Pêches et Océans Canada | Fisheries and Oceans Canada

Are Canadian Pacific groundfishes shifting their distribution in response to local climate velocities?

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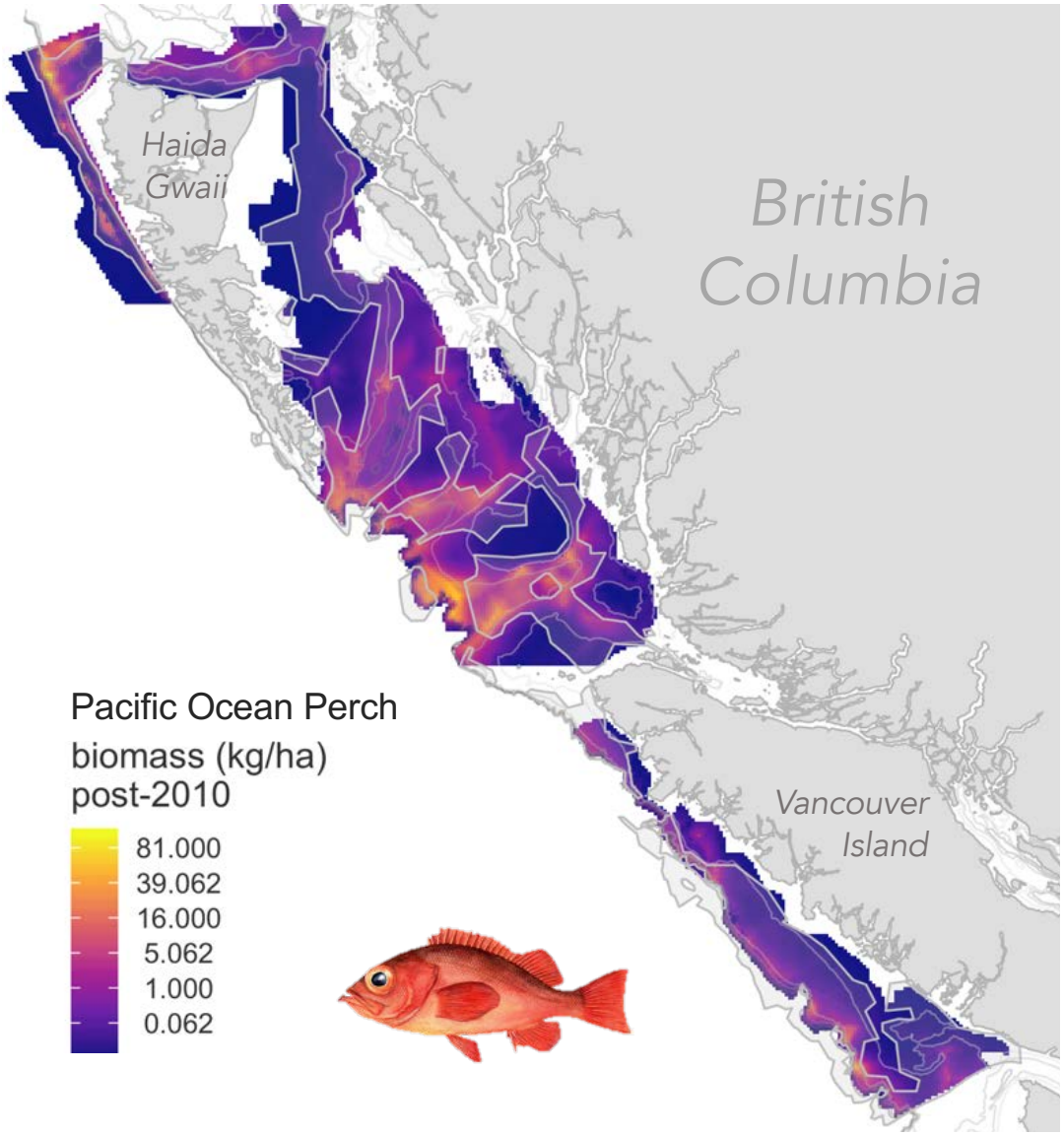
[2]National Oceanographic and Atmospheric Administration

Trawl survey data

- biennial coverage of Canada's Pacific waters
  - ➢ commercial trawl footprint overlaid (in grey)
- random depth-stratified
- size, age, sex for all species caught

species' biomass estimated using a Tweedie distribution in the R package github.com/pbs-assess/sdmTMB



Time scale of climate

Survey sensor-based models

(conditions at time of survey)

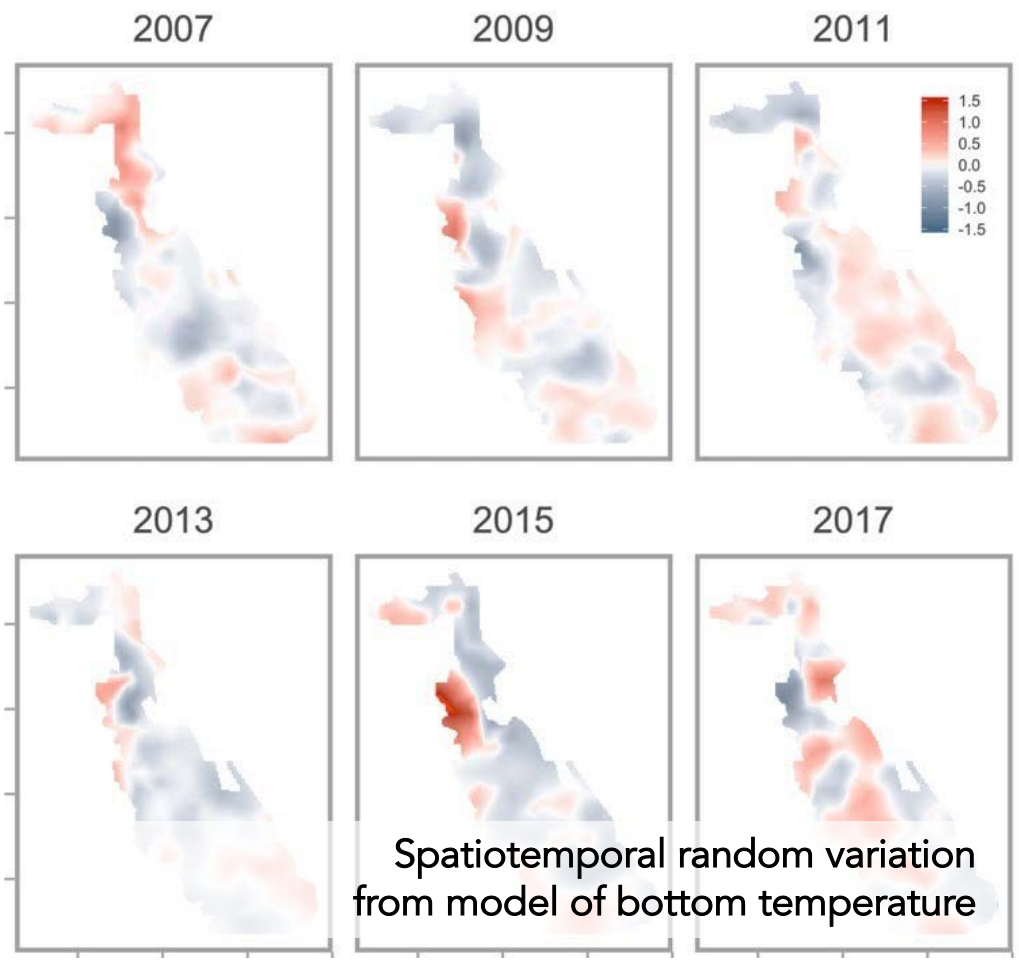
- movement & short-term settlement

Long-term historical

(seasonal & interannual variability)

