



NOAA
FISHERIES

Perspectives on ways complex ecosystem projections can be applied in real-world fisheries management cases

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Early observations...





Fishery data

- Size/biology
- Catch distn
- CPUE
- Fleet dispersion



Survey Results

- Size-age, biological
- Biomass trends
- Species distn
- Environmental characteristics

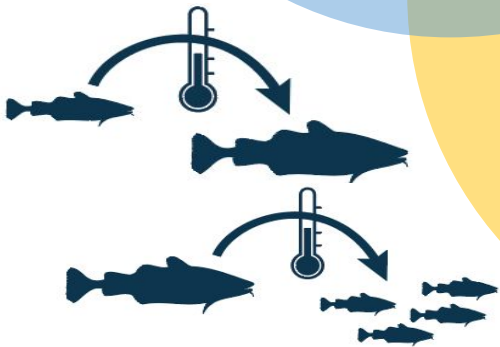
Model and Mgt advice

- Selectivity
- SRR
- Mgt quantities
 - B_{MSY}
 - F_{MSY}

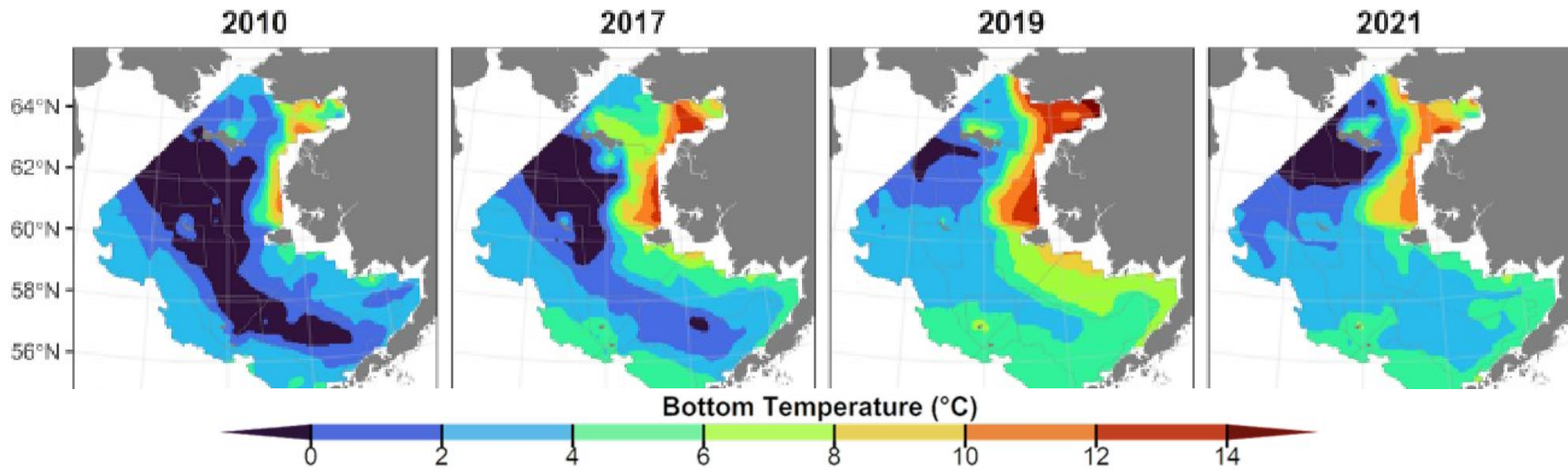


ACLIM products

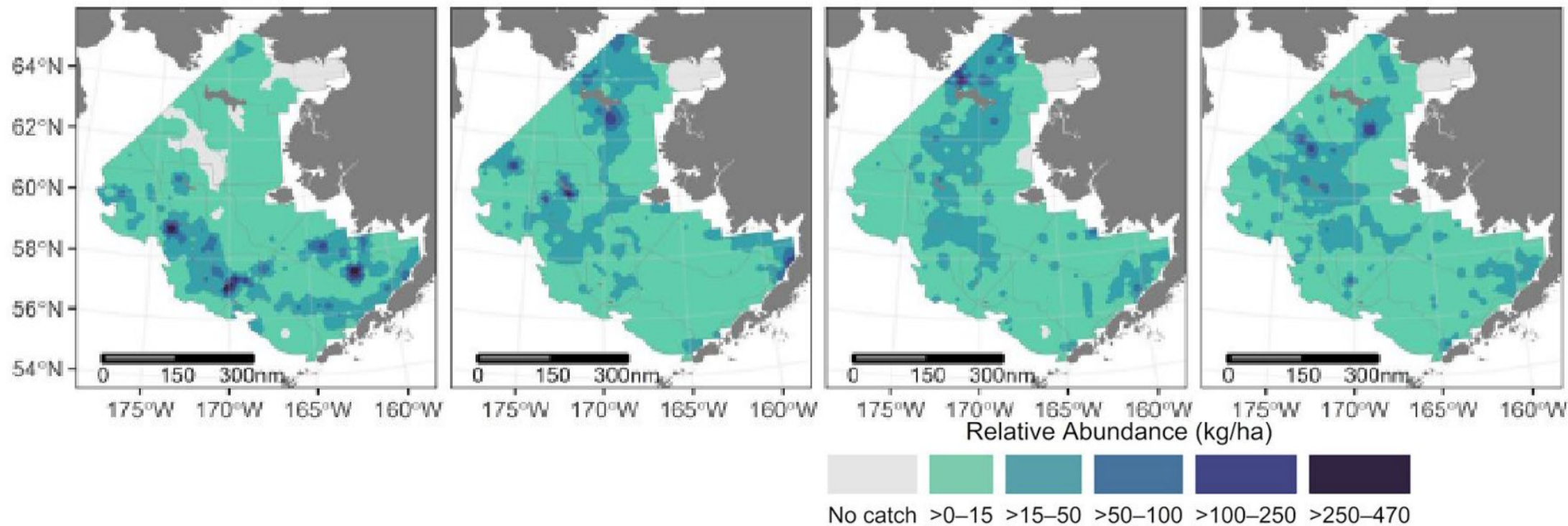
- Hindcast
- GCM scenarios
- Downscaled regional projections



Bottom Temperature



Pacific cod Density

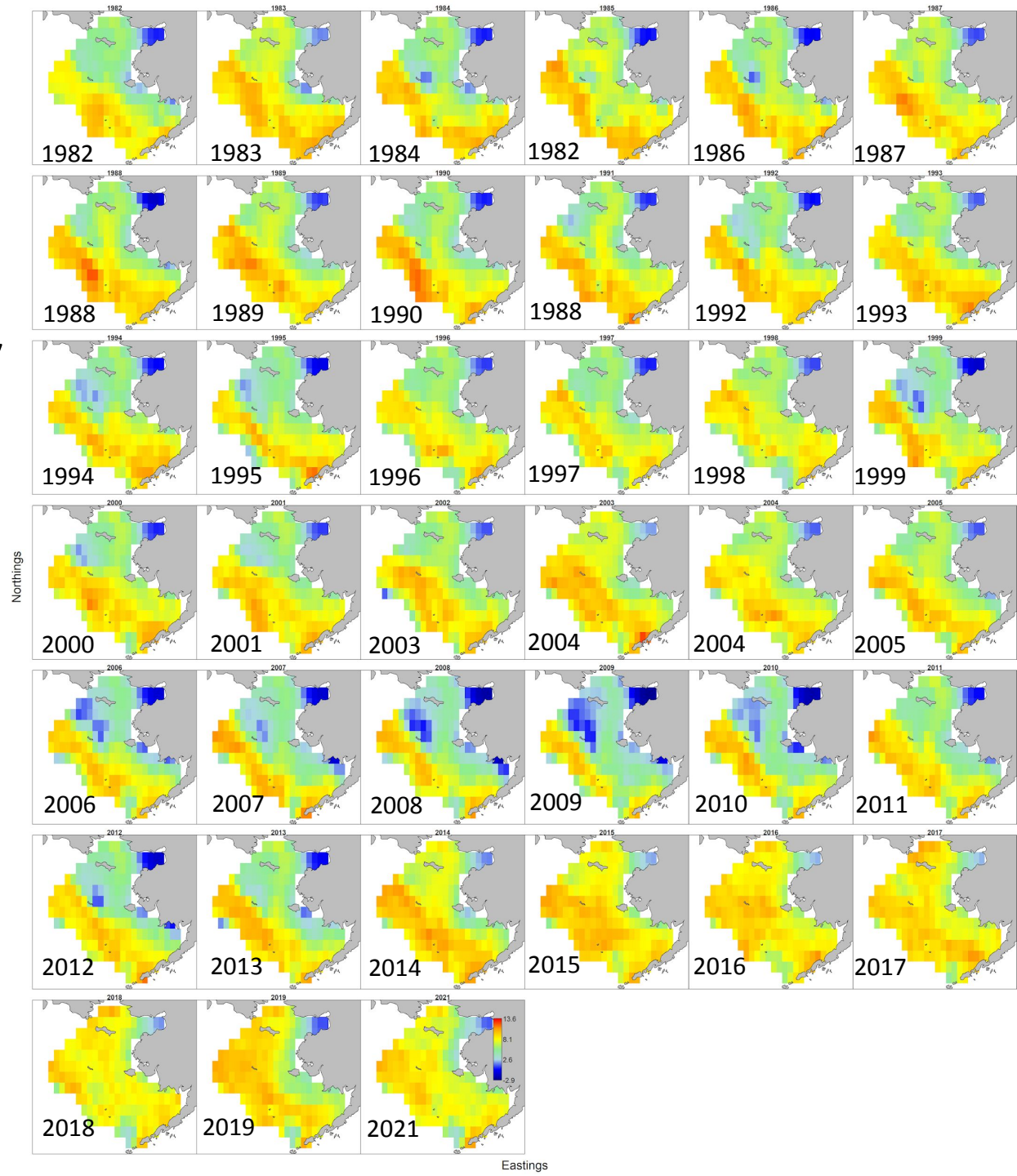
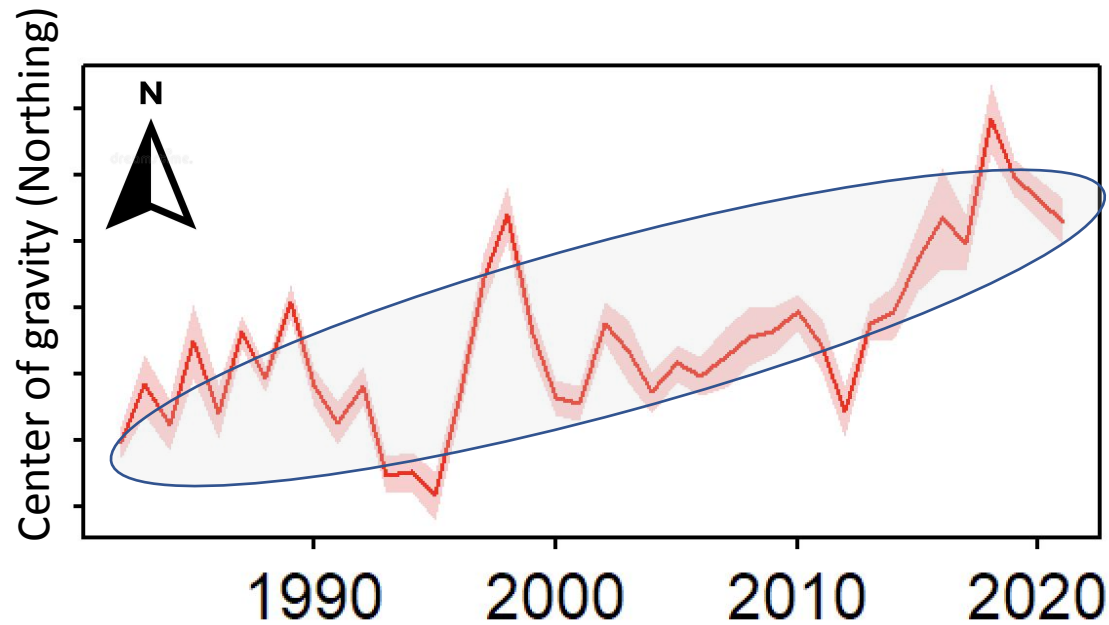


