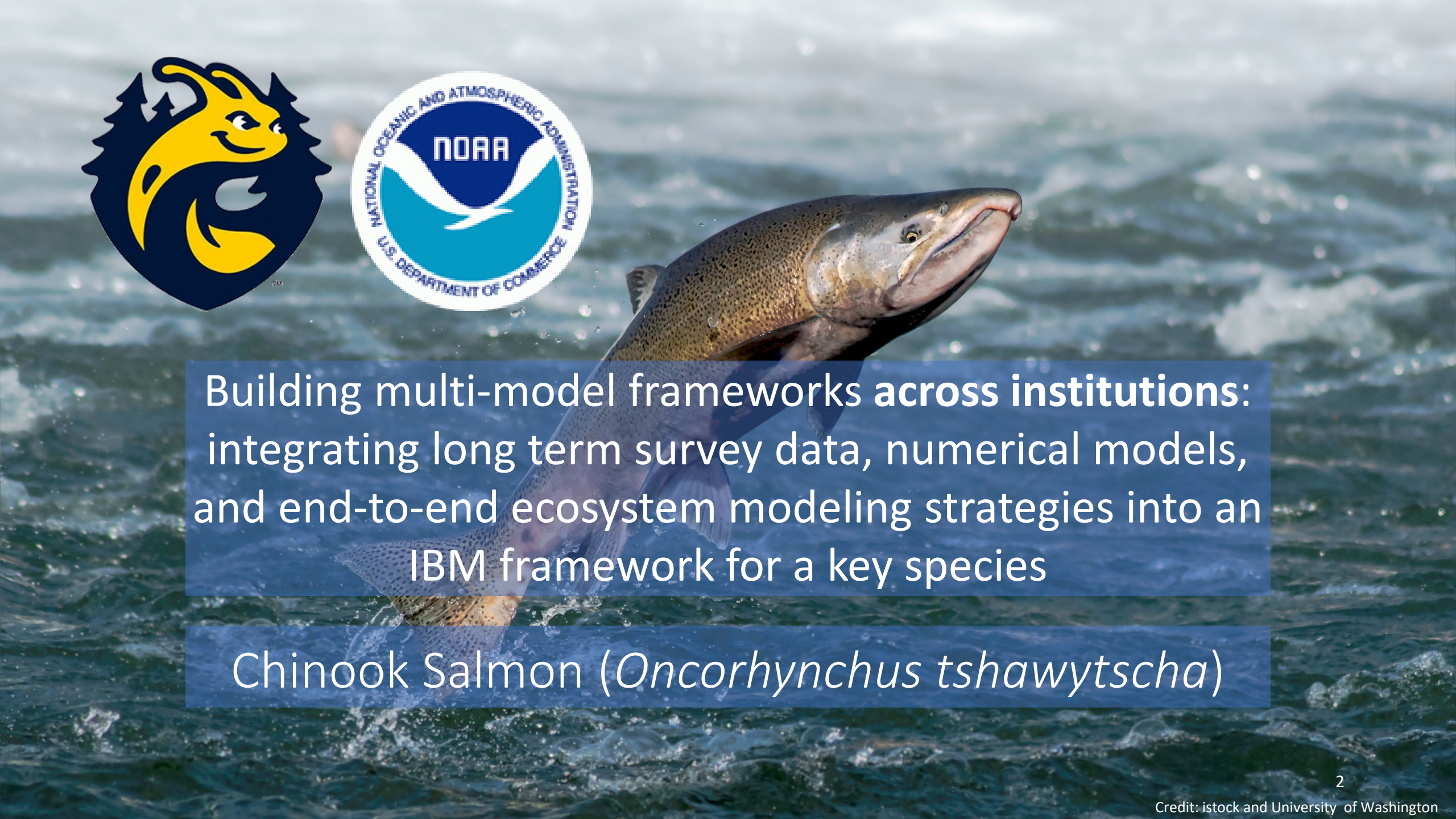
Individual-based modeling of early marine growth and predation in a changing ocean

Authors: **K. Vasbinder**, J. Fiechter, J. Santora, N. Mantua, D. Huff, and B. Wells

University of California Santa Cruz, SWFSC Fisheries Ecology Division, NWFSC Fish Ecology Division

Funding: NOAA SWFSC Santa Cruz CIMEC award 22694-443861-BICVEP (Central Valley Salmon) and NOAA SWFSC IRA



Building multi-model frameworks **across institutions**: integrating long term survey data, numerical models, and end-to-end ecosystem modeling strategies into an IBM framework for a key species

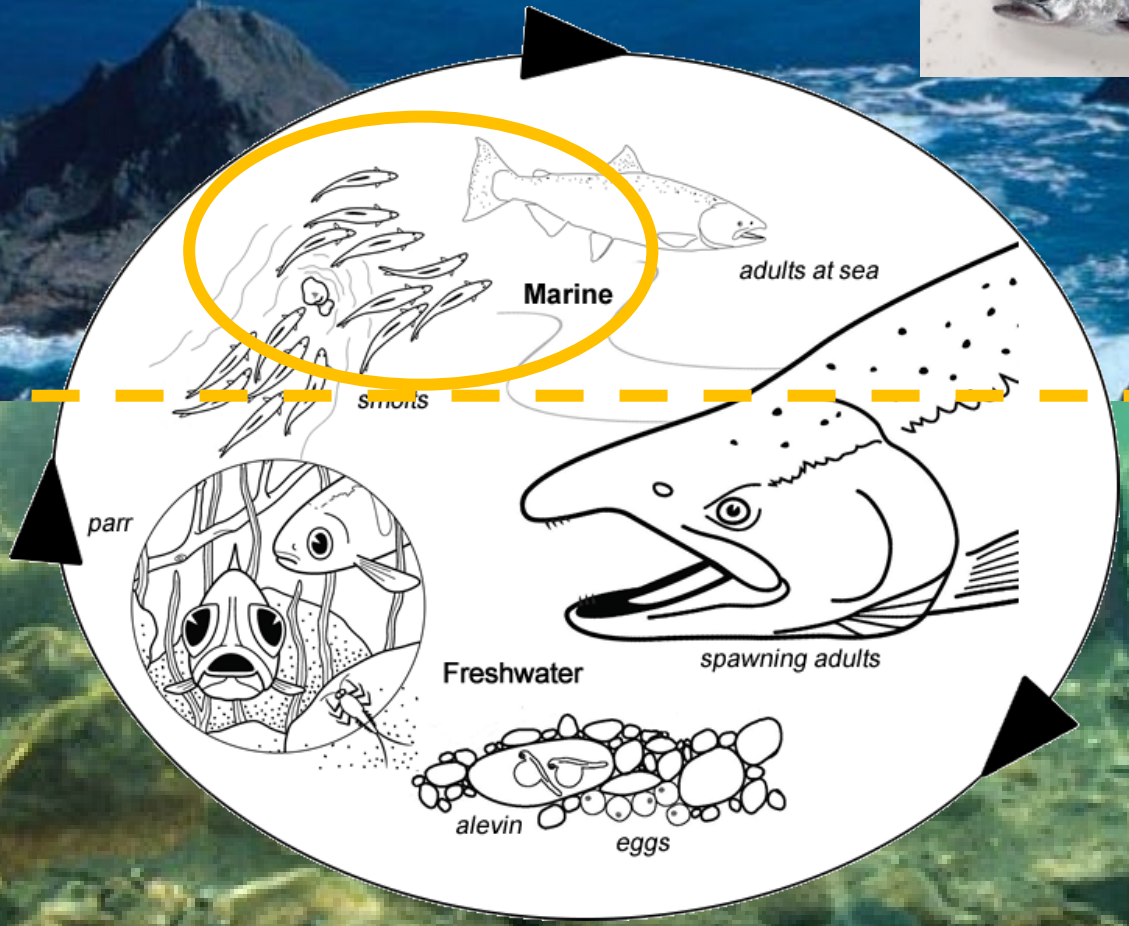
Chinook Salmon (*Oncorhynchus tshawytscha*)

Credit: istock and University of Washington

Lifecycle of Chinook Salmon



Ocean

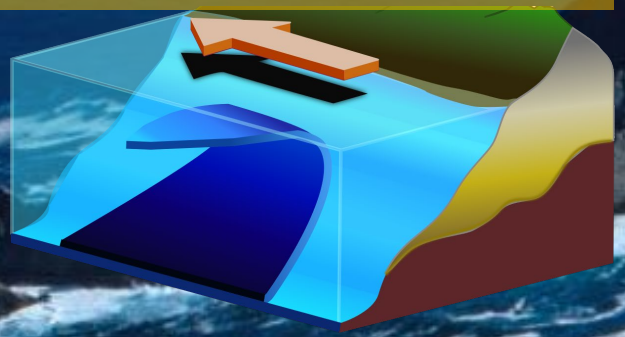


Freshwater
and Estuaries

Life Cycle Image Credit: US Fish and Wildlife Service

Collaborative Ecosystem Modeling Framework

Hydrodynamic Processes (ROMS)



Ocean Physics

Biogeochemical and Lower Trophic Level Processes (NEMUCSC)

Temperature

Krill fields

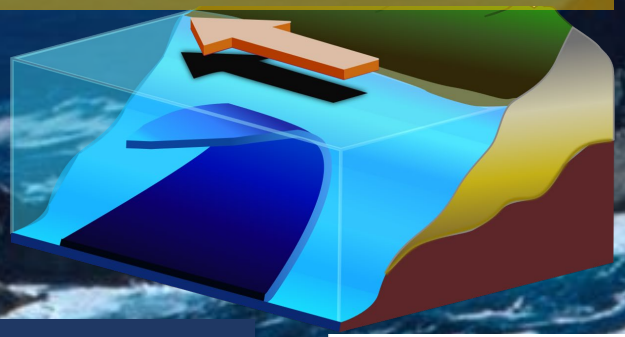
Juvenile salmon growth



This conglomerate of models gets us closer to reality than it would if we used a simple box model!

