



**PACIFIC SALMON  
FOUNDATION**



**INTERNATIONAL  
YEAR OF THE SALMON**



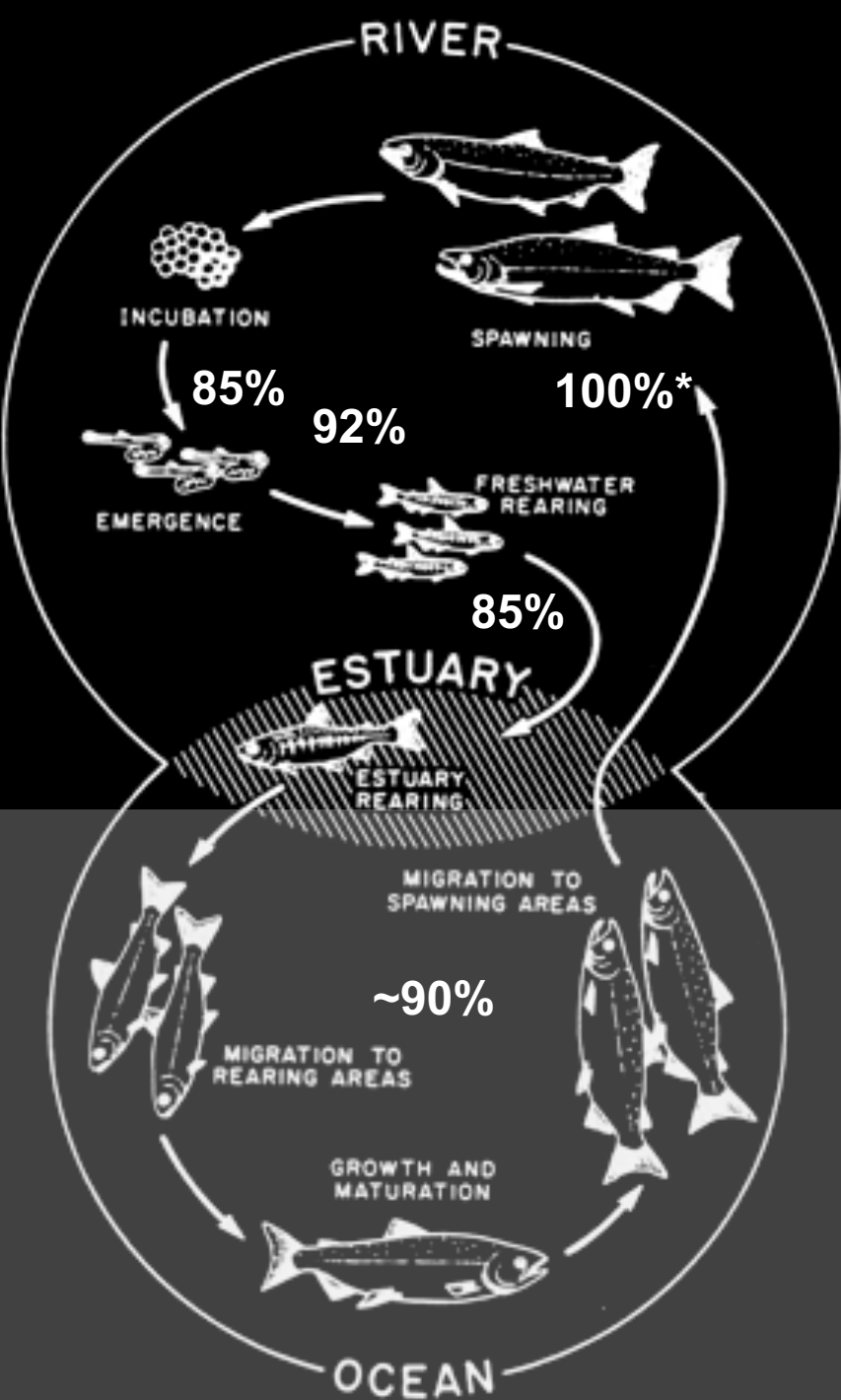
***Exploring the winter salmonosphere  
in the open ocean with genomic tools***



**2022 IYS Synthesis Symposium**

**Christoph Deeg, Andrew Bateman,  
and Kristina Miller**

# The winter ocean: The “black box” of the salmon lifecycle



- Salmon spend most of their life (>2/3) in the open ocean
- Least understood part of lifecycle!
- Ocean survival varies greatly between years and stocks (1-20%)



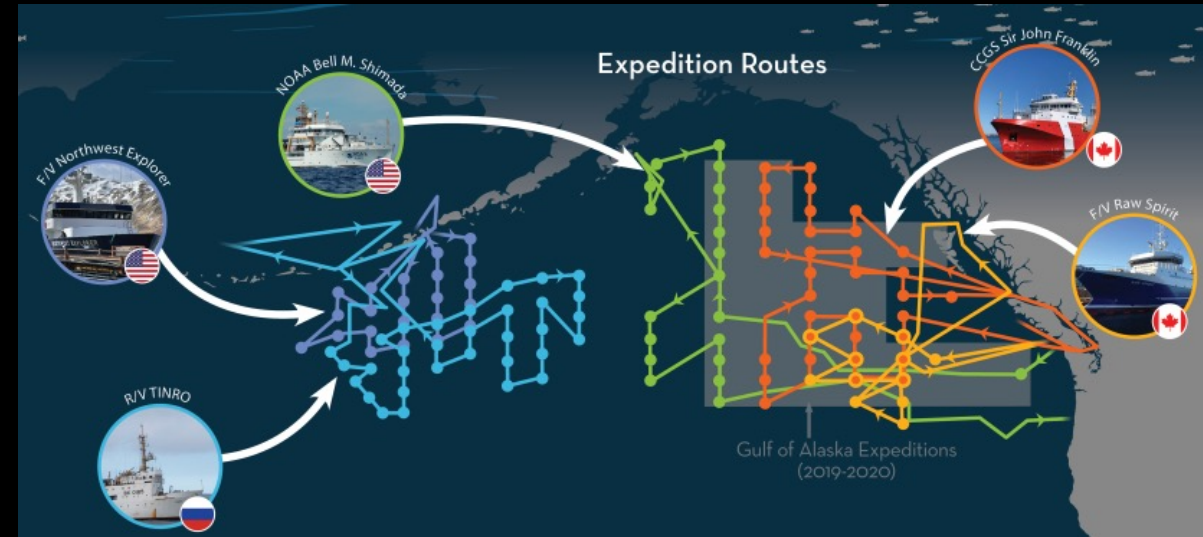
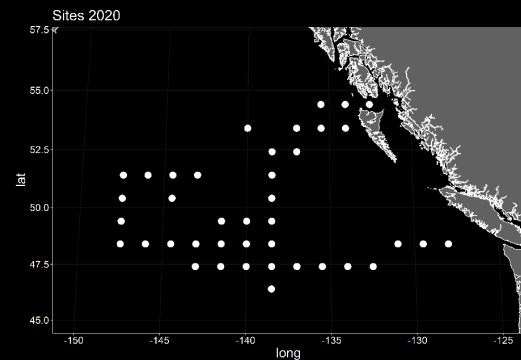
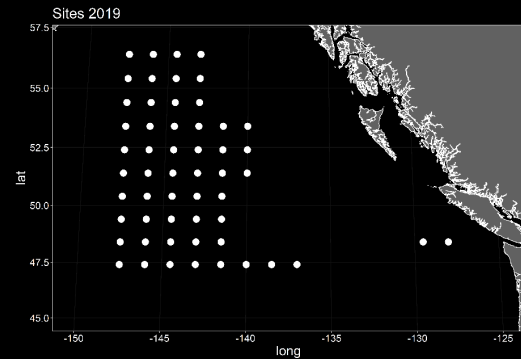


