Pêches et Océans Canada

Fisheries and Oceans Canada

Good, bad, or ugly?

Identifying the impacts of warming waters on British Columbia groundfish productivity for the purpose of developing risk-equivalent management advice

Philina A. English*, Sean C. Anderson, Rowan Haigh, Robyn E. Forrest

Photo credit: 2019 central coast ROV survey

*Philina.English@dfo-mpo.gc.ca

Fish Stocks Provisions in the *Fisheries Act*

In the management of fish stocks (6.1(1)), the setting of limit reference points (6.1(2)) and development of rebuilding plans (6.2(1)), the Minister shall:

> [take] into account the biology of the fish and the environmental conditions affecting the stock

Photo credit: 2018 Northeast Pacific Seamount Expedition

Project objectives

1. Identify relationships between productivity of key Pacific fish stocks and the environment

1. Predict productivity under a range of plausible future conditions

1. Assess risk of not achieving management goals under range of scenarios

Photo credit: 2018 Northeast Pacific Seamount Expedition

Project objectives

1. Identify relationships between productivity of key Pacific fish stocks and the environment

Photo credit: 2018 Northeast Pacific Seamount Expedition

Stocks

Arrowtooth Flounder

Bocaccio

Canary Rockfish

Pacific Cod

Pacific Ocean Perch

Redstripe Rockfish

Rougheye/Blackspotted Rockfish

Sablefish

Shortspine Thornyhead

Silvergray Rockfish

Southern Rock Sole

Walleye Pollock

Widow Rockfish

Yellowmouth Rockfish

Yellowtail Rockfish

Photo credits: NOAA, FishWatch.org, SportfishingReport.com

Approach

1. Wrangle stock assessment outputs into identical formats
2. Calculate ‘production’ and ‘recruits per unit spawning biomass’
3. Choose relevant spatial and temporal scales for each stock
4. Project environmental layers and extract values at these scales
5. Assess relationships between environmental and productivity indices

Photo credit: 2019 central coast ROV survey

Approach

1. Wrangle stock assessment outputs into identical formats
2. Calculate ‘production’ and ‘recruits per unit spawning biomass’
3. Choose relevant spatial and temporal scales for each stock
4. Project environmental layers and extract values at these scales
5. Assess relationships between environmental and productivity indices

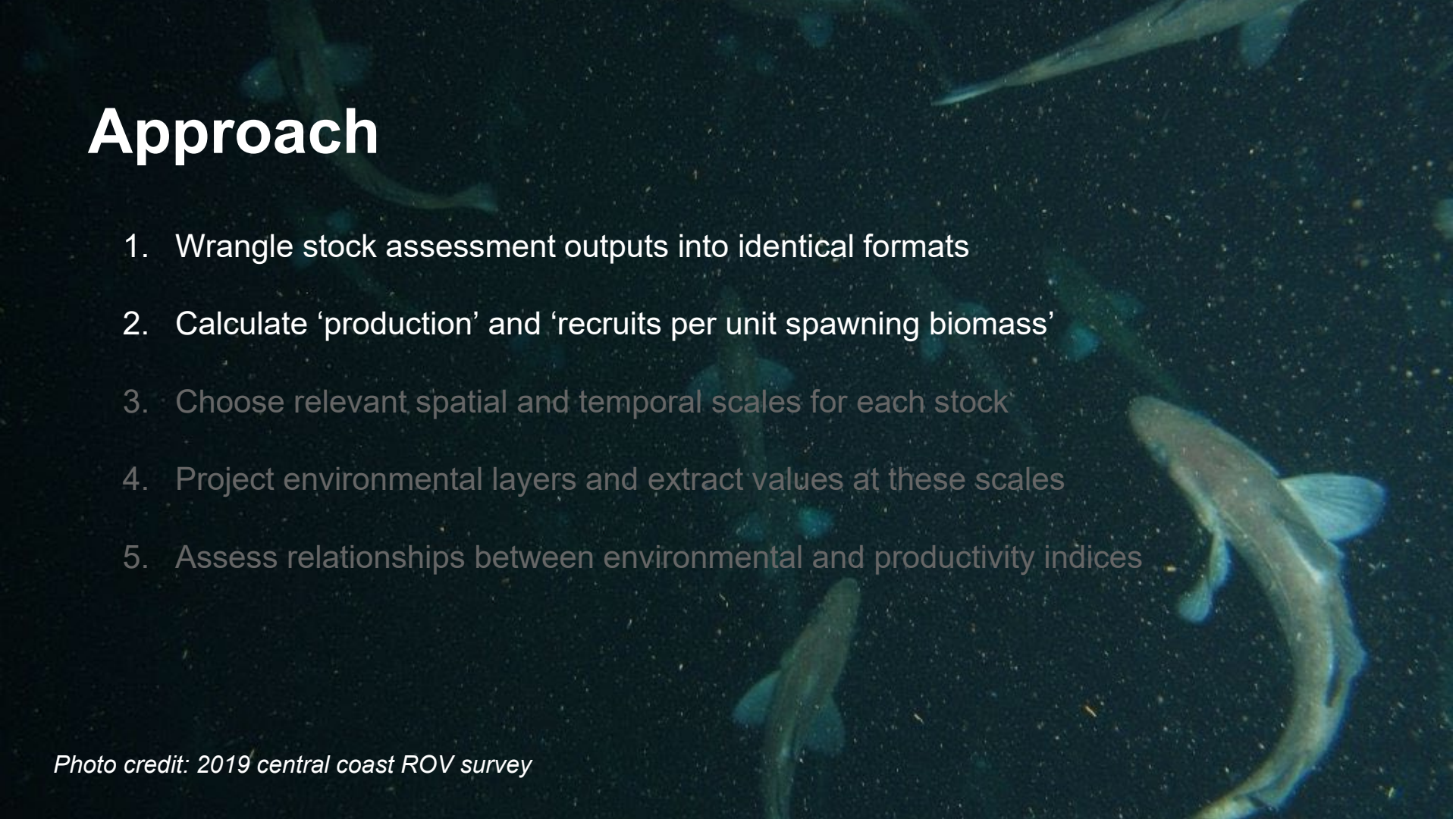
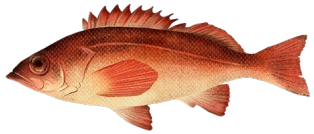


Photo credit: 2019 central coast ROV survey

Surplus production

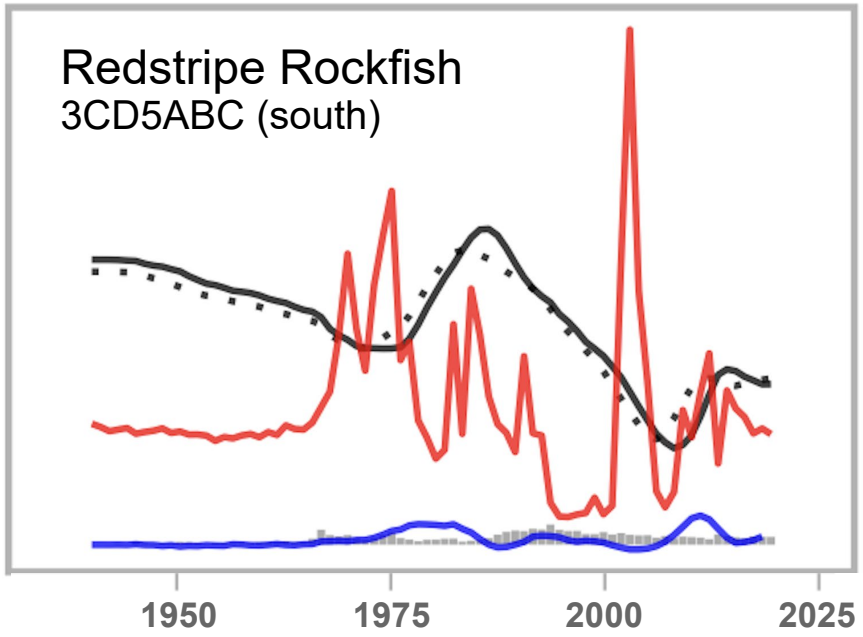


Vulnerable biomass

Spawning biomass

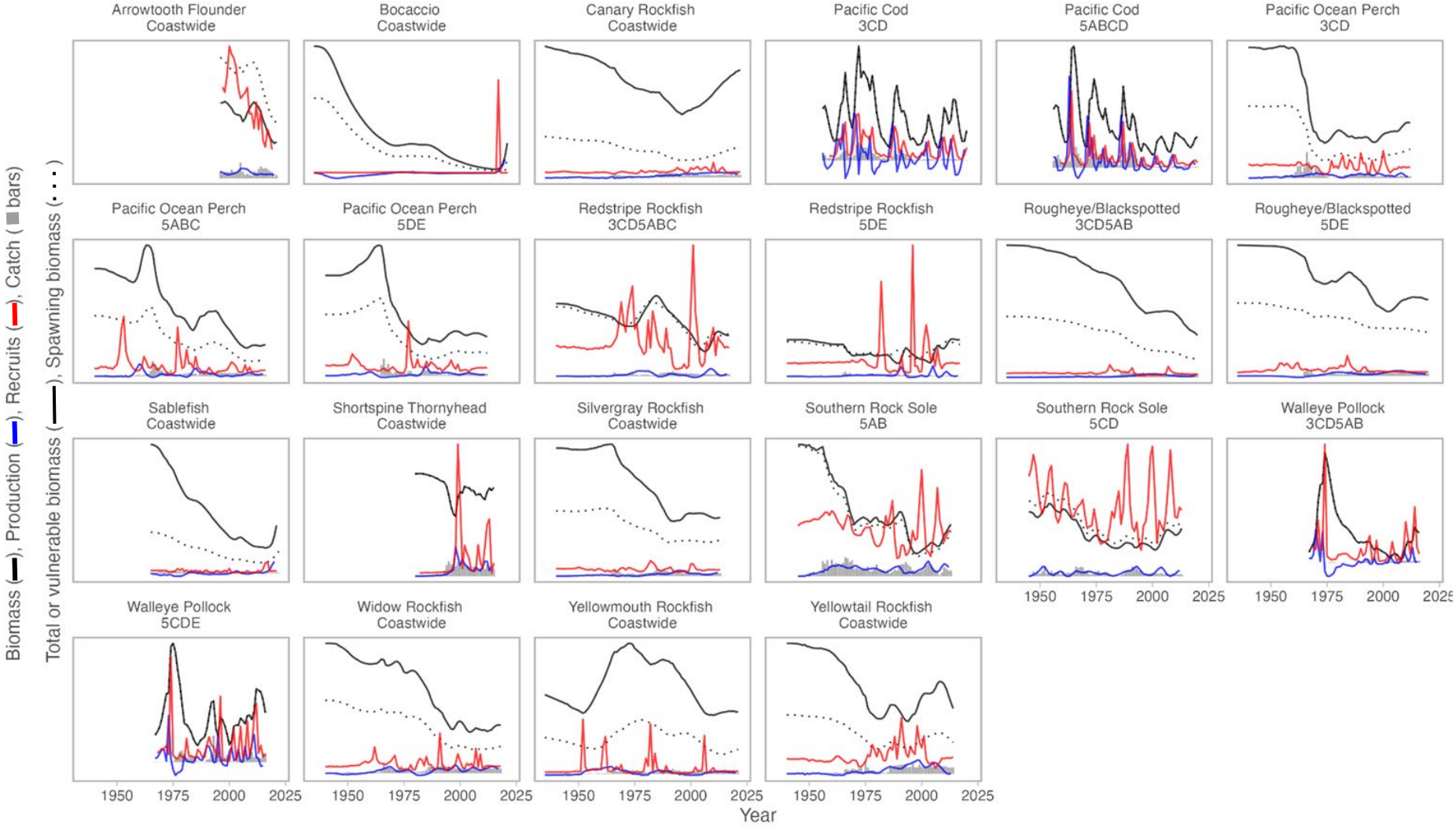
Catch

Total recruits

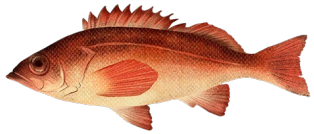


Production

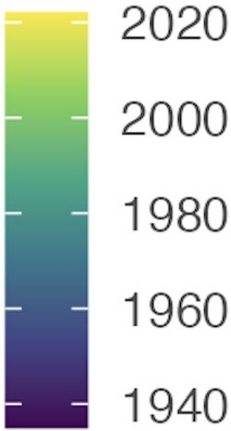
Vulnerable biomass + catch - next year's vulnerable biomass