Ecosystem Modeling Framework

Hydrodynamic Processes (ROMS)

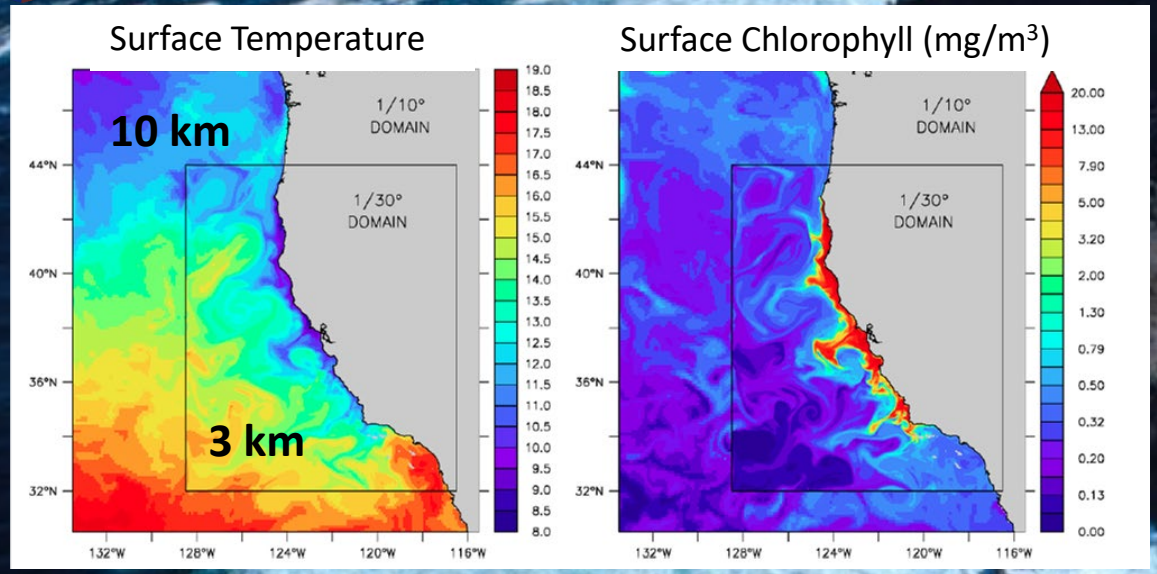


Ocean Physics

Biogeochemical and Lower Trophic Level Processes (NEMUCSC)

ROMS: Regional Ocean Modelling System (ROMS) in the California Current for hydrodynamics

1/30° ROMS model is embedded within a reanalysis of the broader California Current System circulation at 1/10°



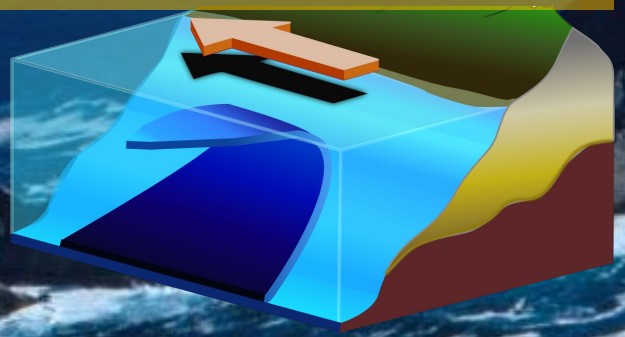
NEMUCSC: North Pacific Ecosystem Model for Understanding Regional Oceanography (NEMURO) customized for the California Current (NEMUCSC) for biogeochemical interactions and generation of the prey (krill) field

Limiting macronutrients, phytoplankton, detritus pools, and zooplankton

Brinton 1962; n.d.; Lavaniegos and Ohman 2007; Fiechter et al. 2018, 2020

Collaborative Ecosystem Modeling Framework

Hydrodynamic Processes (ROMS)



Ocean Physics

Biogeochemical and Lower Trophic Level Processes (NEMUCSC)

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Juvenile salmon growth

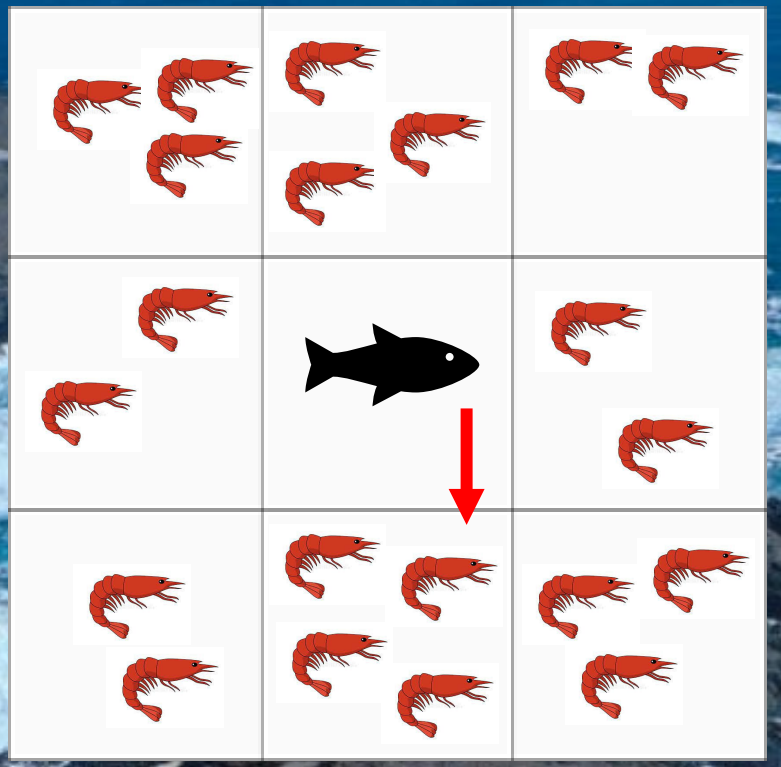


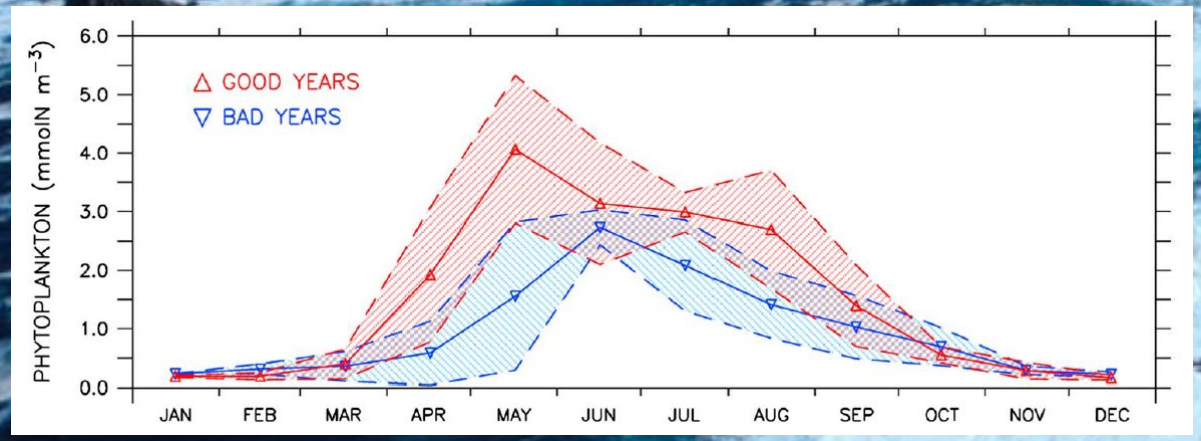
This conglomerate of models gets us closer to reality than it would if we used a simple box model!

Juvenile Salmon Growth Bottom-Up drivers:









Good growth years are linked to stronger, early season upwelling and positive krill anomalies

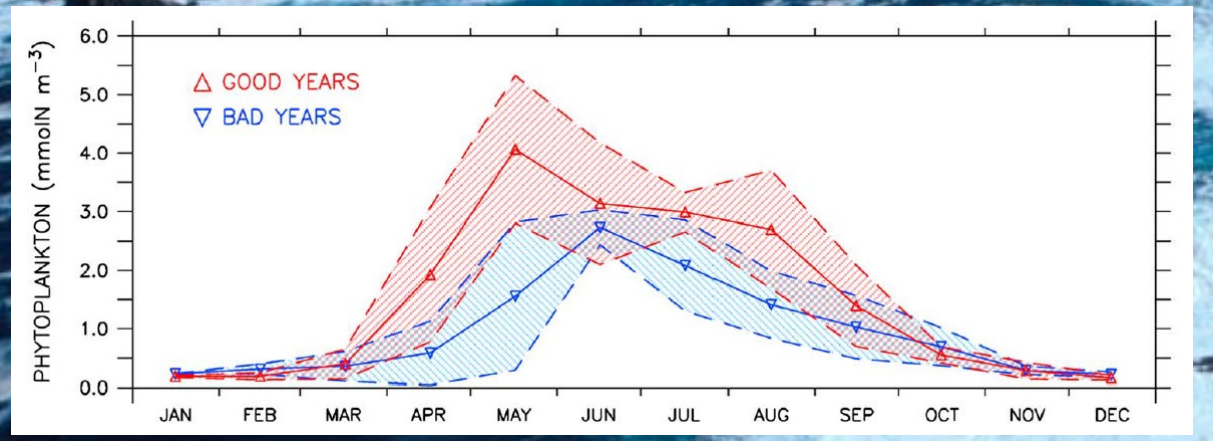
When food is scarce it drives mortality (bottom-up), but when it is plentiful, we need an extra top-down driver to explain mortality.

