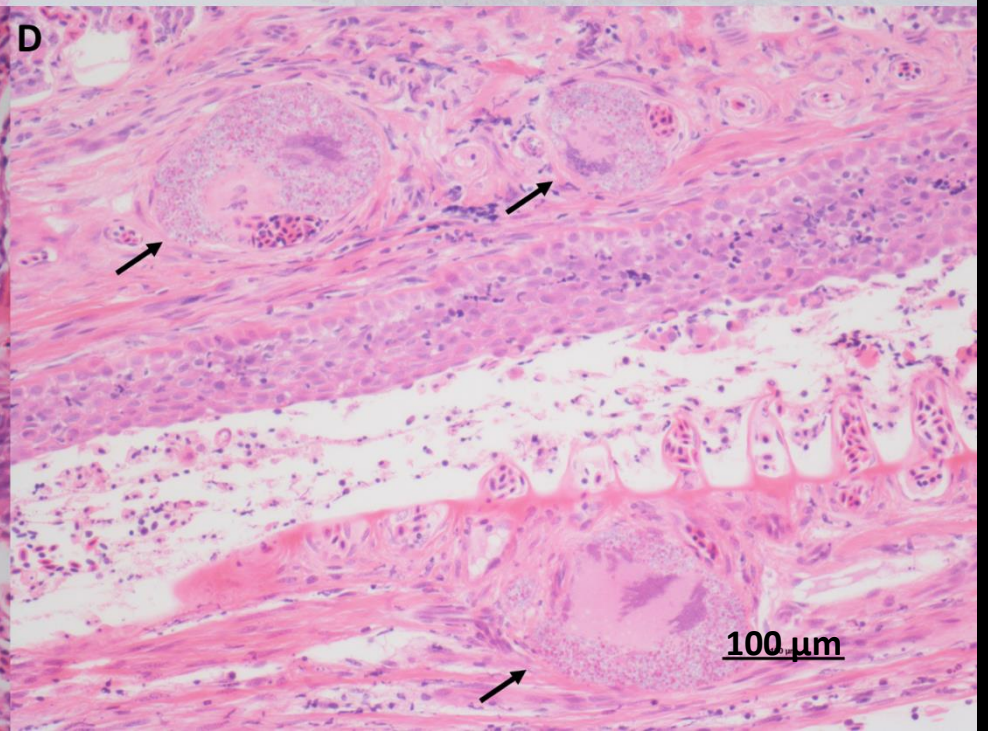


BC coast

GoA







Histology

A. *I. hoferi* in Coho salmon heart. Arrows: Granulomatous (H&E).

B. In situ hybridization (red) of A

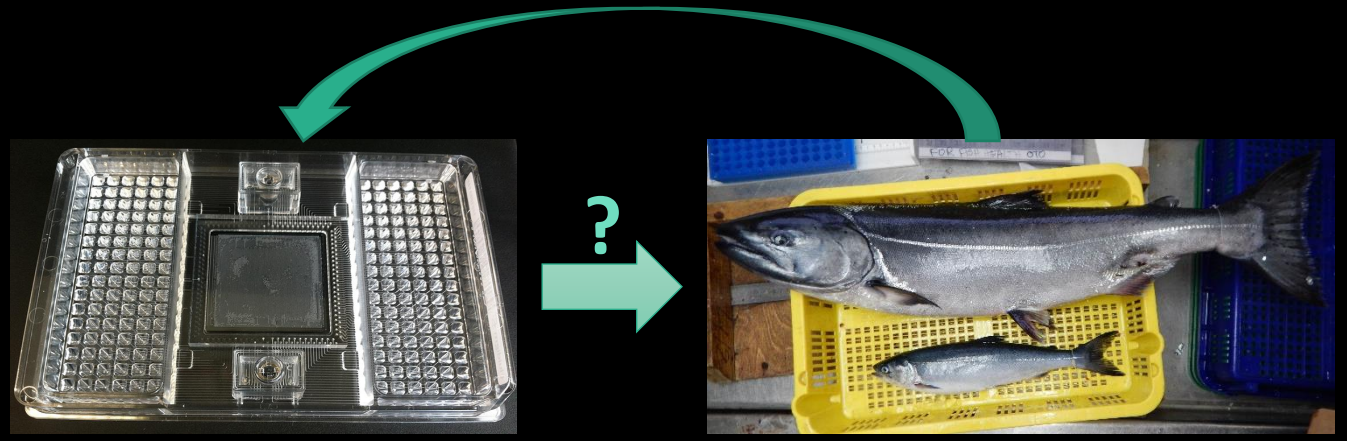
C. *Loma sp.* in Sockeye gills. Arrows: Xenomas (H&E)

D. *Loma sp.* in Coho gills: Arrows: Xenomas (H&E)

Fitchip survey

Assess differential expression of 89 host genes:

- Gill function
  - Hypoxia
  - Osmotic Stress
  - Inflammation
- Infection
  - Immune stimulation
  - Viral disease development
- General Stress
- Thermal Stress
- Morbidity and mortality
  - Mortality Related
  - Imminent Mortality



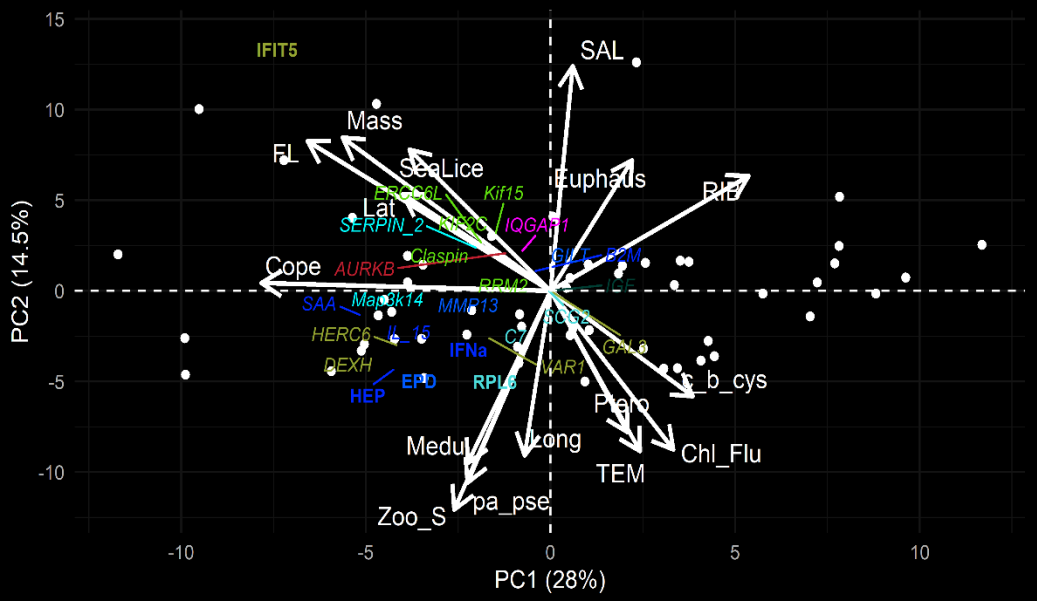
Correlated with:

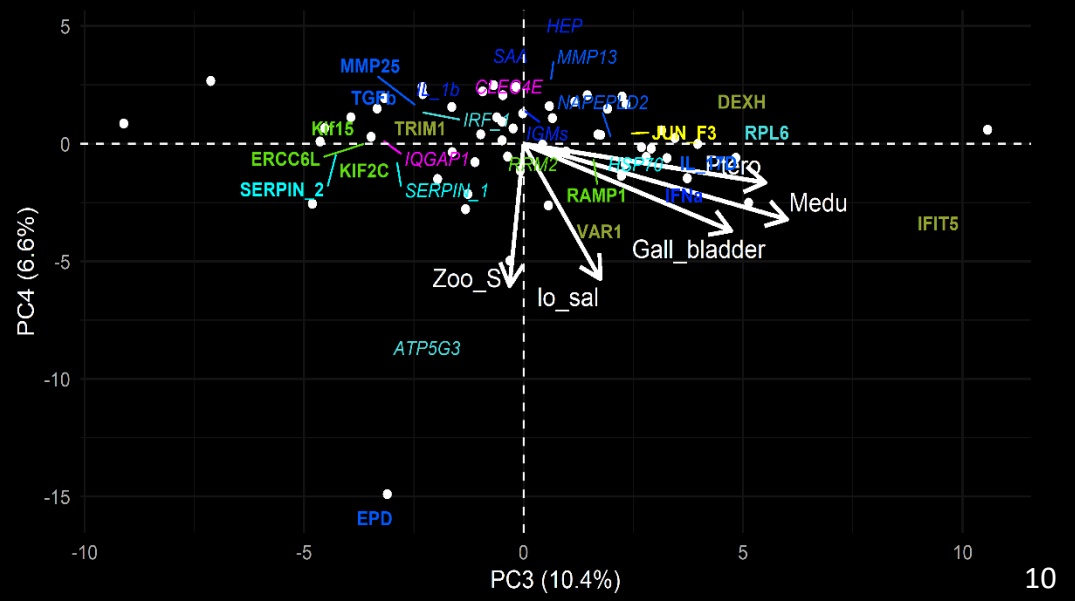
- Physiological condition
- Pathogens
- Stock ID
- Oceanographic variables

Chum gene expression

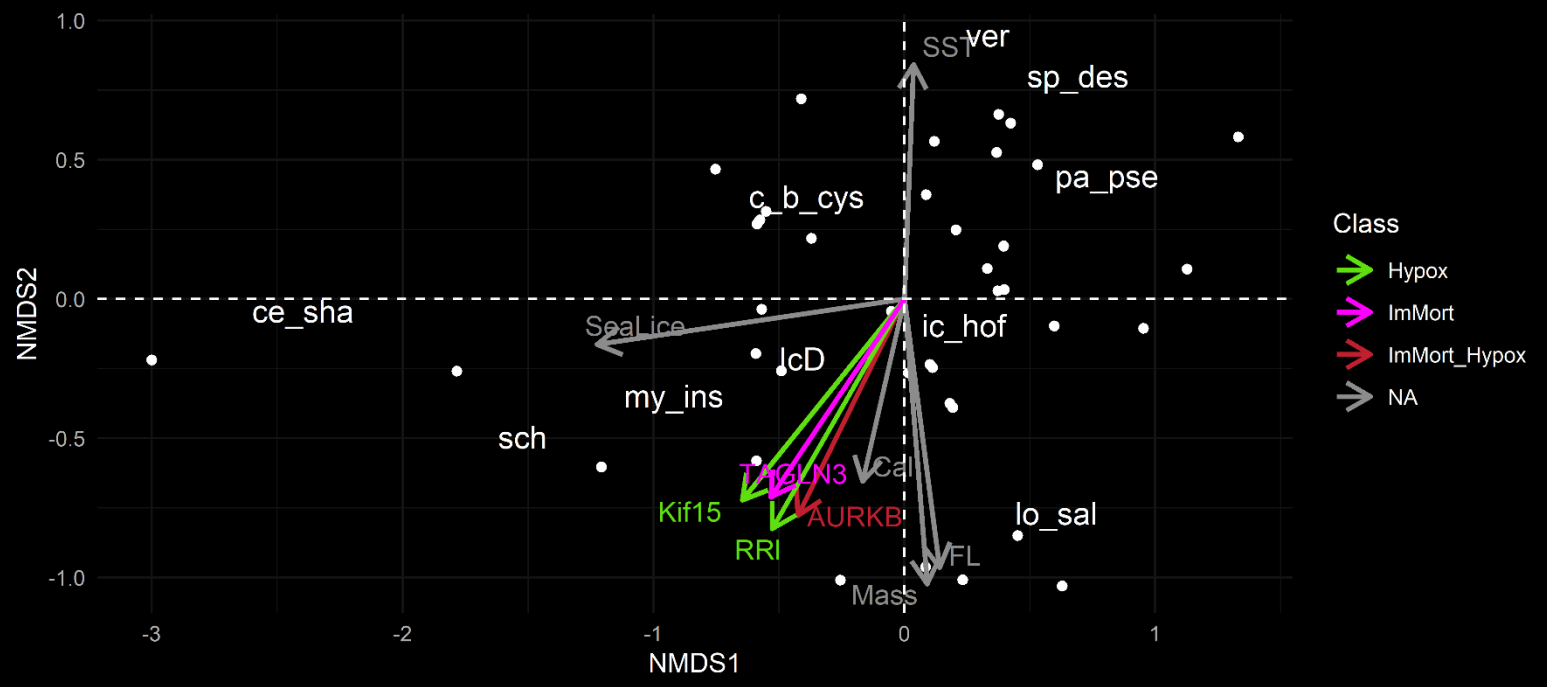
- Immune Stimulation / Inflammation
  - \+ Prey (Hydromedusae)
  - \- Temperature
  - \+ Size (+ Sea lice)
  - \- Relative Infection Burden
  - \- *Ca.* Branchiomonas cysticola