# IYS expeditions

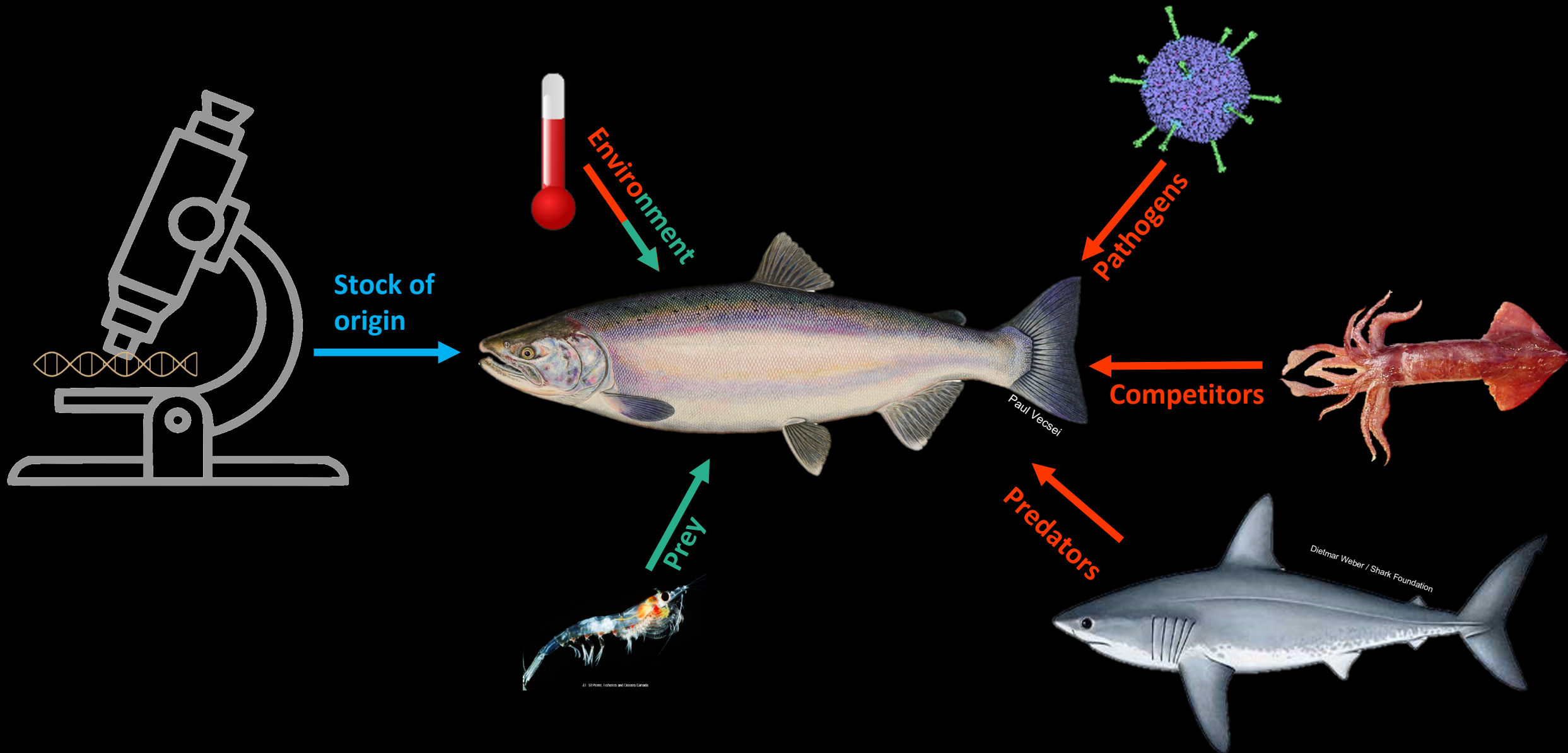


## GoA 2019 & 2020

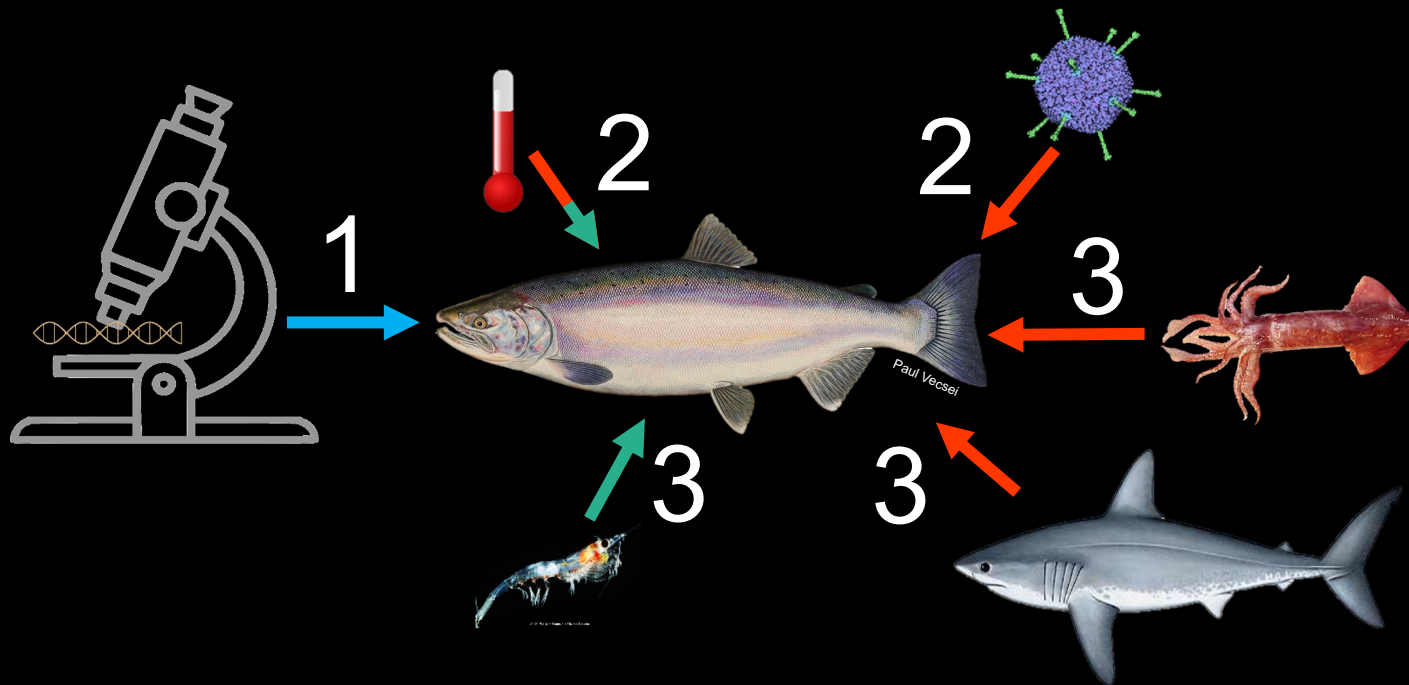
## 2022 Pan-Pacific



# Genomic tools allow us to illuminate the black box!

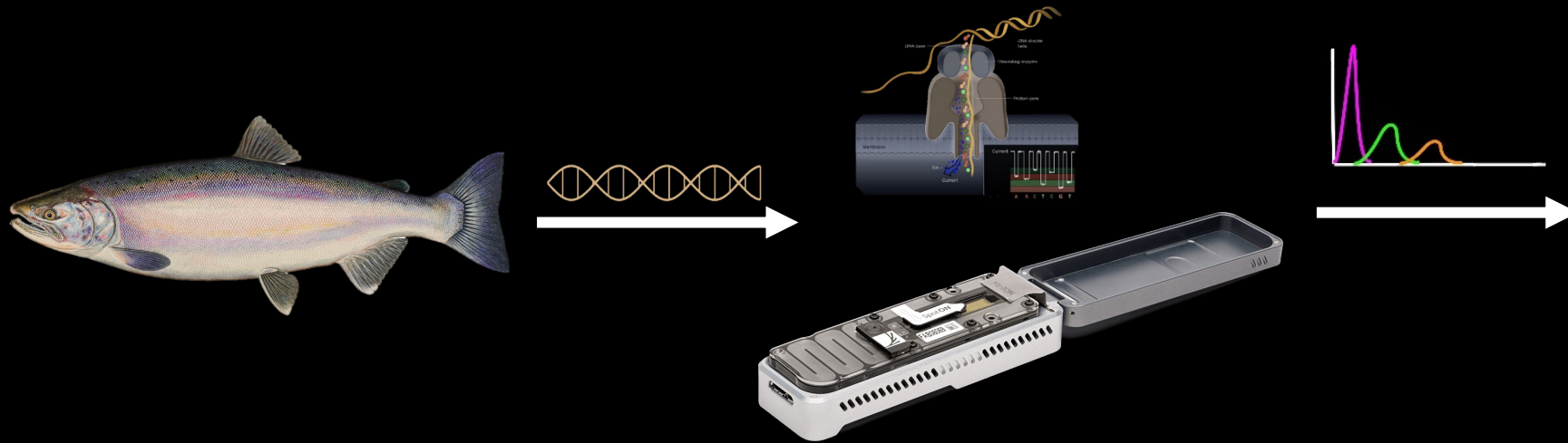
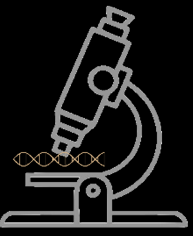


# Genomic tools allow us to illuminate the black box!



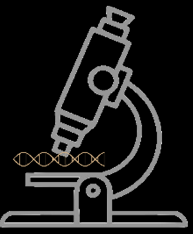
1. Genetic Stock Identification
2. Salmon Fit-Chips
3. Environmental (e)DNA