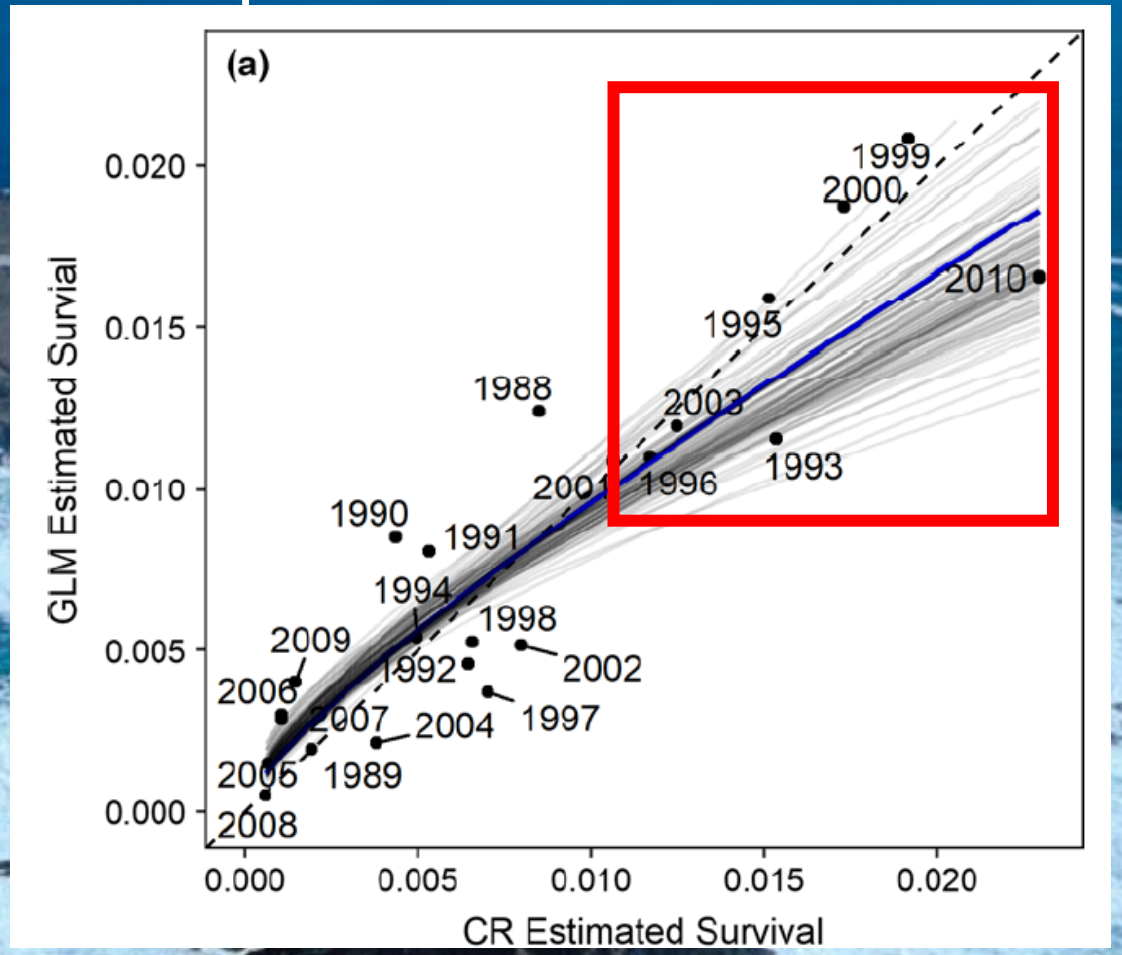
Wells et al. 2017, Fiechter et al. 2015

Juvenile Salmon Growth Bottom-Up drivers:







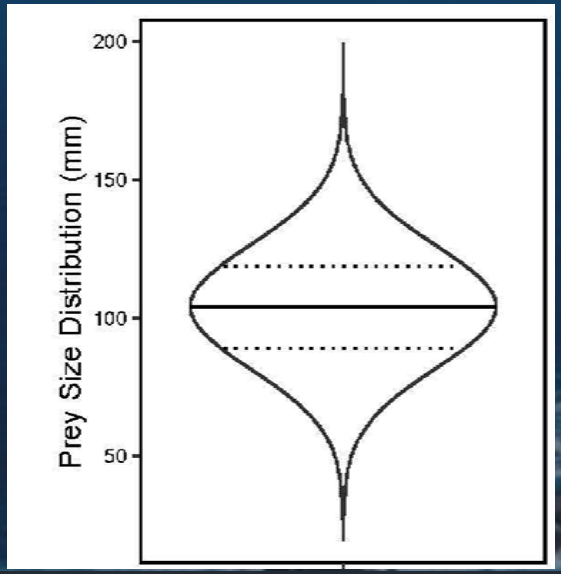


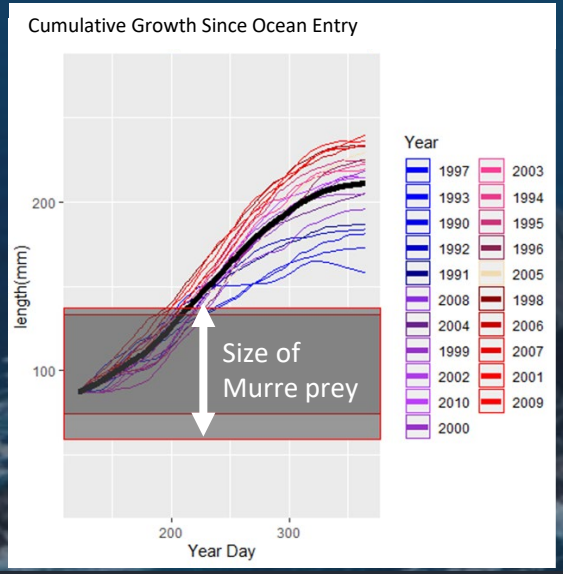
Good growth years are linked to stronger, early season upwelling and positive krill anomalies

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Wells et al. 2017, Fiechter et al. 2015, Henderson et al. 2019

Predator Sub-model





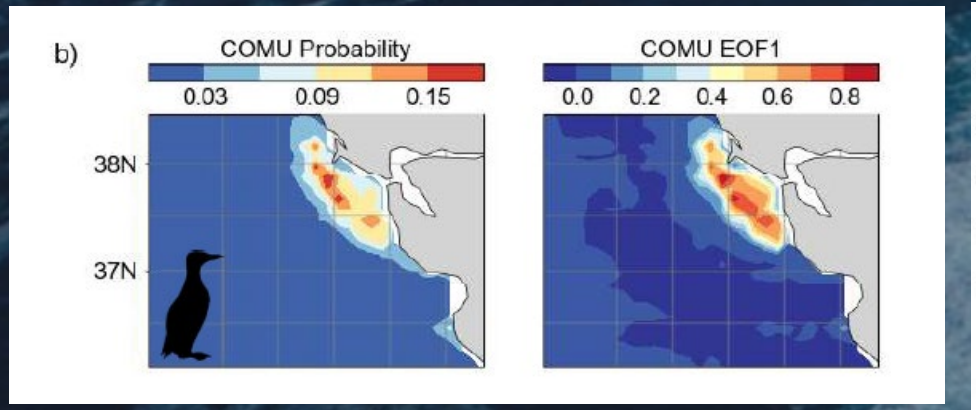
Size-Based Mortality =
(interaction probability between predator and prey)
x
(relationship between predator's prey distribution and prey size)



Photo: National Park Service

Predation Mortality = Size-Based Mortality x Probability of Aggregation x Population x Diet

Murre Probability of Aggregation
(Figure 3b Santora et al 2025)



Pt. Blue's 2023 Report



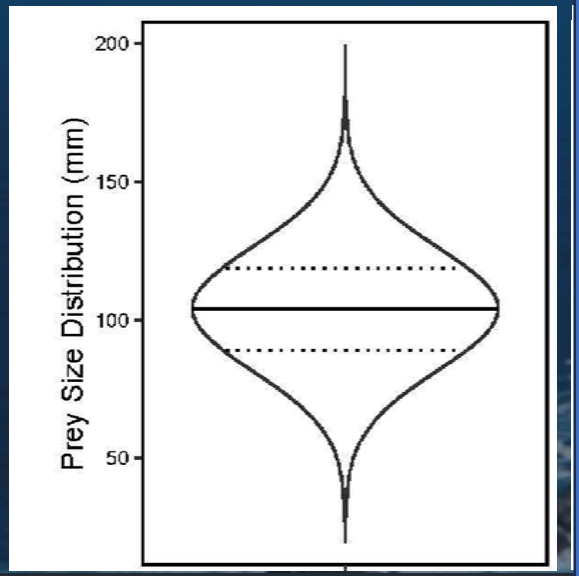






Vasbinder et al. 2024, Santora et al. 2025

Predator Sub-mode



Why include so much ecosystem information?