- Immune Stimulation / Inflammation
  - \- Starvation (gall bladder)
  - *+ Loma sp.*





Chum pathogens

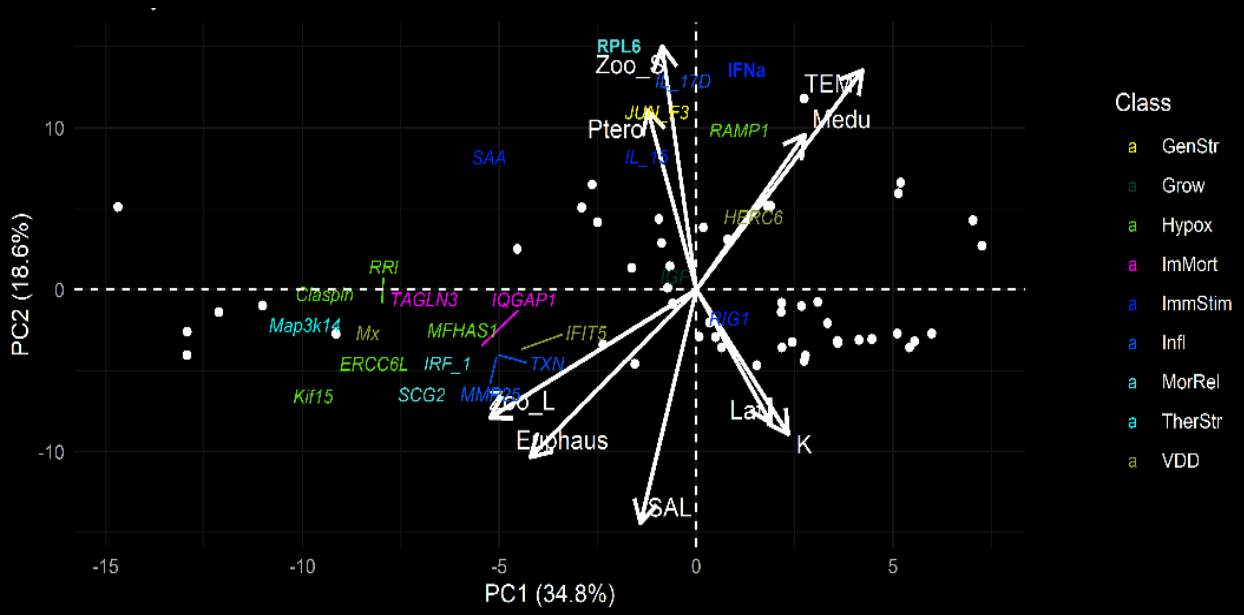


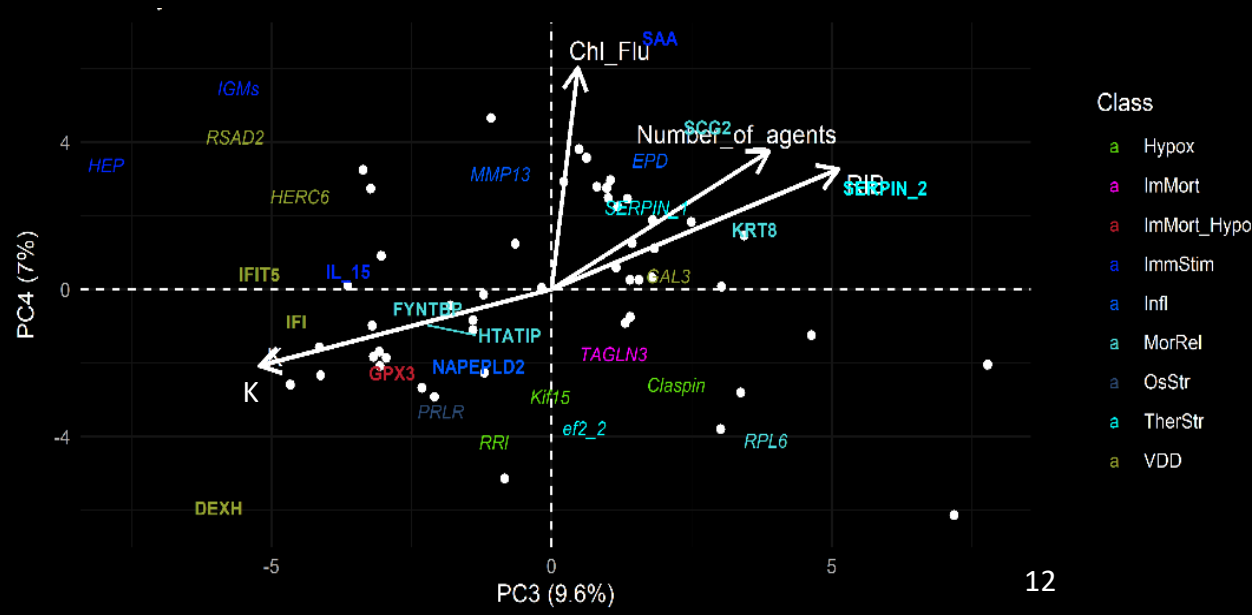
- Size
- Energetics
- Temperature
- Sea lice
- Gill infection -> Respiratory response