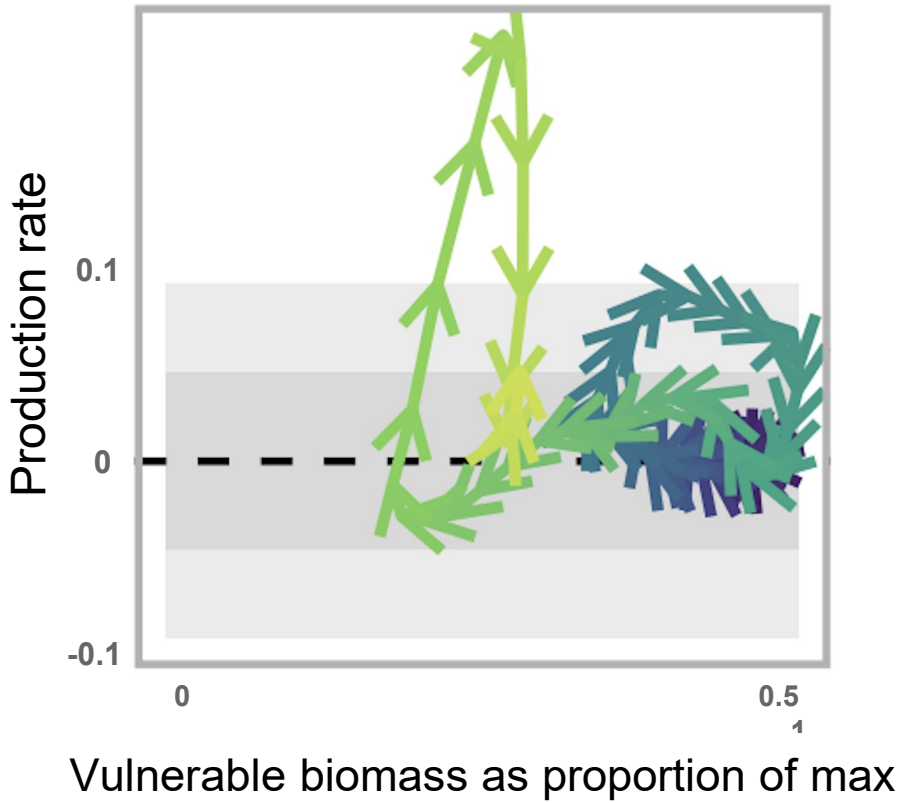

Arrowtooth Flounder Coastwide
Bocaccio Coastwide
Canary Rockfish Coastwide
Pacific Cod 3CD
Pacific Cod 5ABCD
Pacific Ocean Perch 3CD
Pacific Ocean Perch 5ABC
Pacific Ocean Perch 5DE
Redstripe Rockfish 3CD5ABC
Redstripe Rockfish 5DE
Rougheye/Blackspotted 3CD5AB
Rougheye/Blackspotted 5DE
Sablefish Coastwide
Shortspine Thornyhead Coastwide
Silvergray Rockfish Coastwide
Southern Rock Sole 5AB
Southern Rock Sole 5CD
Walleye Pollock 3CD5AB
Walleye Pollock 5CDE
Widow Rockfish Coastwide
Yellowmouth Rockfish Coastwide
Yellowtail Rockfish Coastwide
Biomass (), Production (), Recruits (), Catch (bars)
Total or vulnerable biomass (), Spawning biomass ( )
1950
1975
2000
2025
Year

Surplus production

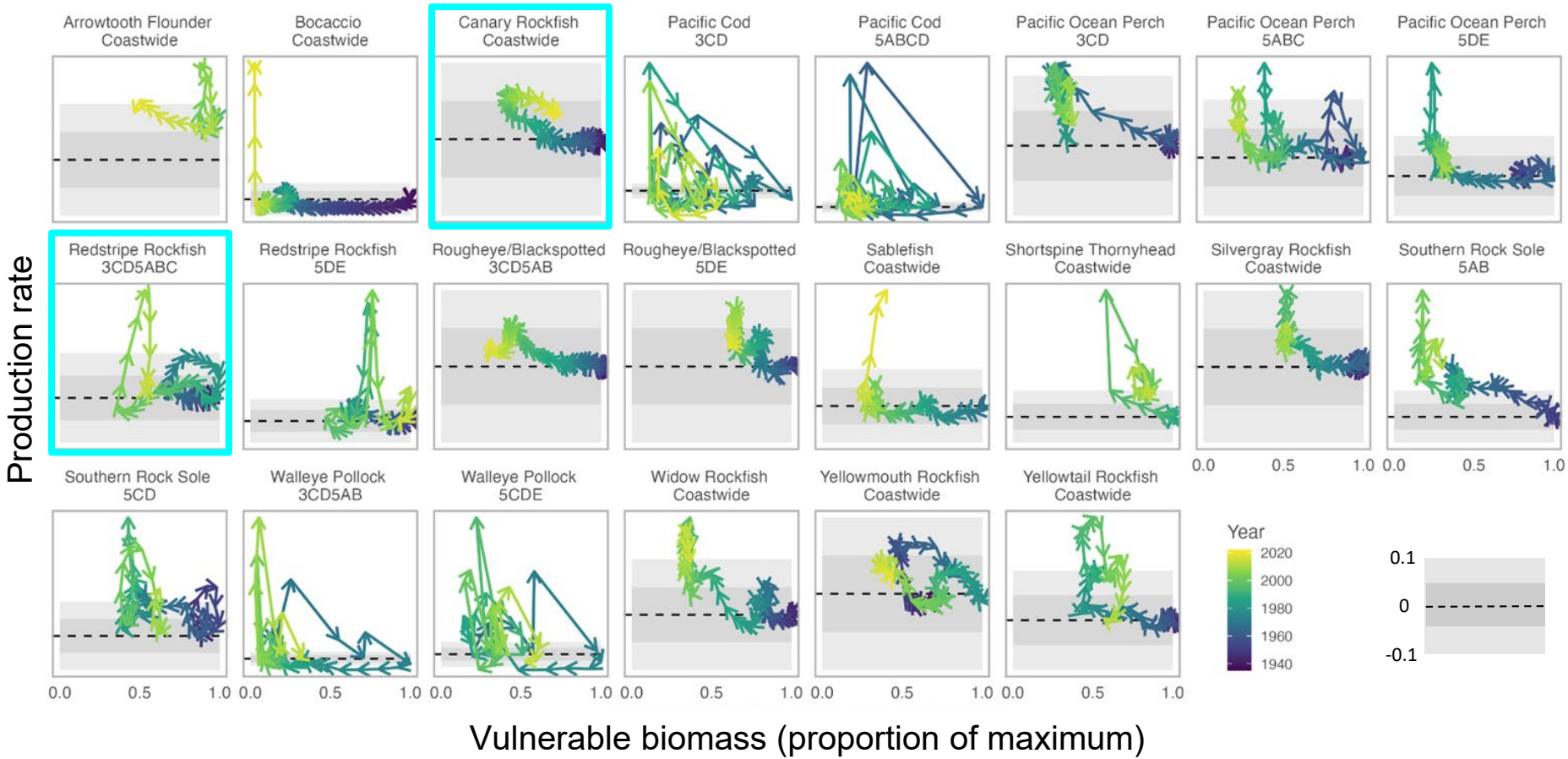


Redstripe Rockfish
3CD5ABC (south)