- survival & productivity

Future projections



Spatiotemporal random variation from model of bottom temperature

I. Estimate local seafloor climate velocities
II. Predict species-specific sensitivities
III. Contrast fish density change with relevant climate velocities

Local climate velocity

- speed and direction an organism would need to move to maintain current climate conditions

Low velocity

Little temporal change

OR

Change occurring in a heterogenous environment

Higher velocity

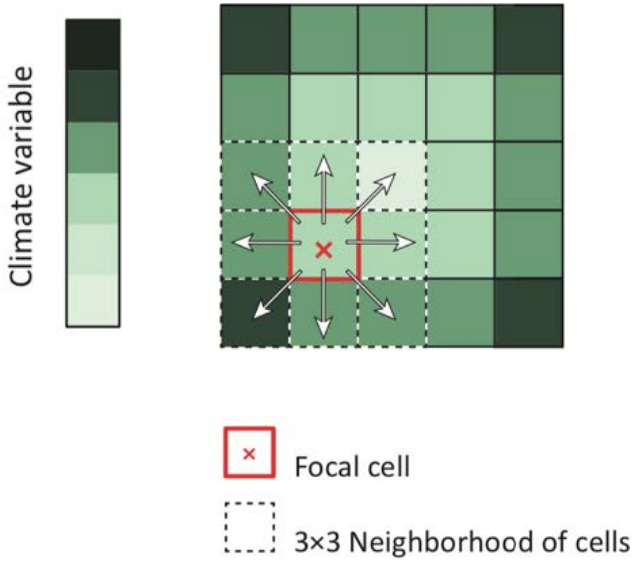
Larger change

OR

Change occurring in spatially homogenous environment

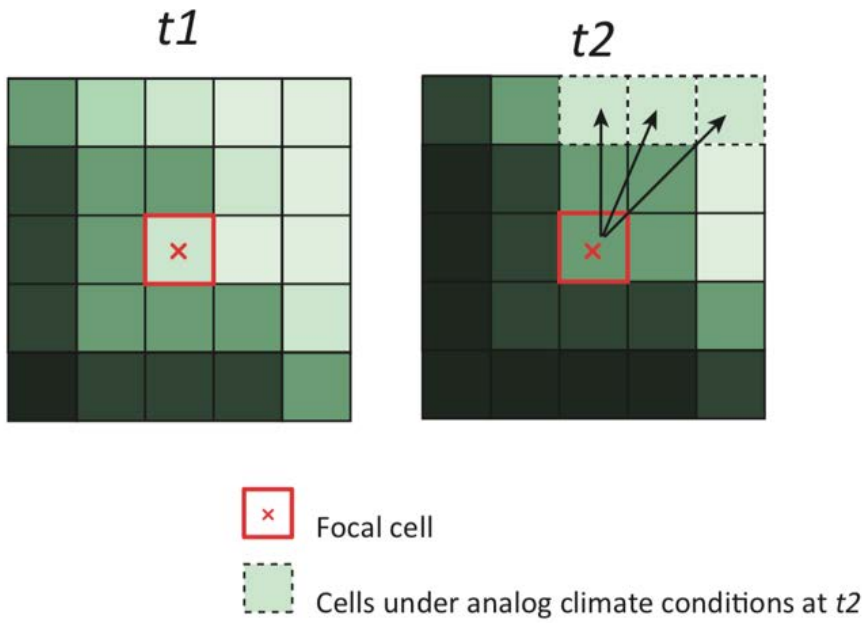
Spatial gradient
(Loarie et al. 2009)

$$\frac{\text{Temporal}}{\text{Spatial}} = \frac{\text{Slope (°C year}^{-1})}{\text{Spatial gradient (°C km}^{-1})} = \text{km year}^{-1}$$



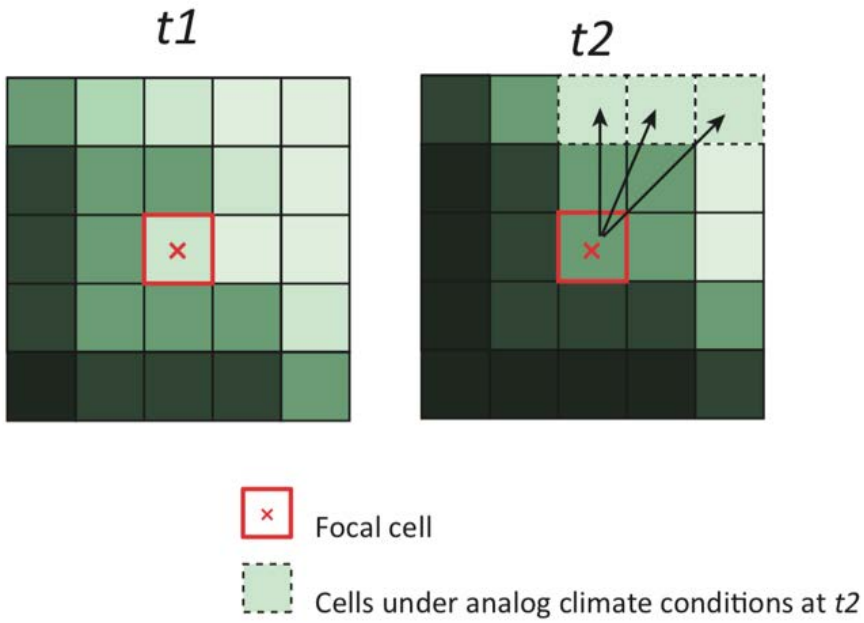
Analog-distance
(e.g. Hamann et al. 2015)

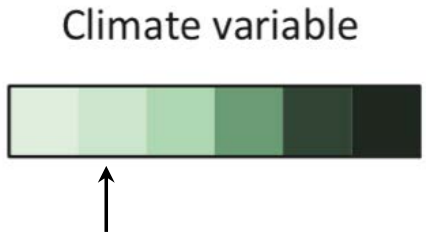
$$\frac{\text{Distance between climate analog (km)}}{\Delta\ \text{Time year(s)}} = \text{km year}^{-1}$$



(Brito-Morales et al. 2018 in Trends in Ecol & Evol)