Sockeye gene expression

- Immune Stimulation
  - Temperature
  + Preferred prey (Euphausiids)
  - Condition factor (K)

- VDD and Immune Stimulation vs. Mortality Related
  + Condition factor (K)
  - Number of agents
  - Relative Infection Burden

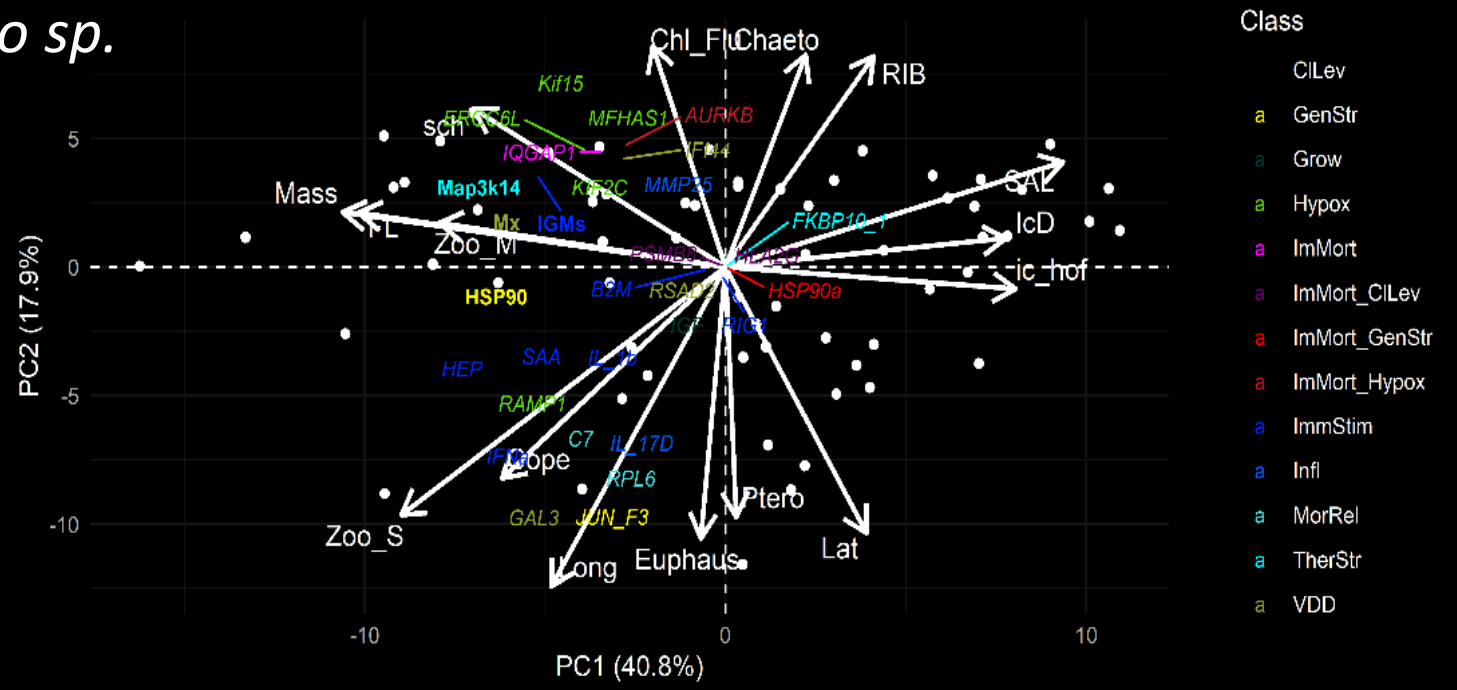




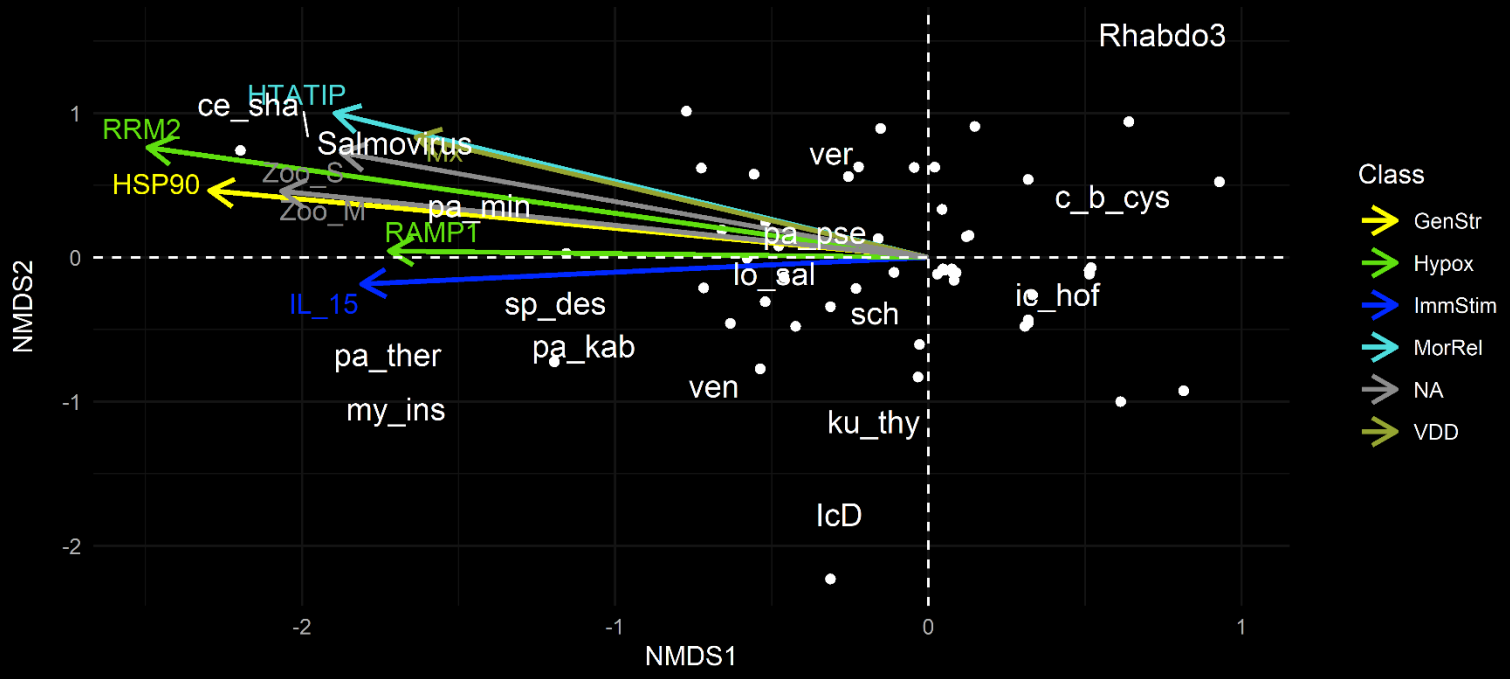
Coho gene expression

- Immune Stimulation