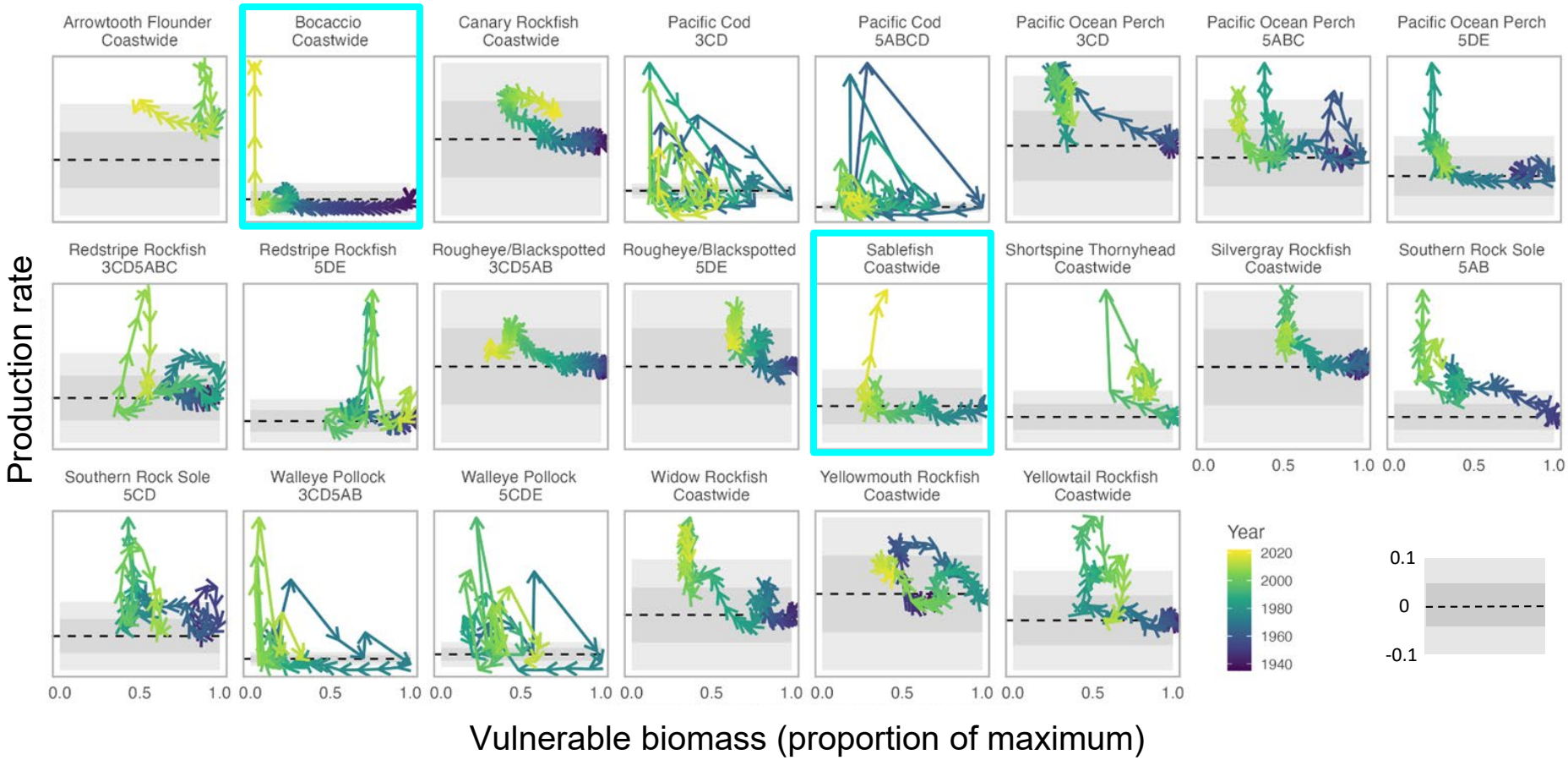




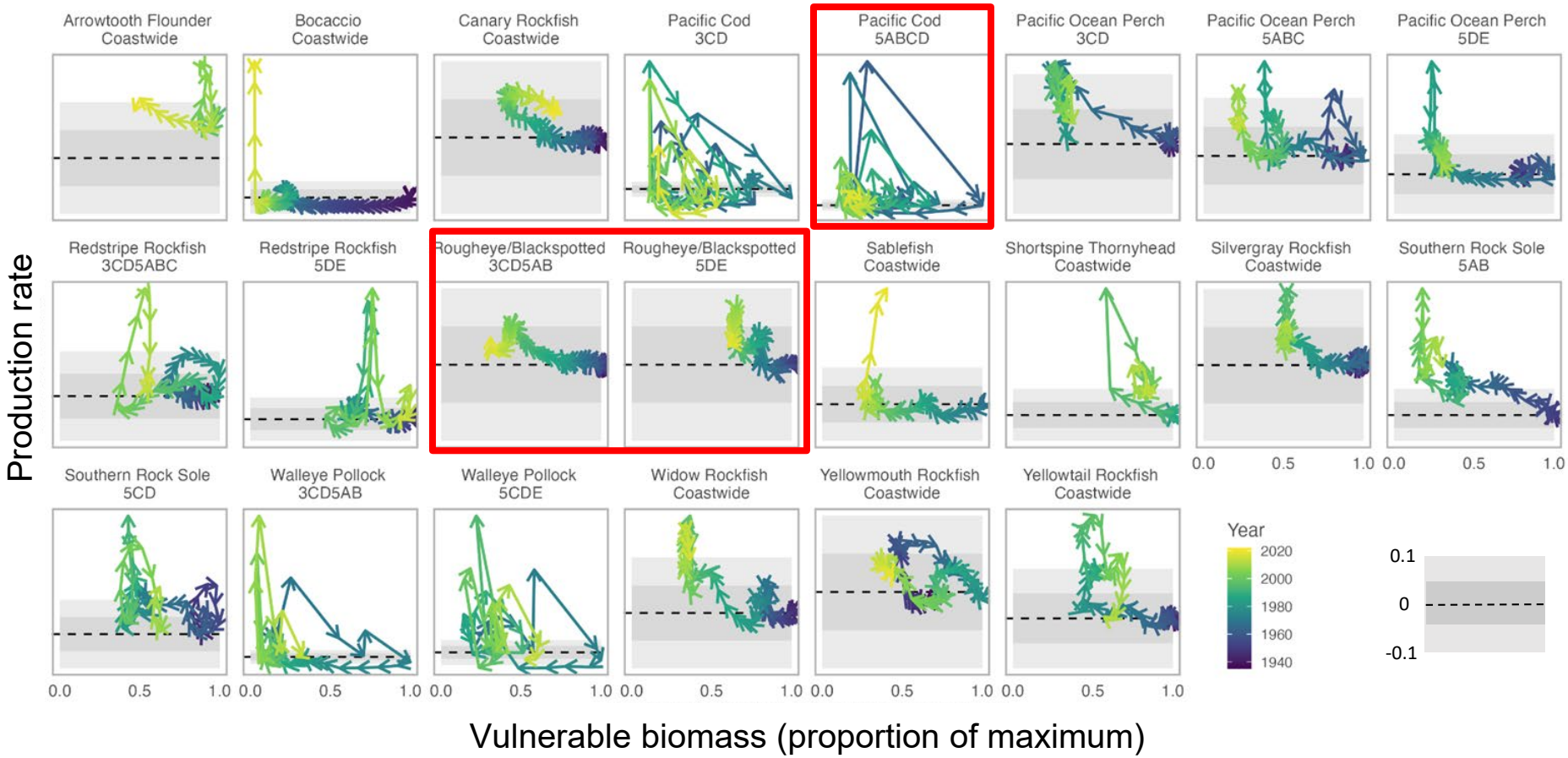
Surplus production



Surplus production



Surplus production



Approach

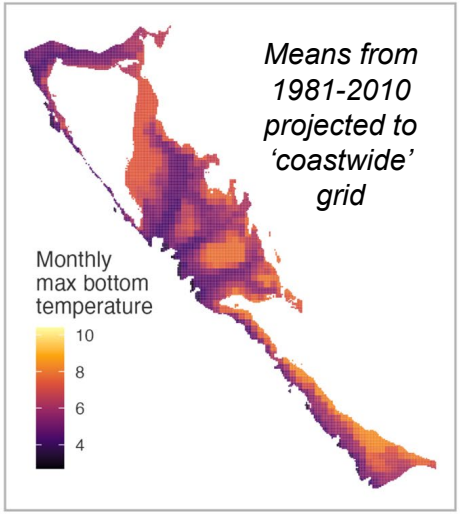
1. Wrangle stock assessment outputs into identical formats
2. Calculate ‘production’ and ‘recruits per unit spawning biomass’
3. Choose relevant spatial and temporal scales for each stock
4. Project environmental layers and extract values at these scales
5. Assess relationships between environmental and productivity indices

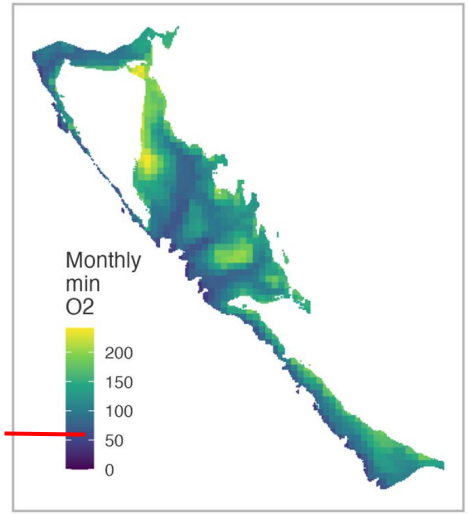
Photo credit: 2019 central coast ROV survey

Environmental data collected, so far

- Temperature at sea floor (http://doi.org/10.22033/ESGF/CMIP6.2921)
  - 1950 - 2014
  - Monthly average values at ~25 km resolution

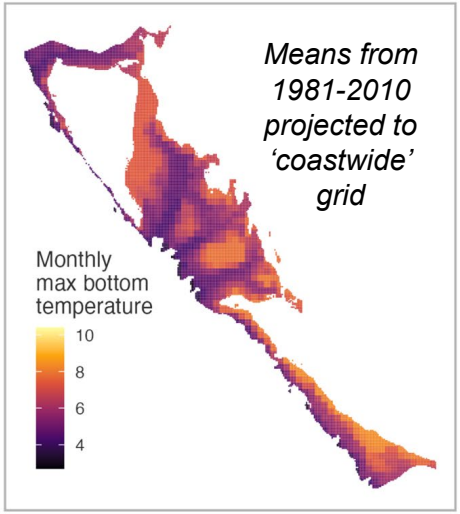
- Regional Ocean Modeling System (ROMS) hindcast (Angelica Peña, DFO)
  - 1981 - 2018
  - Monthly average values at ~3 km resolution
  - Temperature, oxygen (O_2) & salinity
  - At sea floor, averaged for all depths, & at surface



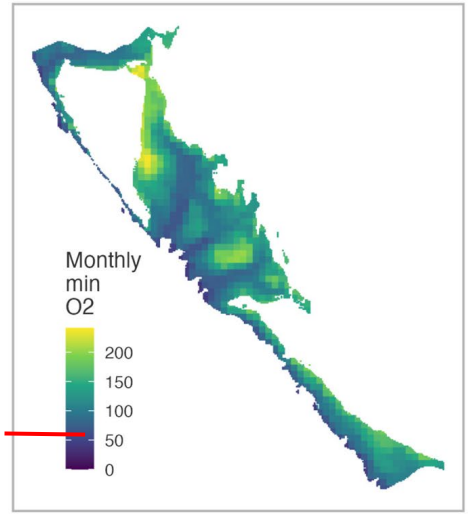


Environmental data collected, so far

- Temperature at sea floor (http://doi.org/10.22033/ESGF/CMIP6.2921)
  - 1950 - 2014
  - Monthly average values at ~25 km resolution

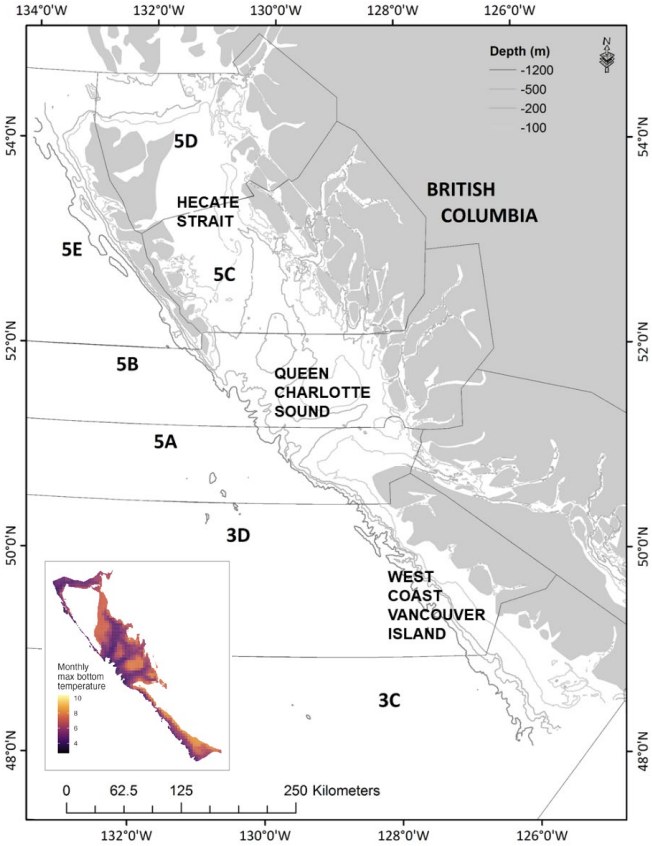


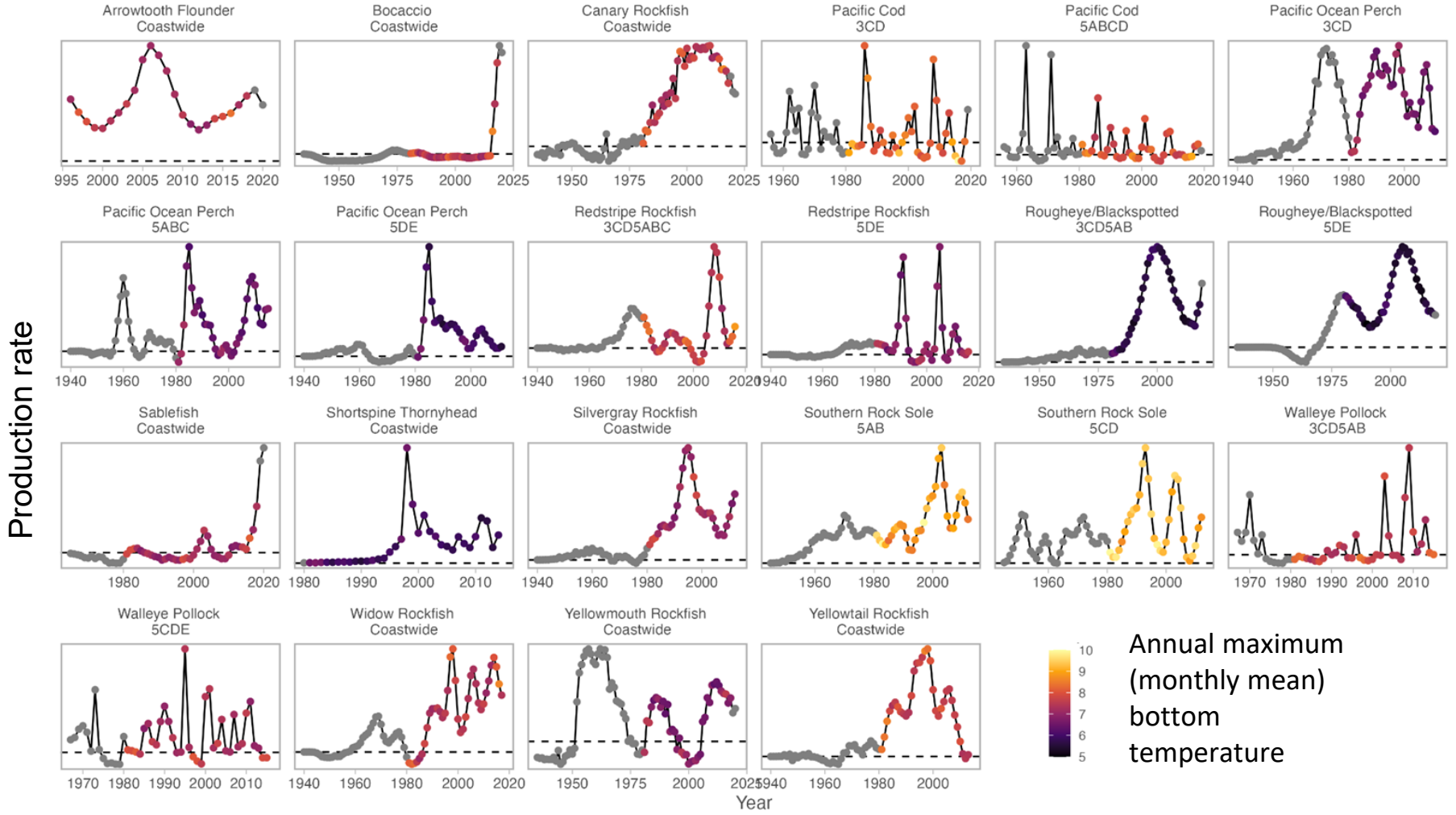
- Regional Ocean Modeling System (ROMS) hindcast (Angelica Peña, DFO)
  - 1981 - 2018
  - Monthly average values at ~3 km resolution
  - Temperature, oxygen (O_2) & salinity
  - At sea floor, averaged for all depths, & at surface