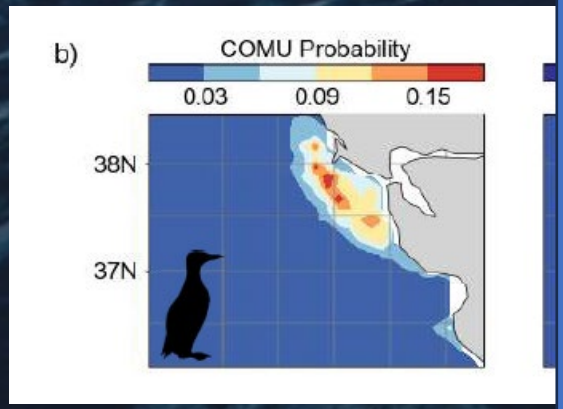


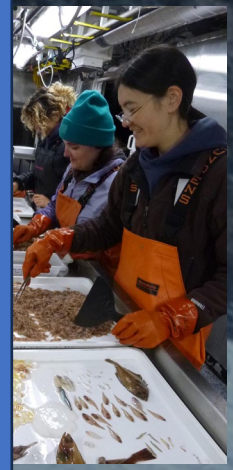
al Park Service

Predation Mortality =

x Population x Diet

Murre Probability of Aggreg
(Figure 3b Santora et al 202



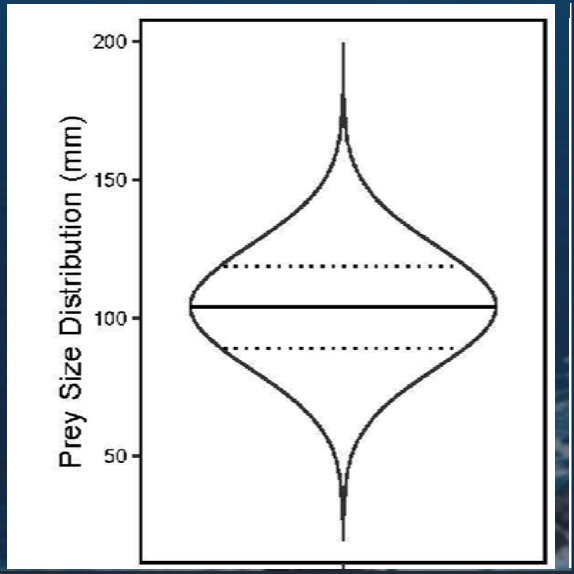






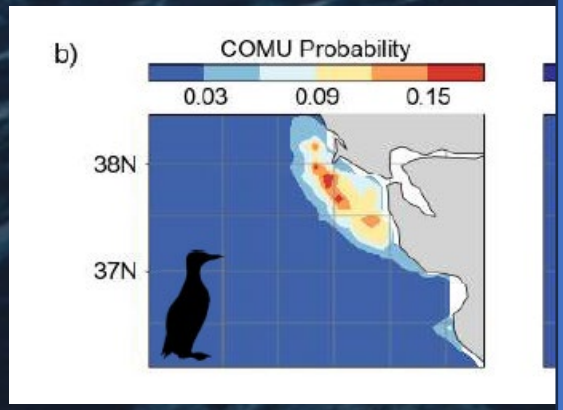
Vasbinder et al. 2024, Santora e

Predator Sub-mode



Predation Mortality =

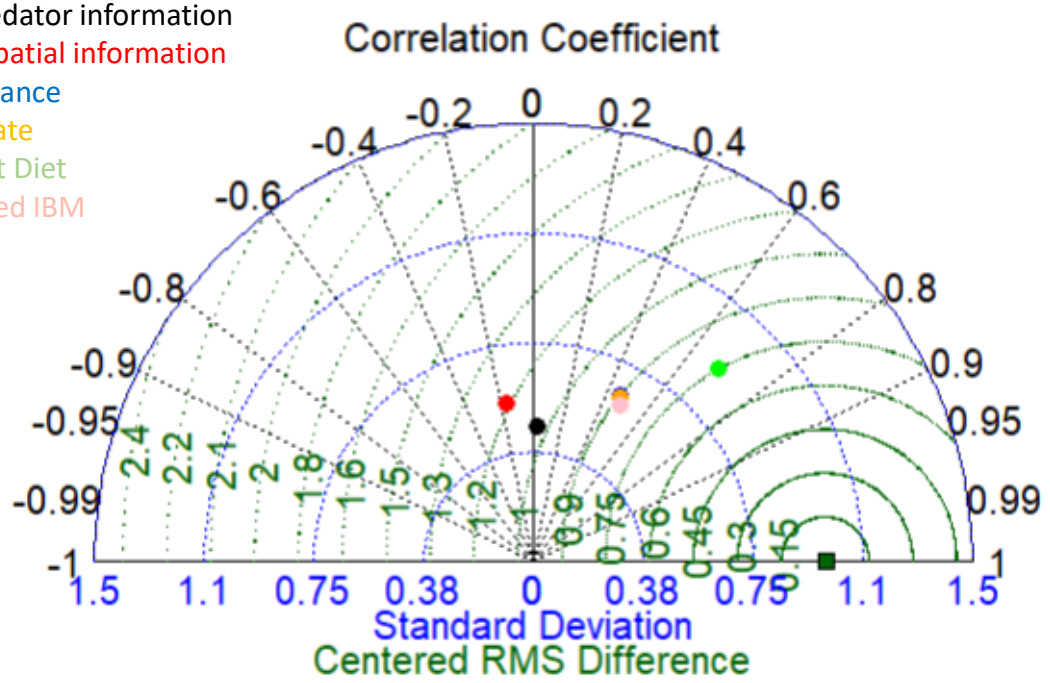
Murre Probability of Aggreg
(Figure 3b Santora et al 202



Vasbinder et al. 2024, Santora e

Why include so much ecosystem information?

No Predator information
Only spatial information
Abundance
Sea-state
Explicit Diet
Updated IBM

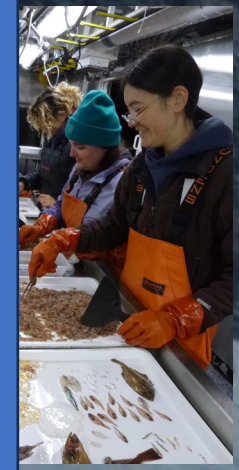


Each new piece of information brings us closer to observed survivals



al Park Service

x Population x Diet







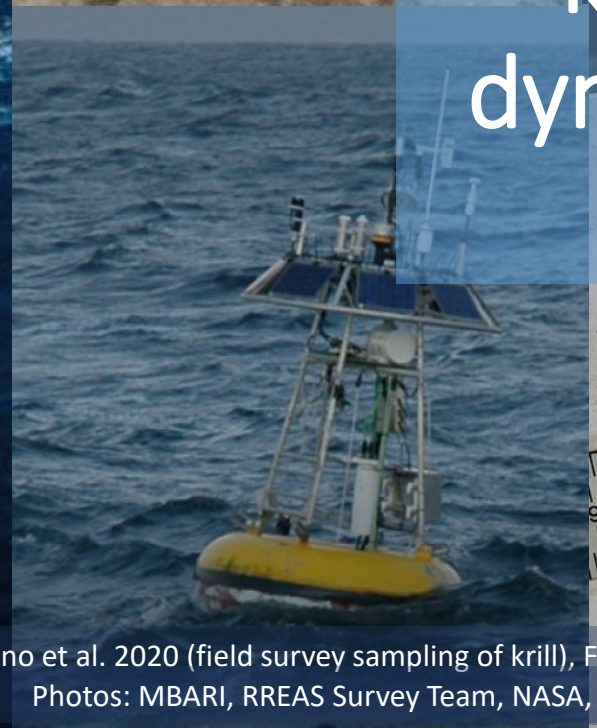
- Physical Oceanography Group (UCSC)
- Fisheries Collaborative Program (UCSC)
- Mooring data from Monterey Bay Aquarium Research Institute (MBARI)
- RREAS shipboard CTD (NOAA)
- Satellite Data (SST, SSH)
- RREAS Krill (NOAA)
- Chipp's Island Research (CDFW)
- RREAS Forage Fish (NOAA)
- Farallon Institute
- Point Blue Conservancy







Environmental variables, krill, forage, and bird dynamics all validated on empirical data







Schroeder et al. 2014 (environmental variables), Cimino et al. 2020 (field survey sampling of krill), Fiechter et al. 2020 (modeled krill hotspots match observed hotspots) , Sakuma et al. 2006 (RREAS sampling methods)

Photos: MBARI, RREAS Survey Team, NASA, Robert Lee, AP Press and LA Times, USFWS, Common Murre Restoration Project