  - + Prey (Pteropods and Euphausiids)
  - + Size
  - - Relative Infection Burden
  - - *Ichthyophonus hoferi*
  - - *Ichthyobodo sp.*

- Respiratory response
  - + *Ca.* Syngnamydia salmonis



Coho pathogens

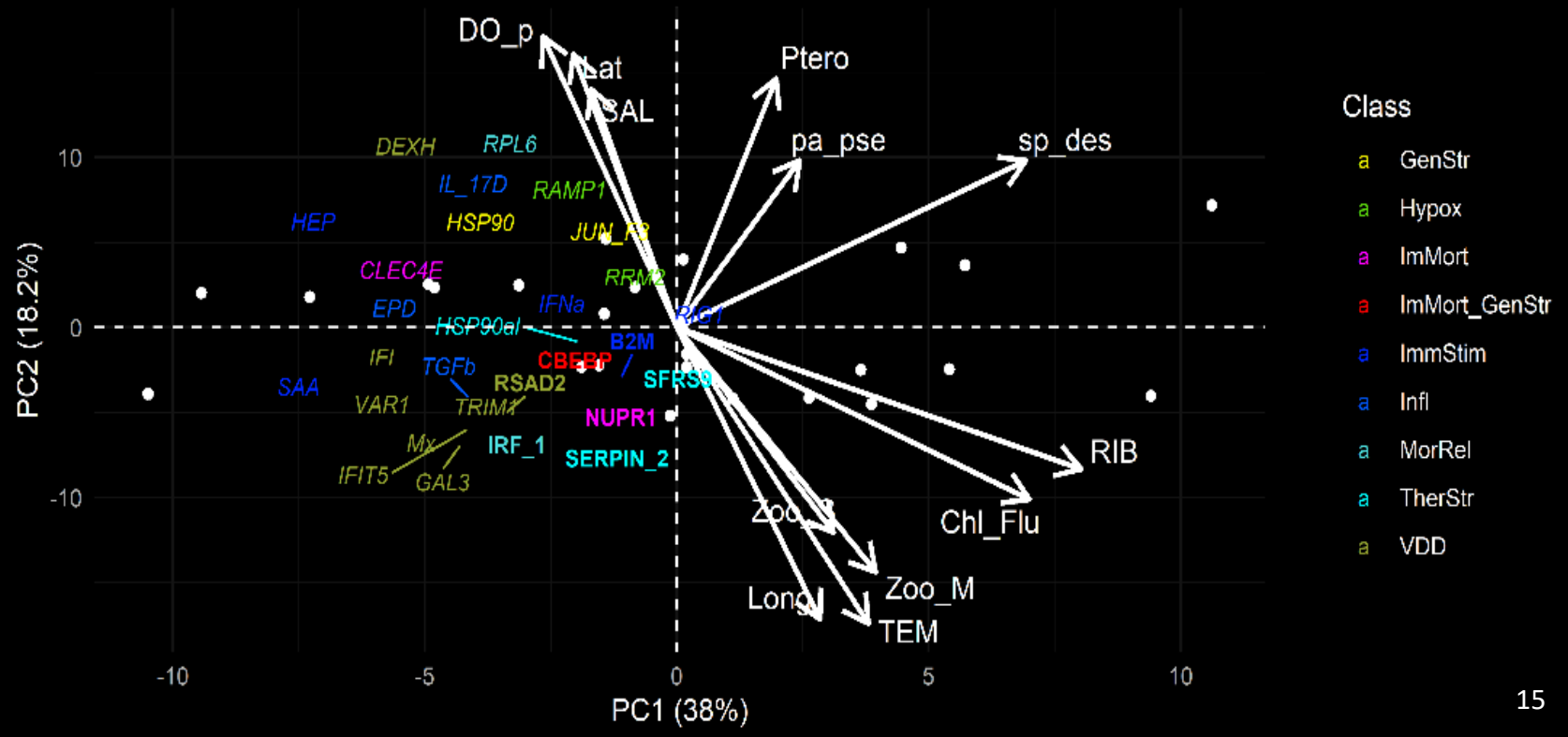


- Stock of origin
- Respiratory response to Gill infection
- Immune response to uncommon pathogens
- Zooplankton abundance