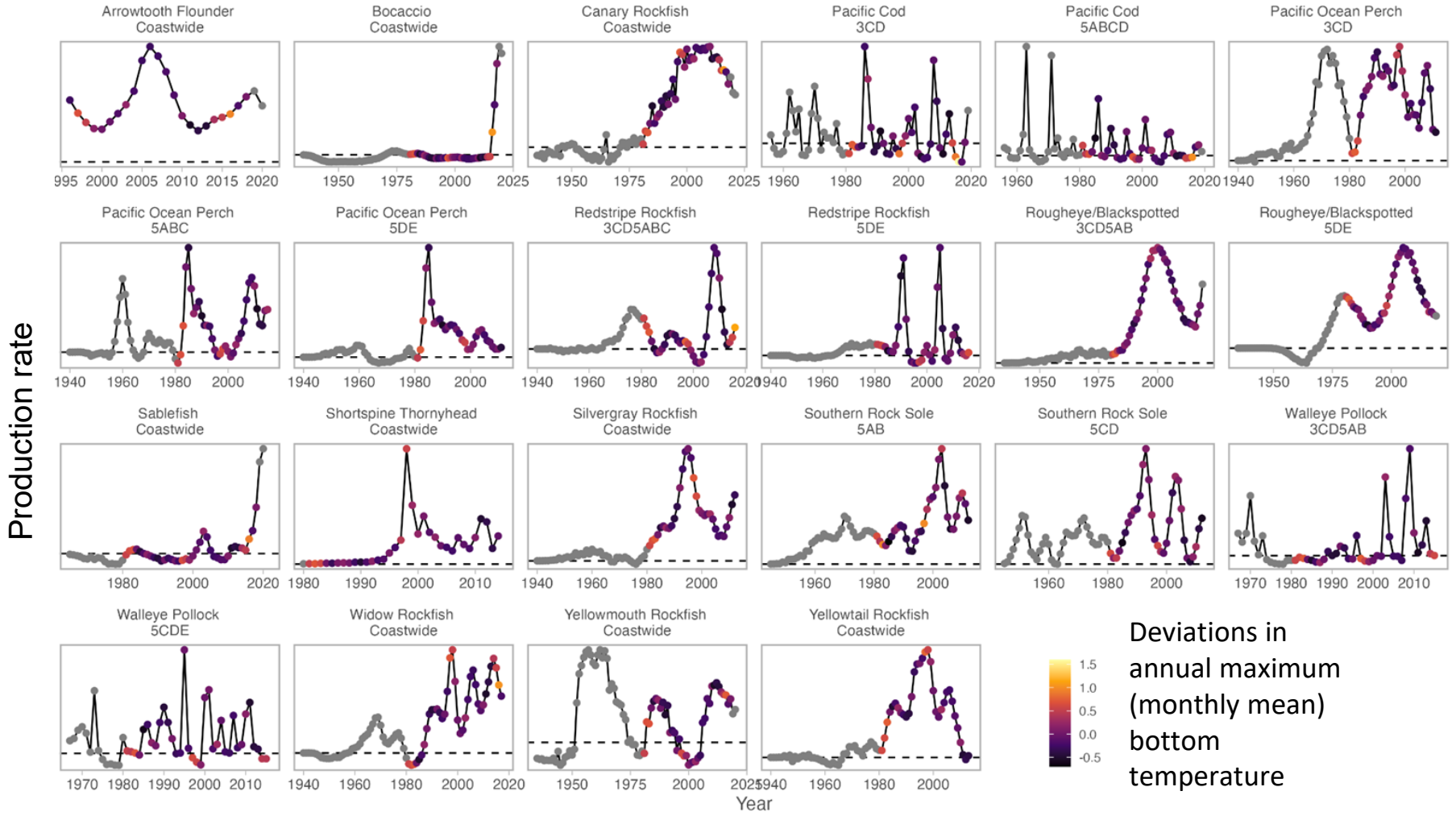


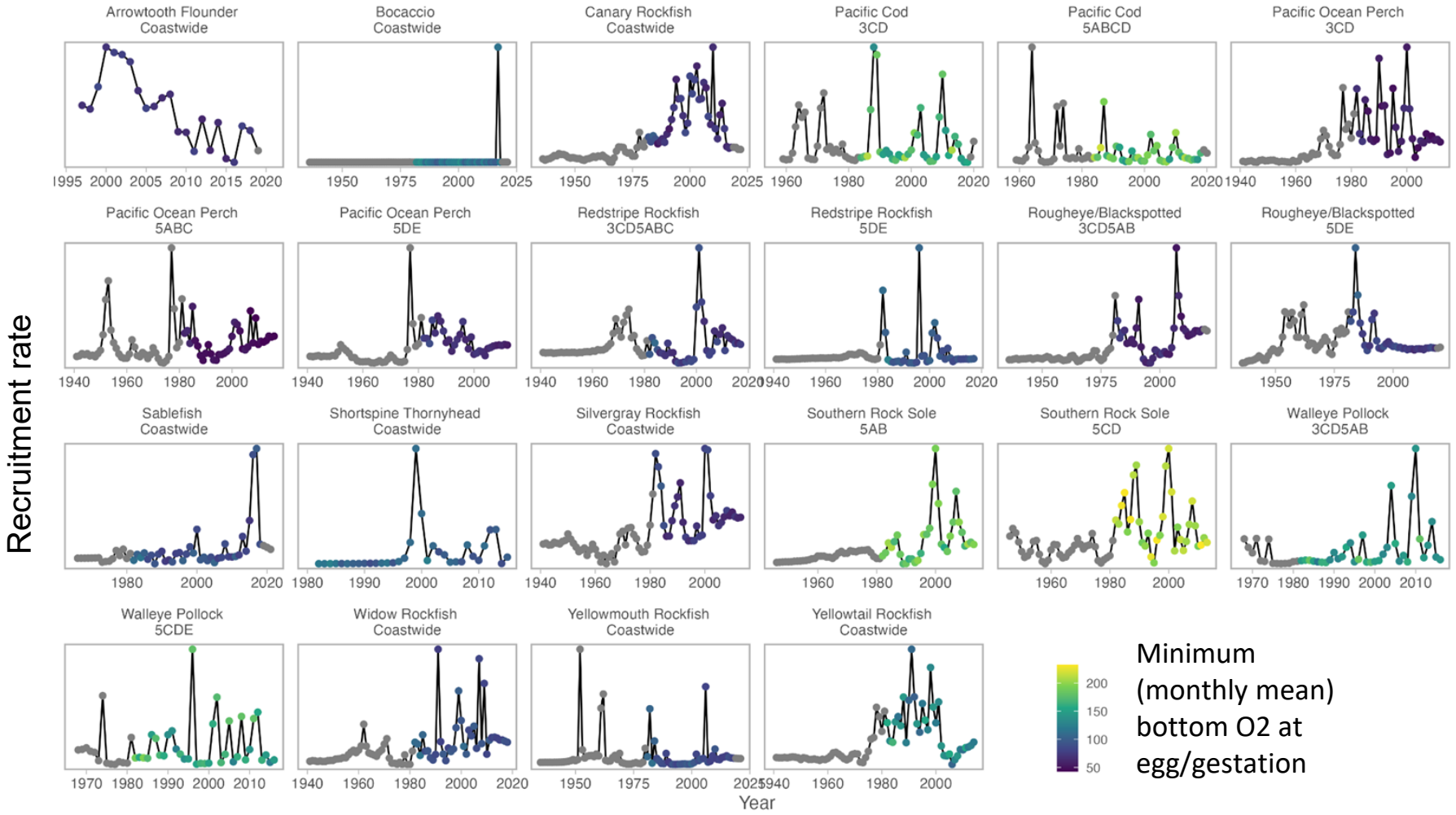
Defining relevant spatial and temporal scales

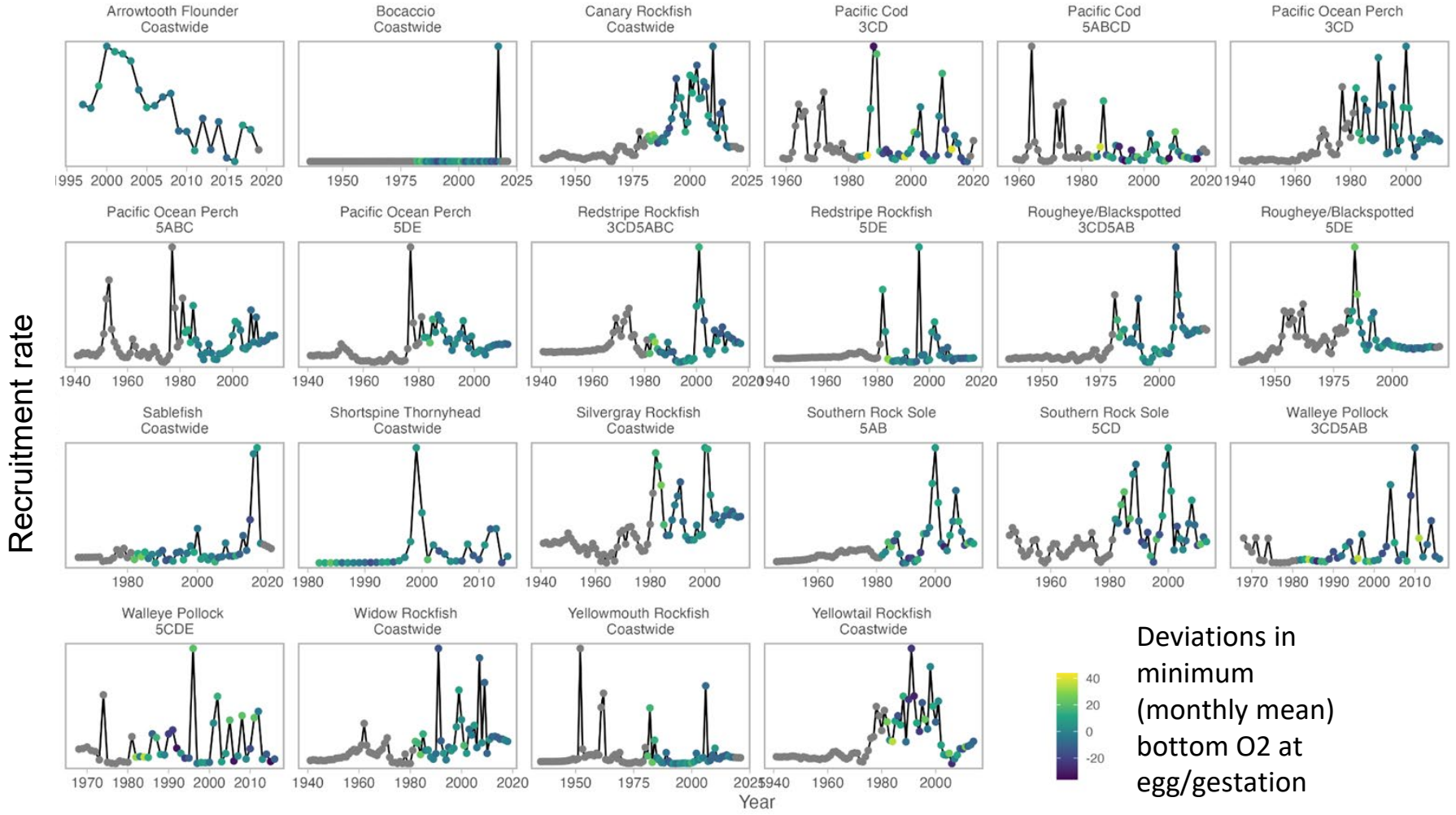
- Spatial area in stock definition
  - Clipped to offshore grid (in inset)
- Production-relevant scales
  - **Occupied depths** (weighted 95% quantile from surveys)
  - **Annual max of mean monthly temperature** *vs. a mean of means?*
  - Current year + *previous years, but how many?*
- Recruitment-relevant scales
  - Egg/gestation depths & months (literature/maturity data)
  - Larval depths & months (literature)
    - Sea surface for pelagic larvae and juveniles
    - If settlement shallow or timing unclear, used rest of year