# Part 1: In-field Genetic Stock Identification

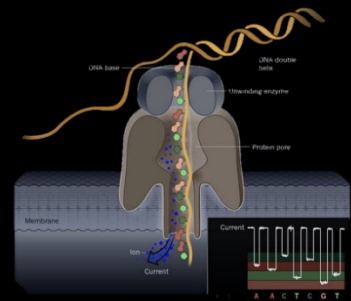


Where is a salmon from?  
Sequence the “genomic fingerprint”

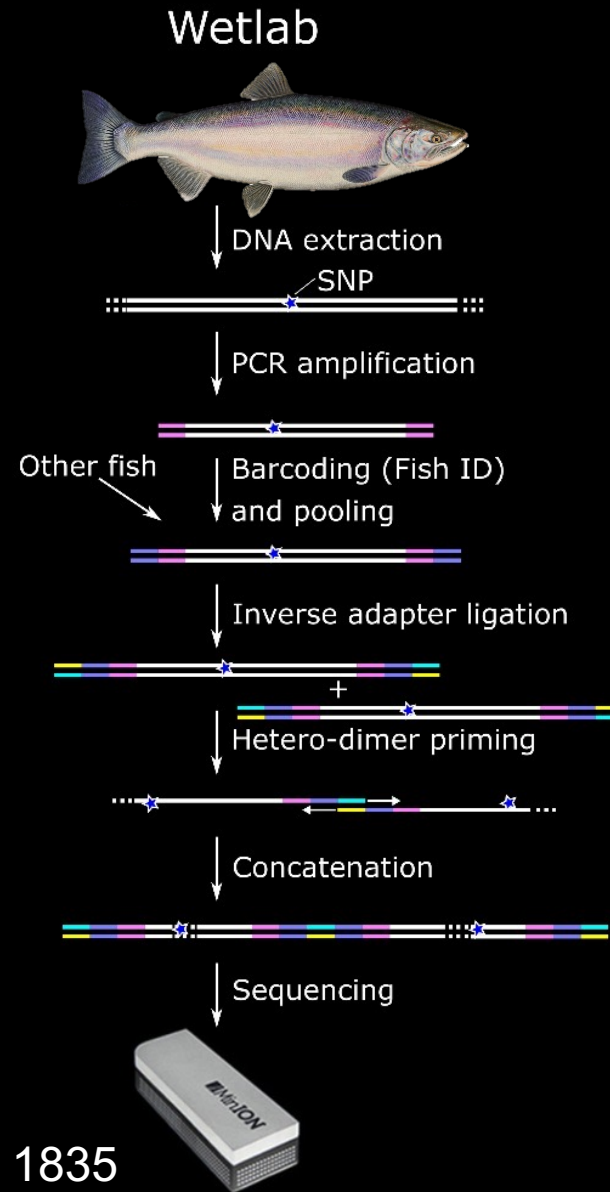
# GSI: Genetic Stock Identification



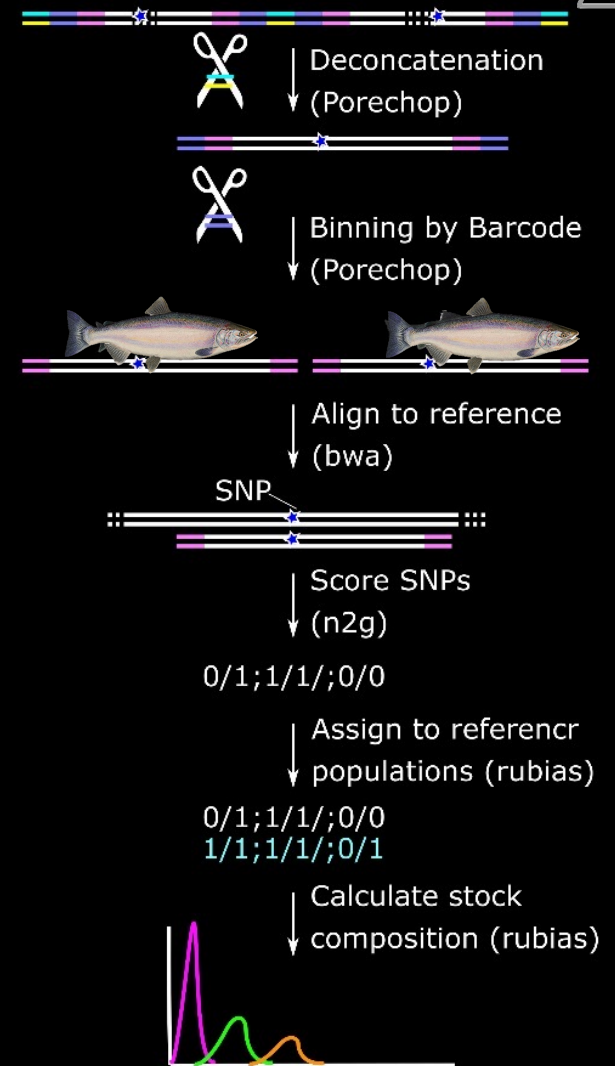
- Single Nucleotide Polymorphisms
- “Genotyping by the thousands” – GT-seq
  - Large batches and complex infrastructure
  - Centralized
- Nanopore sequencing
  - Portable!
  - Democratize stock ID



# “Nano to geno”: N2G



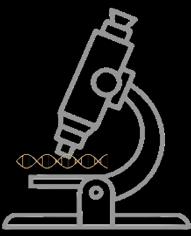
## Computational analysis



Deeg et al. (2022) *Molecular Ecology*, 22, 1824– 1835  
<https://doi.org/10.1111/1755-0998.13595>



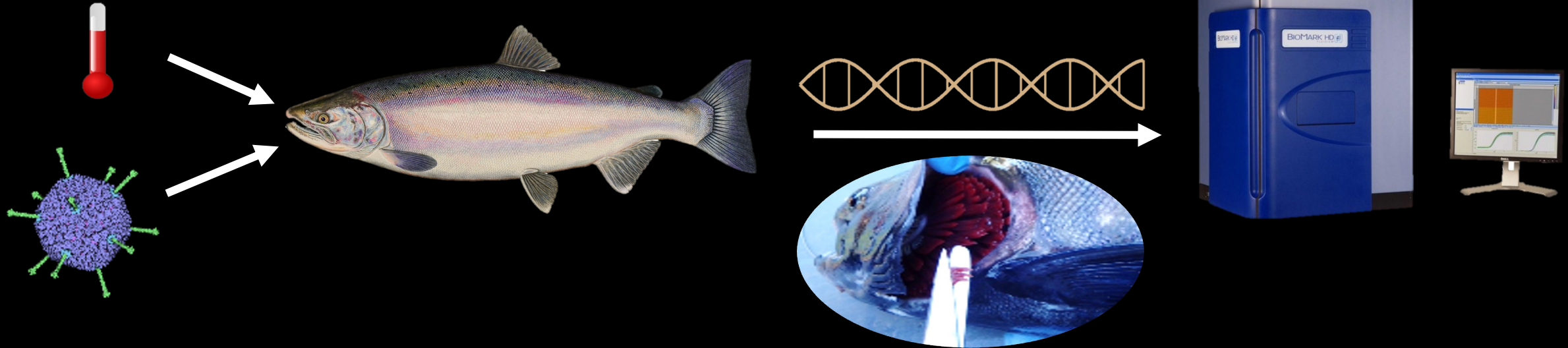
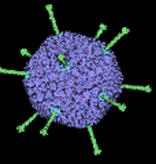
# GSI for the people!



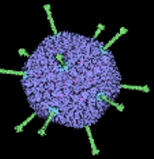
- Simplify and speed up workflow -> User Friendly
- Independent GSI for diverse stakeholders
  - First Nations
  - eNGOs
  - Independent researches



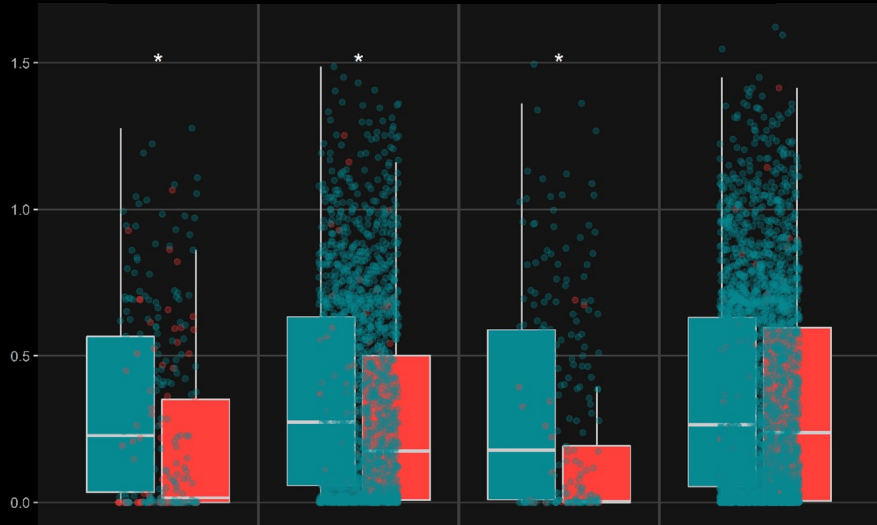
# Part 2: Salmon Fit-Chips Pathogens and Stress