Sophie Webb/NOAA/Point Blue




Sarah K Schoen for USGS

Expand Trophic Structure to Include Alternative Forage



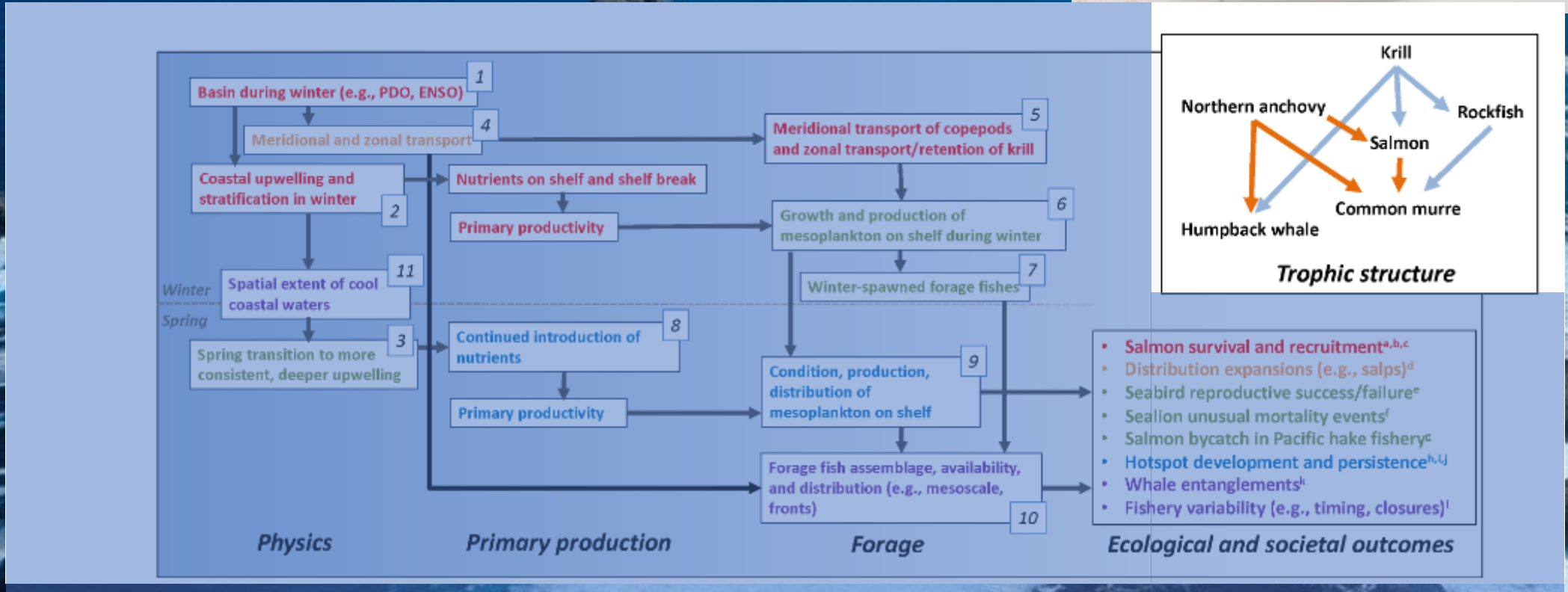
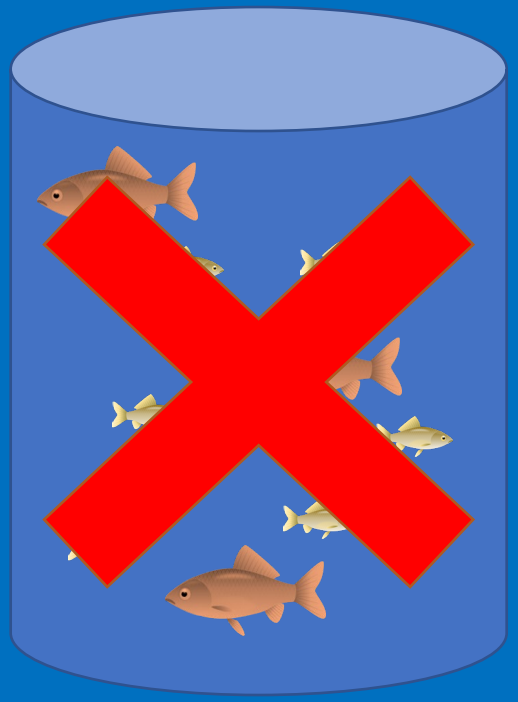
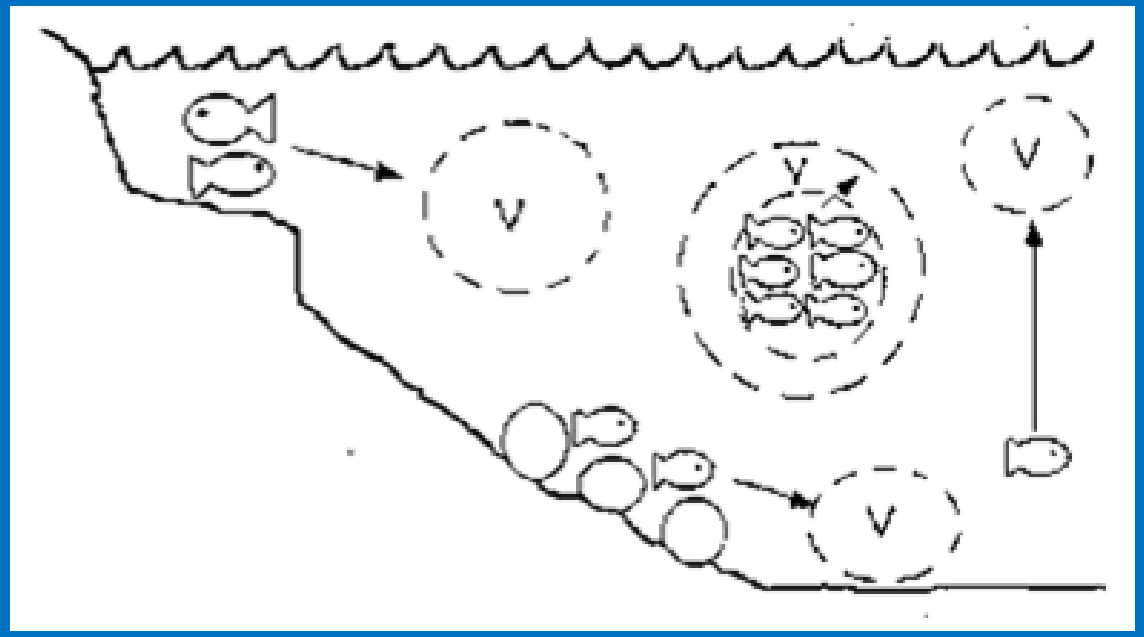


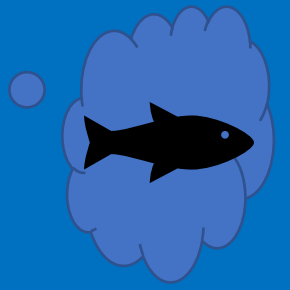
Figure 2 Wells BK and Santora JA (2023) Front. Mar. Sci. 10:1192052. doi: 10.3389/fmars.2023.1192052

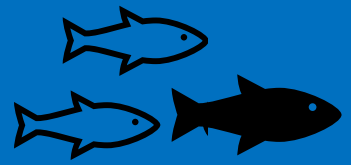
Foraging Arena Theory



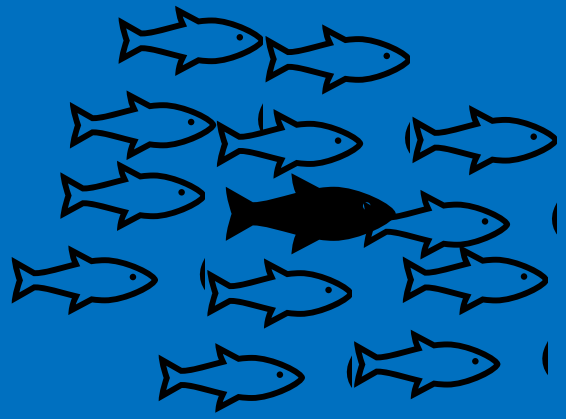








Vs.



- The ocean is not a vat reaction
- Instead, refuge exists that allow young fish to be protected from predators

Walters, C.J. and F. Juanes, 1993. Recruitment Limitation as a Consequence of Natural Selection for use of Restricted Feeding Habitats and Predation Risk Taking by Juvenile Fishes. Can. J. Fish. Aquat. Sci. 50: 2058-2070.