Arrowtooth Flounder
Coastwide
Bocaccio
Coastwide
Canary Rockfish
Coastwide
Pacific Cod
3CD
Pacific Cod
5ABCD
Pacific Ocean Perch
3CD
Pacific Ocean Perch
5ABC
Pacific Ocean Perch
5DE
Redstripe Rockfish
3CD5ABC
Redstripe Rockfish
5DE
Rougheye/Blackspotted
3CD5AB
Rougheye/Blackspotted
5DE
Sablefish
Coastwide
Shortspine Thornyhead
Coastwide
Silvergray Rockfish
Coastwide
Southern Rock Sole
5AB
Southern Rock Sole
5CD
Walleye Pollock
3CD5AB
Walleye Pollock
5CDE
Widow Rockfish
Coastwide
Yellowmouth Rockfish
Coastwide
Yellowtail Rockfish
Coastwide
Production rate
Year
Annual maximum (monthly mean) bottom temperature


Arrowtooth Flounder Coastwide
Bocaccio Coastwide
Canary Rockfish Coastwide
Pacific Cod 3CD
Pacific Cod 5ABCD
Pacific Ocean Perch 3CD
Pacific Ocean Perch 5ABC
Pacific Ocean Perch 5DE
Redstripe Rockfish 3CD5ABC
Redstripe Rockfish 5DE
Rougheye/Blackspotted 3CD5AB
Rougheye/Blackspotted 5DE
Sablefish Coastwide
Shortspine Thornyhead Coastwide
Silvergray Rockfish Coastwide
Southern Rock Sole 5AB
Southern Rock Sole 5CD
Walleye Pollock 3CD5AB
Walleye Pollock 5CDE
Widow Rockfish Coastwide
Yellowmouth Rockfish Coastwide
Yellowtail Rockfish Coastwide
Production rate
Year
1.5
1.0
0.5
0.0
-0.5
Deviations in annual maximum (monthly mean) bottom temperature


Arrowtooth Flounder
Coastwide
Bocaccio
Coastwide
Canary Rockfish
Coastwide
Pacific Cod
3CD
Pacific Cod
5ABCD
Pacific Ocean Perch
3CD
Pacific Ocean Perch
5ABC
Pacific Ocean Perch
5DE
Redstripe Rockfish
3CD5ABC
Redstripe Rockfish
5DE
Rougheye/Blackspotted
3CD5AB
Rougheye/Blackspotted
5DE
Sablefish
Coastwide
Shortspine Thornyhead
Coastwide
Silvergray Rockfish
Coastwide
Southern Rock Sole
5AB
Southern Rock Sole
5CD
Walleye Pollock
3CD5AB
Walleye Pollock
5CDE
Widow Rockfish
Coastwide
Yellowmouth Rockfish
Coastwide
Yellowtail Rockfish
Coastwide
Recruitment rate
Year
200
150
100
50
Minimum
(monthly mean)
bottom O2 at
egg/gestation


Arrowtooth Flounder
Coastwide
Bocaccio
Coastwide
Canary Rockfish
Coastwide
Pacific Cod
3CD
Pacific Cod
5ABCD
Pacific Ocean Perch
3CD
Pacific Ocean Perch
5ABC
Pacific Ocean Perch
5DE
Redstripe Rockfish
3CD5ABC
Redstripe Rockfish
5DE
Rougheye/Blackspotted
3CD5AB
Rougheye/Blackspotted
5DE
Sablefish
Coastwide
Shortspine Thornyhead
Coastwide
Silvergray Rockfish
Coastwide
Southern Rock Sole
5AB
Southern Rock Sole
5CD
Walleye Pollock
3CD5AB
Walleye Pollock
5CDE
Widow Rockfish
Coastwide
Yellowmouth Rockfish
Coastwide
Yellowtail Rockfish
Coastwide
Recruitment rate
Year
40
20
0
-20
Deviations in minimum (monthly mean) bottom O2 at egg/gestation

Approach

1. Wrangle stock assessment outputs into identical formats
2. Calculate ‘production’ and ‘recruits per unit spawning biomass’
3. Choose relevant spatial and temporal scales for each stock
4. Project environmental layers and extract values at these scales
5. Assess relationships between environmental and productivity indices

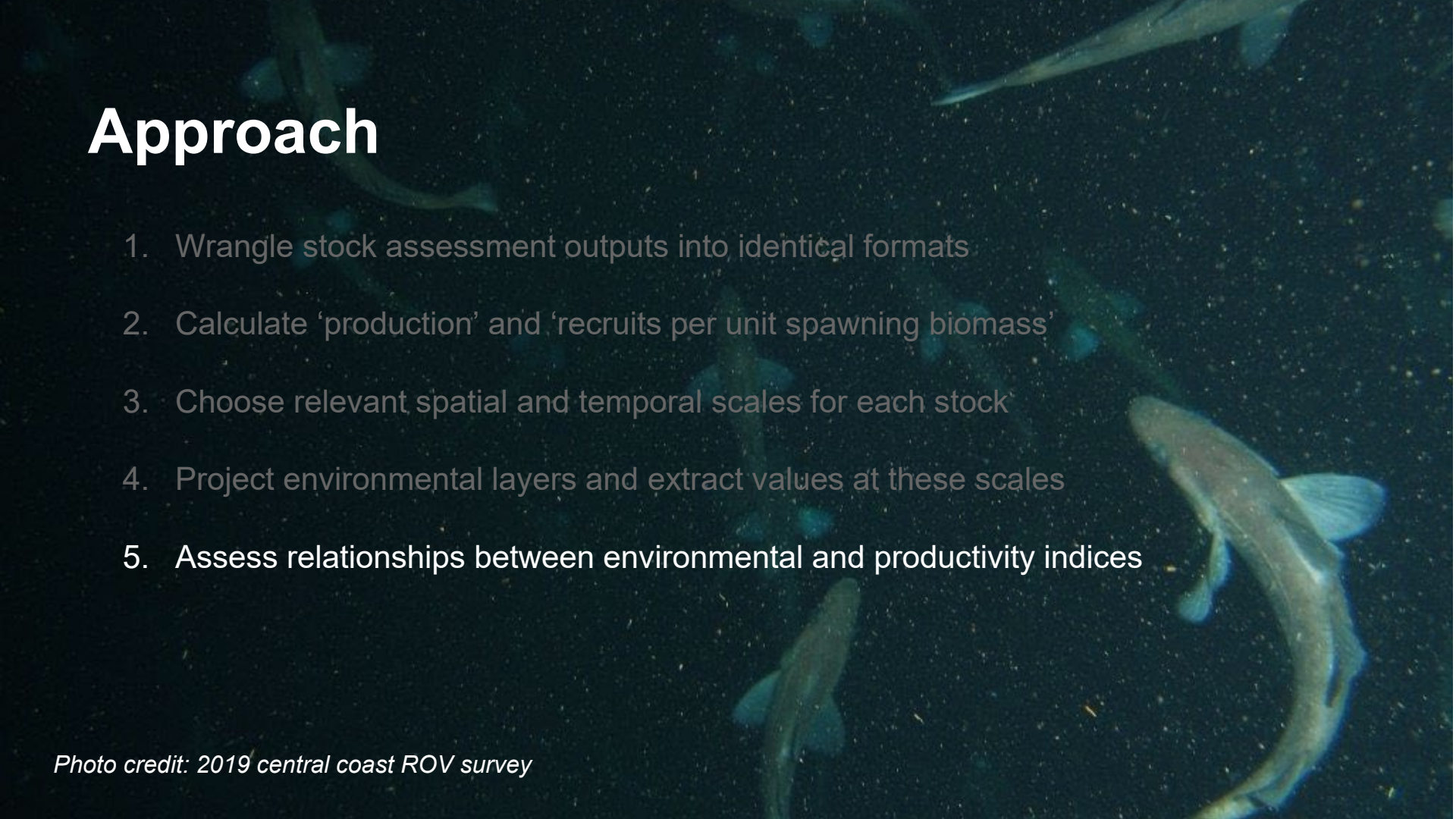
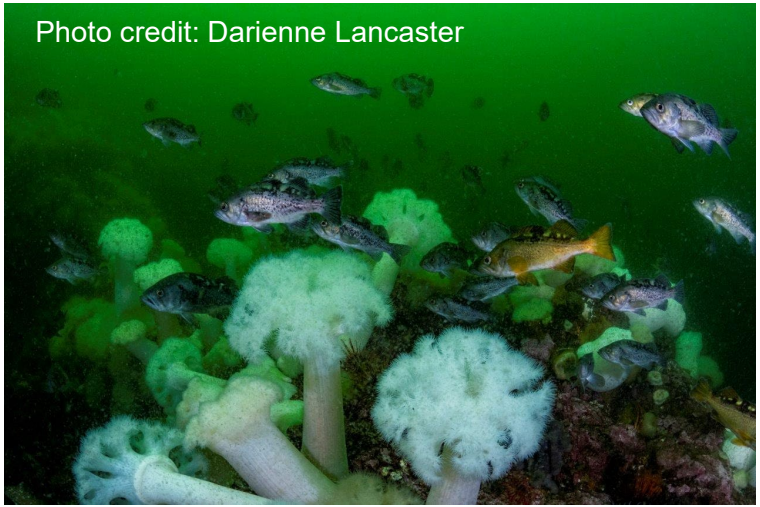
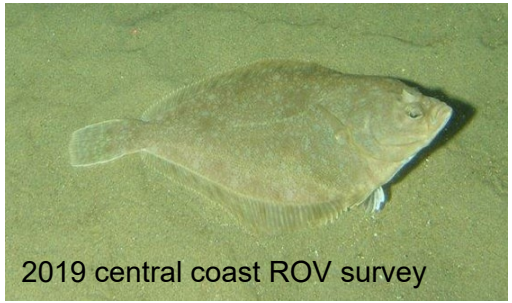


Photo credit: 2019 central coast ROV survey

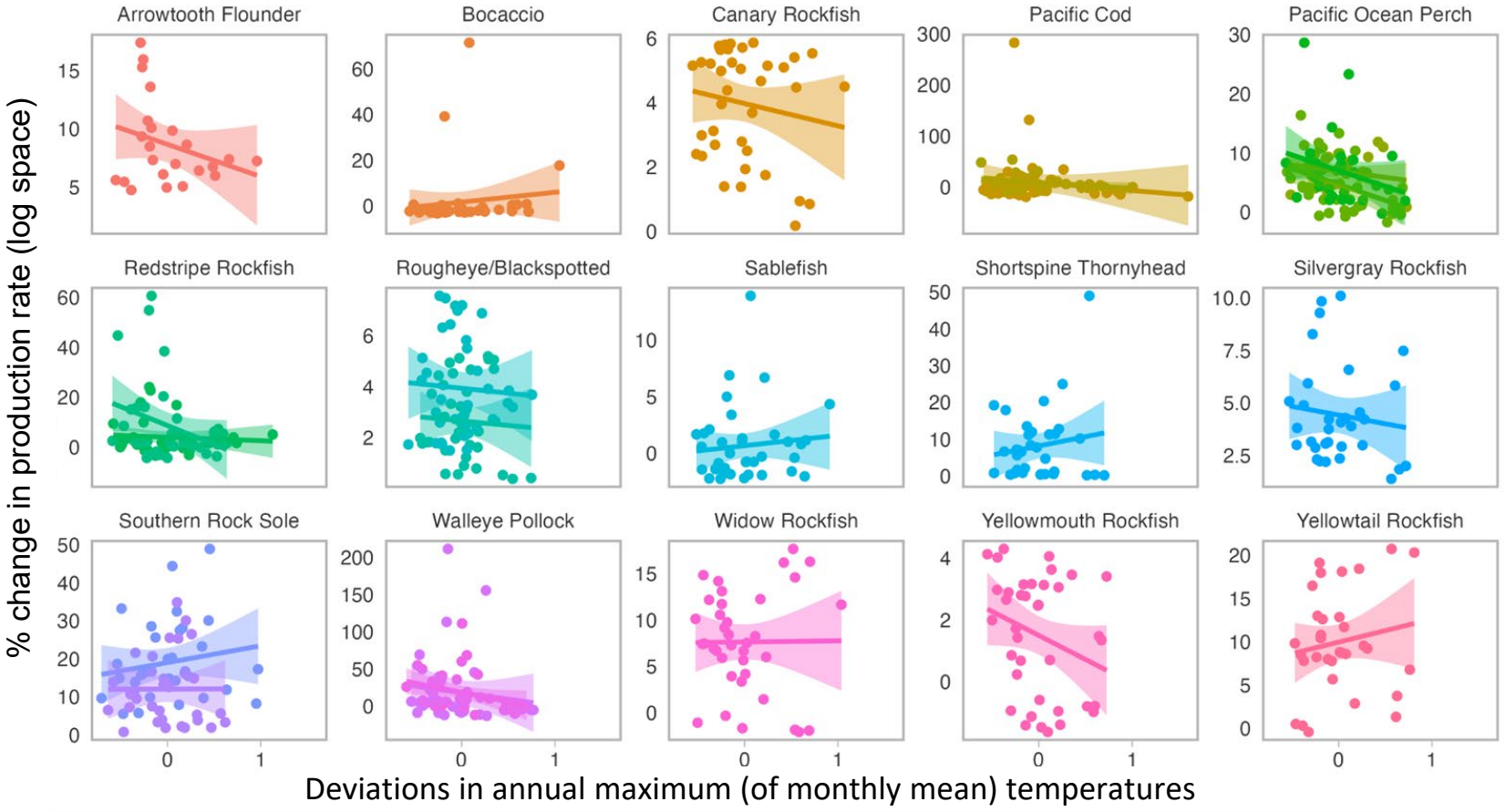
Bayesian hierarchical models

- One hypothesis at a time, across species
  - Prior for a concave down relationship on quadratic Normal(-0.15, 0.15^2)
  - Variability among species/stocks is estimated as a normal distribution
- First pass…