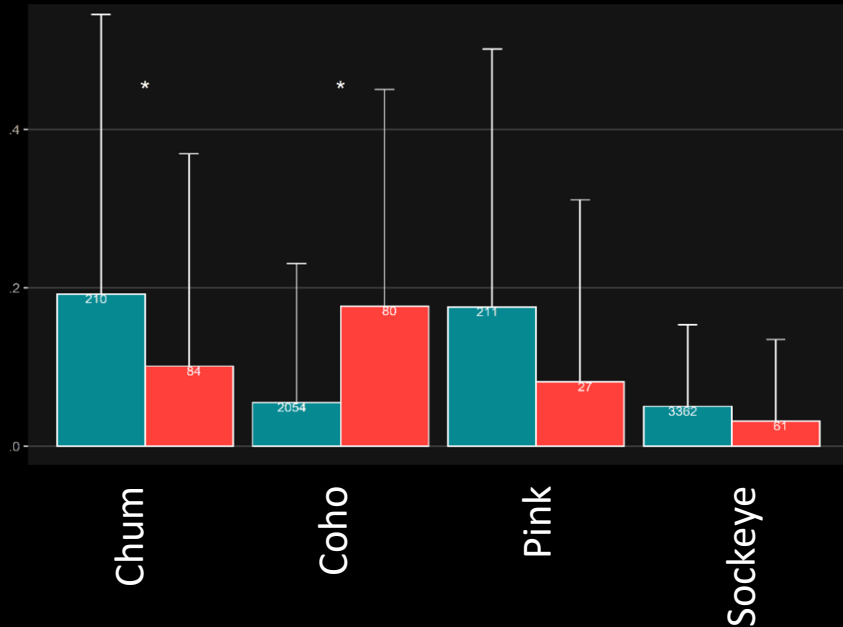
**What pathogens and stressors affect salmon?  
qPCR screening for infectious agents and stress  
response gene expression**



Shannon Diversity of Pathogens



Relative Infection Burden (RIB)



# Fewer pathogens in GoA compared to coast (2019)



*Ichthyophonus hoferi*



Coho: Viral encephalopathy and retinopathy virus (VER)



*Loma sp.*



*Ca. Branchiomonas cysticola*



Sockeye: *Sphaerothecum destruens*



Acquired via prey

Gill disease spread between salmon

Common gill disease

From Freshwater Mixture effect



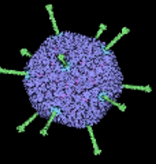
BC coast



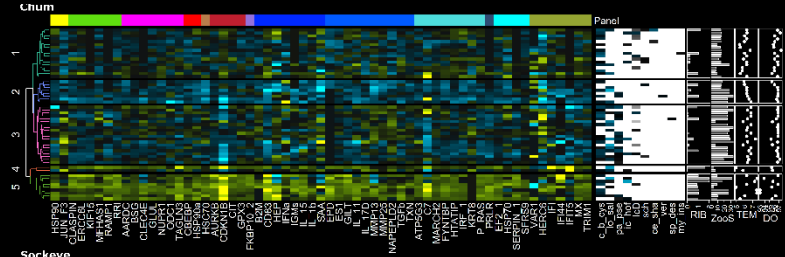
GoA

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

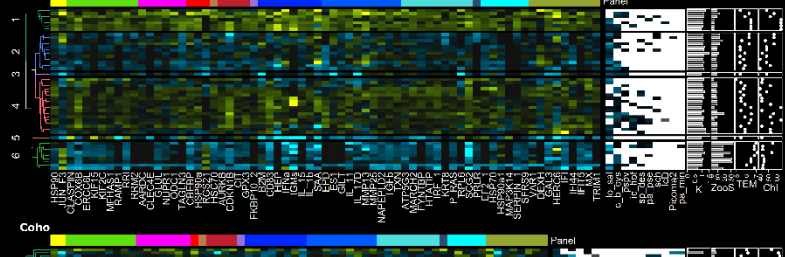
# Gene expression: Cumulative effects of environment and pathogens



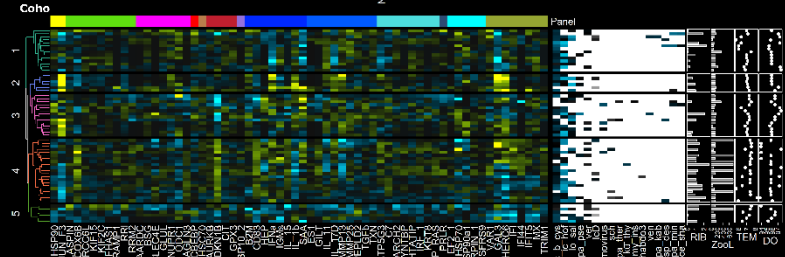
Chum



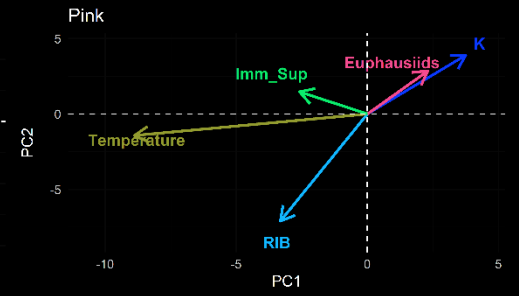
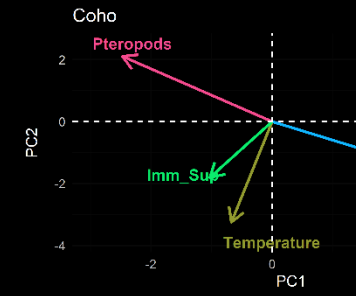
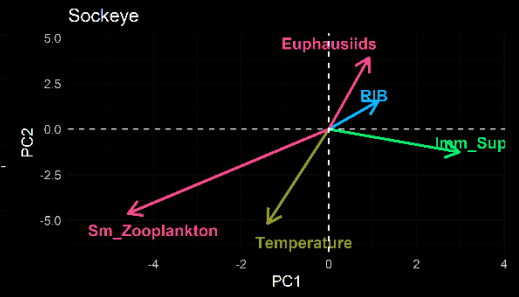
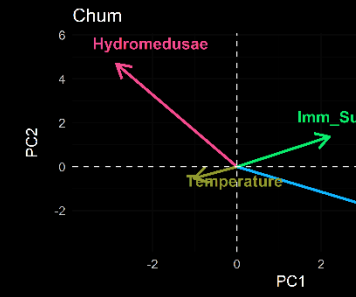
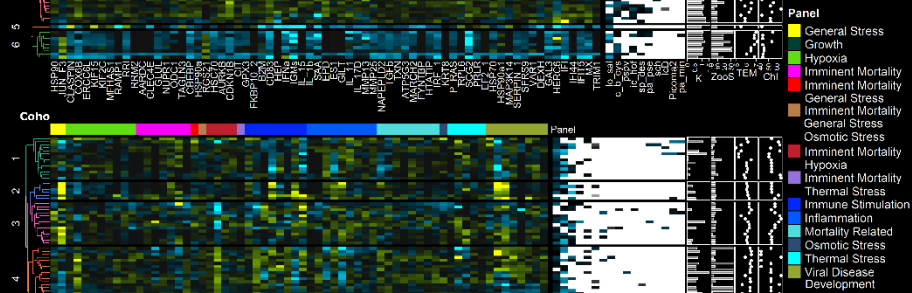
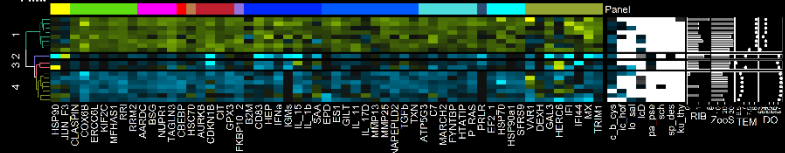
Sockeye



Coho



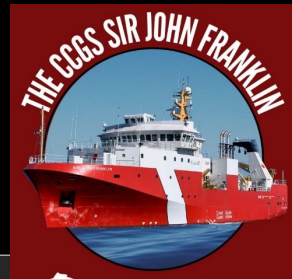
Pink



- Temperature and prey -> Metabolic reprogramming
- Immunosuppression -> elevated infection burden
- Deeg et al. (2022) *FACETS*. 7(): 247-285. <https://doi.org/10.1139/facets-2021-0052>