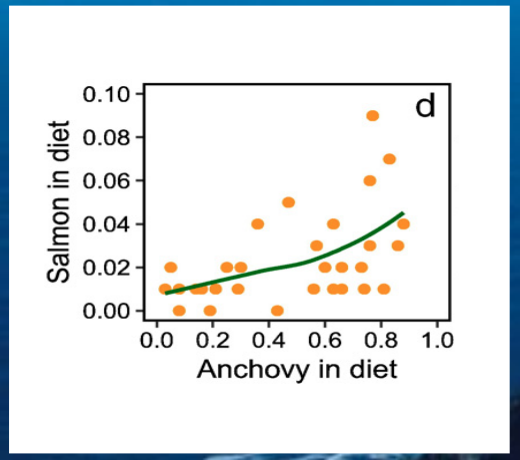

Sophie Webb/NOAA/Point Blue








Sarah K Schoen for USGS













Figures from Wells et al. 2017

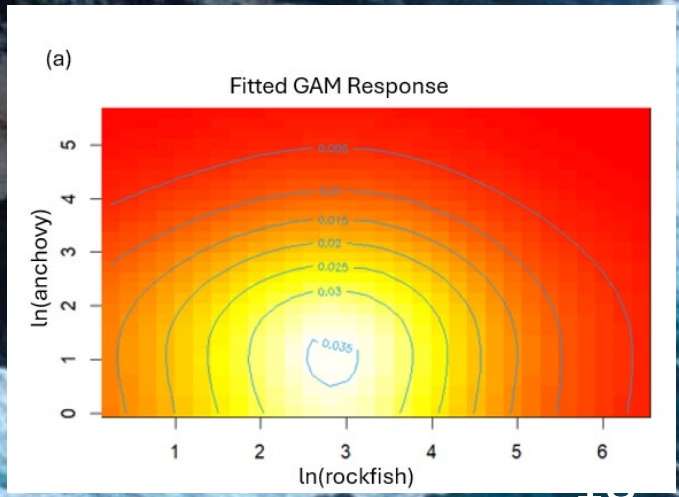

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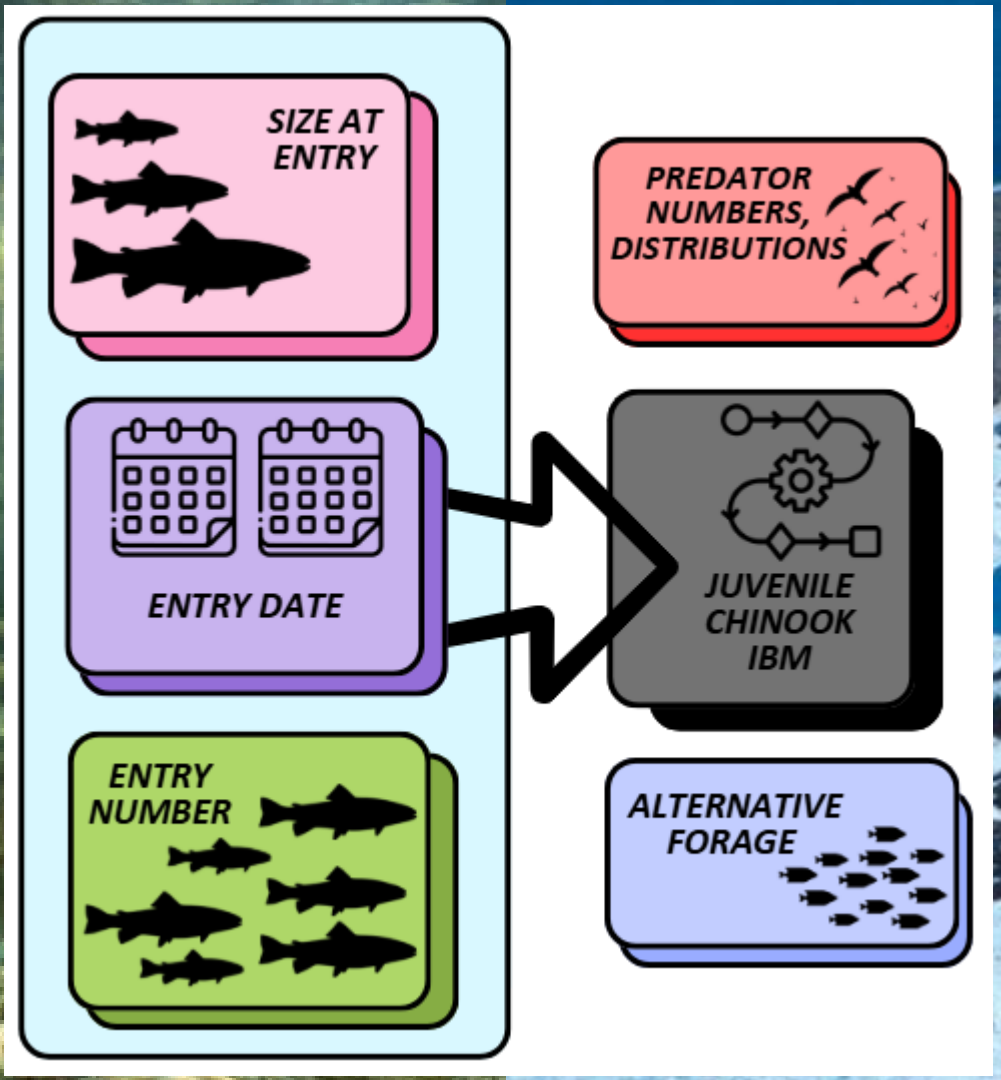



Sarah K Schoen for USGS


(a)
Fitted GAM Response
ln(anchovy)
ln(rockfish)
0
1
2
3
4
5
6
0.005
0.01
0.015
0.02
0.025
0.03
0.035