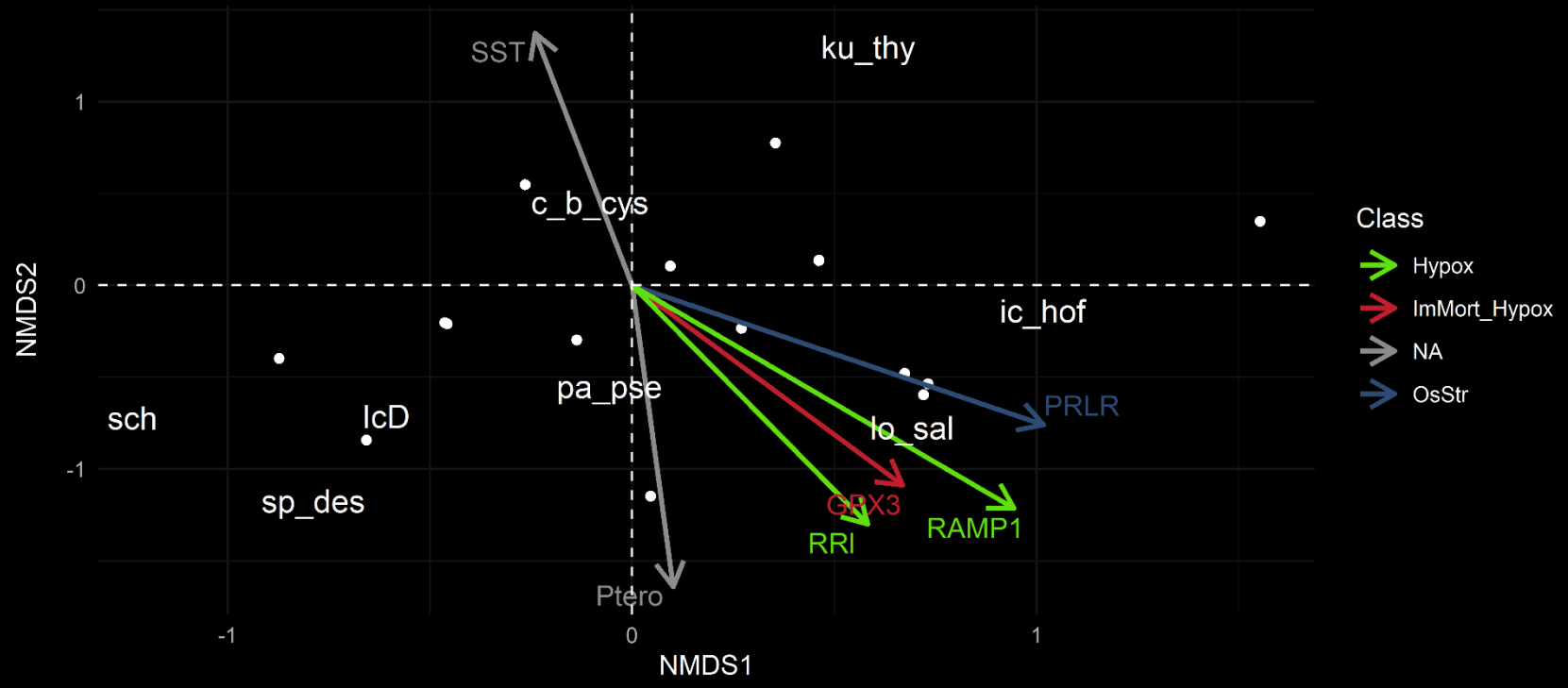
Pink gene expression

- Immune Stimulation and VDD
  - Temperature
  - Relative Infection Burden
  - *Parvicapsula pseudobranchicola*
  - *Sphaerothecum destruens*

- VDD co-expression: Unknown viruses?



Pink Pathogens



- Pteropod abundance vs. Temperature
- Gill infection -> Respiratory response

Health of overwintering Salmon in the GoA 2019 Pathogens

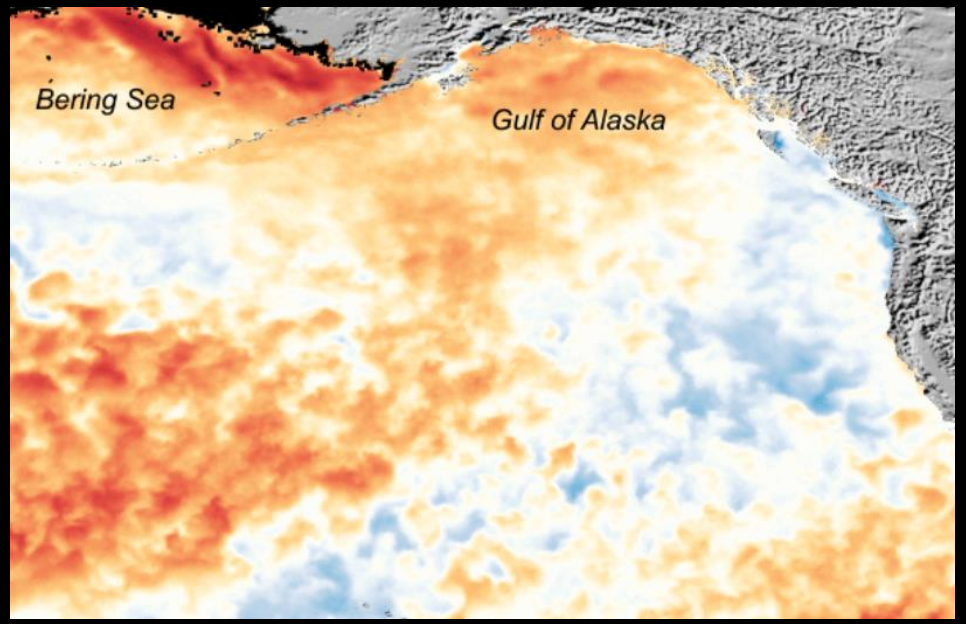
- GoA has lower pathogen burden, number, and diversity
  - Higher RIB in Coho
  - Fewer coastal and freshwater pathogens
- High prevalence pathogens:
  - *Loma sp.*
  - *Ca.* Branchiomonas cysticola
  - *Ichthyophonus hoferi*
  - Coho: Viral encephalopathy and retinopathy virus (VER)
  - Sockeye: *Sphaerothecum destruens*

Trophic transmission

- Unknown viruses in Pink?

Health of overwintering Salmon in the GoA 2019 Stressors

- Respiratory response to gill infection (Pink, Chum, Coho)
  - *Loma sp.*
  - *Ca.* Syngnamydia salmonis
  - *Parvicapsula pseudobranchicola*
- Energetics
  - Prey availability vs. Temperature ~ Immunosuppression
    - Starvation (Chum)
    - Size dependent (Chum and Coho)
  - Immunosuppression ~ Higher Infection Burden
    - Condition factor and energy density (Chum and Sockeye)
    - Size dependent (Chum and Coho)
  - Pathogen susceptibility caused by immunosuppression in in small salmon with poor energetics?