*Chrysaora melanaster*



East

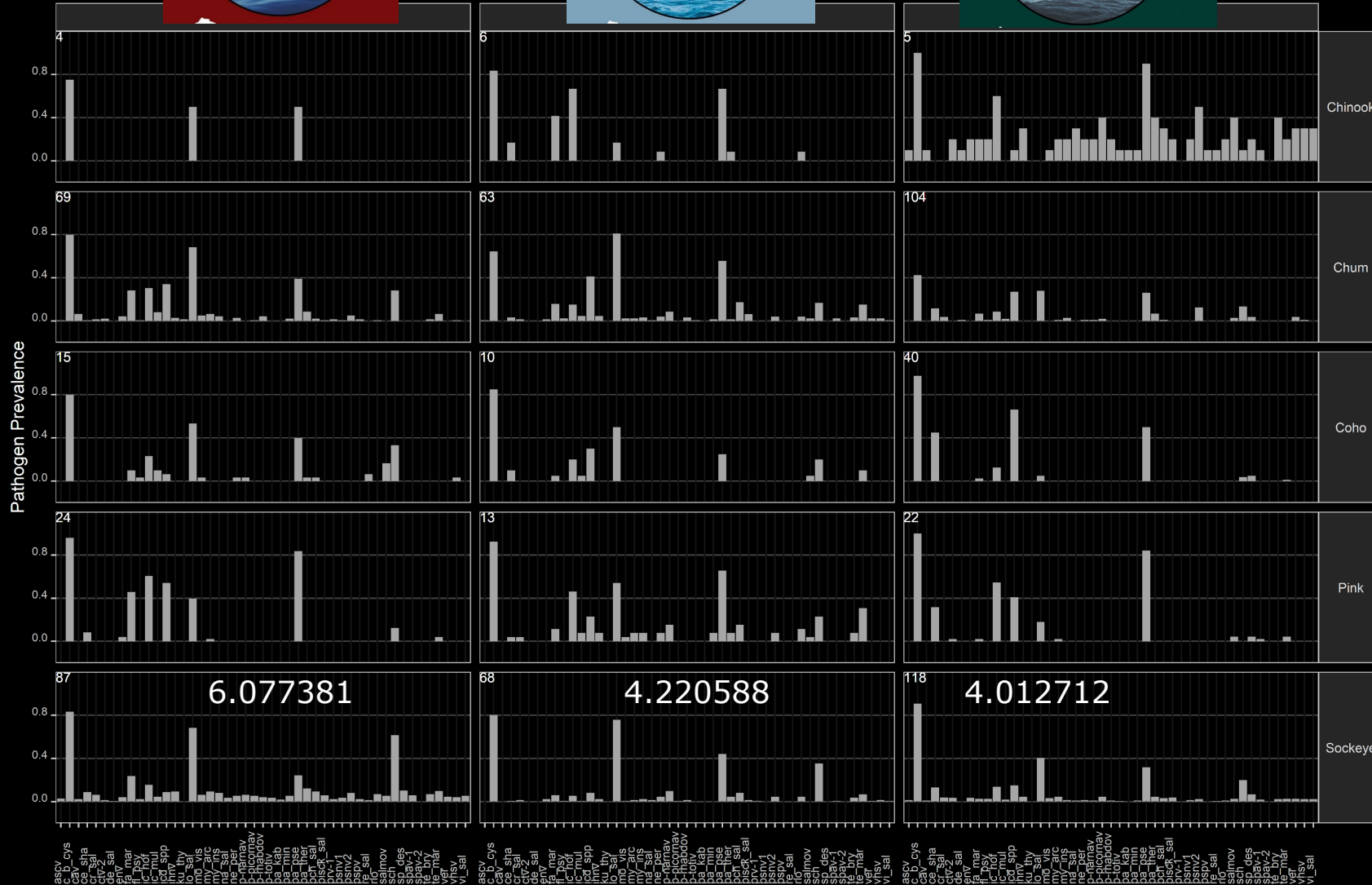


Central



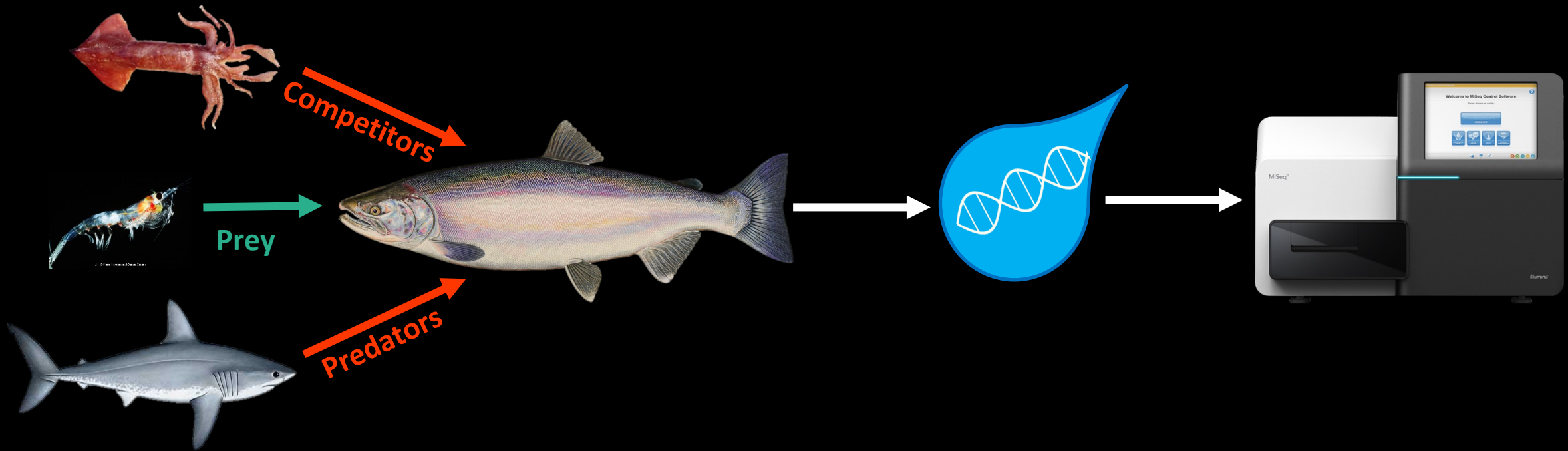
West

# 2022 IYS: Pathogen prevalence



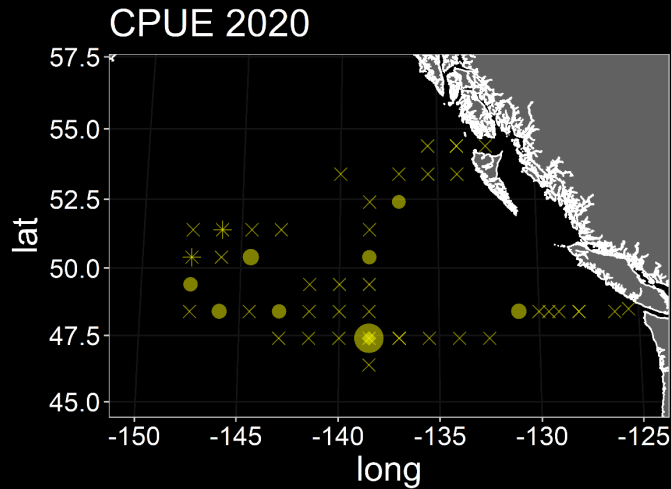
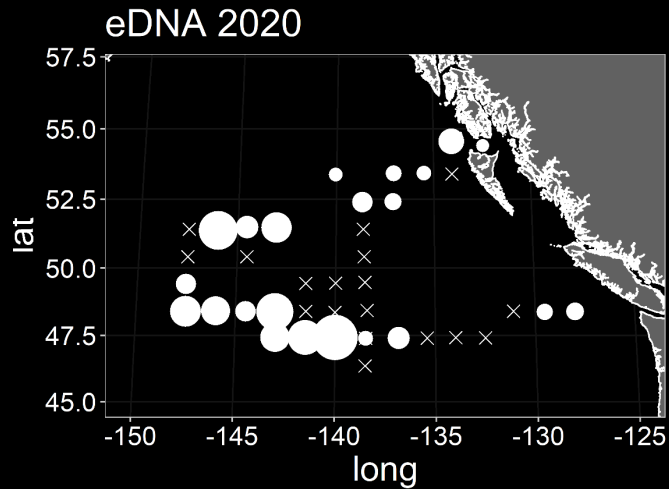
Karia Kaukinen