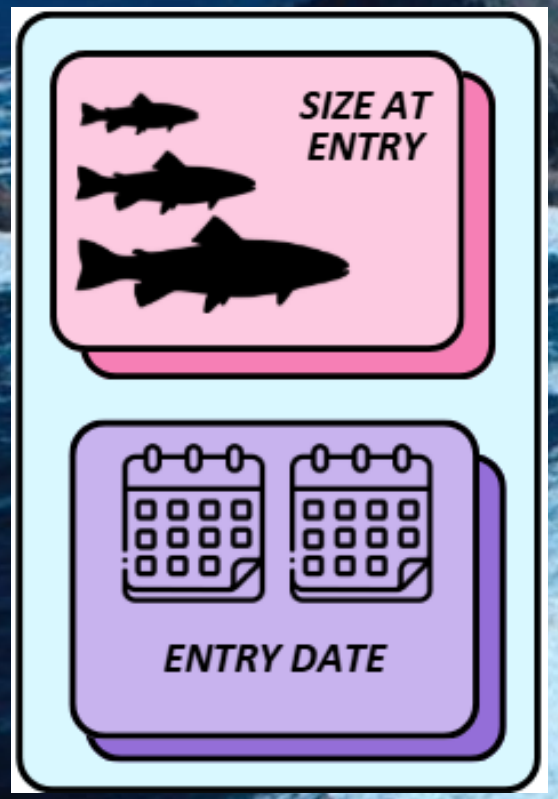

PREDATOR NUMBERS, DISTRIBUTIONS
JUVENILE CHINOOK IBM
ALTERNATIVE FORAGE

Freshwater


SIZE AT ENTRY
ENTRY DATE
ENTRY NUMBER
PREDATOR NUMBERS, DISTRIBUTIONS
JUVENILE CHINOOK IBM
ALTERNATIVE FORAGE

Levers to investigate carry-over effects





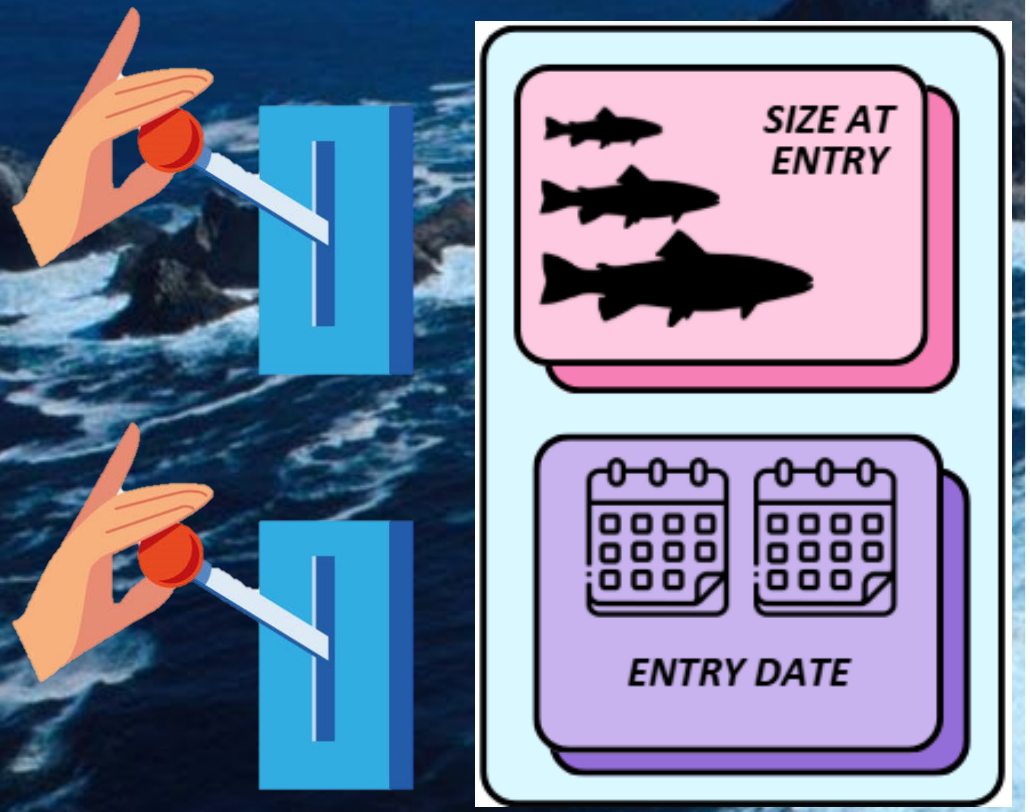
Water Resource Management Models

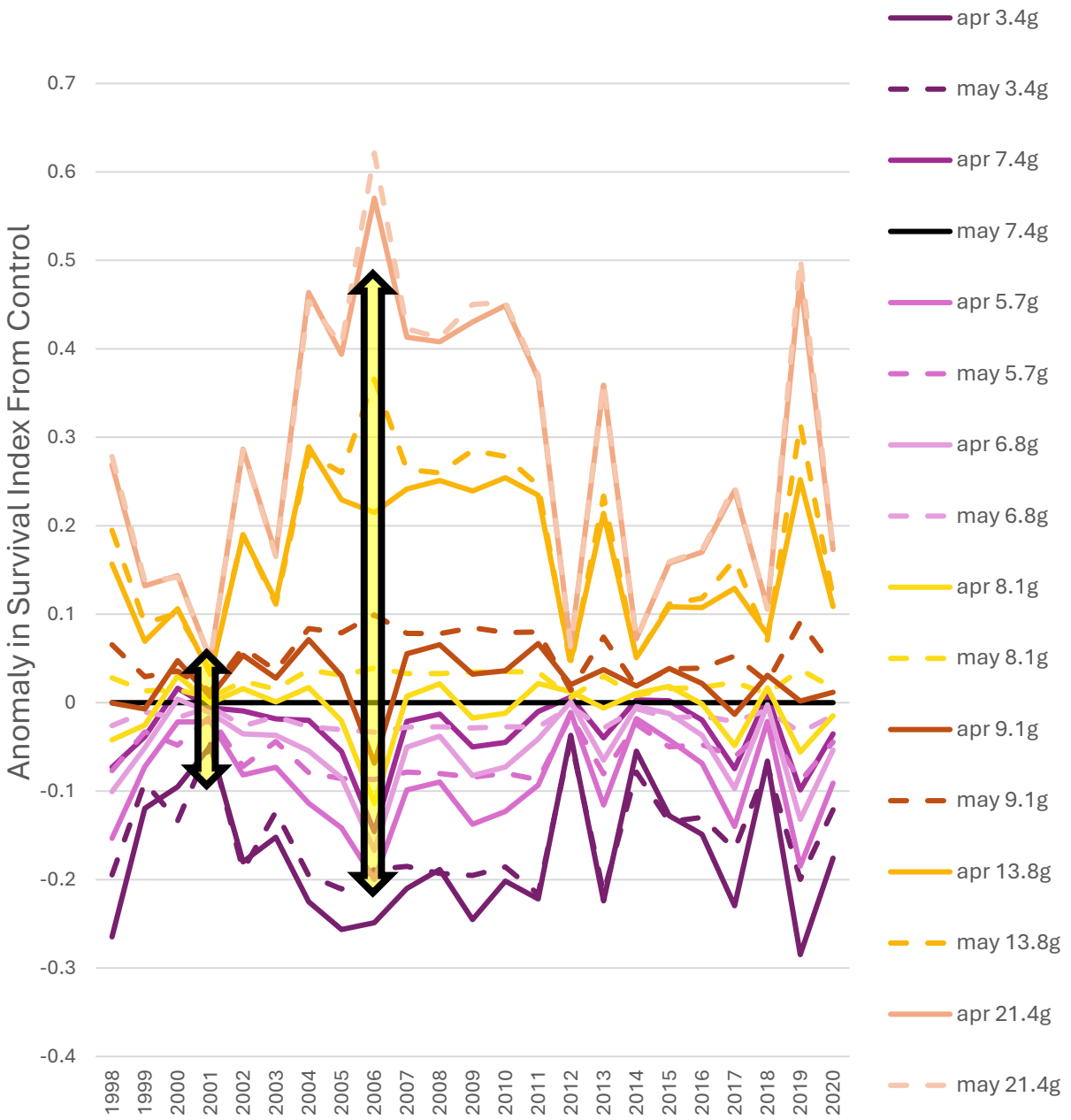
Cold water release models

Thermal Habitat Models and Stream flow Models

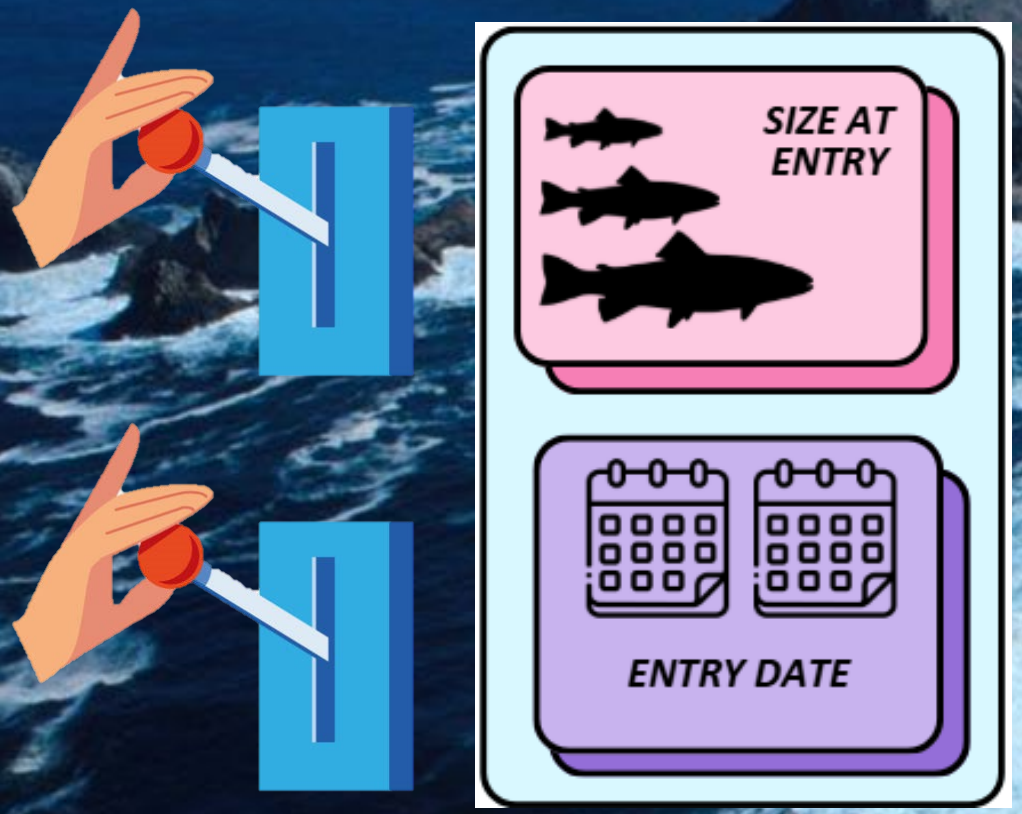
Freshwater management: Power et al. 2024, Yates et al. 2008, Kiernan et al. 2012

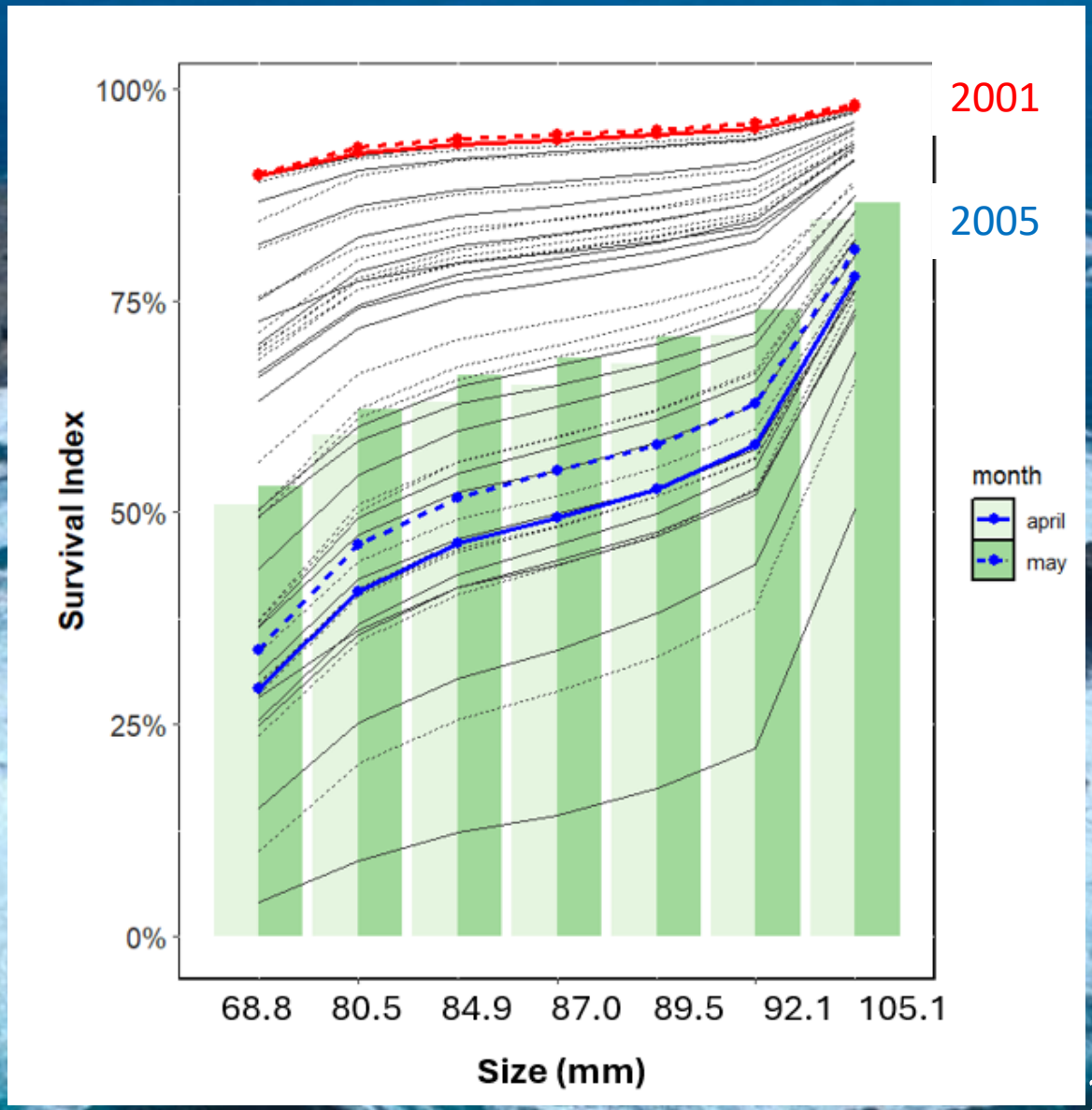
Levers to investigate carry-over effects