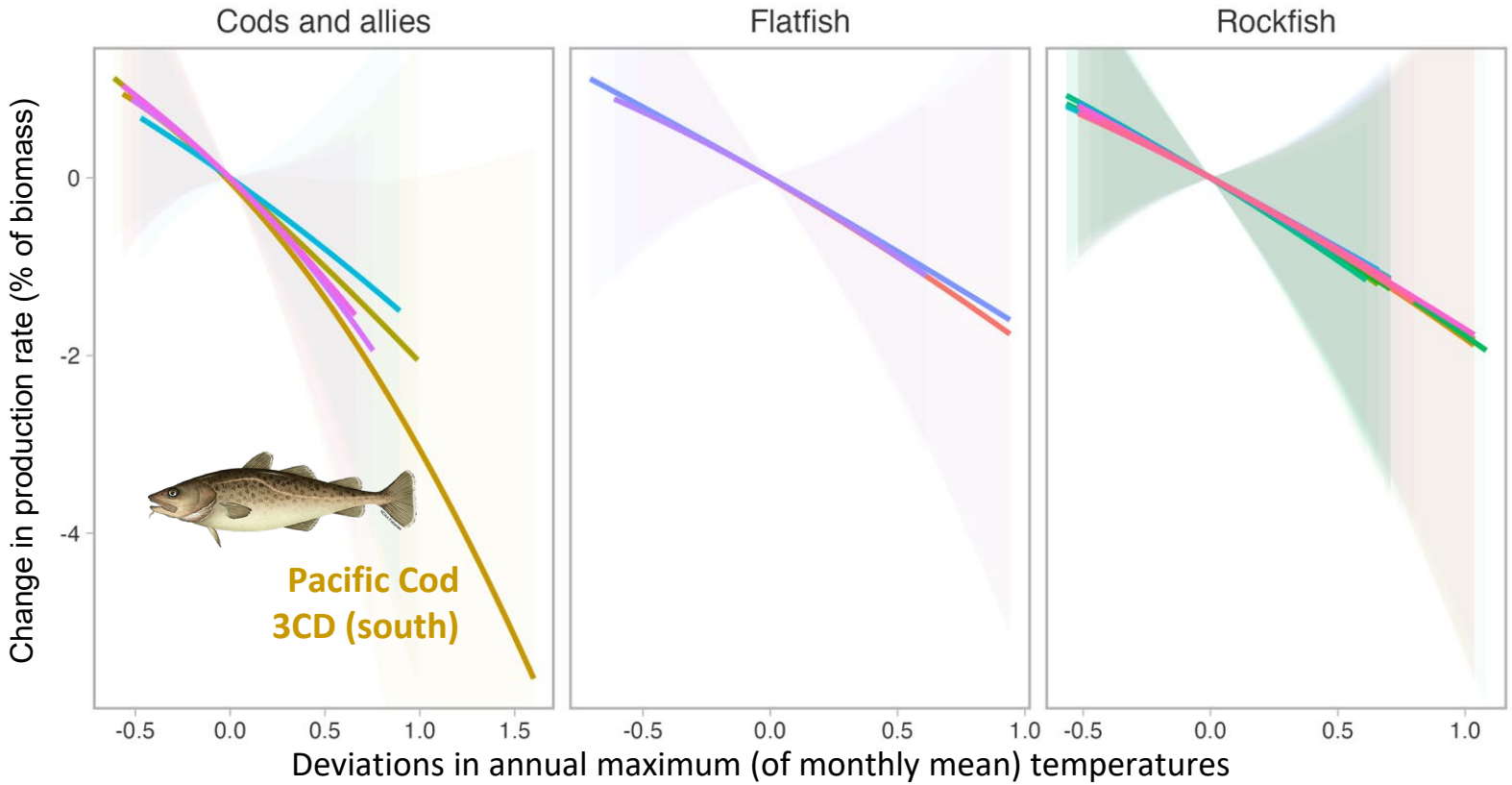




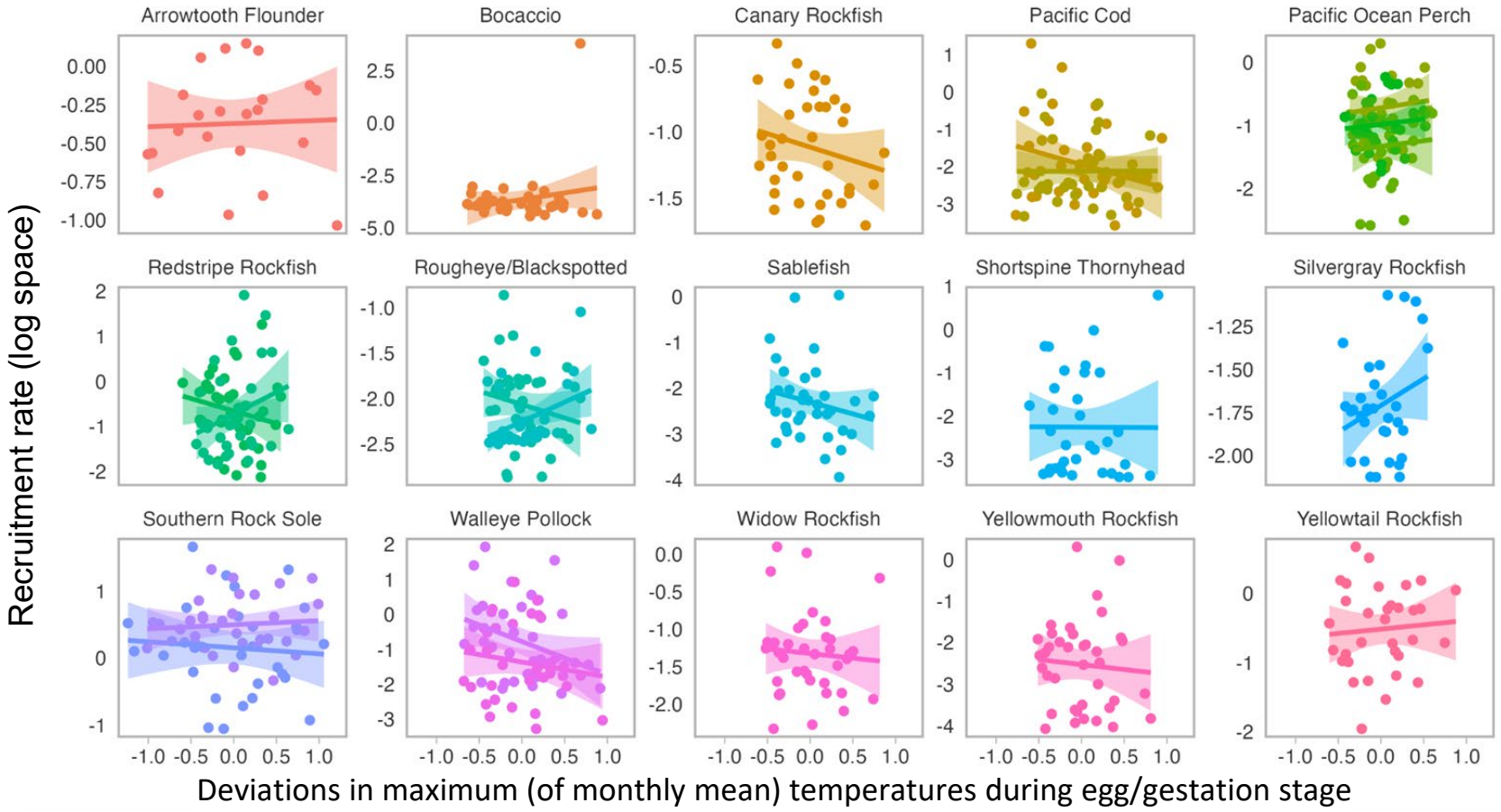
Annual max temperature on surplus production



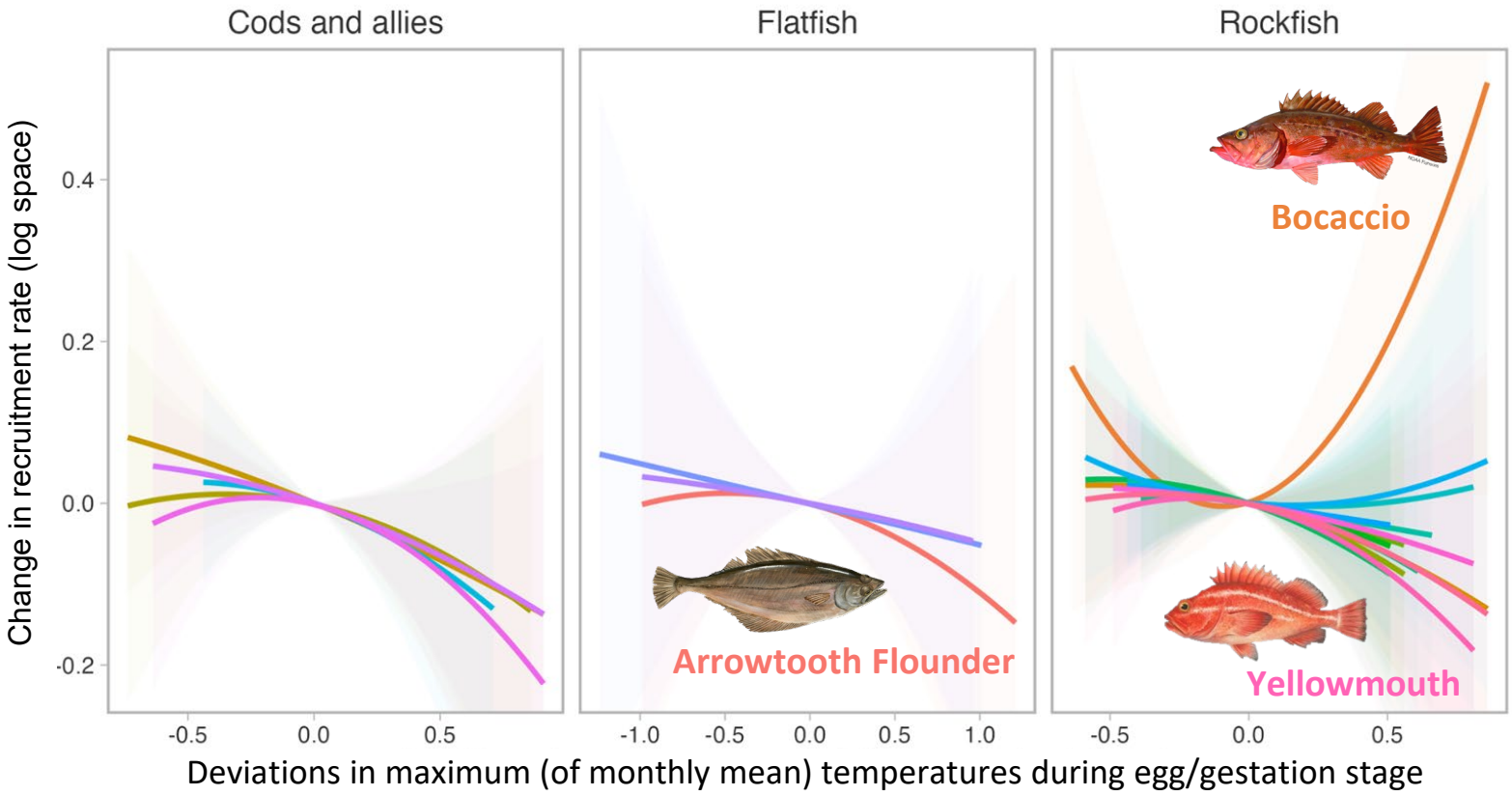
Current year, annual max temperature on surplus production