# Part 3: Environmental (e)DNA

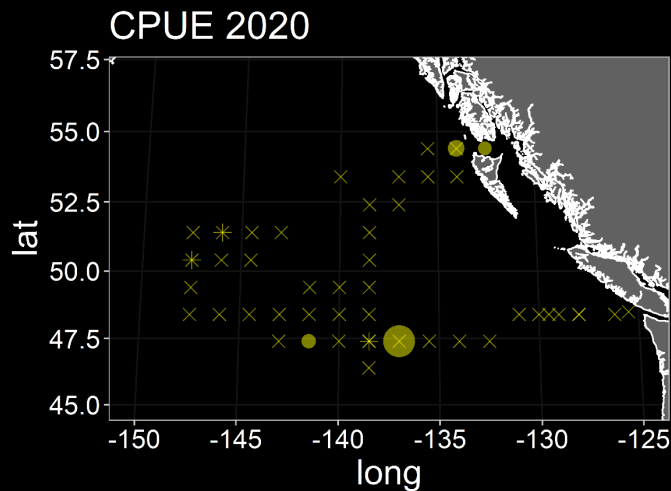
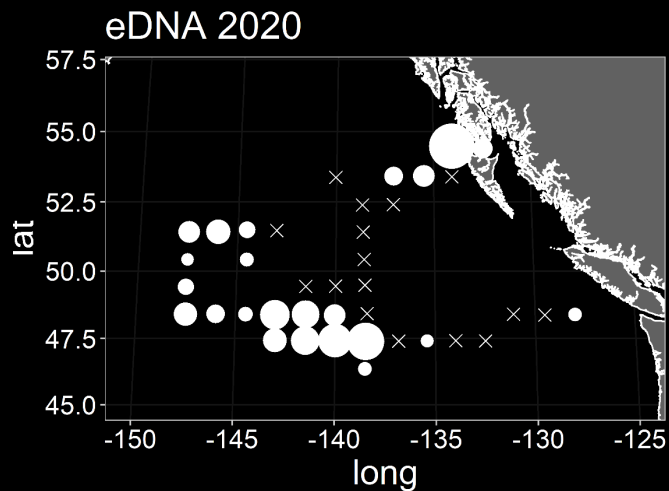


What is the **environment** like for salmon?  
eDNA survey of the winter salmonosphere

# Gulf of Alaska eDNA: Salmon

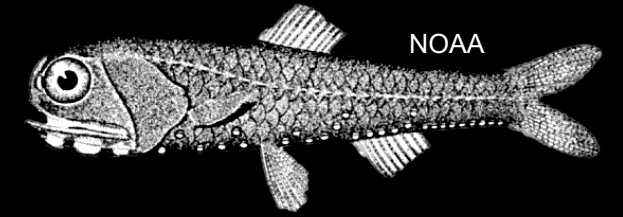
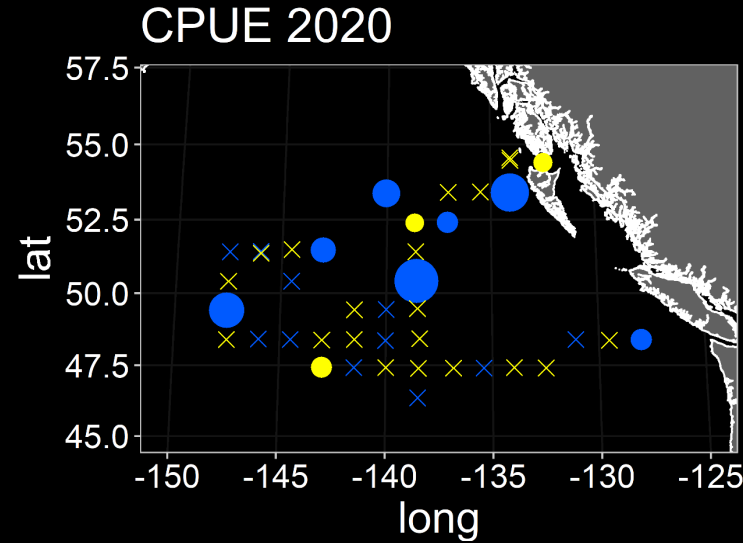
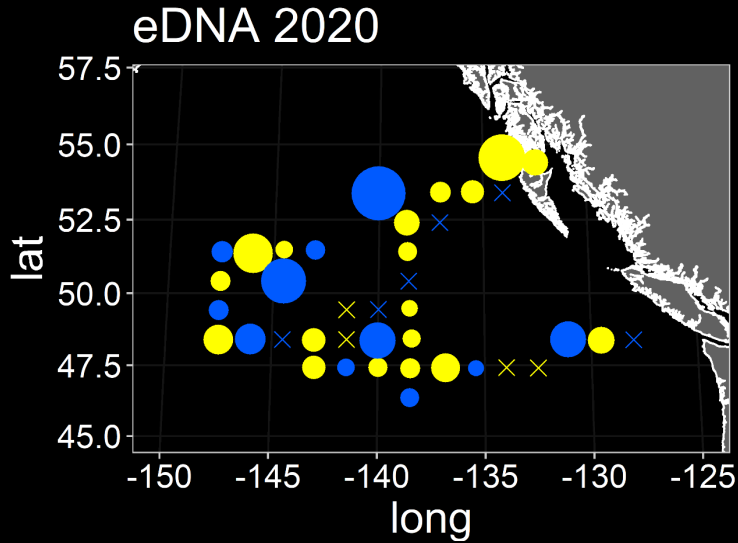


**Coho salmon (*Oncorhynchus kisutch*)**

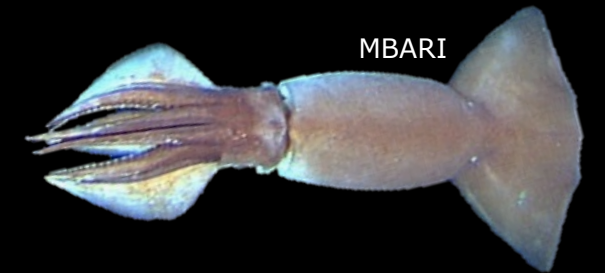
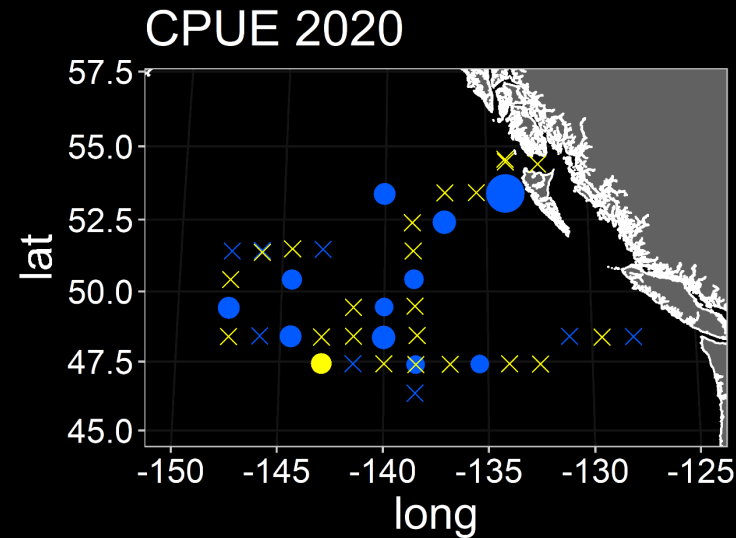
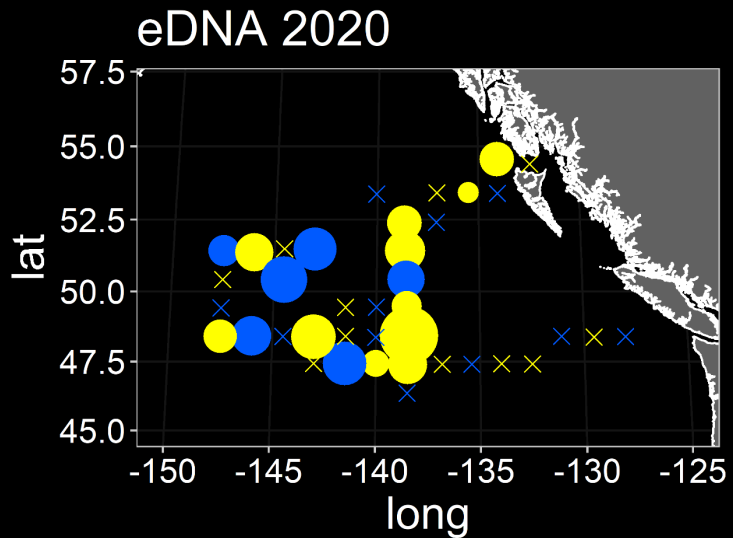