Defining analogous climate: choose a threshold

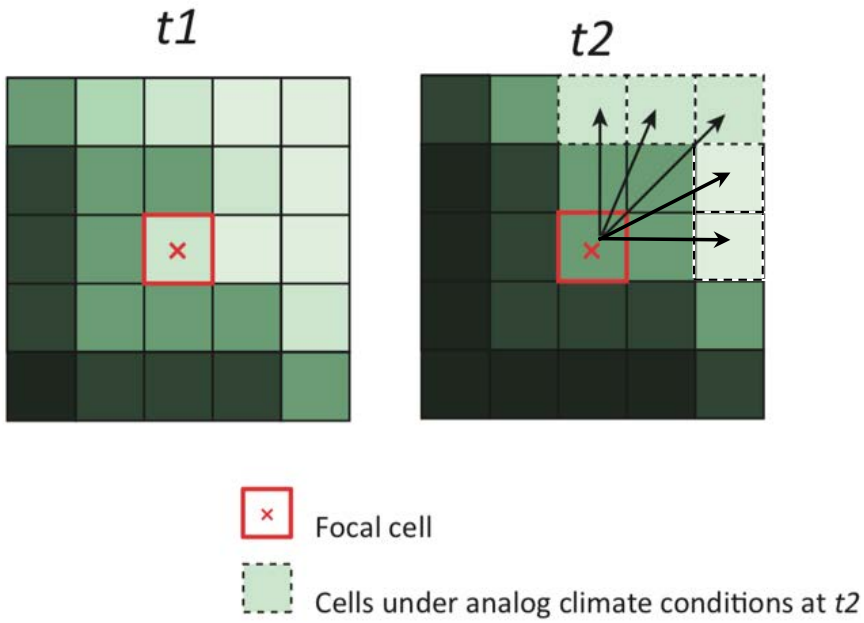


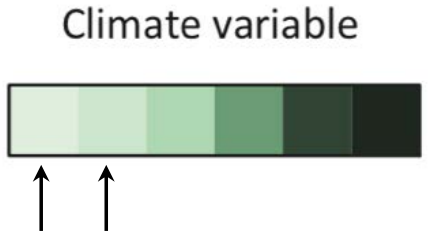


Bins based on range
(e.g. ± 0.5 °C)

Range can be subjectively chosen or derived from past climate variability.

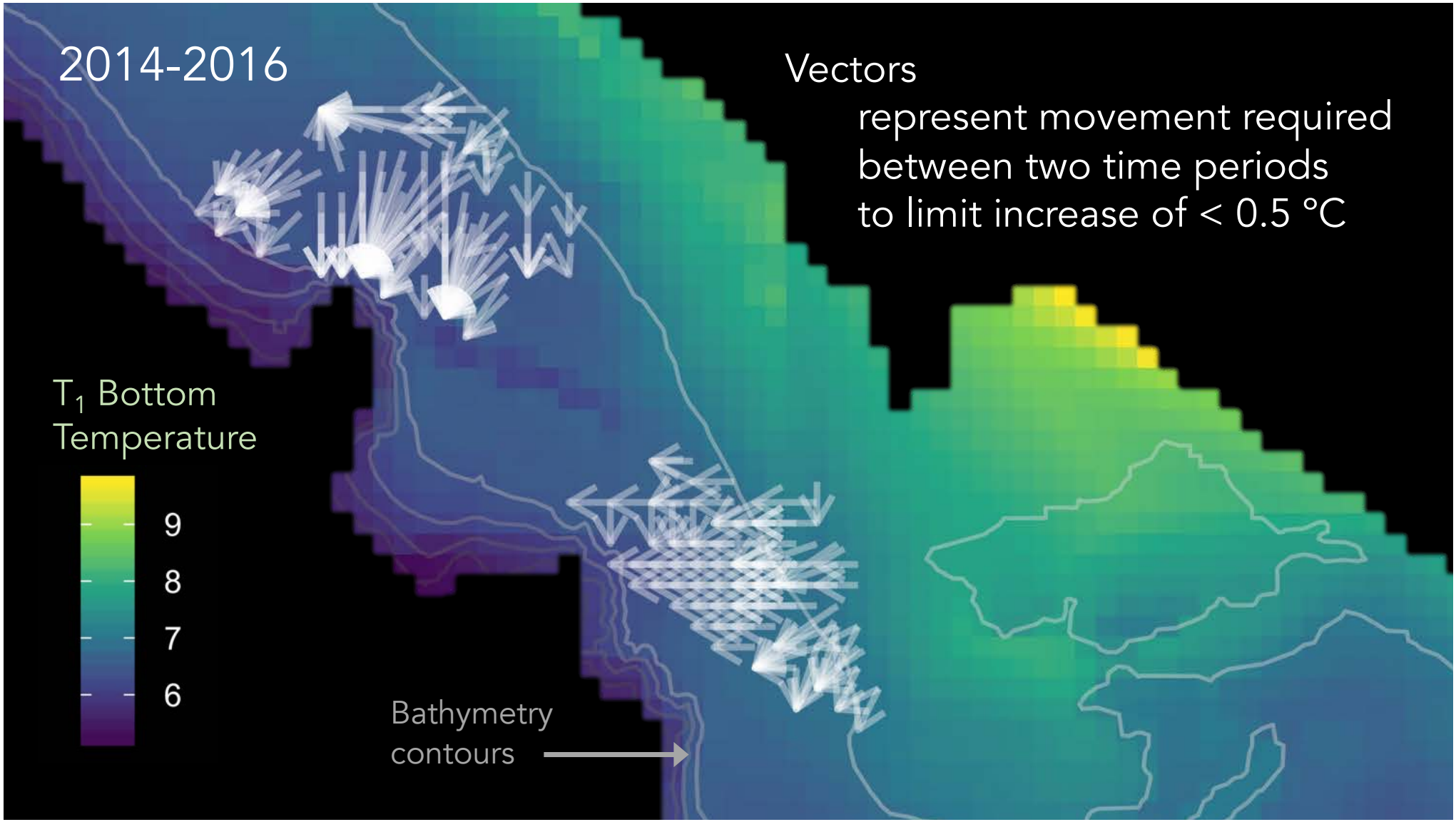
Defining analogous climate: *asymmetrical* threshold