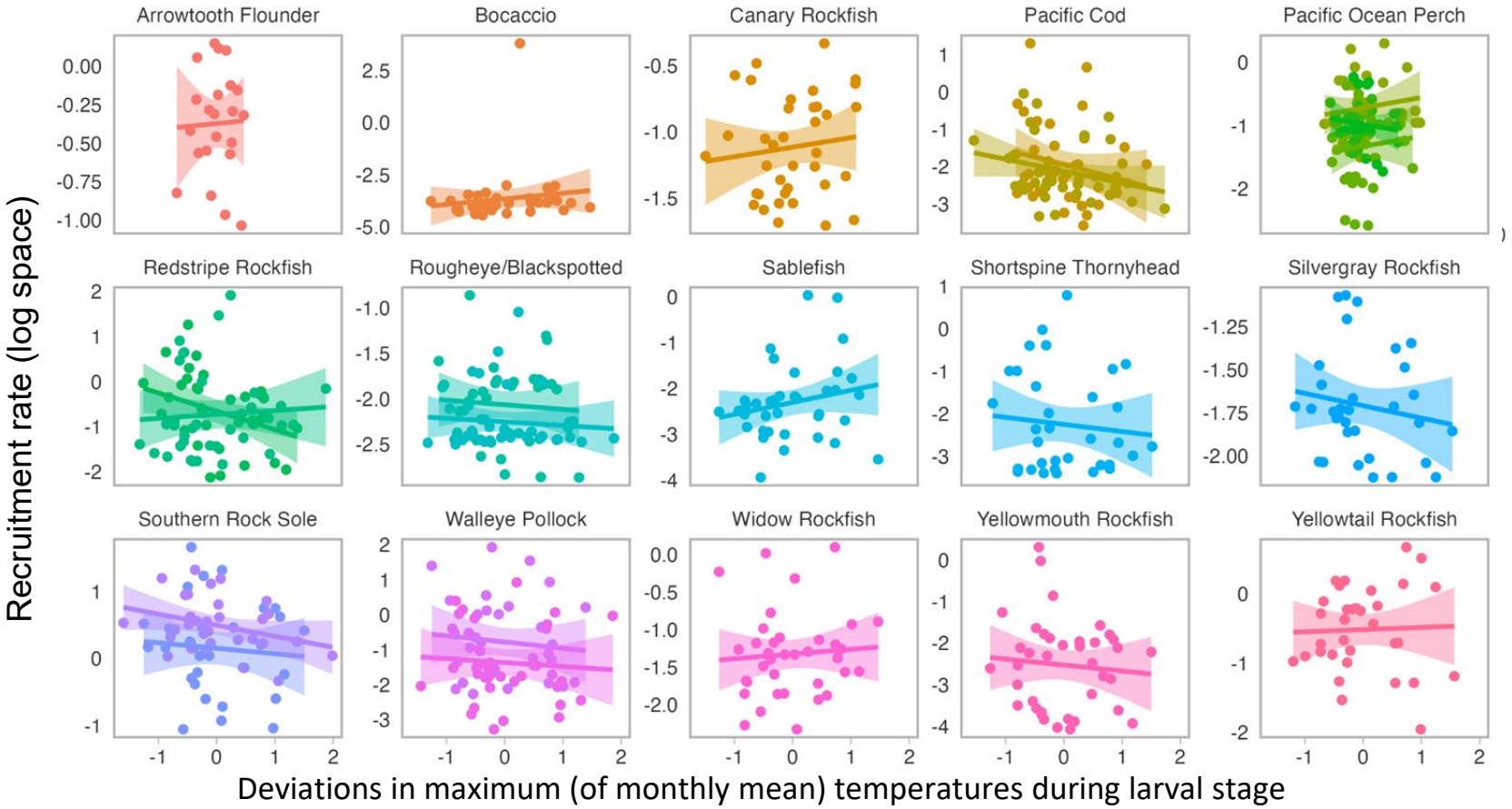
Temperature at eggs/gestation stage on recruitment



Temperature at eggs/gestation stage on recruitment



Temperature at larval stage on recruitment



Temperature at larval stage on recruitment

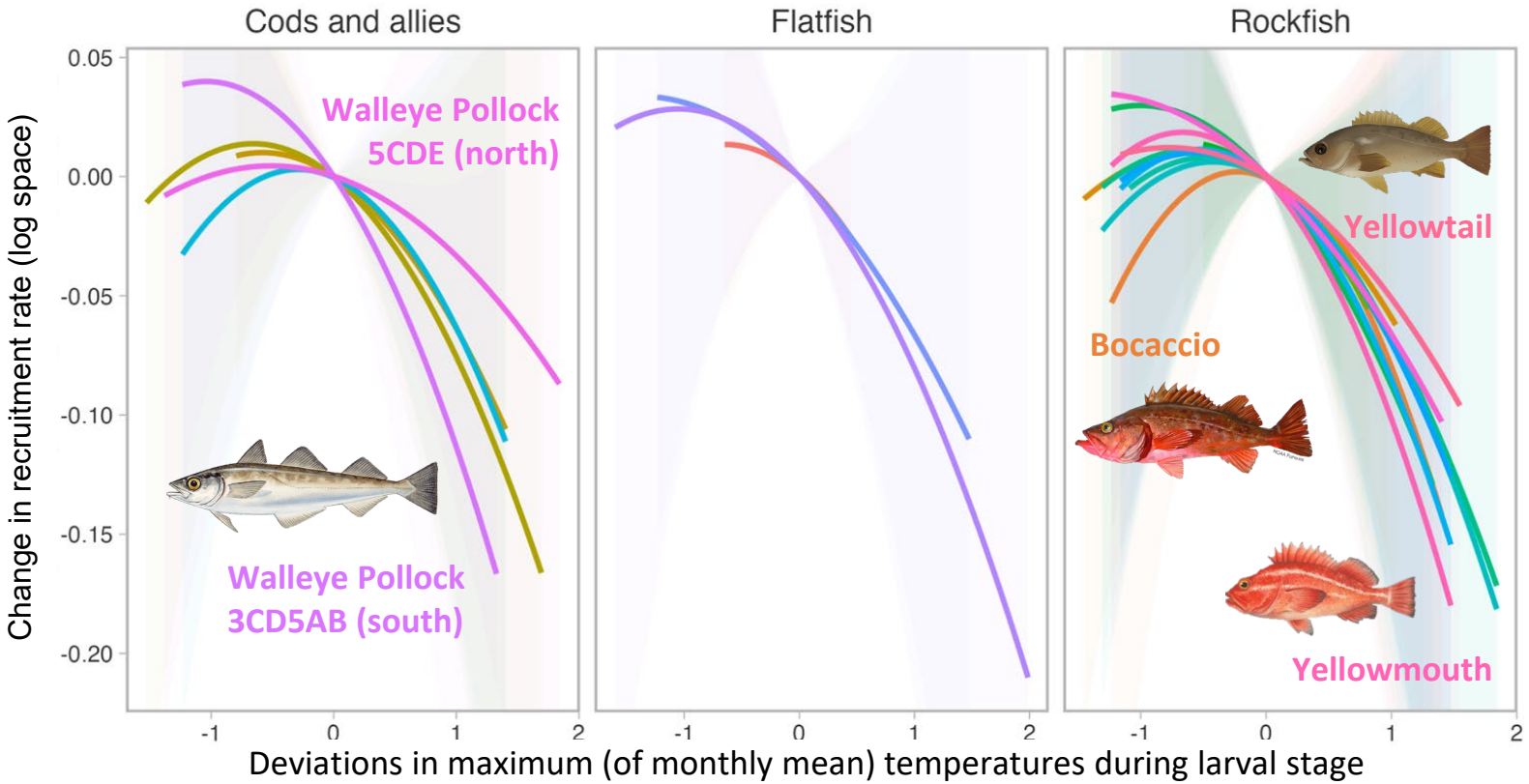
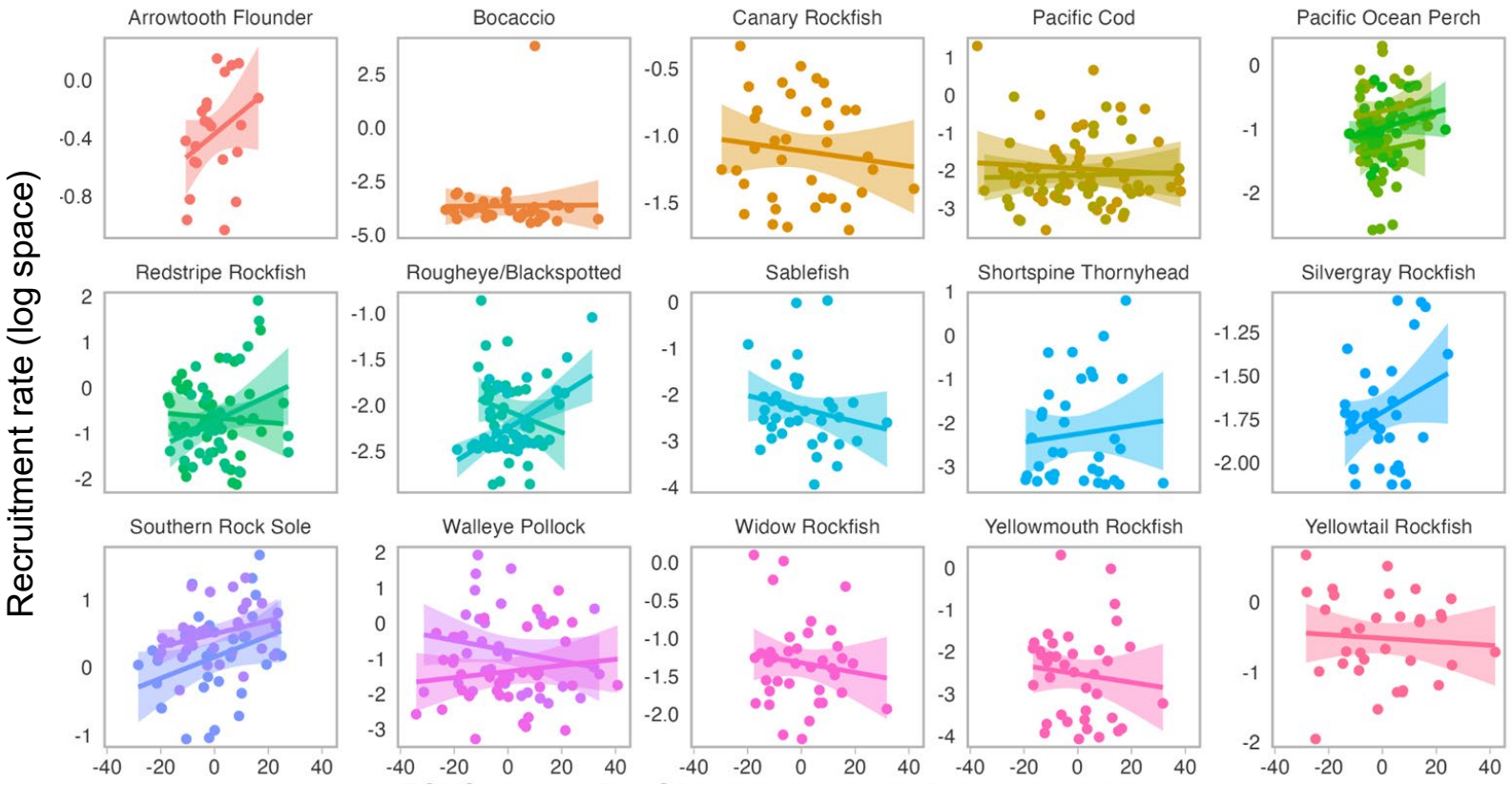
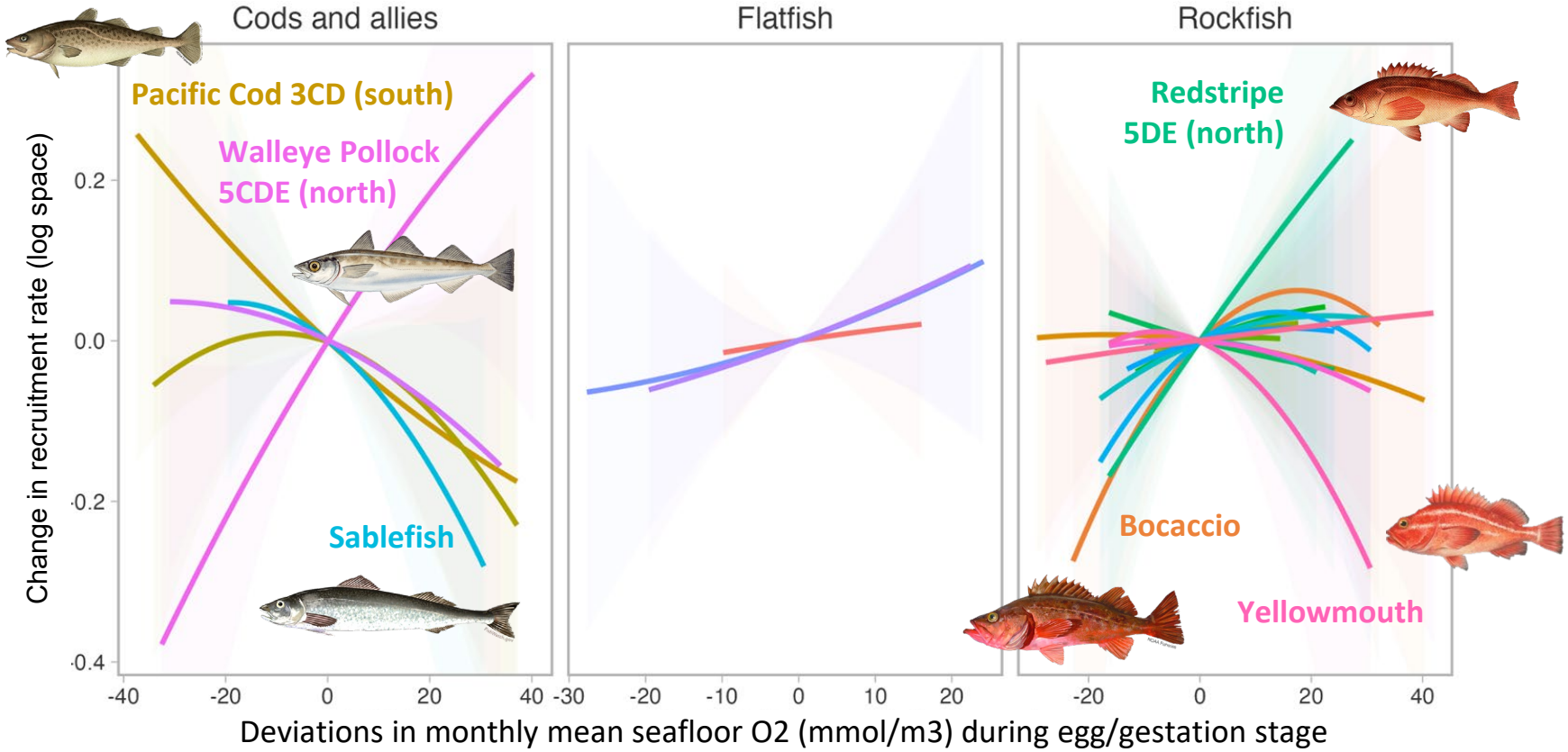