Pacific cod appear to be spatially structured
by bottom temperature

to some degree...what about pollock?

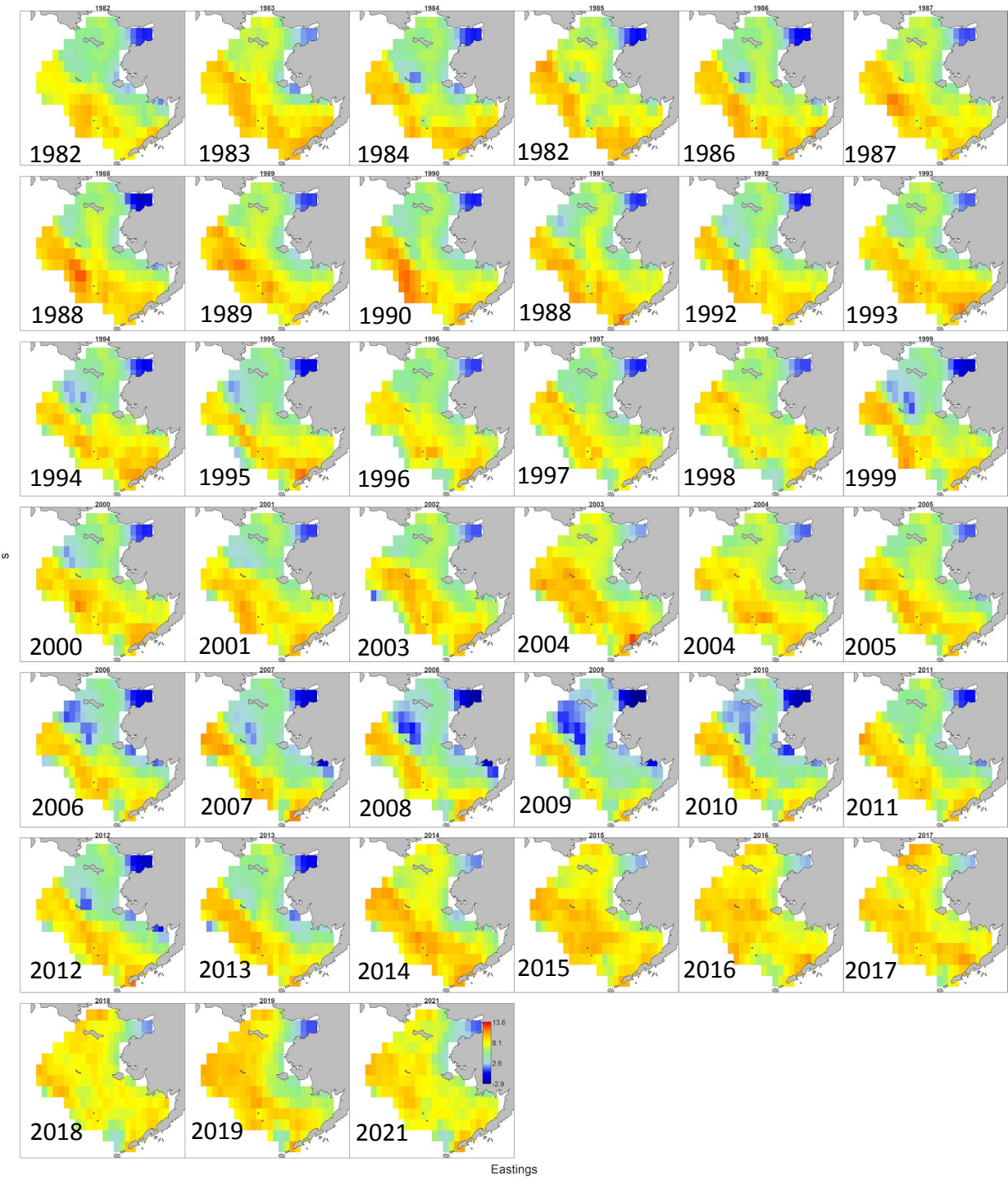
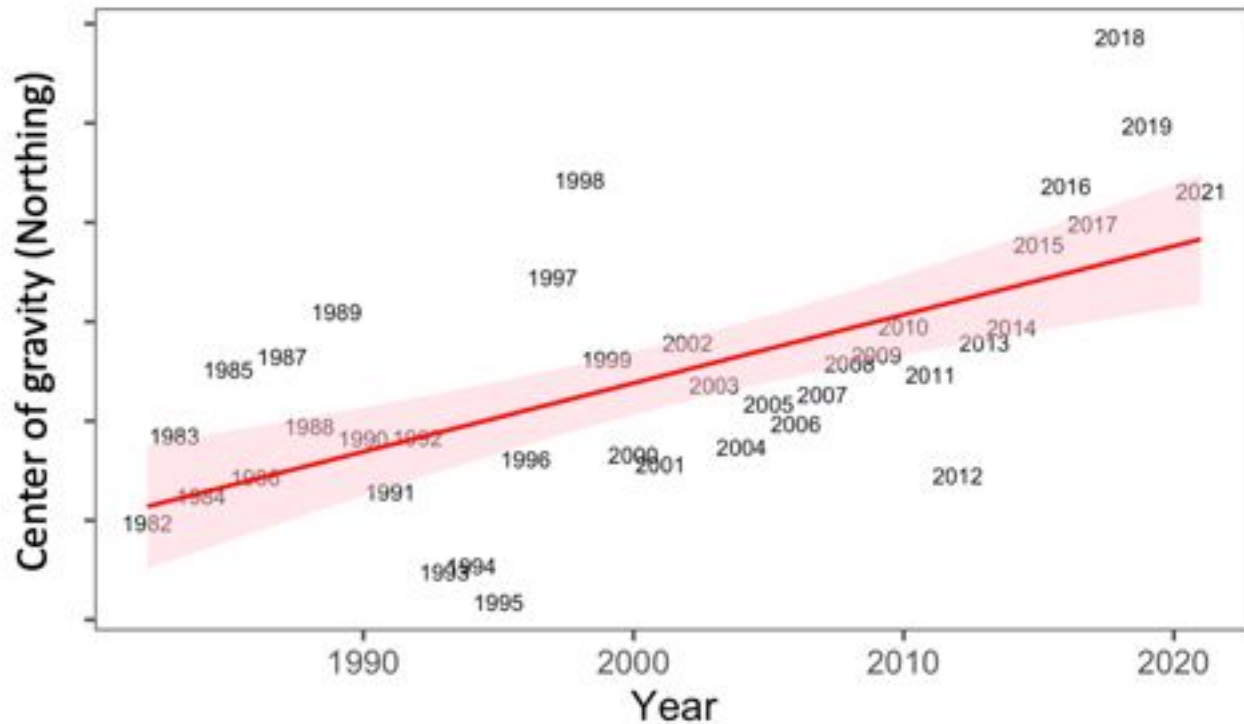
Shifts in pollock distribution