**Pink salmon (*Oncorhynchus gorbusha*)**

# Gulf of Alaska eDNA: Competitors



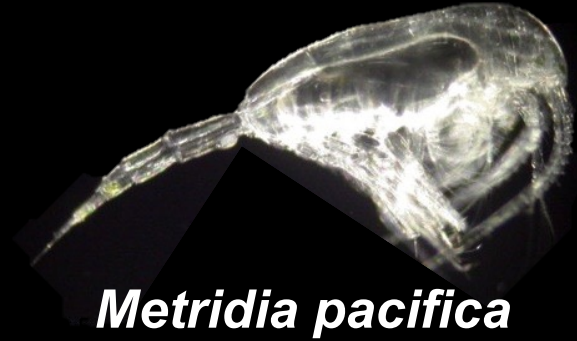
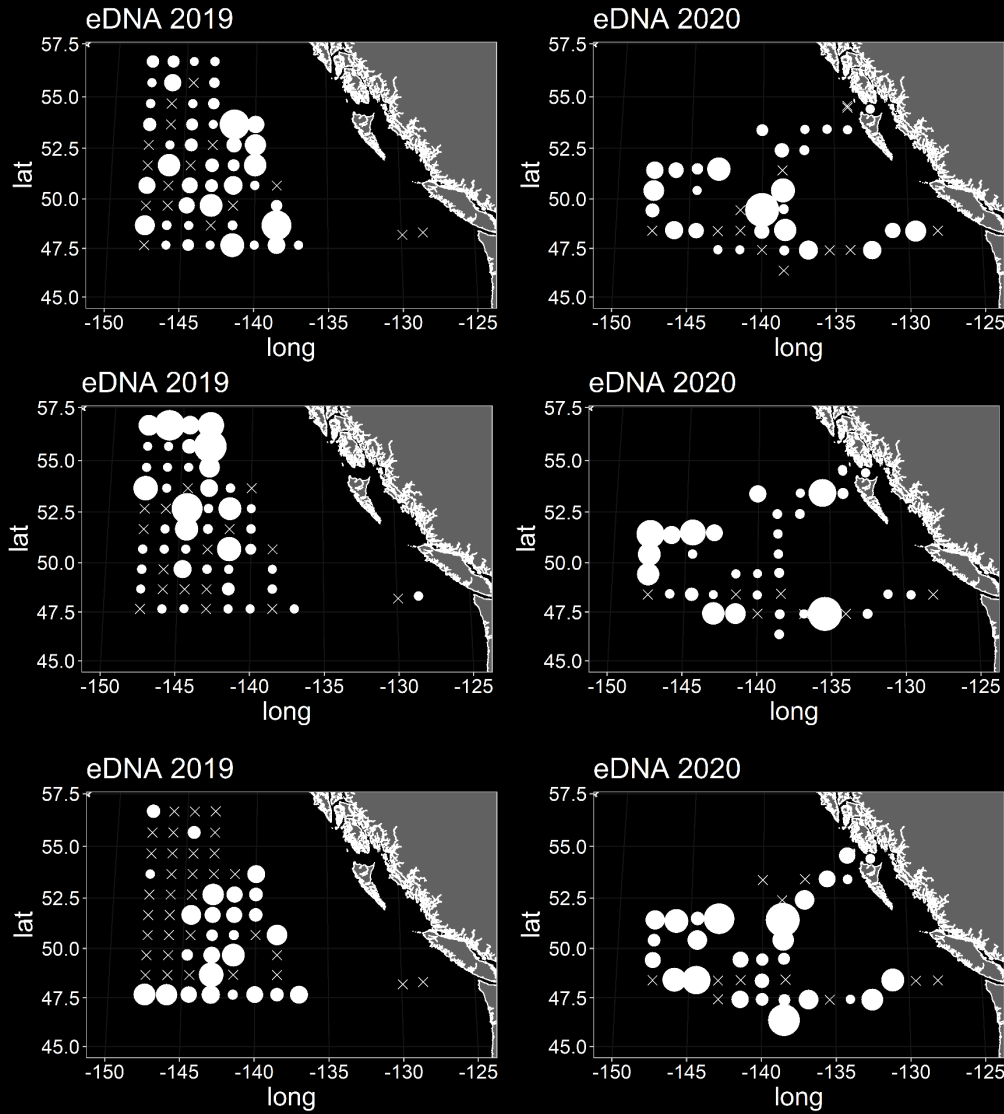
**California headlightfish**  
(*Diaphus theta*)



**Boreopacific armhook squid**  
(*Gonatopsis borealis*)



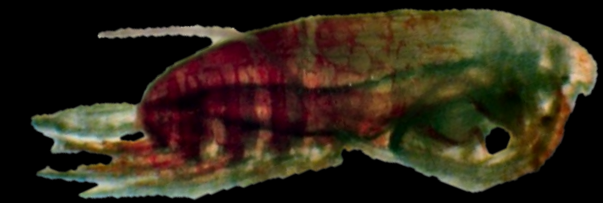
# Gulf of Alaska eDNA: Prey



*Metridia pacifica*

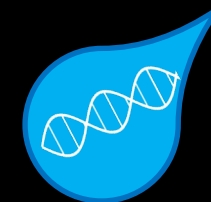


*Neocalanus flemingeri*

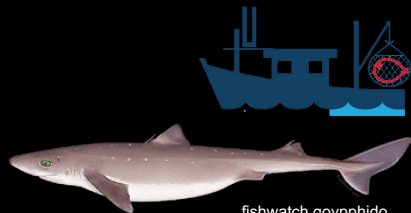


*Neocalanus plumchrus*

# Gulf of Alaska eDNA: Predators



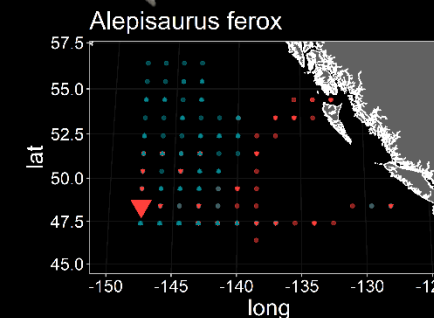
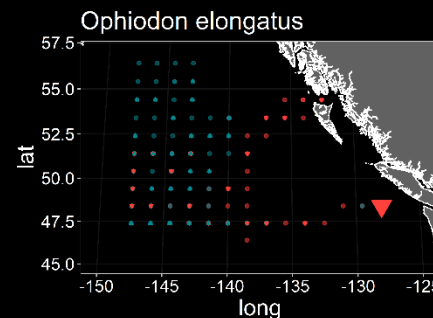
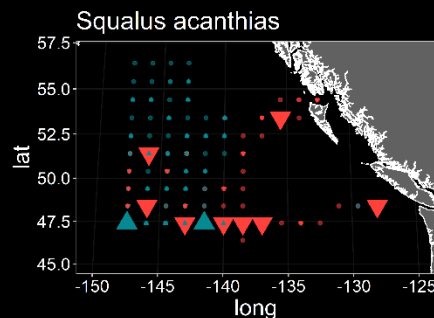
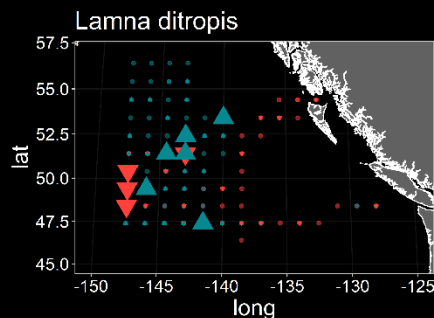
Dietmar Weber / Shark Foundation



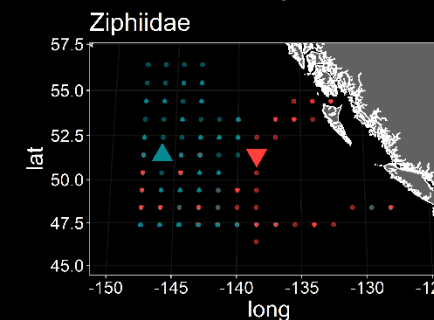
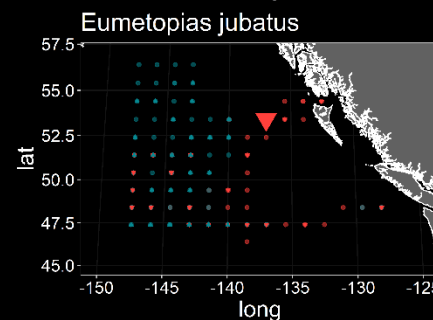
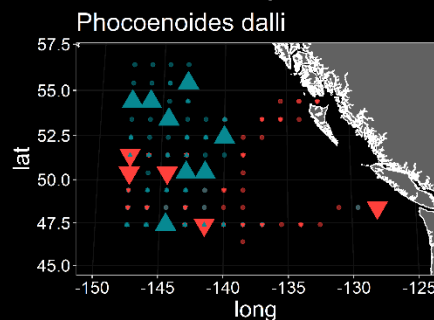
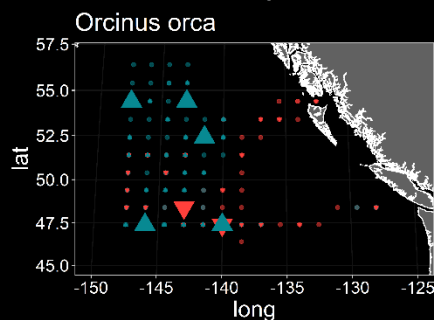
fishwatch.govpphido