El Niño: SST departure Feb 2019 (NOAA)

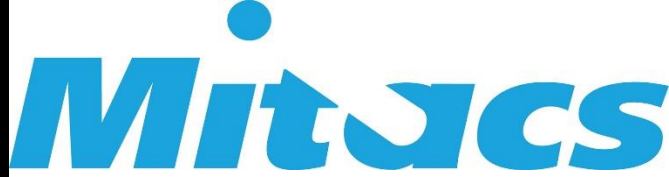
Thank you!

Organization:

- Dick Beamisch

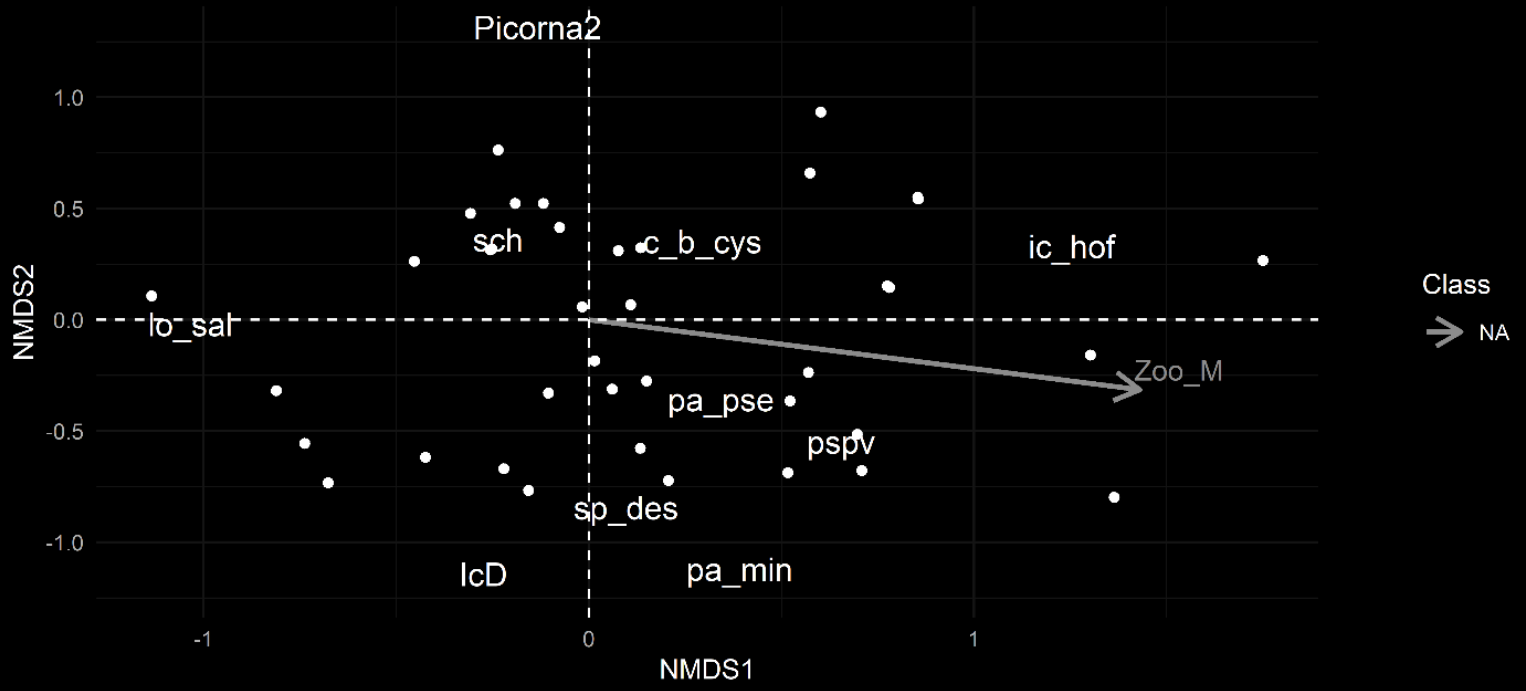
Data contribution:

- MGL Stock ID
- Brian Hunt
- Alexander Slabinsky
- Evgeny Pakhomov
- Chrys Neville
- Charlie Waters