- NMFS summer bottom trawl survey
- Fishery INDEPENDENT
- VAST model estimates

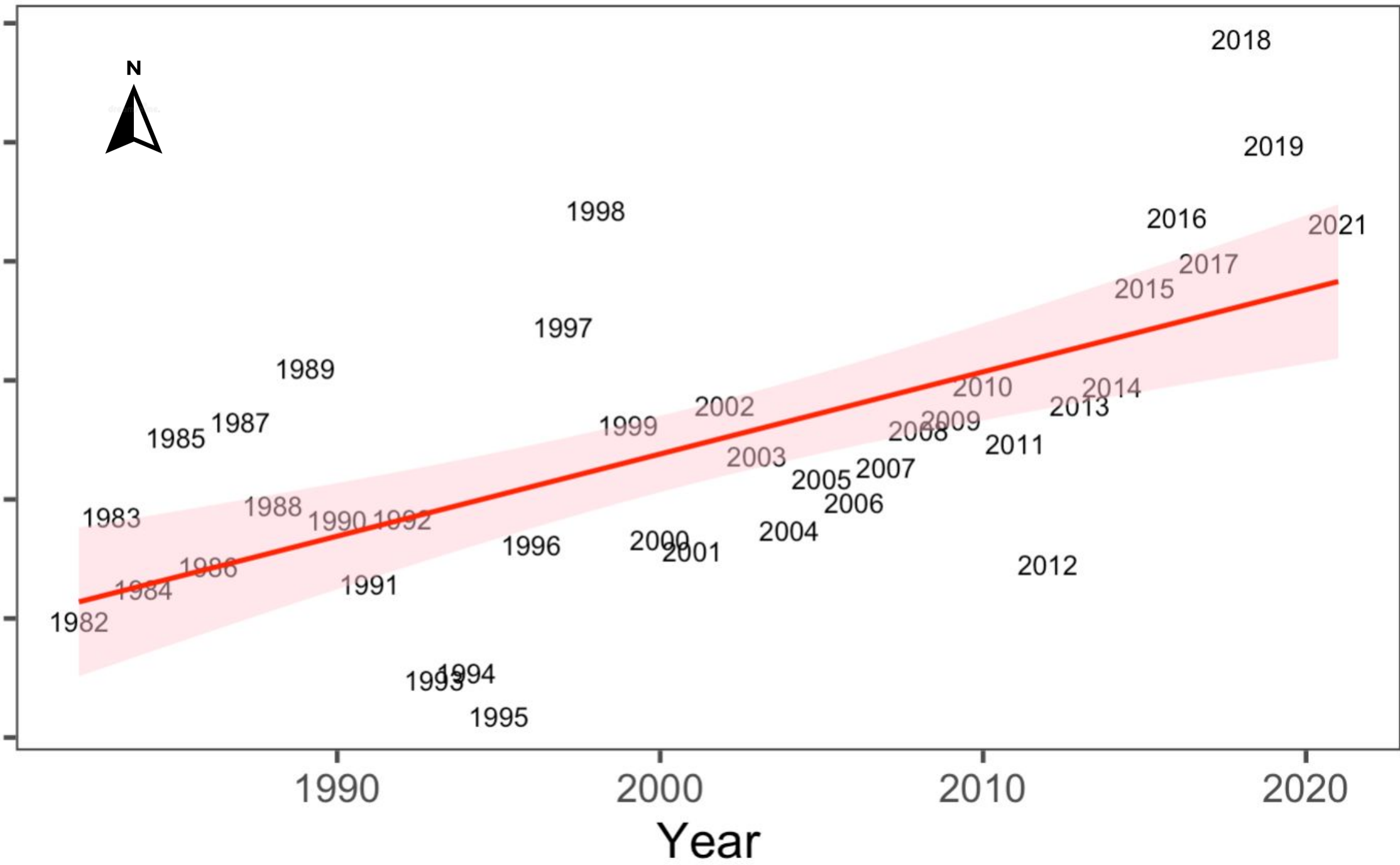


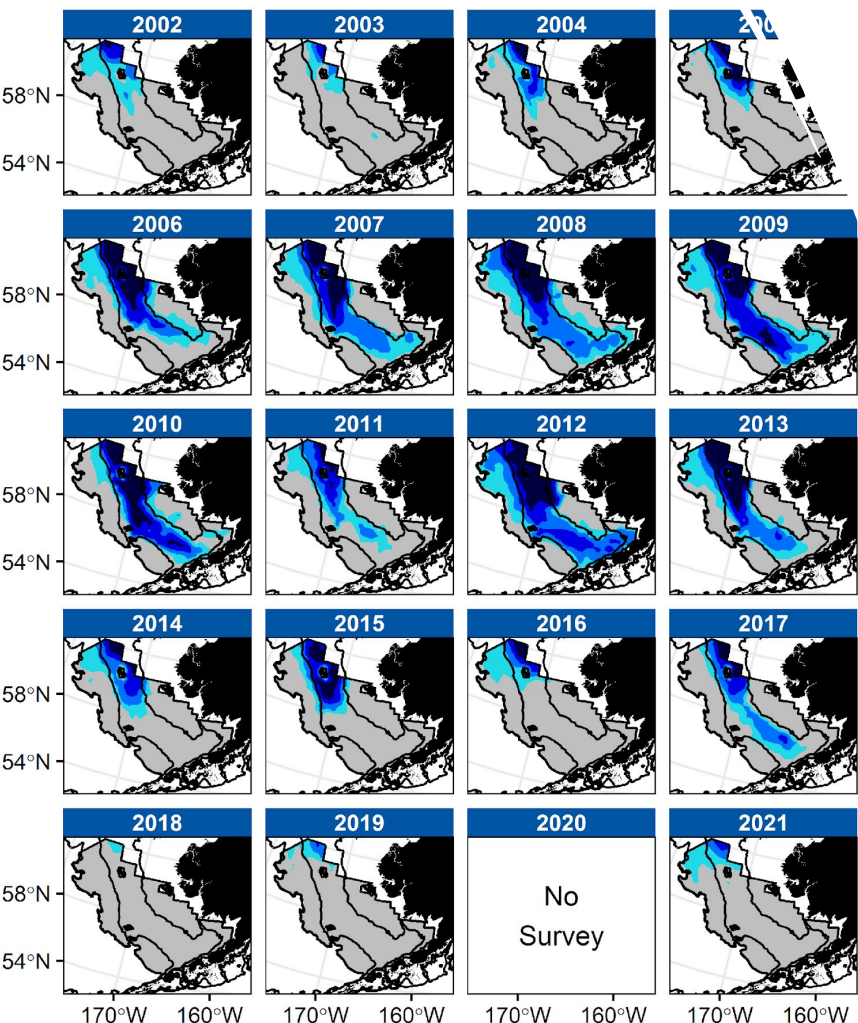
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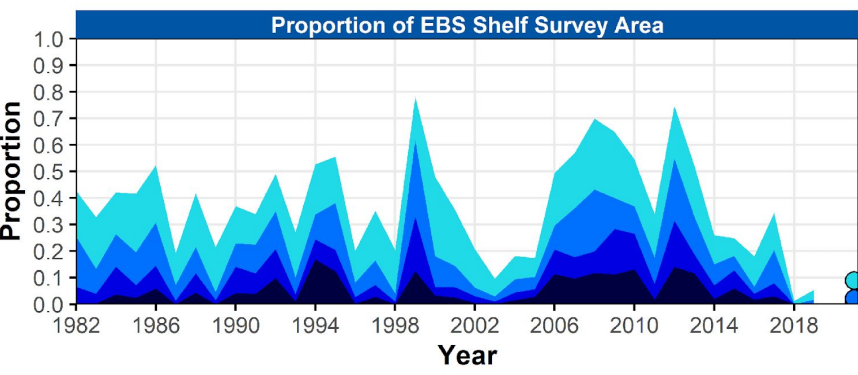
Center of gravity (Northing)





Another survey product: Bottom Temperature

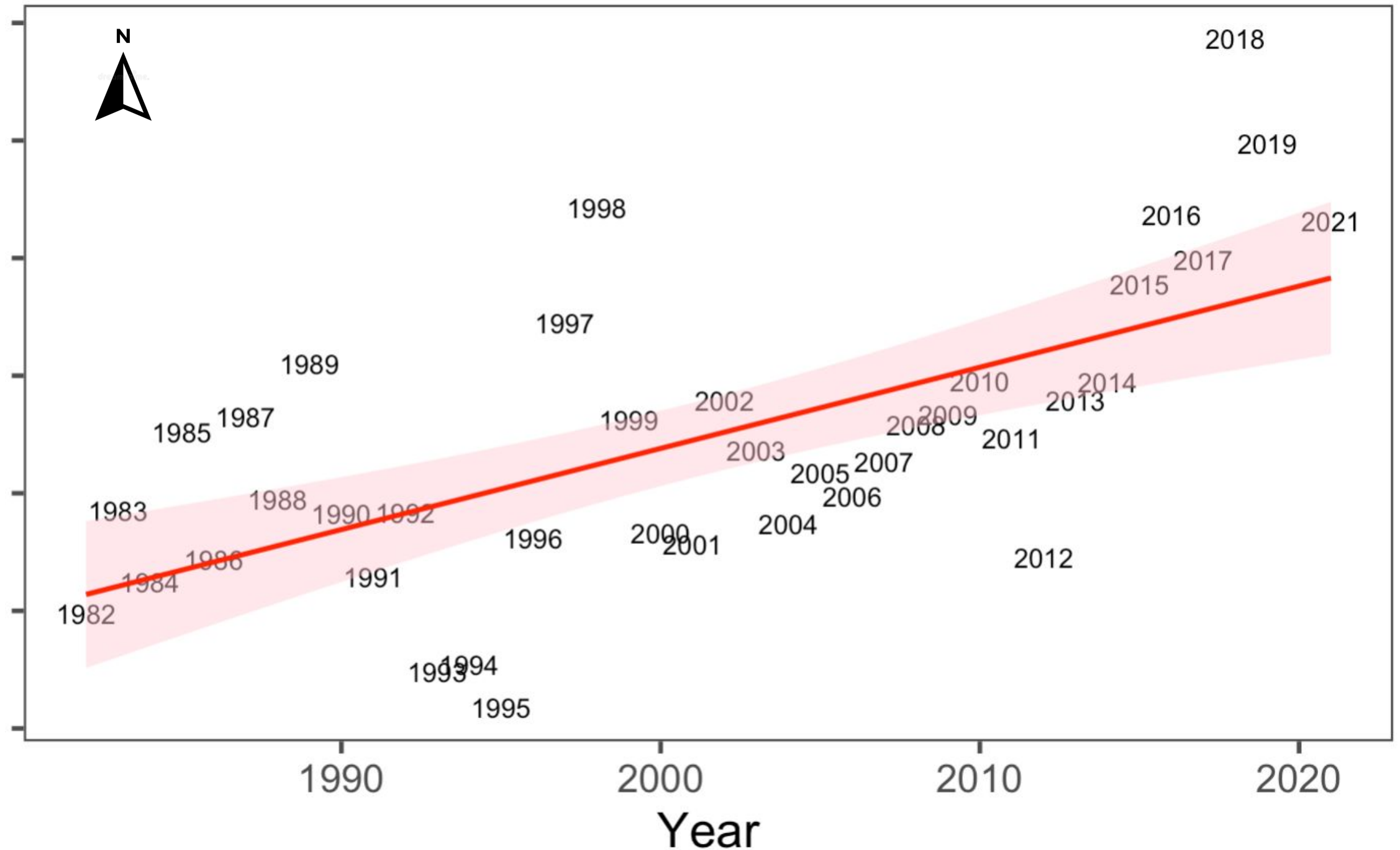
Bo.
Tem.