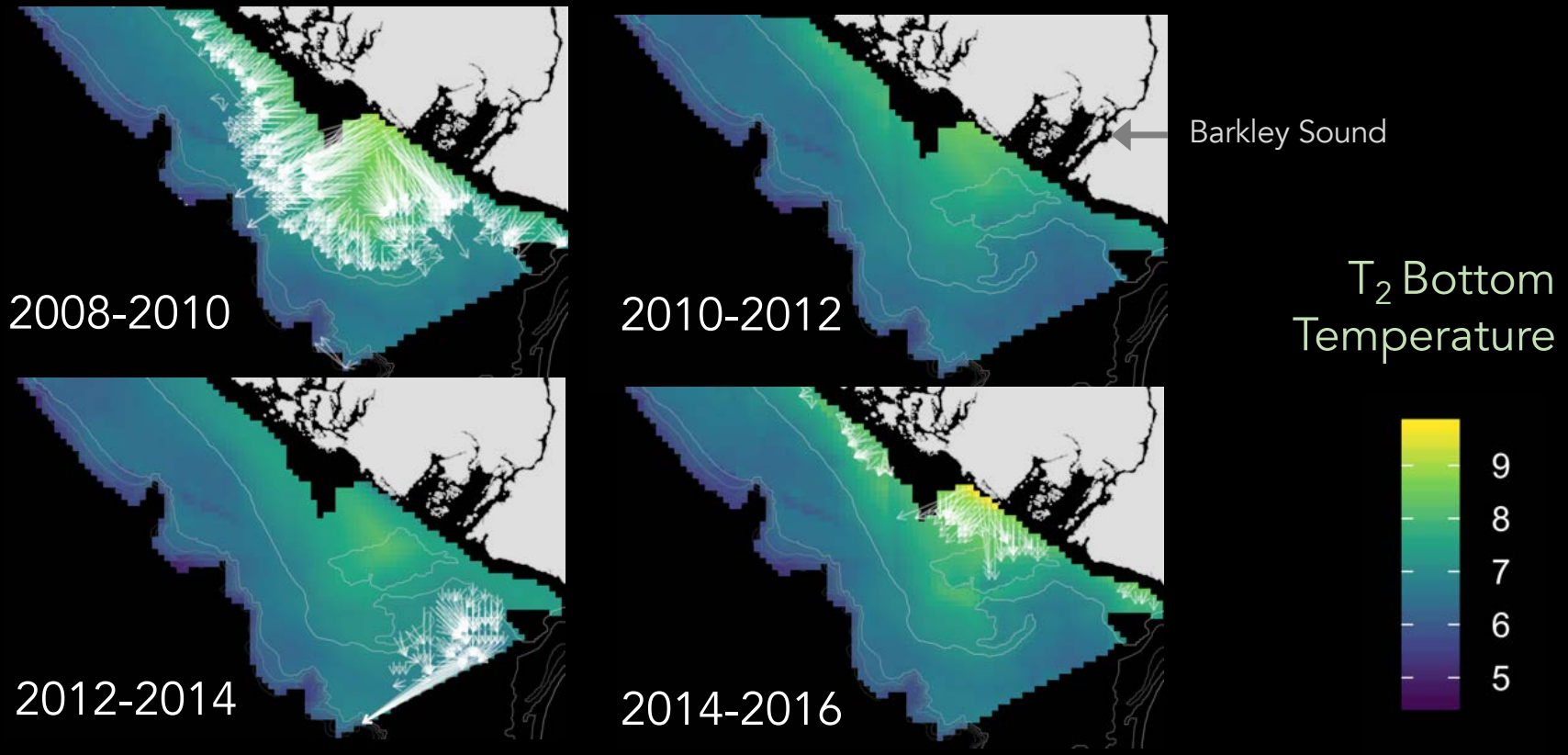


defined asymmetrically
(increase of ≤ 0.5 °C)

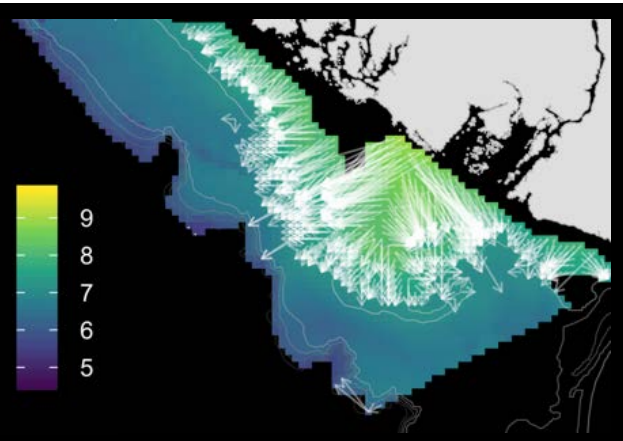
Still must choose a maximum threshold that defines “analogous” climate.


2014-2016
Vectors
represent movement required
between two time periods
to limit increase of < 0.5 °C
T_1 Bottom
Temperature
9
8
7
6
Bathymetry
contours

All 0.5 °C vectors for portion of west coast Vancouver Island



2010 Bottom Temperature



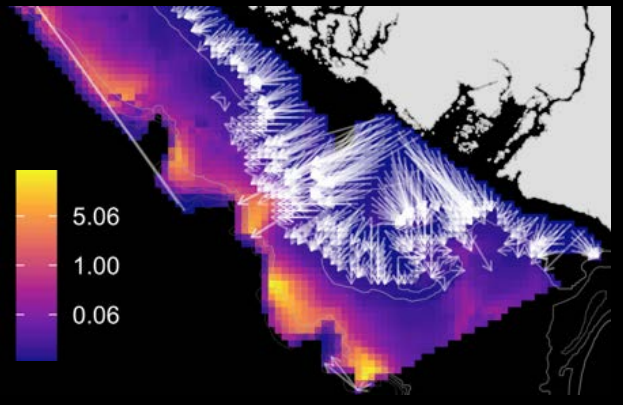
Velocities can be left general

OR

Informed by species characteristics

- limit vector lengths to max dispersal distances
- filter based on species occurrence/abundance
- define analogous climate based on physiological response curves

2008-2010 vectors



2008 Pacific Ocean Perch biomass (kg/ha)

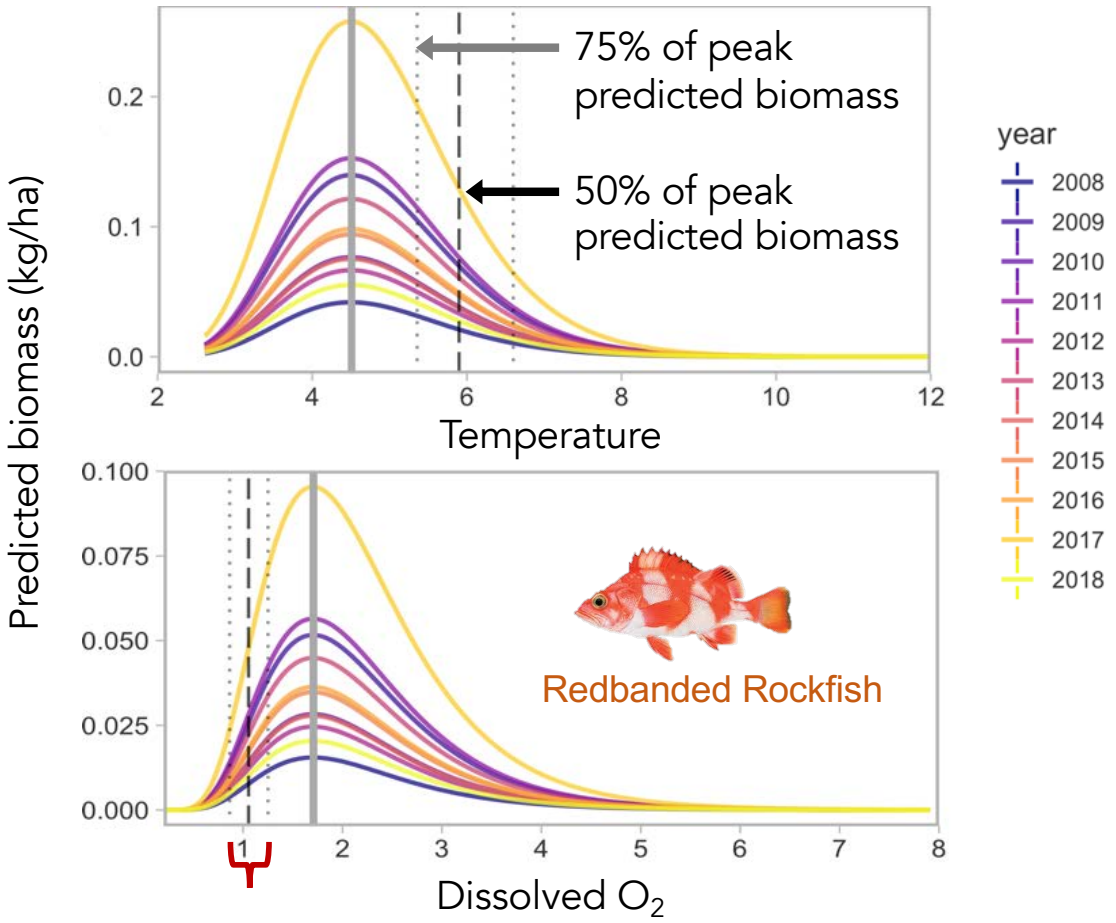
I. Estimate local seafloor climate velocities
II. Predict species-specific sensitivities
III. Contrast fish density change with relevant climate velocities