Photo credit: NOAA

Oxygen at eggs/gestation stage on recruitment



Oxygen at eggs/gestation stage on recruitment

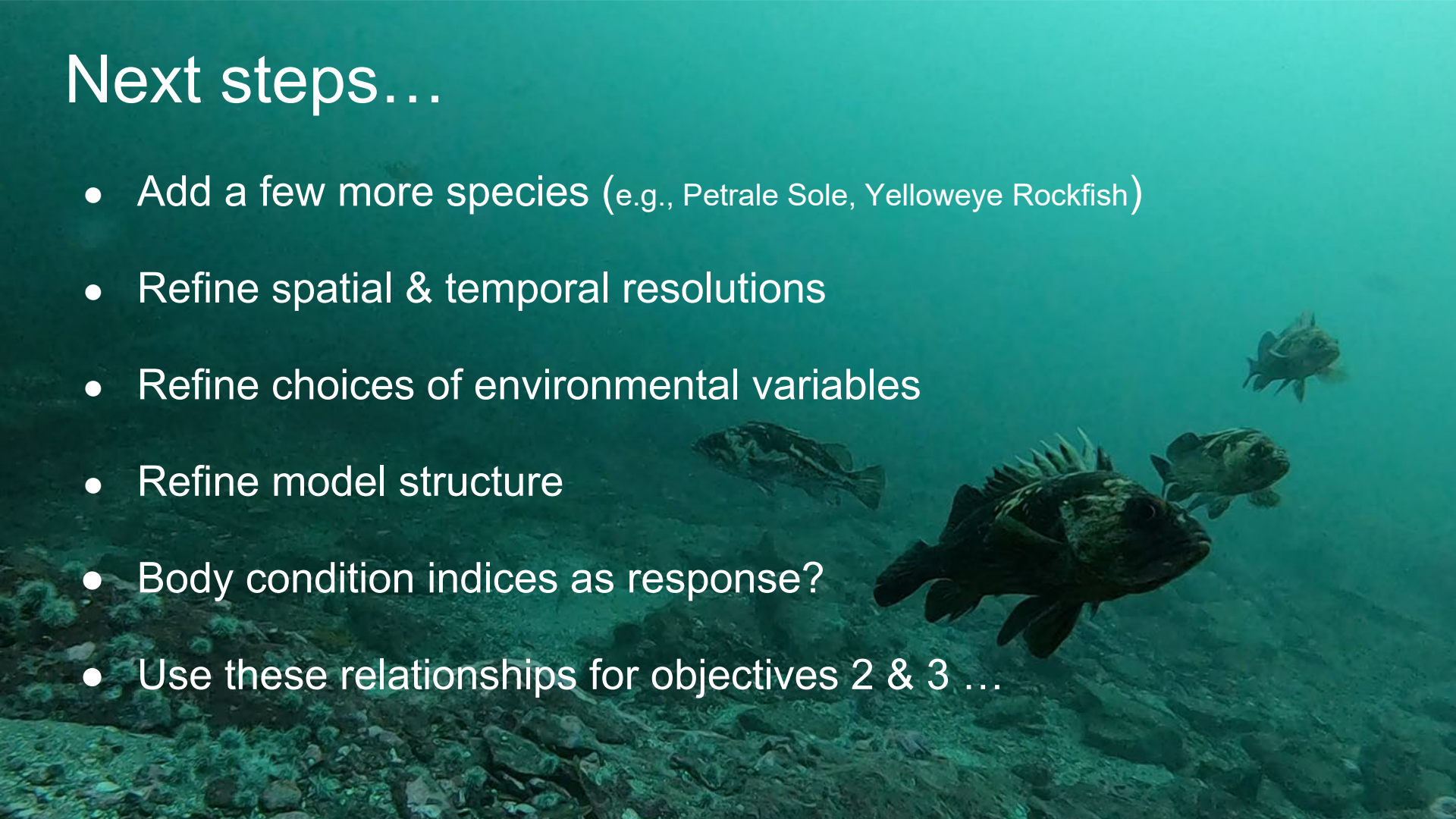


Caveats

- These types of relationships are notorious for breaking down (*Myers 1998*)
  - Hierarchical approach can help, but only so much
  - Implications of priors need further investigation
- Stock assessment outputs are estimates (*Brooks and Debora 2015*)
  - Uncertainties already huge without propagating their uncertainty
- Stock level response & spatiotemporal resolutions of climate values
  - Masks a lot of local environmental variability – some locations more important?
  - All occupied depths within stock area weighted equally
  - Some egg & larval distributions not well known, or not well implemented
  - Min and max are calculated across months for each location
  - So far, aggregating spatially only using means

Next steps…

- Add a few more species (e.g., Petrale Sole, Yelloweye Rockfish)
- Refine spatial & temporal resolutions
- Refine choices of environmental variables
- Refine model structure
- Body condition indices as response?
- Use these relationships for objectives 2 & 3 …



Next steps…

PLOS ONE

RESEARCH ARTICLE

Fish harvesting advice under climate change: A risk-equivalent empirical approach

Daniel E. Duplisea[1]*, Marie-Julie Roux[1], Karen L. Hunter[2], Jake Rice[3]

1 Fisheries and Oceans Canada, Institut Maurice-Lamontagne, Mont-Joli, QC, Canada, **2** Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada, **3** Fisheries and Oceans Canada, National Headquarters, Ottawa, ON, Canada

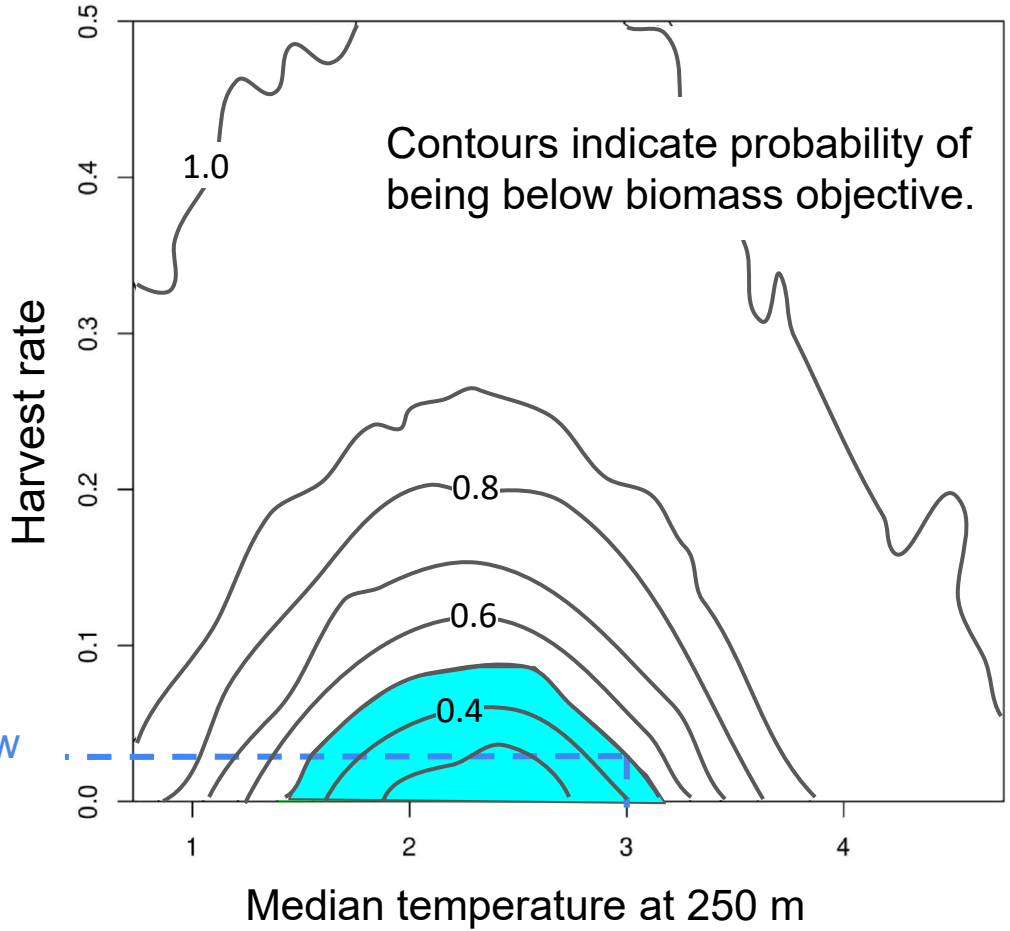
* Daniel.Duplisea@dfo-mpo.gc.ca

Next steps…

- Case study of Greenland Halibut in Gulf of St Lawrence

  Blue zone = combinations temperature and harvest rate that would achieve a 50% probability of being above the target biomass

If median temperature increases to 3°C, exploitation rate must be below 0.05 to maintain risk objective



Questions or suggestions?

Philina.English@dfo-mpo.gc.ca