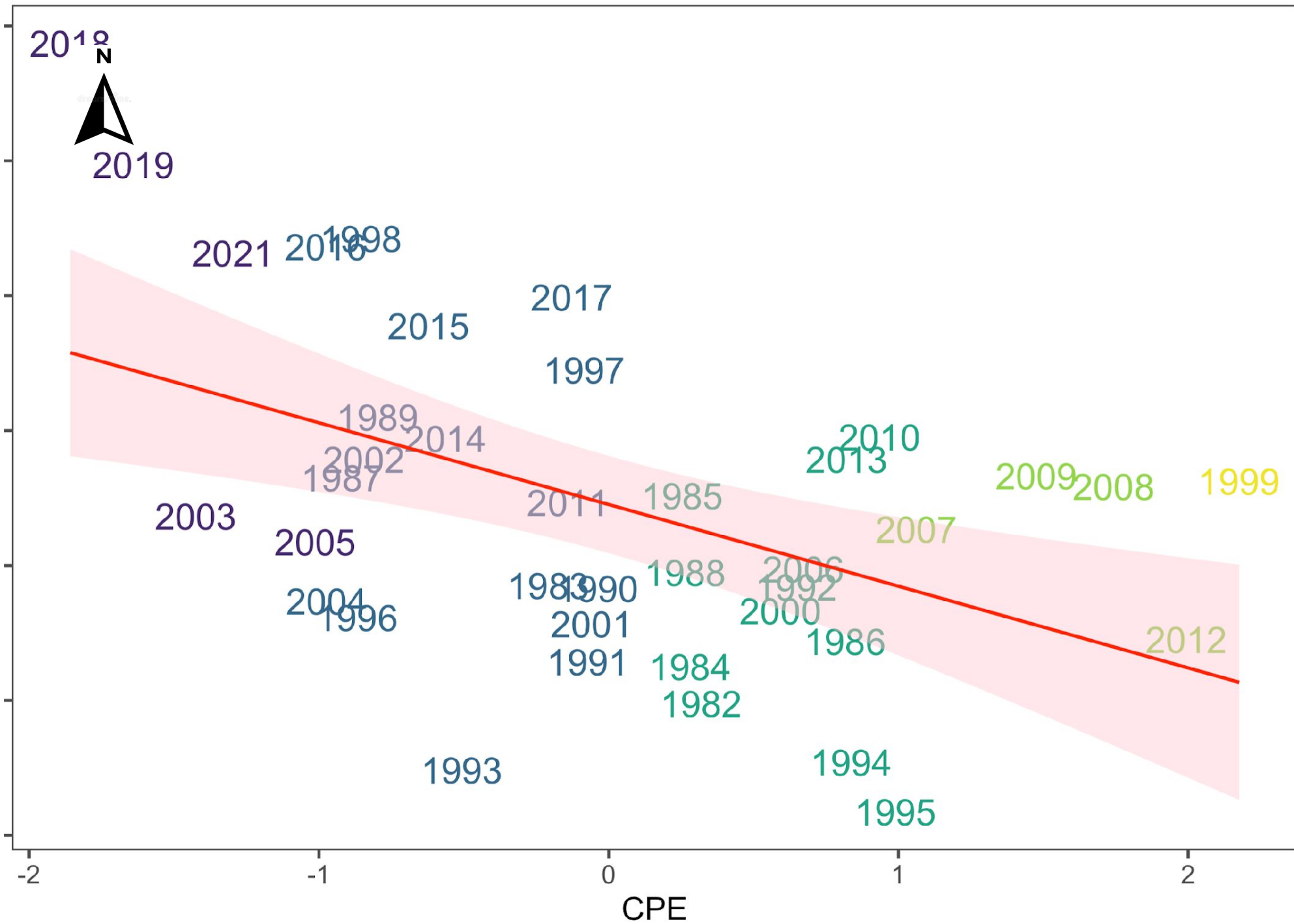
```
df_cpe <- coldpool:::cold_pool_index |>
dplyr::select(year=YEAR,CPE=AREA_LTE2_KM2)
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Sean Rohan and Lewis Barnett R package
<https://github.com/afsc-gap-products/coldpool>

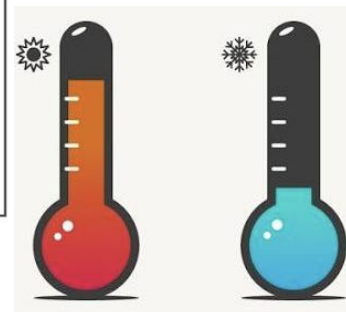
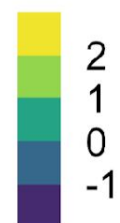
Center of gravity (Northing)



Center of gravity (Northing)

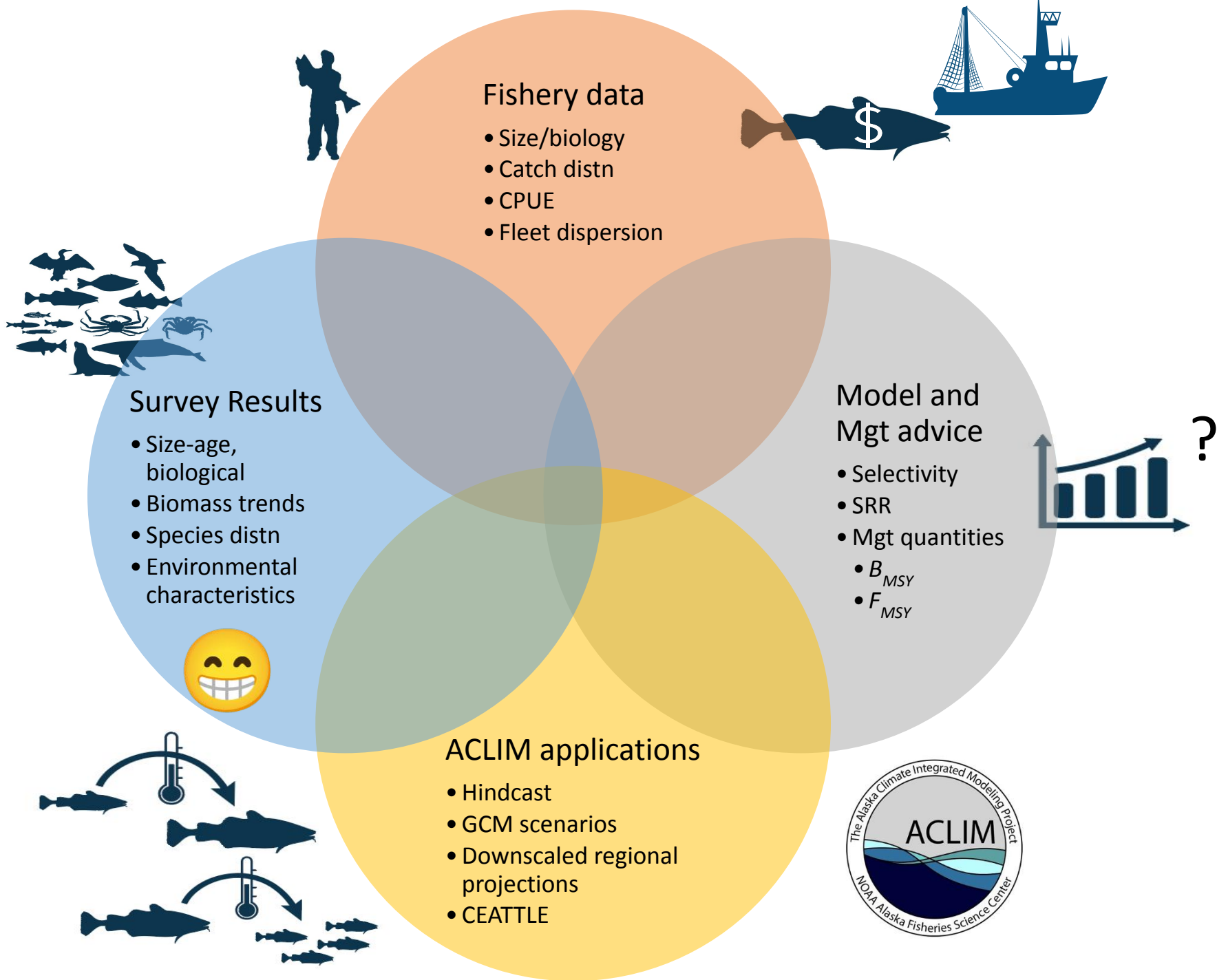


CPE



Yes, groundfish distribution appears to be affected by temperature
at least for pollock and cod

And driver likely the cold-pool extent (CPE)



What is the Alaska Climate Integrated Modeling Project?



Operational suite of coupled socio-ecological models for climate fisheries hindcasts, forecasts, projections and Management Strategy Evaluation

www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project



**NOAA
FISHERIES**



Global Climate Models (x 7)

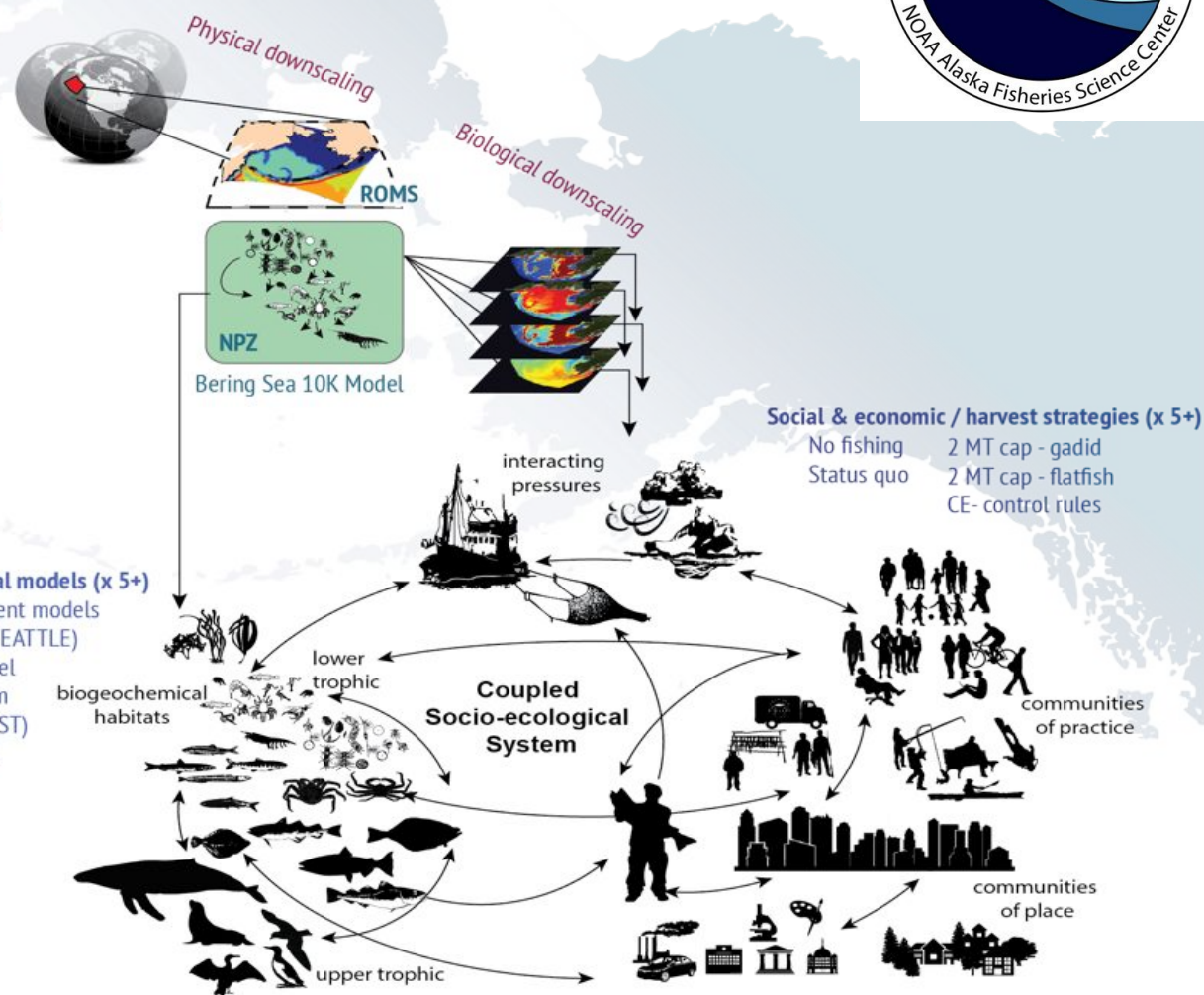
- ECHO-G
- MIROC3.2 med res.
- CGCM3-t47
- CCSM4-NCAR-PO
- MIROCESM-C-PO
- GFDL-ESM2M*-PO
- GFDL-ESM2M*-PON

Projection Scenarios (x3)