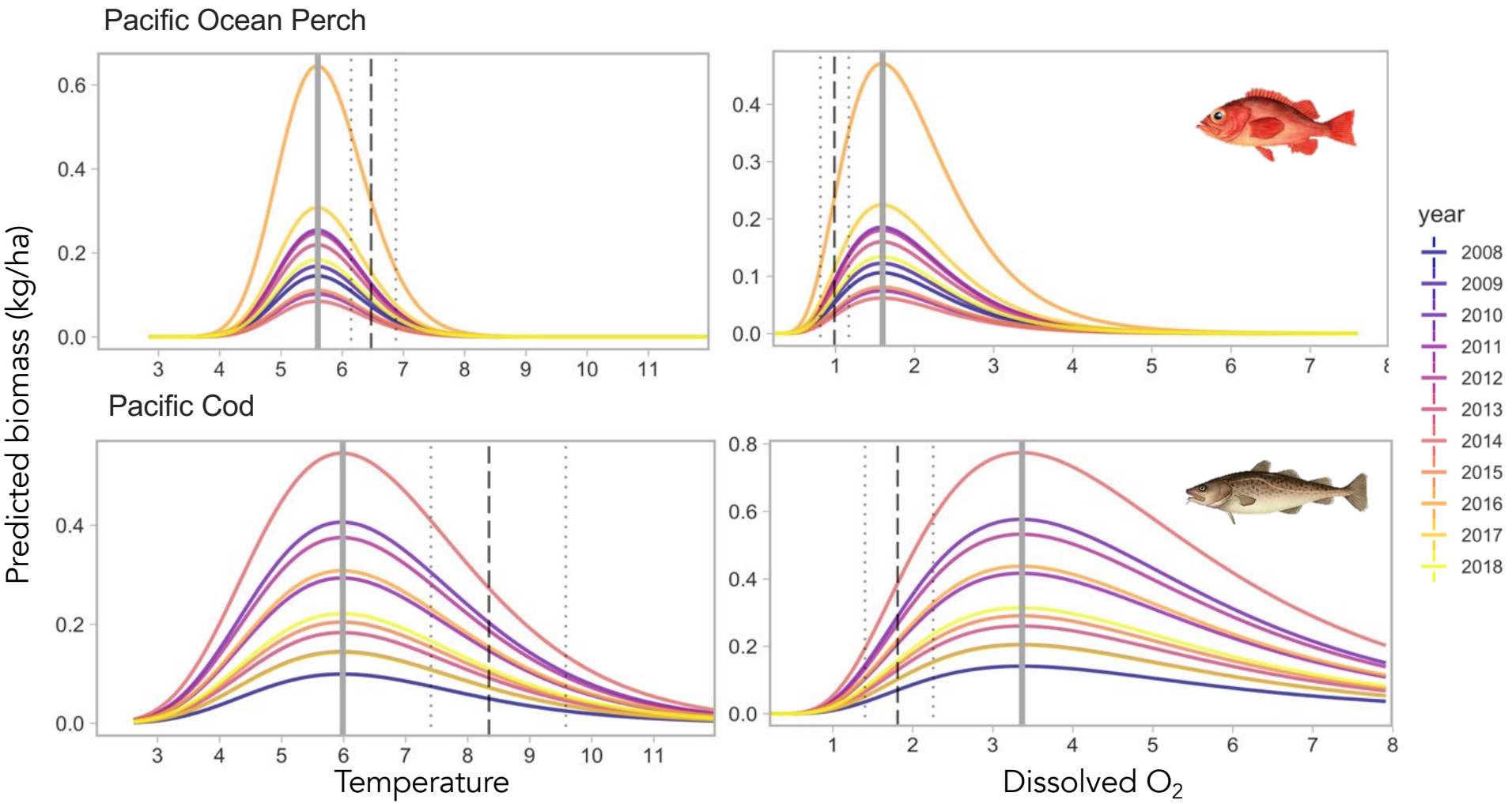
Species-specific sensitivities

We built species distribution models with quadratic effects of temperature, DO and depth

Filter for only vectors crossing 50% threshold

Can also create vectors of change based on breadth of curve
(eg. 75% threshold - 25% threshold)




Pacific Ocean Perch
Pacific Cod
Predicted biomass (kg/ha)
Temperature
Dissolved O_2
year
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