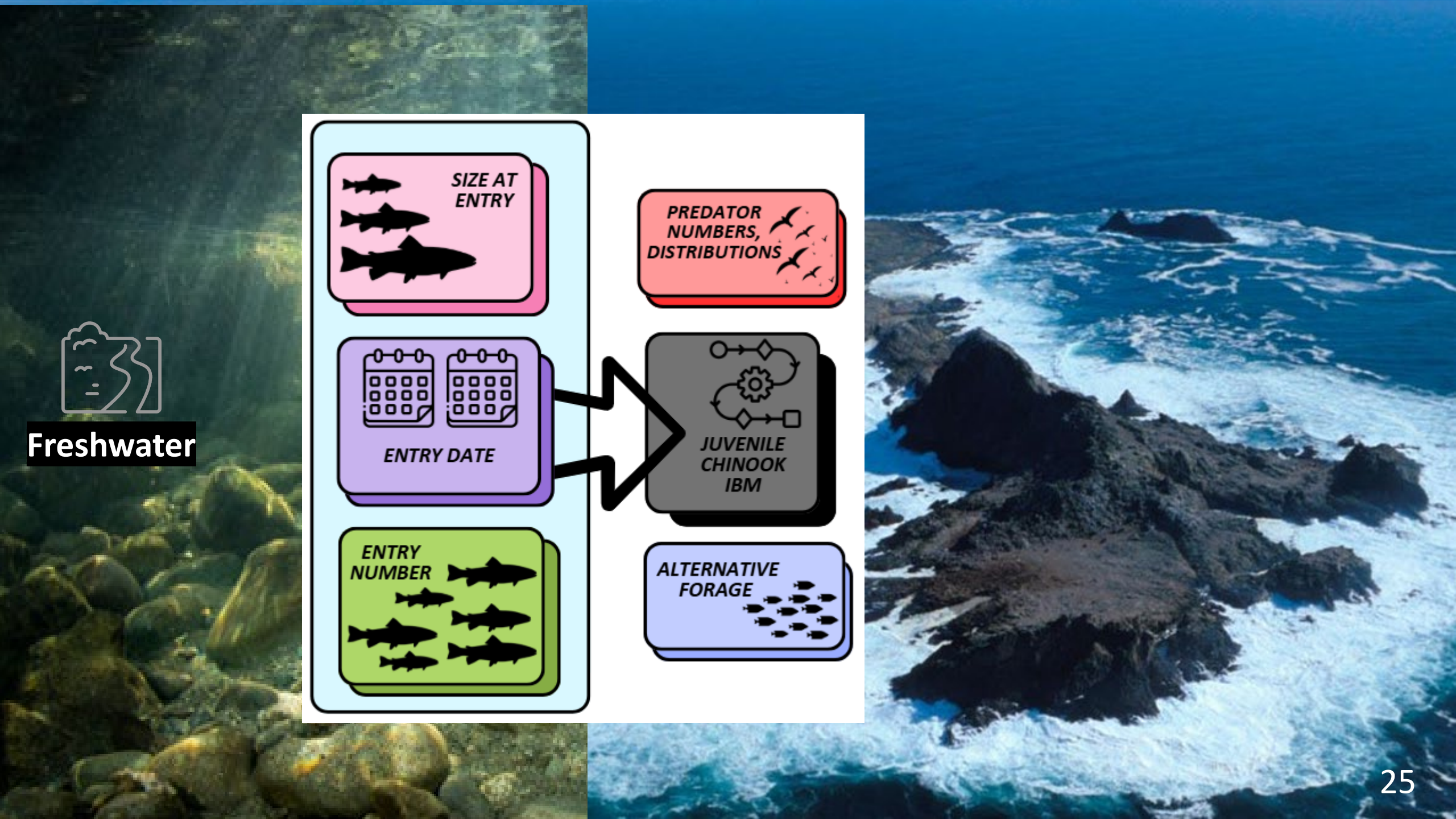




Levers to investigate carry-over effects

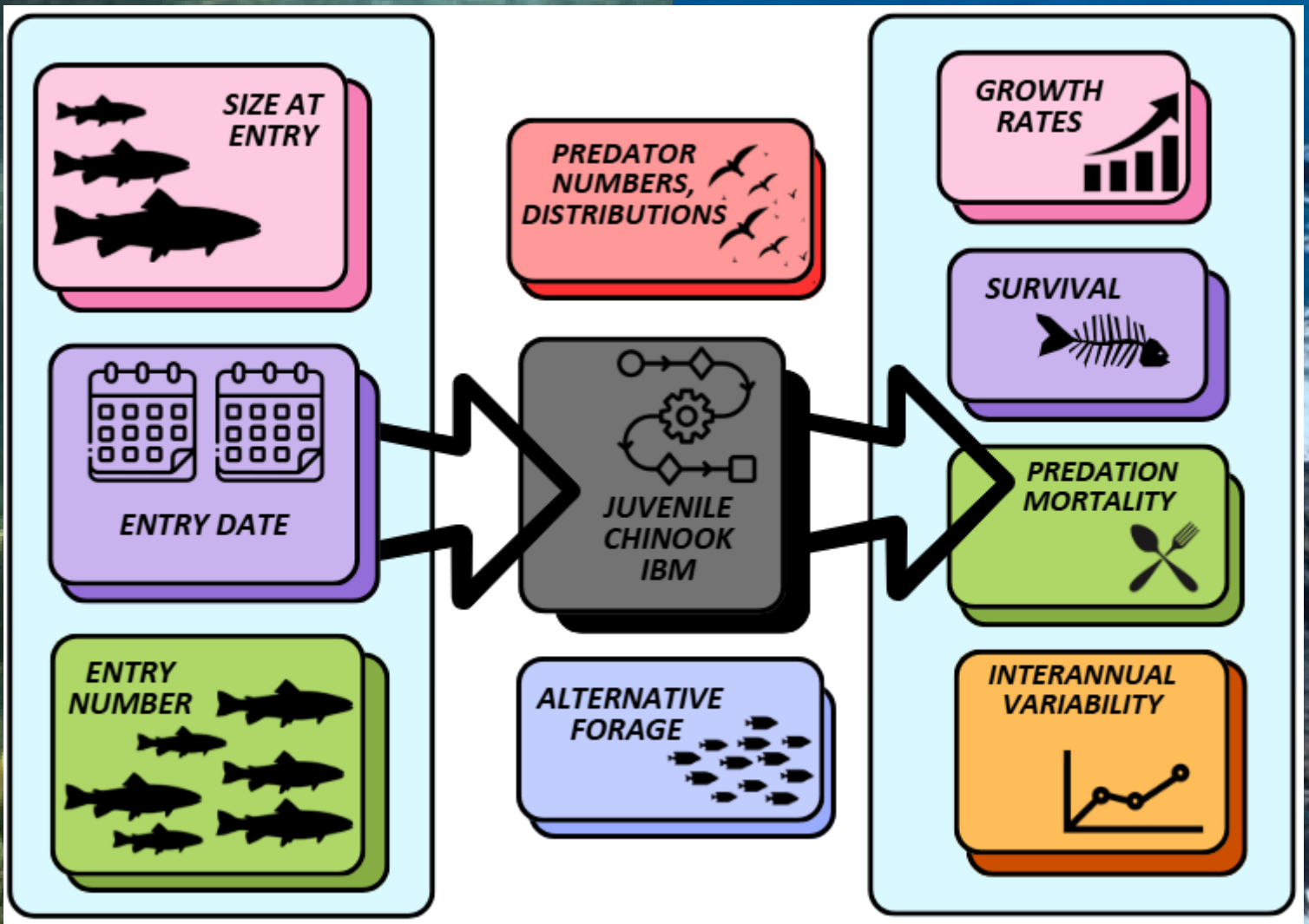





Freshwater
SIZE AT ENTRY
ENTRY DATE
ENTRY NUMBER
PREDATOR NUMBERS, DISTRIBUTIONS
JUVENILE CHINOOK IBM
ALTERNATIVE FORAGE

Collaborative Potential

Freshwater



Ocean

Modeling endeavors focused on anadromous fish have to be collaborative in nature, as carryover effects from freshwater impact survival at sea





Credit: istock and University of Washington

Questions?

Find me at: **kvasbind@ucsc.edu, kelly.vasbinder@noaa.gov**

For more information on our modeling framework:

- Vasbinder et al. 2025, PLOS Climate
- Vasbinder et al. 2024, Fish Oce
- Henderson et al. 2018, Fish Oce
- Fiecther et al. 2015, GRL
- Fiechter et al. 2018, GRL
- Santora et al. 2014, Ecol. App.
- Wells et al. 2012, MEPS
- Wells et al. 2016, MEPS
- Wells et al. 2017, J. Mar. Sys.
- Sabal et al. 2020, MEPS
- MacFarlane 2010, CJFAS
- Friedman et al. 2019, Ecosphere
- Schroeder et al. 2014, GRL
- Cimino et al. 2020, Ecography

UC SANTA CRUZ