- AR4 A1B
- AR5 RCP 4.5
- AR5 RCP 8.5

Climate Enhanced Biological models (x 5+)

- CE- single-spp assessment models
- CE- multi-spp model (CEATTLE)
- CE- Size spectrum model
- CE- Ecopath with Ecosim
- End-to-End model (FEAST)
- CE- spatial MICE model
- CE- IBM (crab)





Example:

Bottom temperature output from Global Model vs. Regional Model (higher resolution)

CFSR/CFSv2-Op.Anal. (July 1)



Bering 10K (July 1)



Global Climate Models

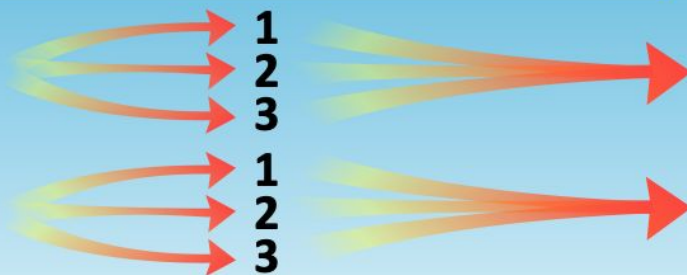
Regional Model

Projected Carbon Emissions



No Mitigation

Some Mitigation



Produces **high res** projections for "cold pool," bottom temperature, and zooplankton abundance under each of 6 future regional climate scenarios fed into 3 multi-species models



Socio-economic Model

Adjusted Fishing Mortality

Target Fishing Mortality

Acceptable Biological Catch

EBFM
Total Allowable Catch

Catch

Harvest Control Rule Cap

Catch

No effect of 2 m MT CAP

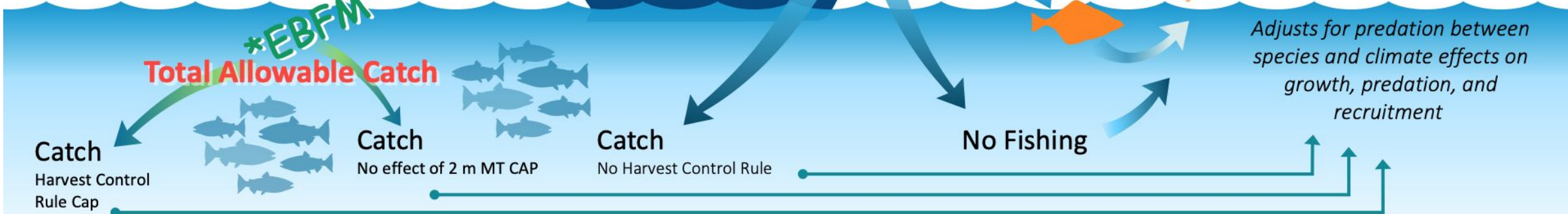
Catch

No Harvest Control Rule

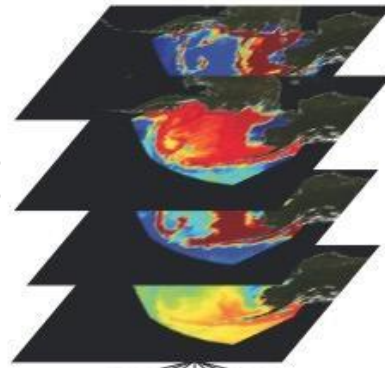
No Fishing

Climate Enhanced Fisheries and Food Web Models