efishalbum.com



▲ 2019  
▲ 2020



Uko Gorter



<http://cetus.ucsd.edu/>



NOAA

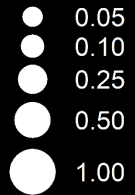


# Gulf of Alaska eDNA: Predators



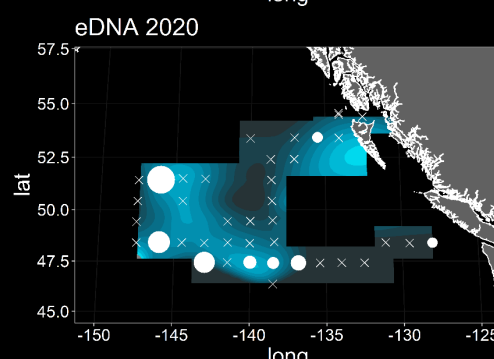
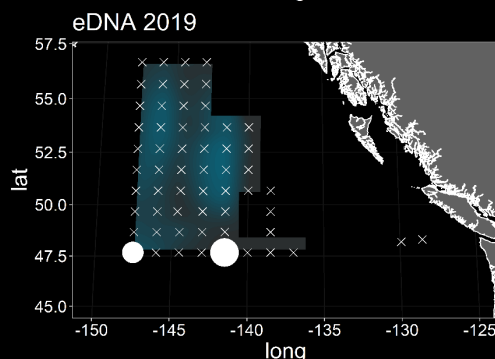
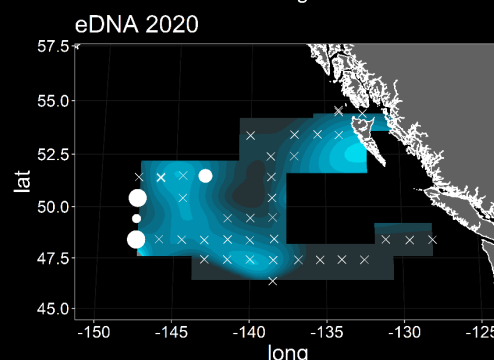
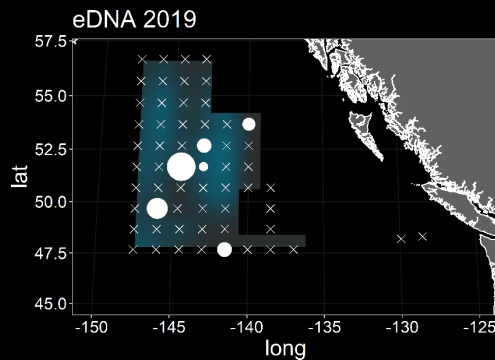
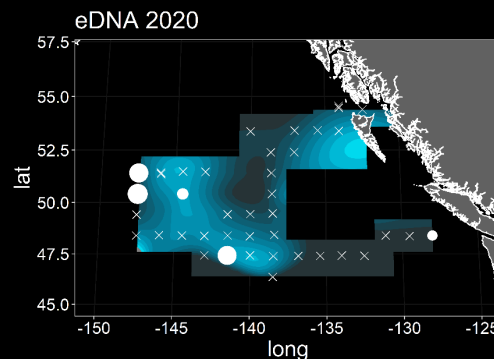
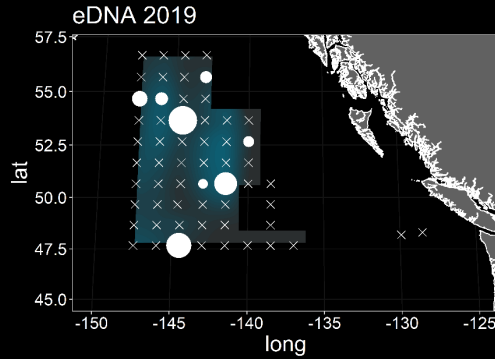
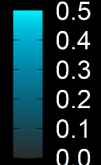
Predator

eDNA Index



Oncorhynchus spp.

eDNA Index



<http://cetus.ucsd.edu/>

**Dall's porpoise** (*Phocoenoides dalli*)



Dietmar Weber / Shark Foundation

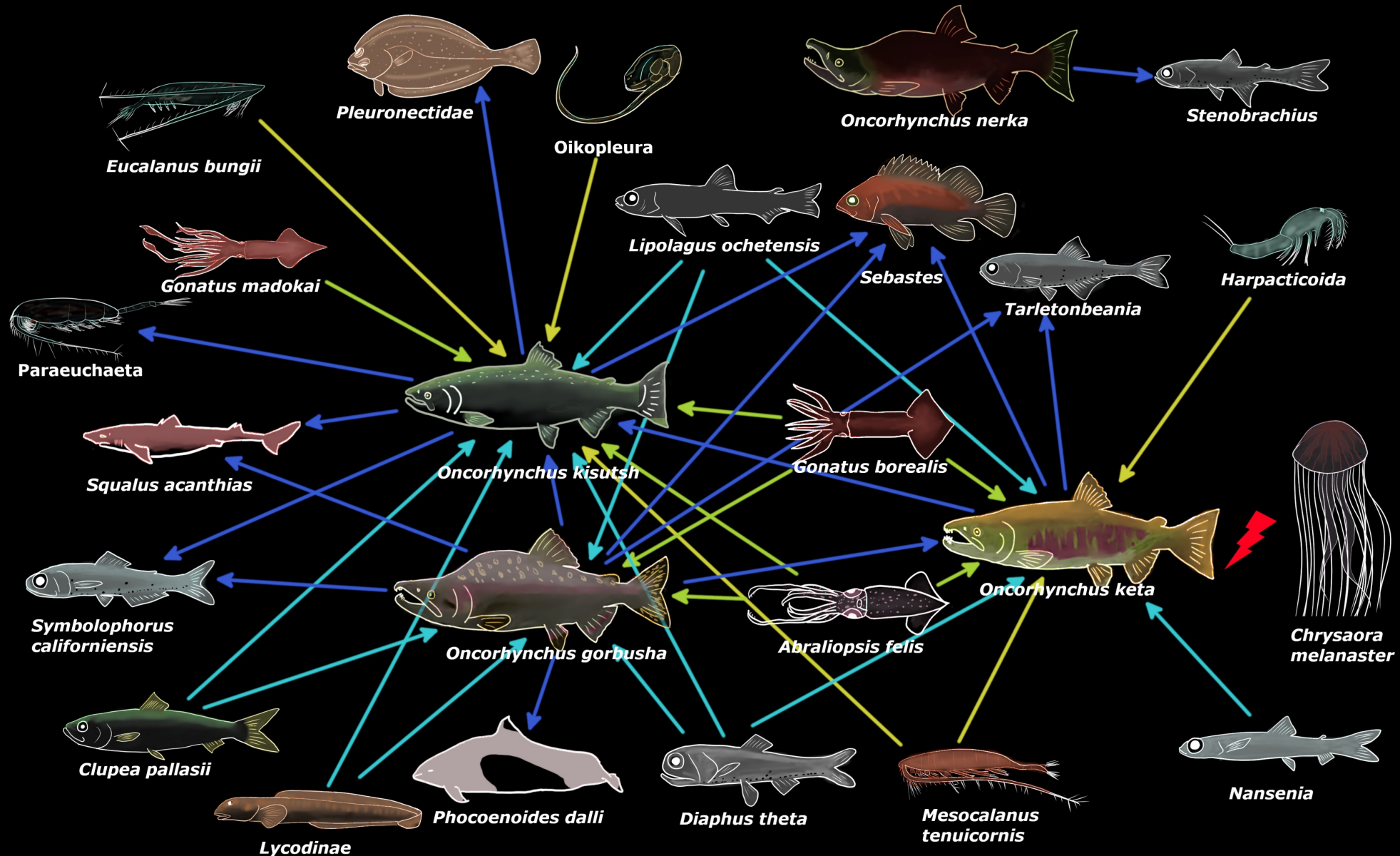
**Salmon shark** (*Lamna ditropis*)



[fishwatch.govpphido](http://fishwatch.govpphido)

**Spiny dogfish** (*Squalus acanthias*)

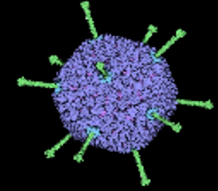
# GoA eDNA Co-occurrence Network



# Thank you!



PACIFIC SALMON  
FOUNDATION



- Mark Saunders
- Caroline Graham
- Richard Beamish
- Brian Riddell
- Shaorong Li
- Svetlana Esenkulova
- Brian Hunt
- Angela Schulze

- Ben Sutherland
- Tobi Ming
- Colin Wallace
- Kim Jonsen
- Kelsey Flynn
- Eric Rondeau
- Terry Beacham

- Karia Kaukinen
- Albina Kanzeparova
- Alexei Somov
- Svetlana Esenkulova
- Emiliano Di Cicco
- Amy Tabata
- Tobi Ming
- Shaorong Li
- Gideon Mordecai
- Angela Schulze