Species-specific vectors

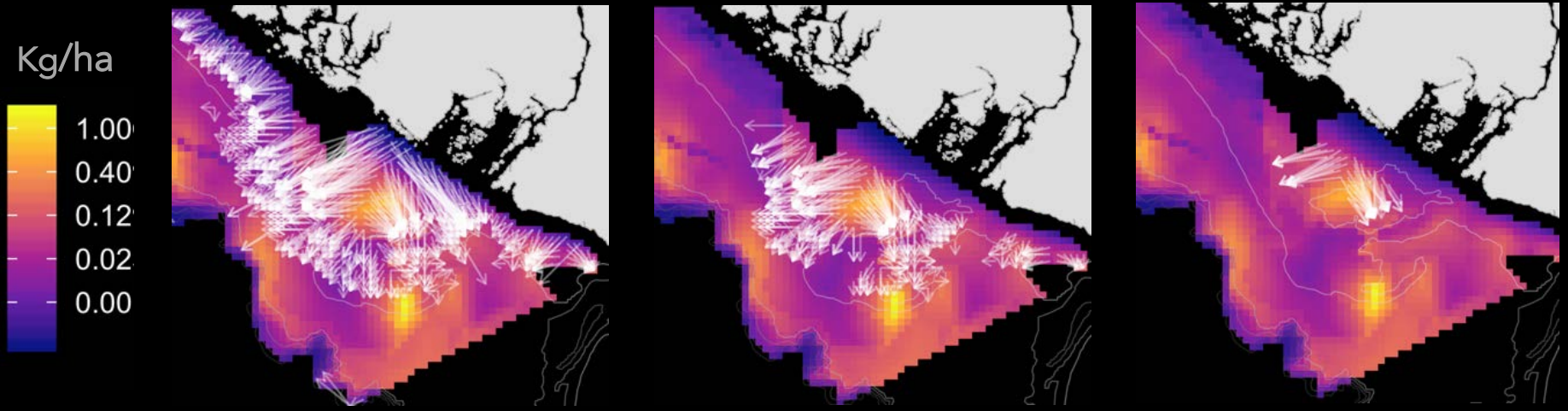
Pacific Cod biomass in 2008 +

vectors illustrate movement that limits temperature increase to < 0.5 °C in 2010

all vectors

vectors accounting for 95% of biomass

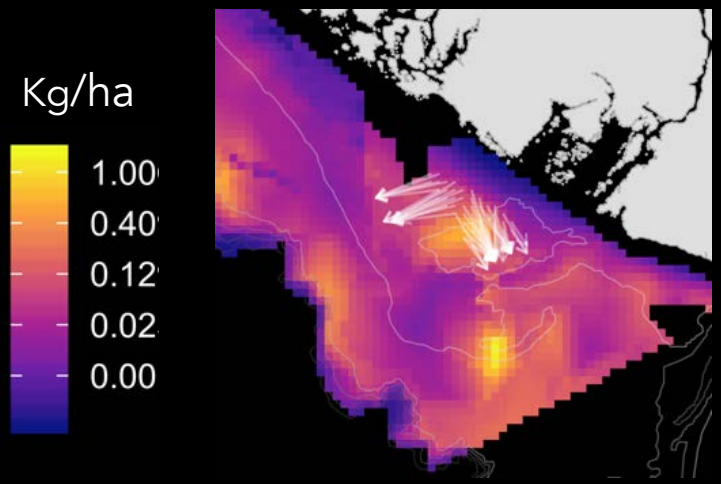
vectors exceeding sensitivity threshold



Species-specific vectors

Pacific Cod biomass in 2008 +

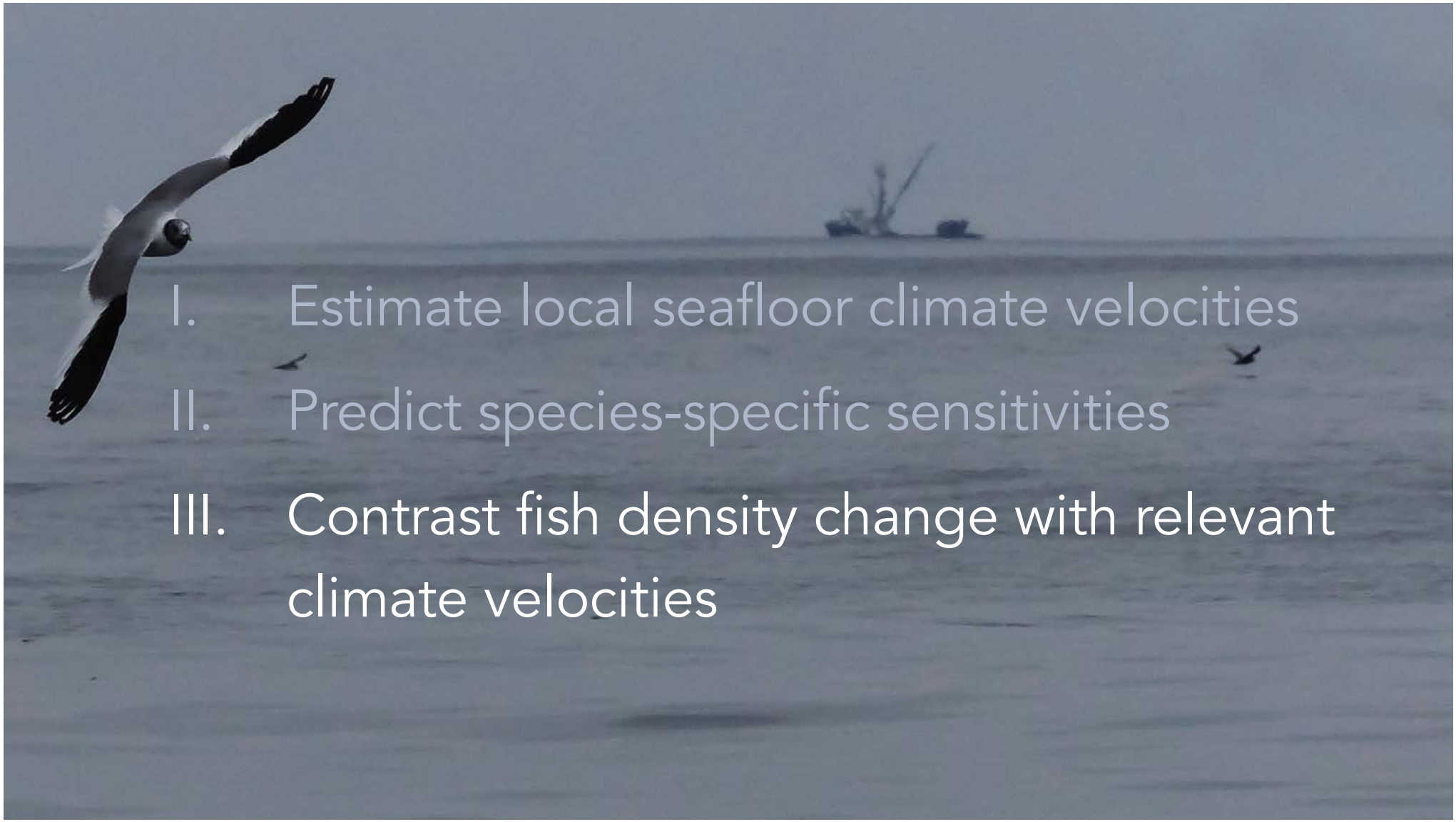
vectors that limit temperature increase to < 0.5 °C in 2010



Climate Pressure Score:

biomass weighted
sum of vector lengths

e.g. Pacific Cod 2010 score = 0.5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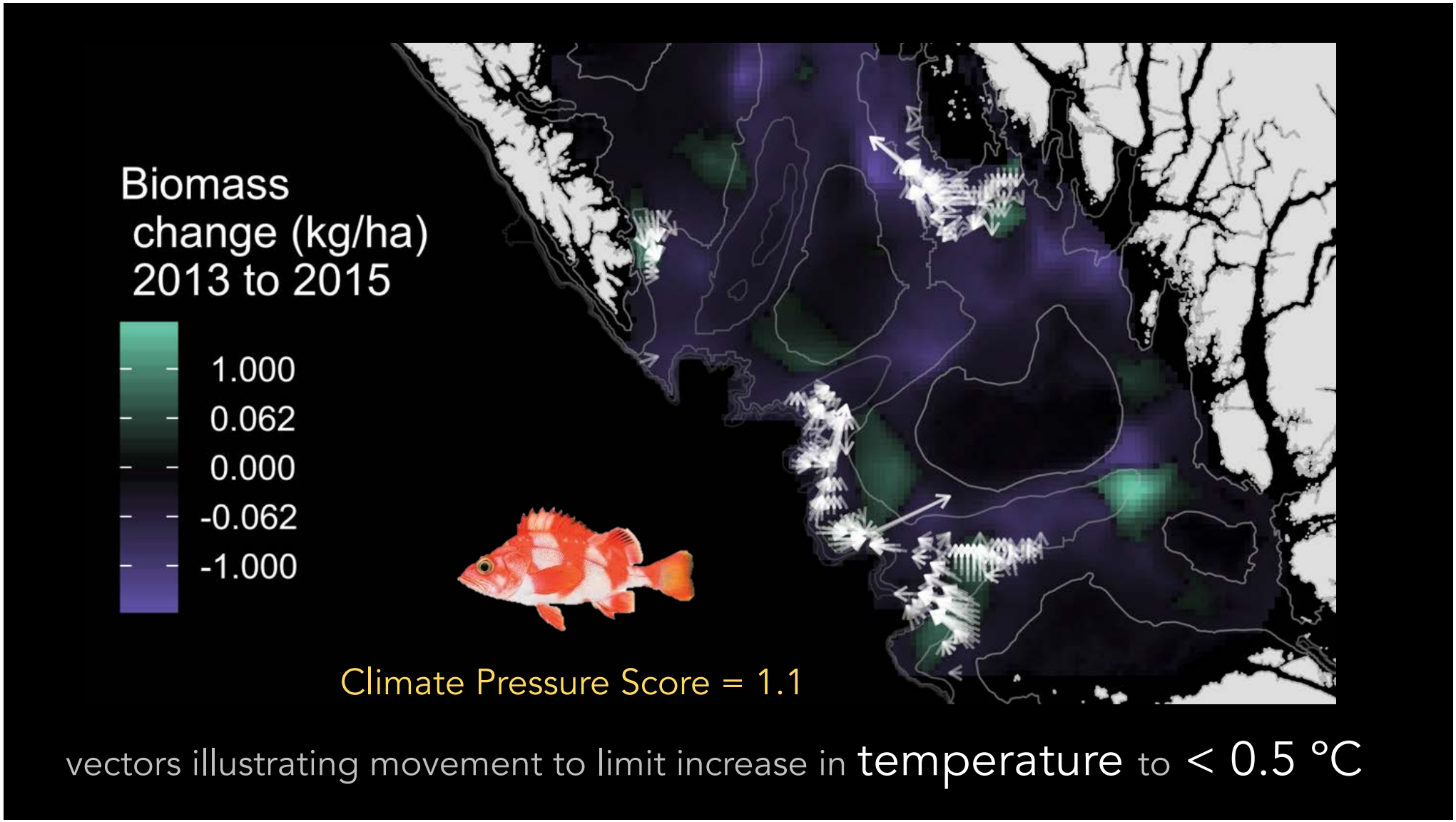
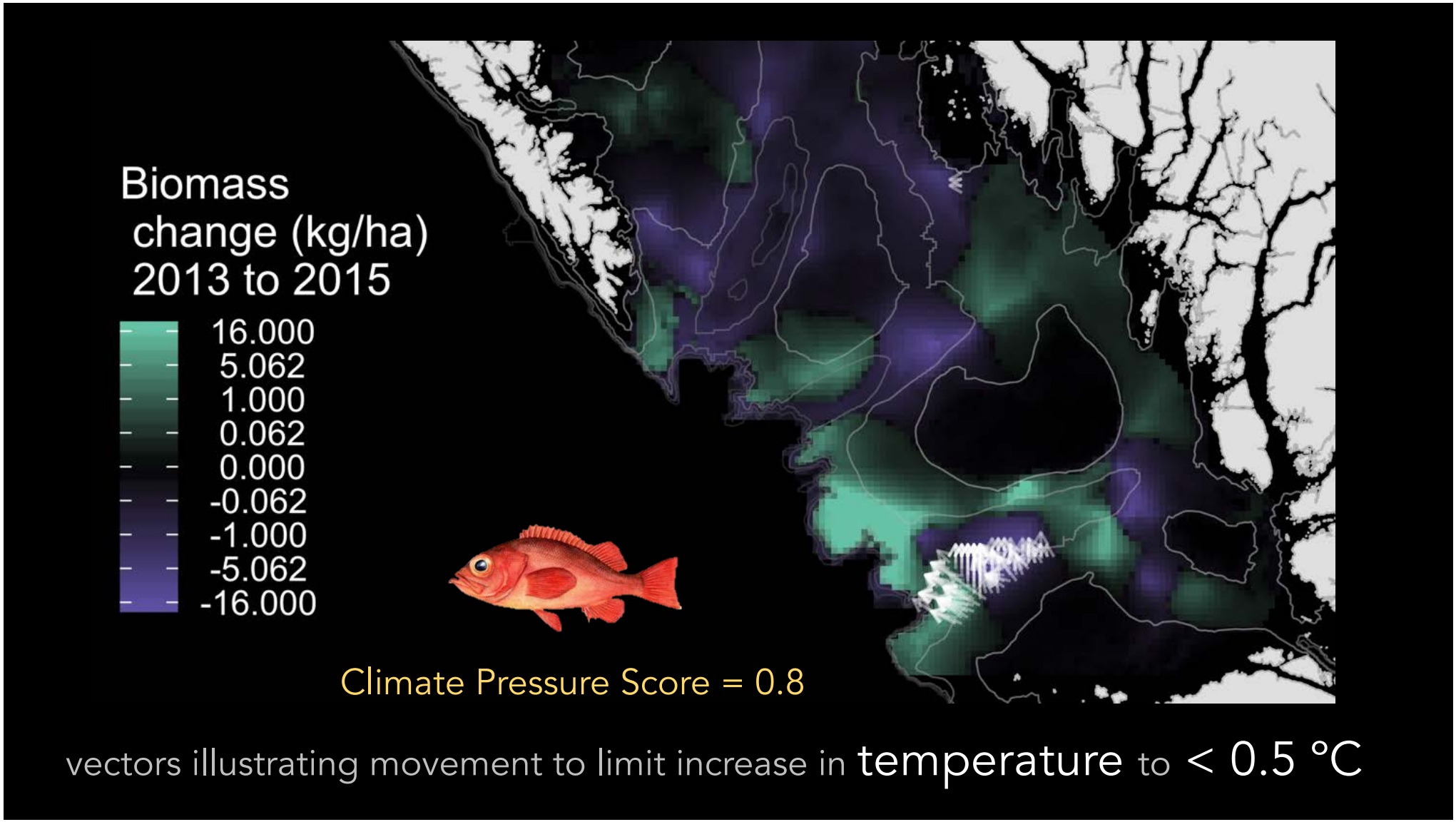
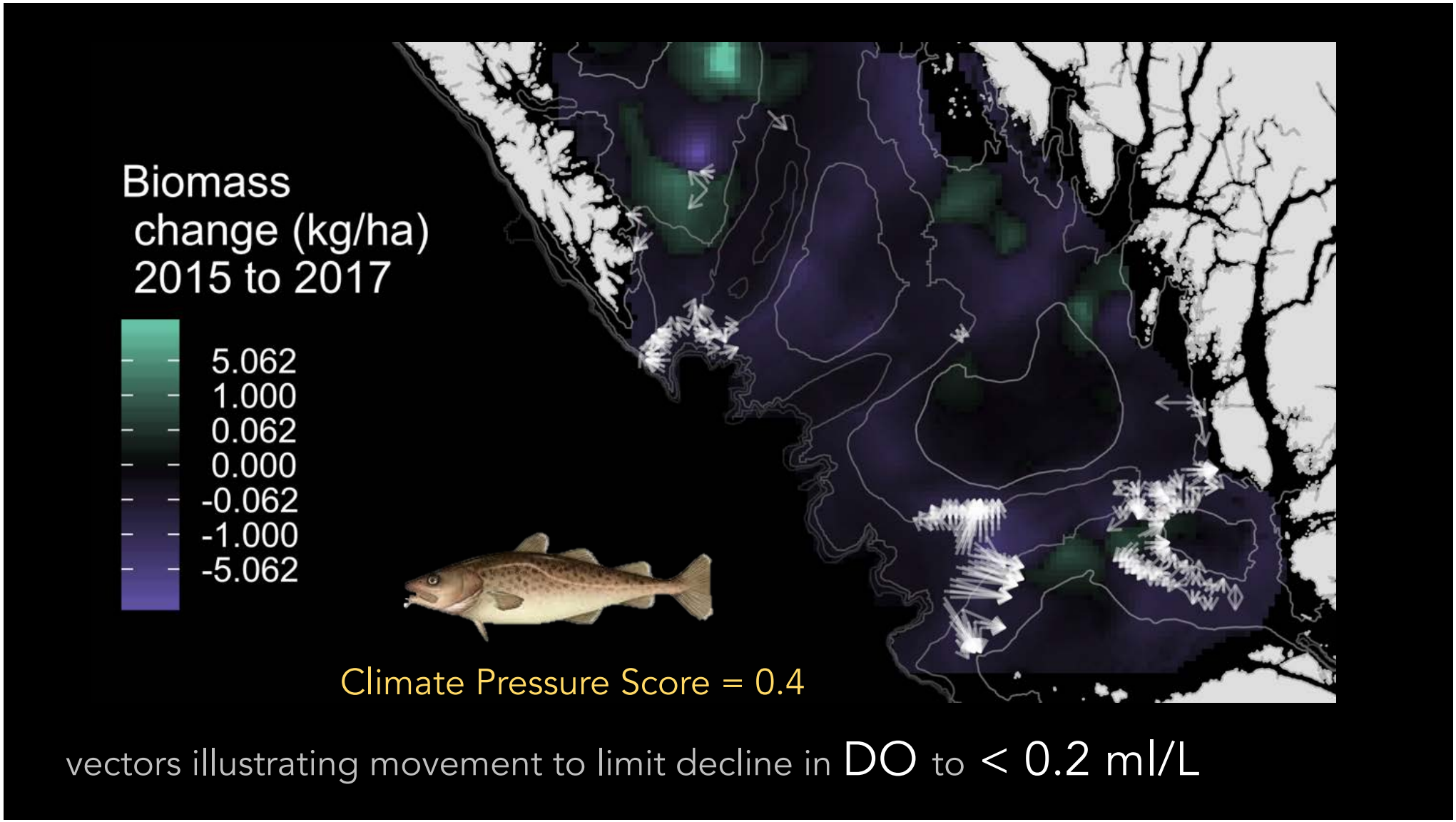
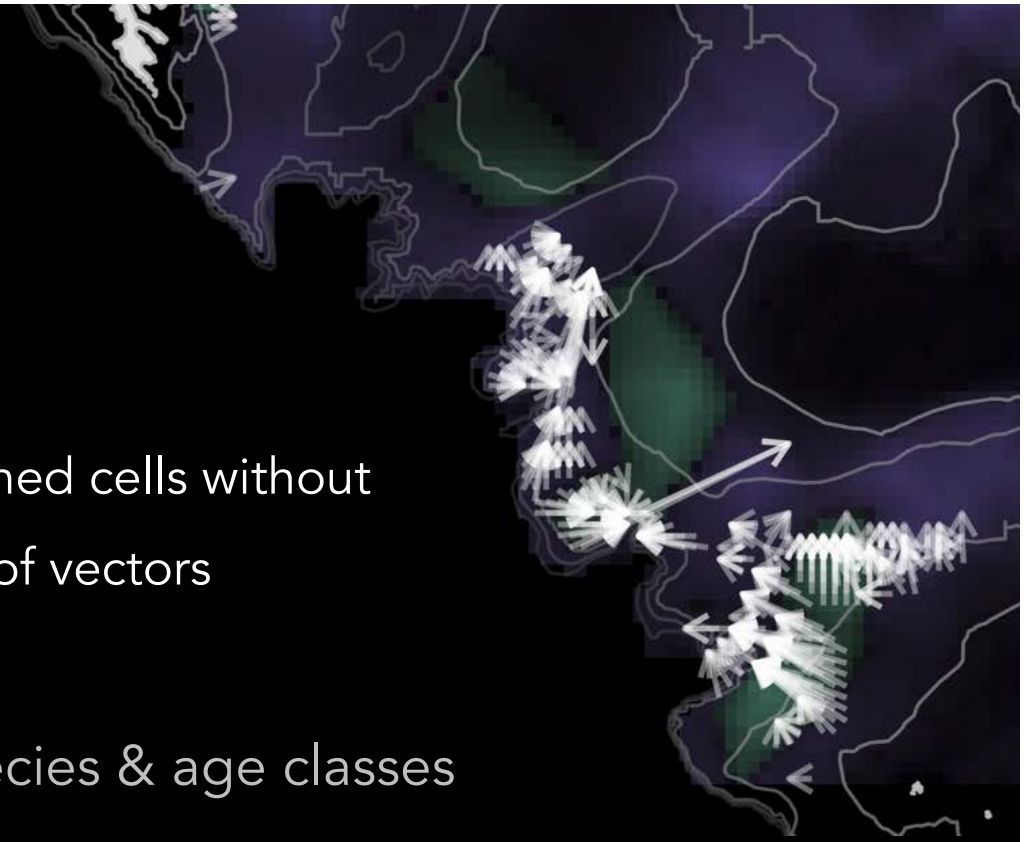

Biomass
change (kg/ha)
2013 to 2015
1.000
0.062
0.000
-0.062
-1.000
Climate Pressure Score = 1.1
vectors illustrating movement to limit increase in temperature to < 0.5 °C


Biomass
change (kg/ha)
2013 to 2015
16.000
5.062
1.000
0.062
0.000
-0.062
-1.000
-5.062
-16.000
Climate Pressure Score = 0.8
vectors illustrating movement to limit increase in temperature to < 0.5 °C



vectors illustrating movement to limit decline in DO to < 0.2 ml/L

Statistical approach…



Biomass change ~

- cells with vectors vs. matched cells without
- cells at the heads vs. tails of vectors

Meta-analysis across years, species & age classes

So far we don’t see consistent patterns… why?

Next steps

Expand temporal scale of climate

- ROMS estimates of seasonal variability

Refine thresholds

- GAMMs, priors, other ideas?
- scale change threshold to response curve breadth

Many hands!

Thank you!
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