Adjusts for predation between species and climate effects on growth, predation, and recruitment



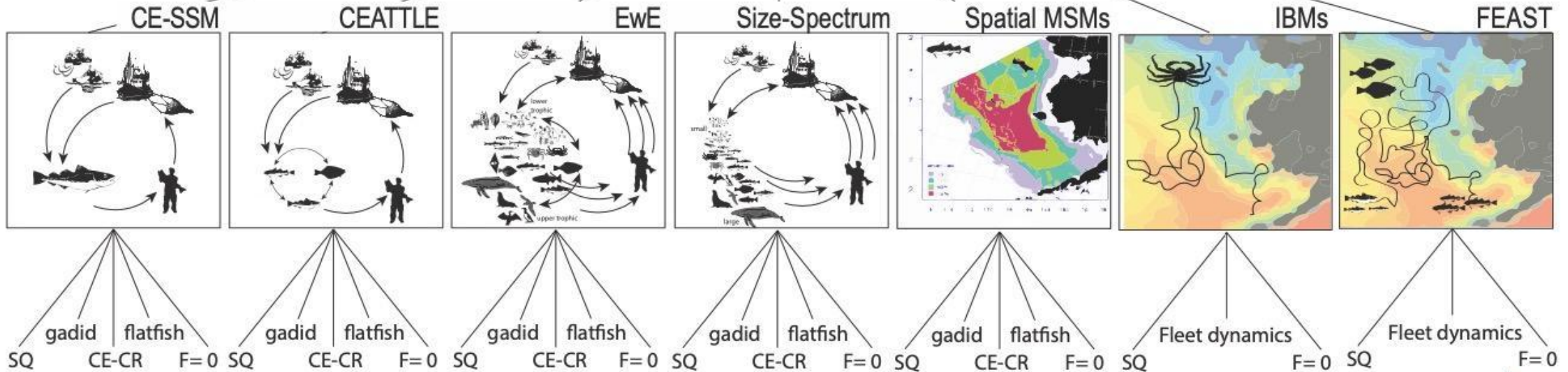
The Alaska Climate Integrated Modeling Project



Downscaled hindcast/projections:

- CORE-CFSR Hindcast (1960-2017)
- ECHO-G (AR4 A1B)
- MIROC3.2 med res. (AR4 A1B)
- CGCM3-t47 (AR4 A1B)
- CCSM4-NCAR- PO (AR5 RCP 4.5 & 8.5)
- CCSM4-NCAR- PON (AR5 RCP 8.5)
- MIROCESM-C- PO (AR5 RCP 4.5 & 8.5)
- GFDL-ESM2M*- PO (AR5 RCP 4.5 & 8.5)
- GFDL-ESM2M*- PON (AR5 RCP 8.5)

Bering Sea Models



explicit drivers of population variability (climate & food-web); high computational demand

implicit drivers of population variability (random error); low computational demand & multiple iterations

Climate scenarios

RCP 4.5

RCP 8.5

Earth system models

CESM

GFDL

MIROC

Whitehouse et al. 2021

Front. Mar. Sci., 03 February 2021
Sec. Marine Fisheries, Aquaculture and
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<https://doi.org/10.3389/fmars.2021.624301>

This article is part of the Research Topic
Using Ecological Models to Support and Shape Environmental Policy Decisions