INTERNATIONAL
YEAR OF THE SALMON

Sockeye pathogens

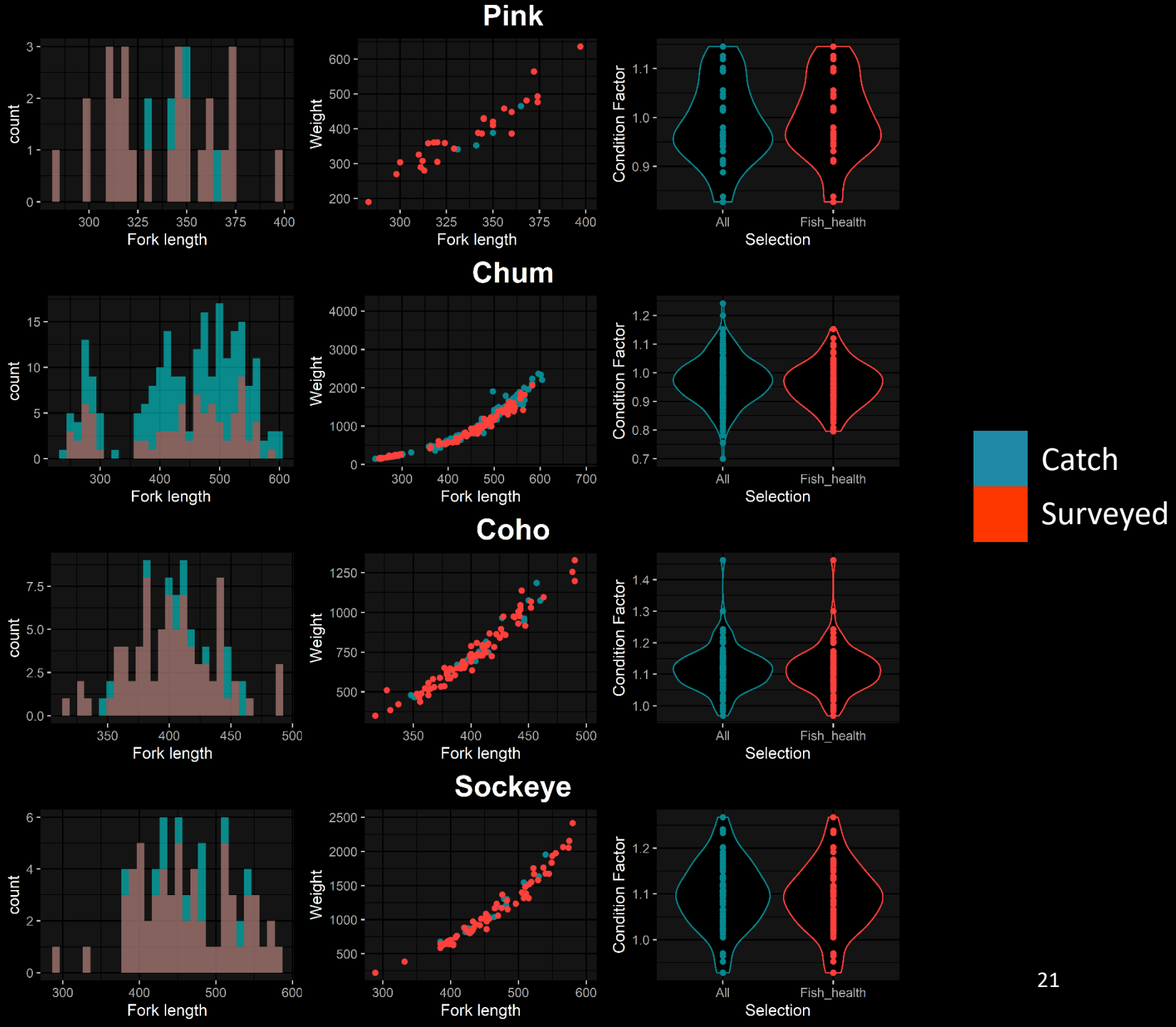


Class
NA

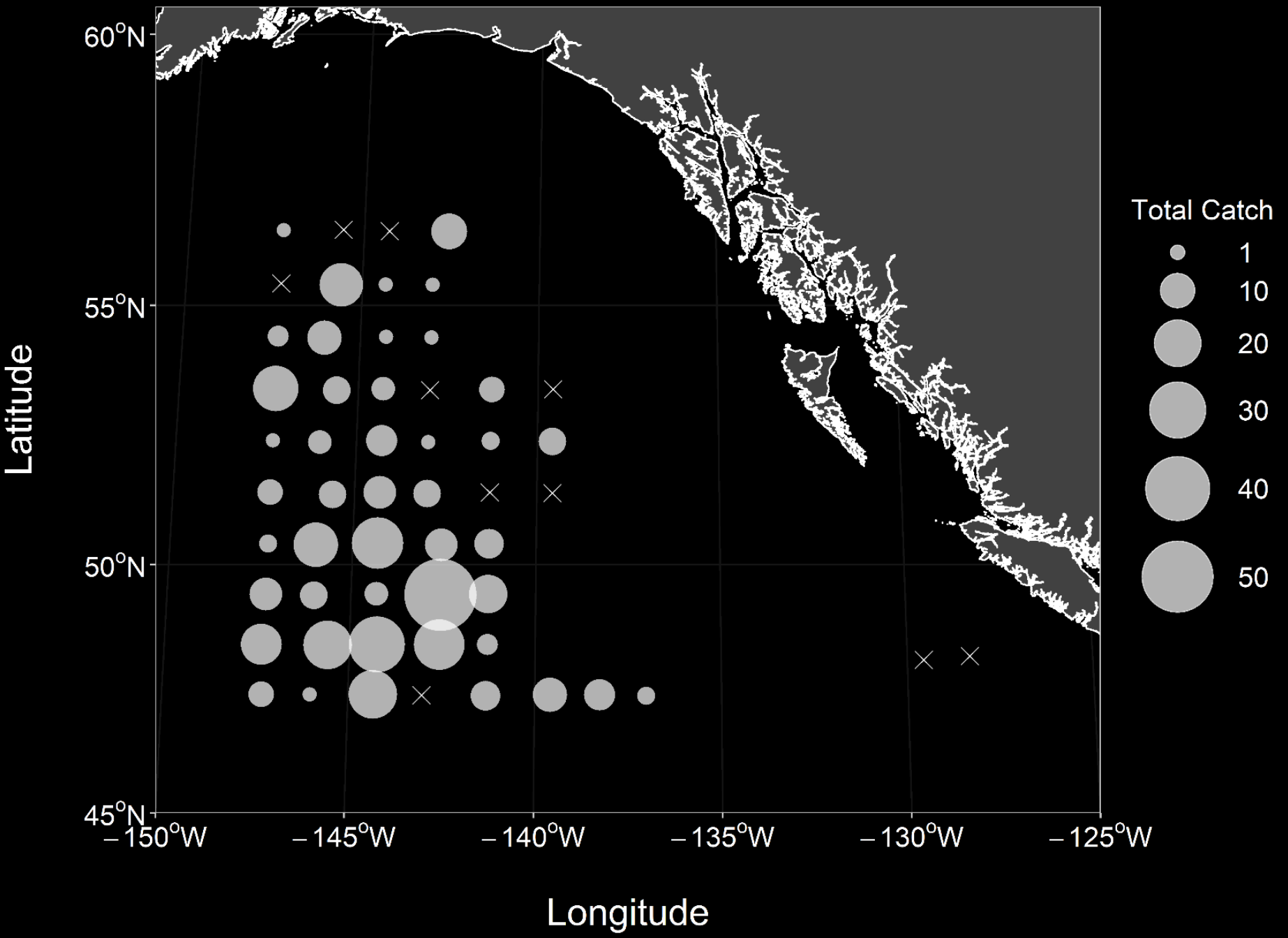
- Zooplankton abundance

IYS GoA 2019 catches

- 253 Salmon assessed out of 422
  - 84 Chum
  - 80 Coho
  - 61 Sockeye
  - 27 Pink salmon
  - (3 Chinook)



IYS GoA 2019



422 Salmon