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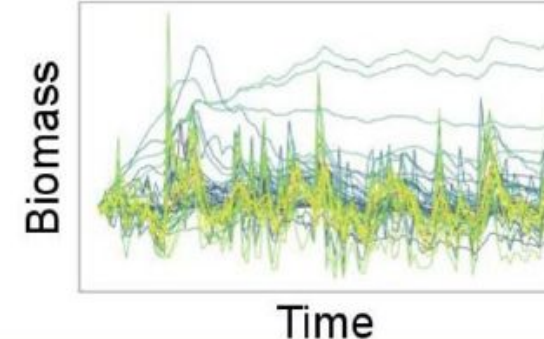
Bottom–Up Impacts of Forecasted Climate Change on the Eastern Bering Sea Food Web

George A. Whitehouse^{1,2,3*}, Kerim Y. Aydin², Anne B. Hollowed², Kirstin K. Holsman²,
Wei Cheng^{1,4}, Amanda Faig³, Alan C. Haynie², Albert J. Hermann^{1,4}, Kelly A. Kearney^{1,2},
André E. Punt³ and Timothy E. Essington³

Fisheries scenarios

1. Status quo
2. Gadid preference
3. Flatfish preference
4. No Fishing

Food web model



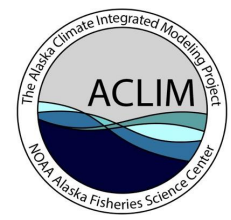
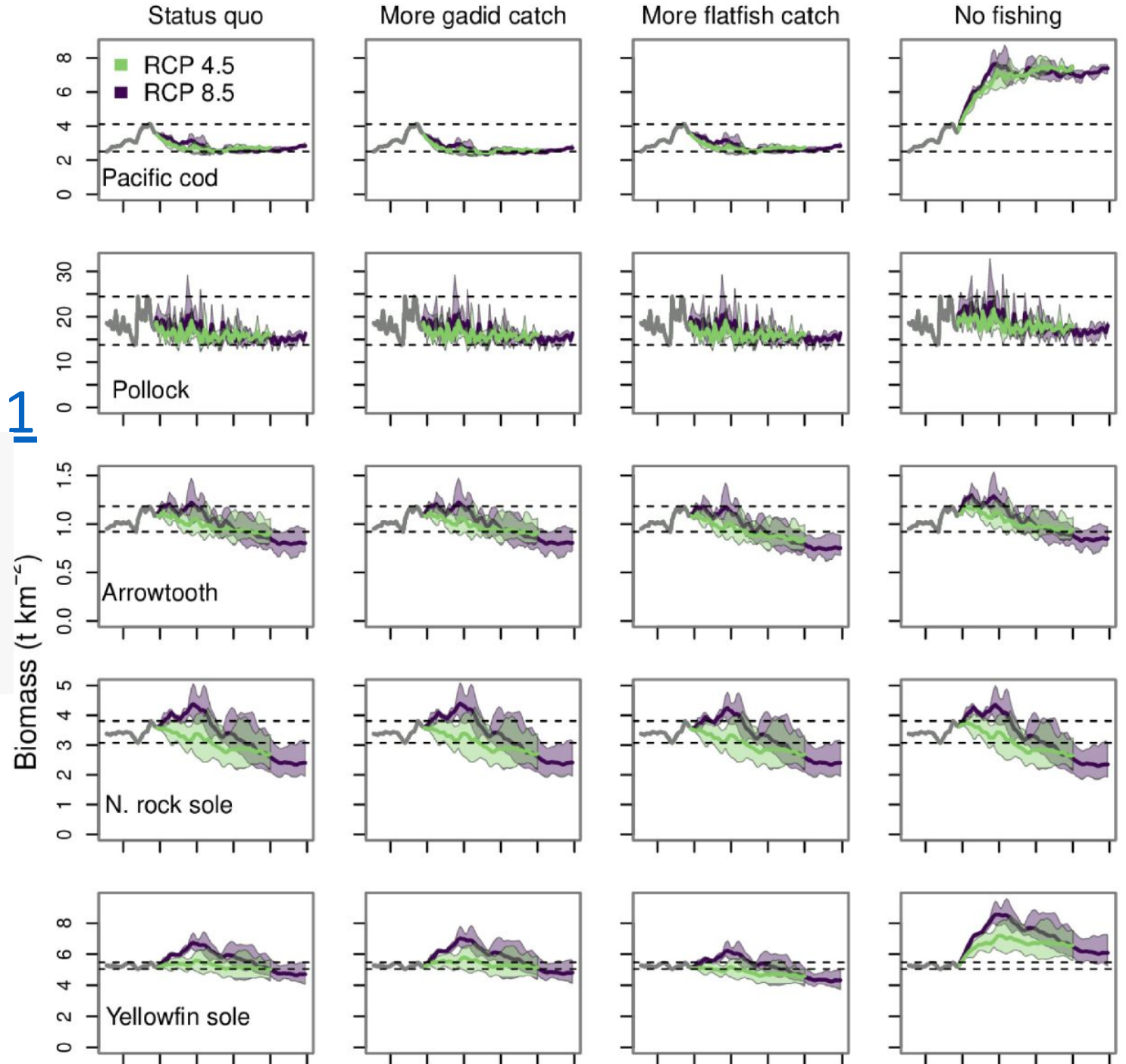
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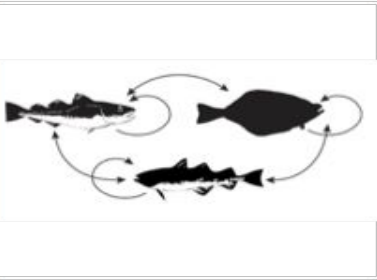


CEATTLE (Eastern Bering Sea)



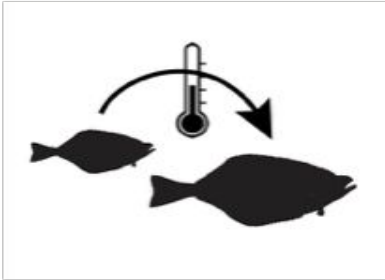
Kirstin Holsman

Mortality



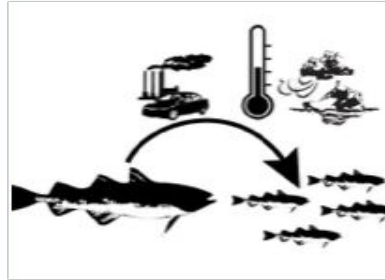
- Empirical diets
- Bioenergetics

Weight @ Age



- Empirical
- VonB with Temp

Rec



- Climate-S/R
- S/R
- mean R

HCRs



- Climate ABC
- MMSY
- MEY
- SPR
- Aggregate MSY

2021 Climate-enhanced multi-species Stock Assessment for walleye pollock, Pacific cod, and arrowtooth flounder in the South Eastern Bering Sea

Kirstin K. Holsman, Jim Ianelli, Kerim Aydin, Grant Adams, Kelly Kearney, Kalei Shotwell, Grant Thompson, and Ingrid Spies

kirstin.holsman@noaa.gov November 2021

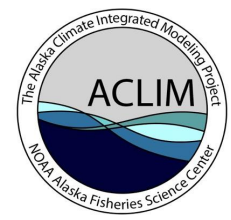
Alaska Fisheries Science Center, National Marine Fisheries Service, NOAA,
7600 Sand Point Way N.E., Seattle, Washington 98115

Operational advice

- Appendix to BSAI pollock assessment (2016 to now)
- M2 index for EBS ecosystem status report (2016 to now)
- M2 index for ESP (2020 to now)

Research

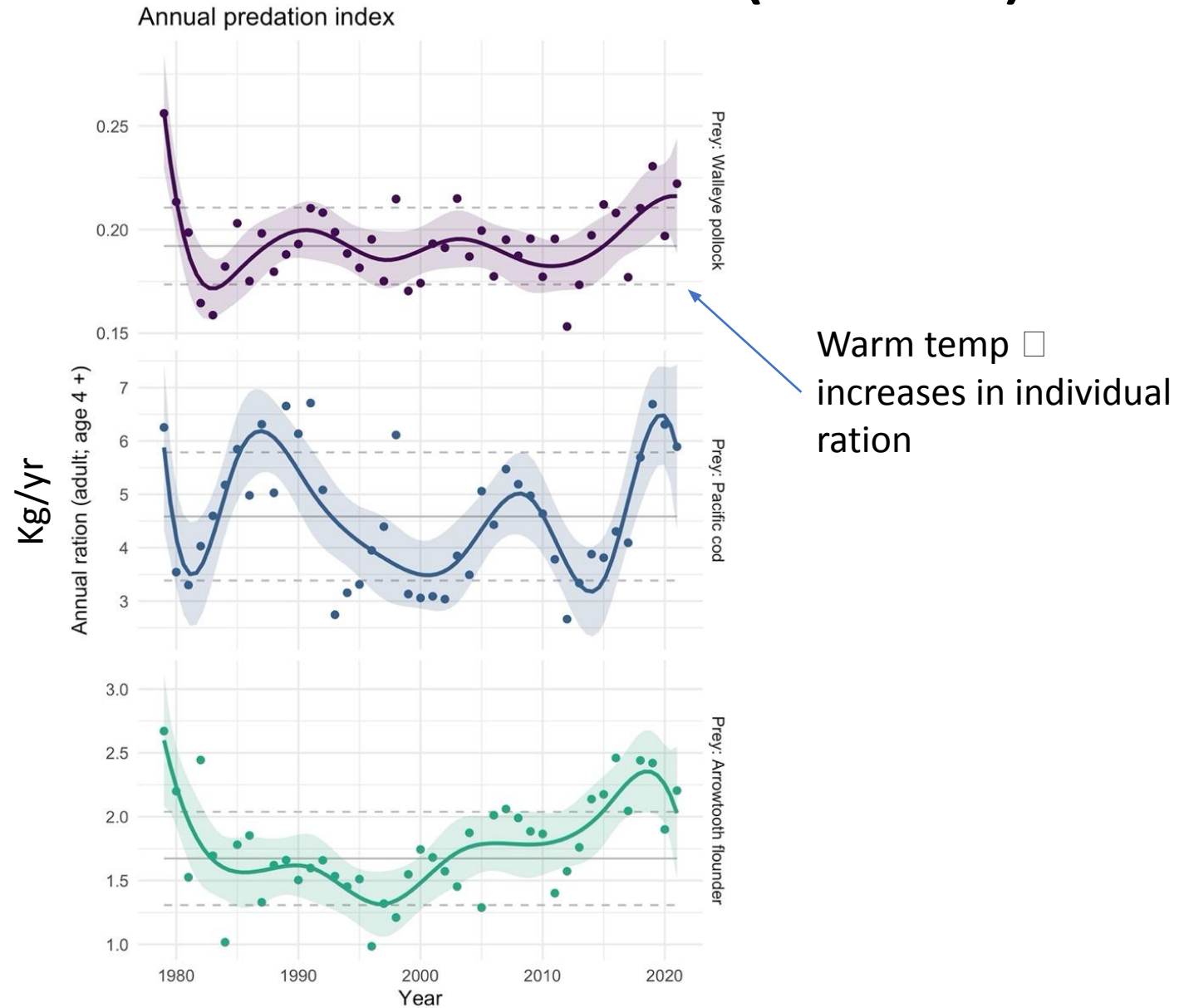
- ACLIM - climate MSE
- Lenfest NFS
- Lenfest ocean wealth



Increase in energetic demand (ration)



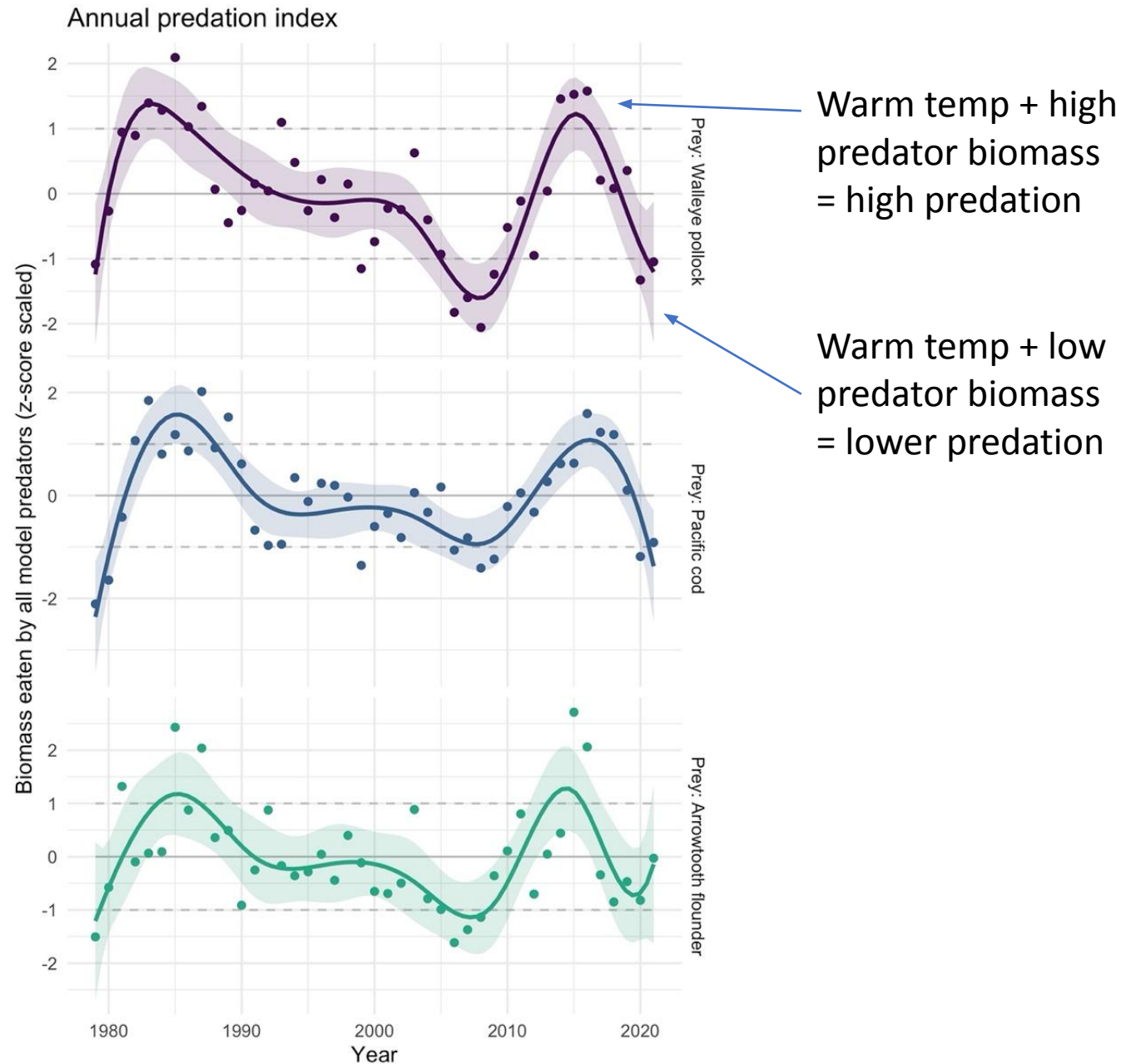
Kirstin Holsman



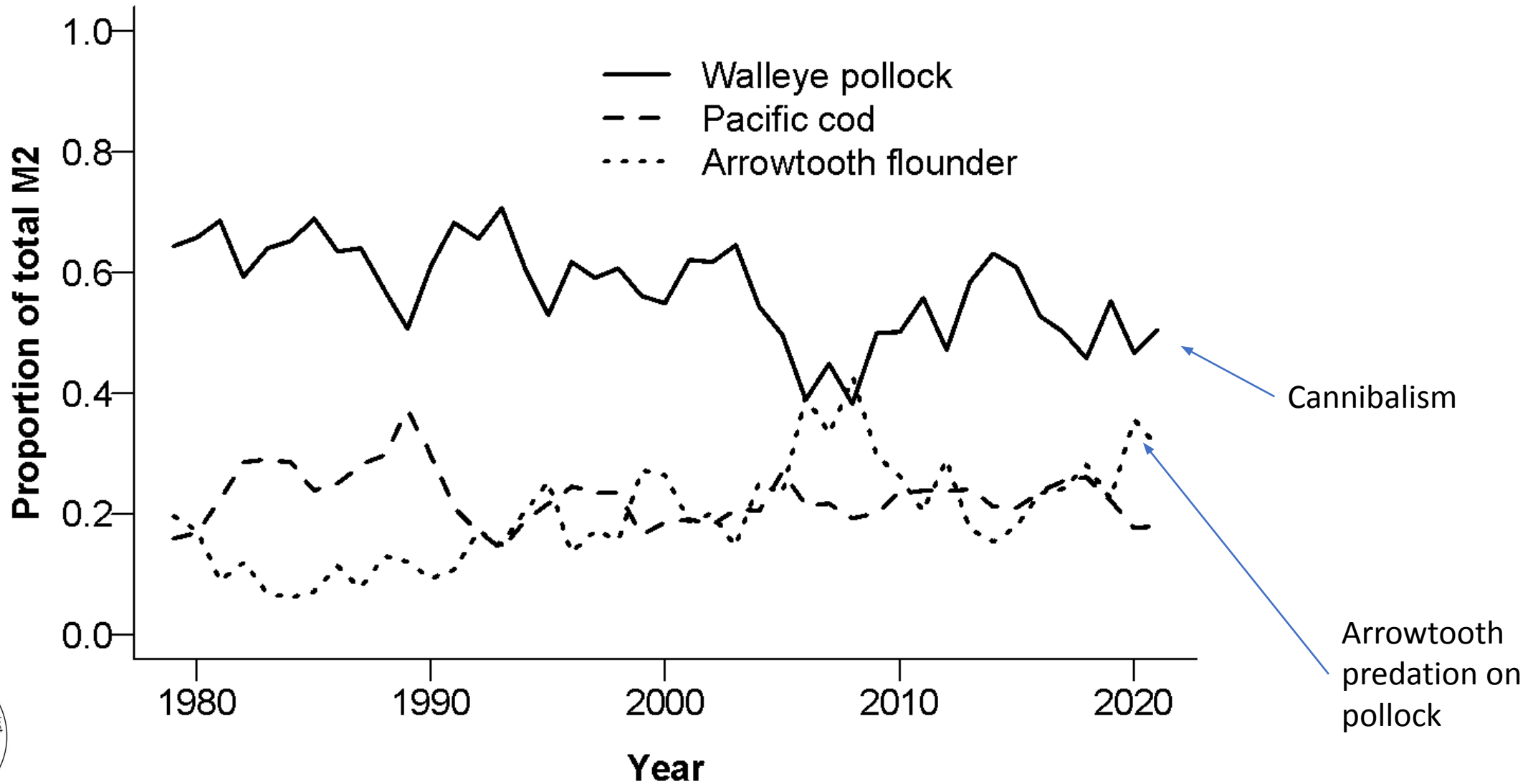
Declines in predation index

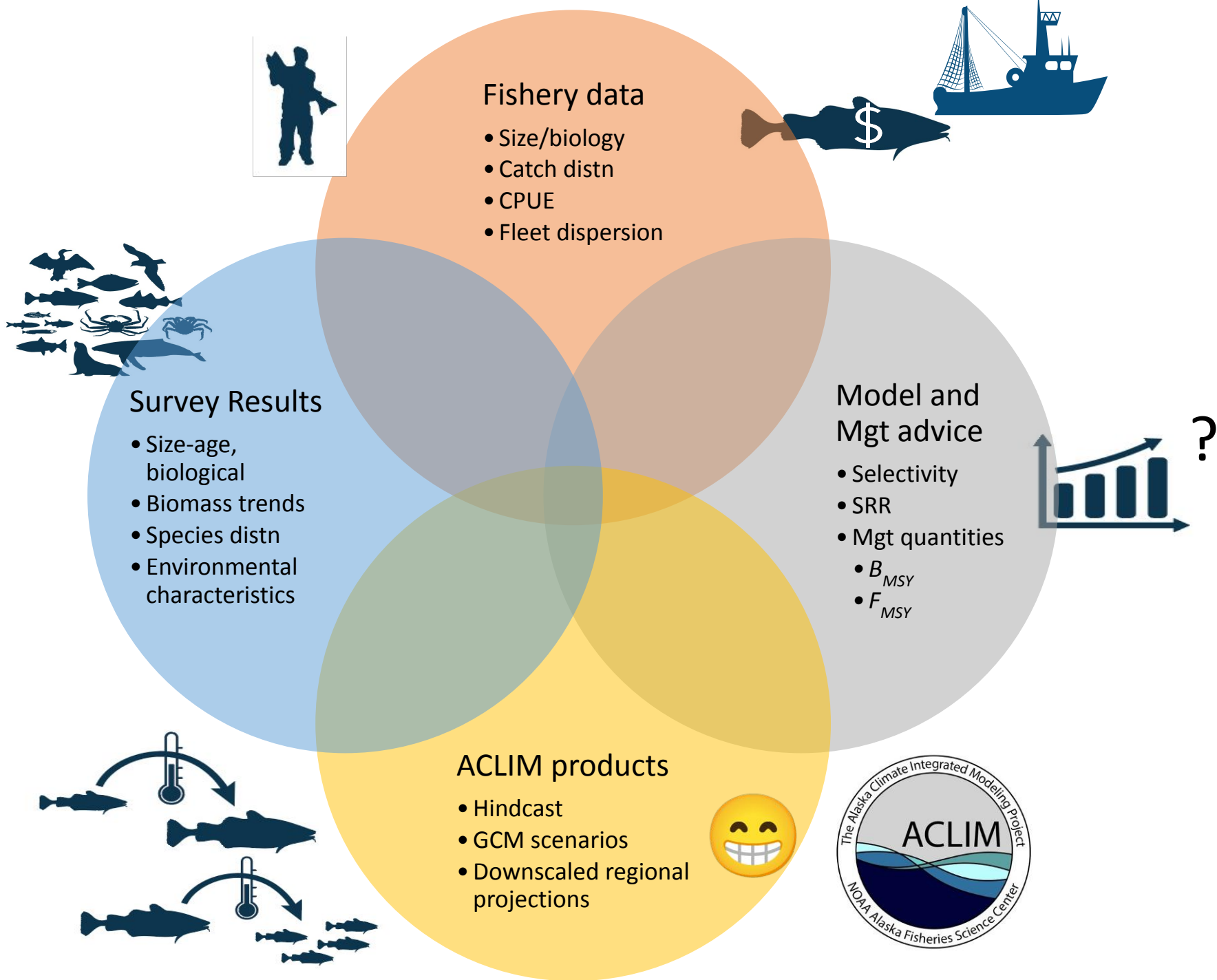


Kirstin Holsman



Pollock Predation Mortality

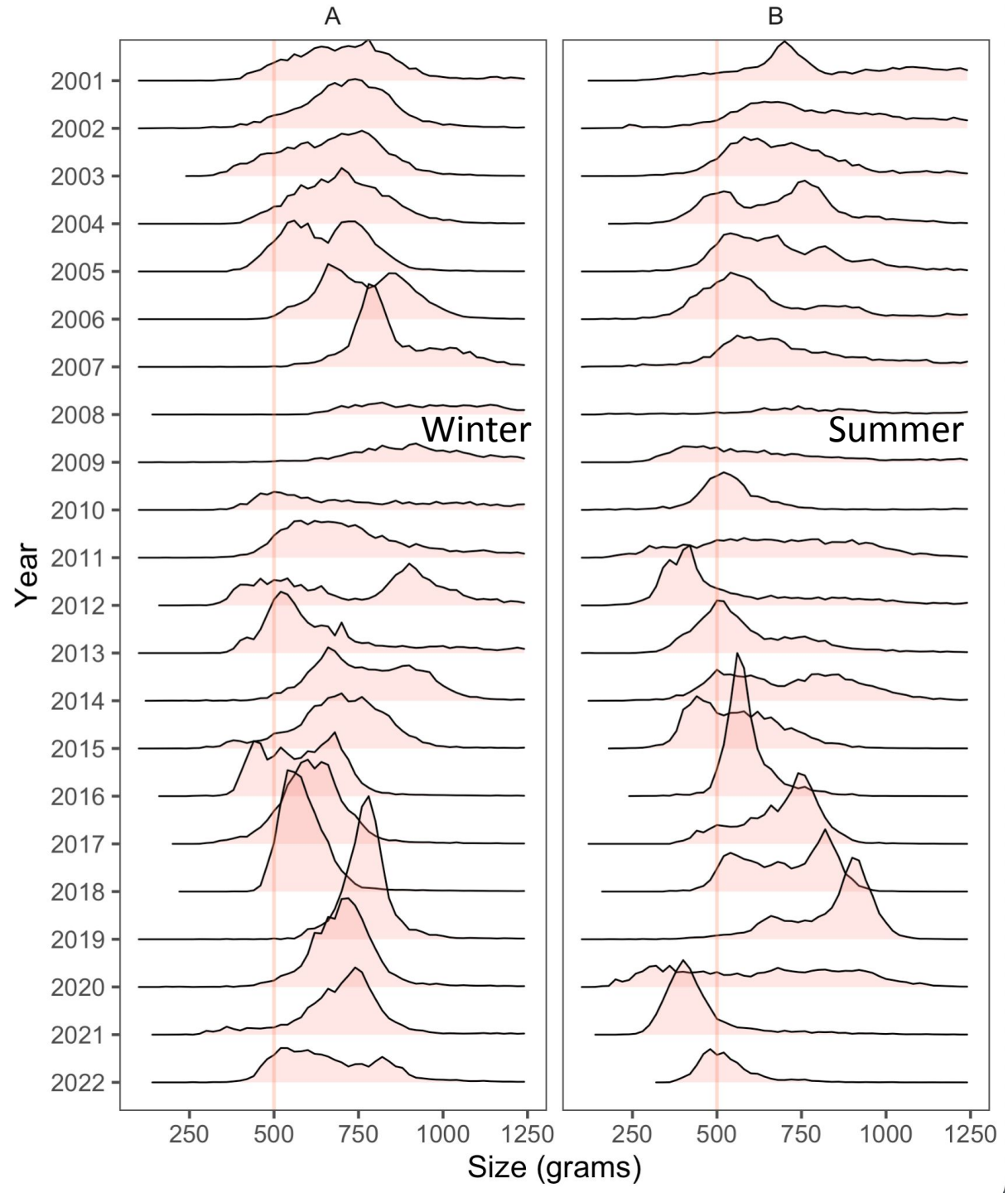






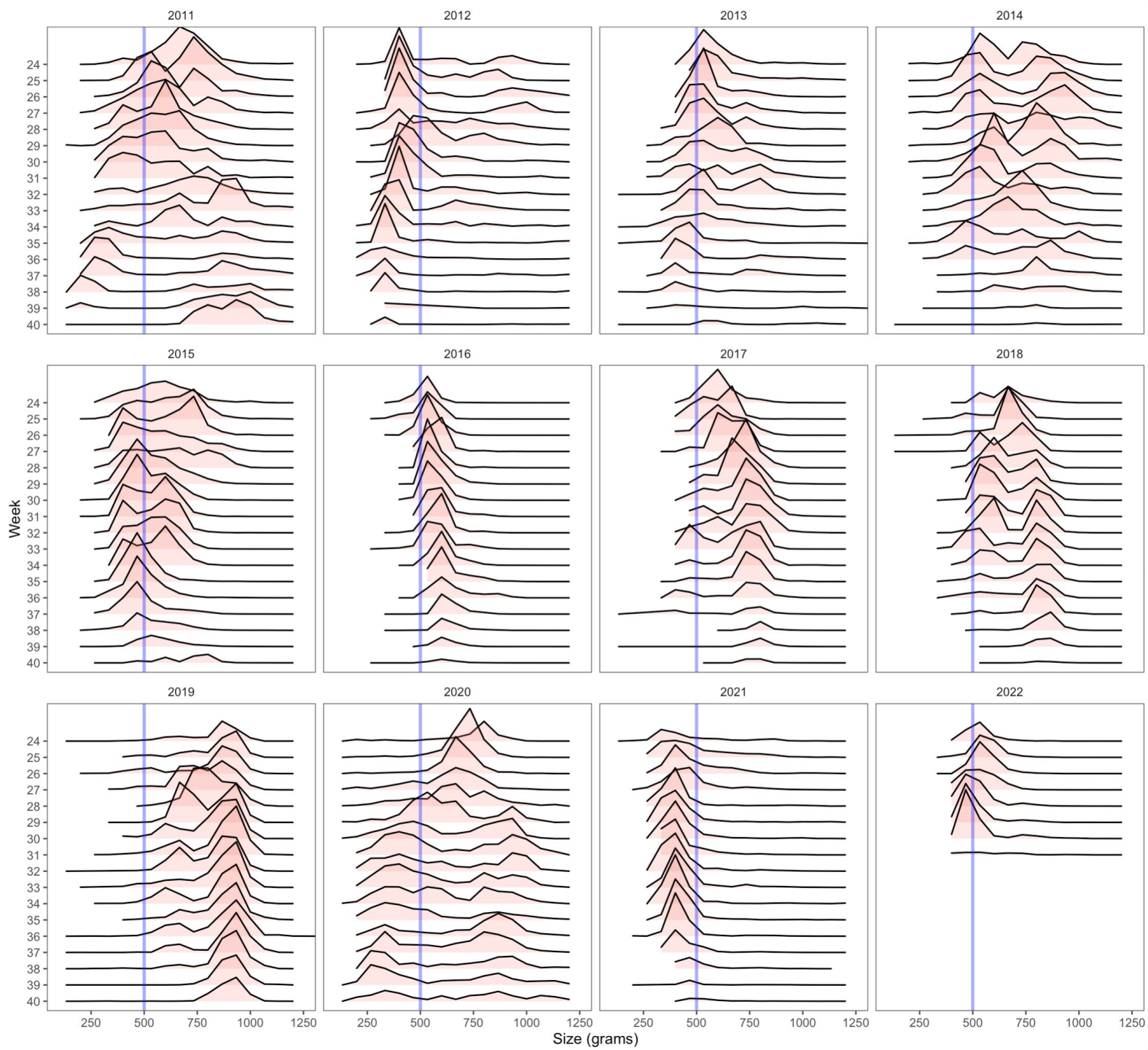
Bering Sea Pollock Fishing conditions

Trends in
weight
frequency
of catch

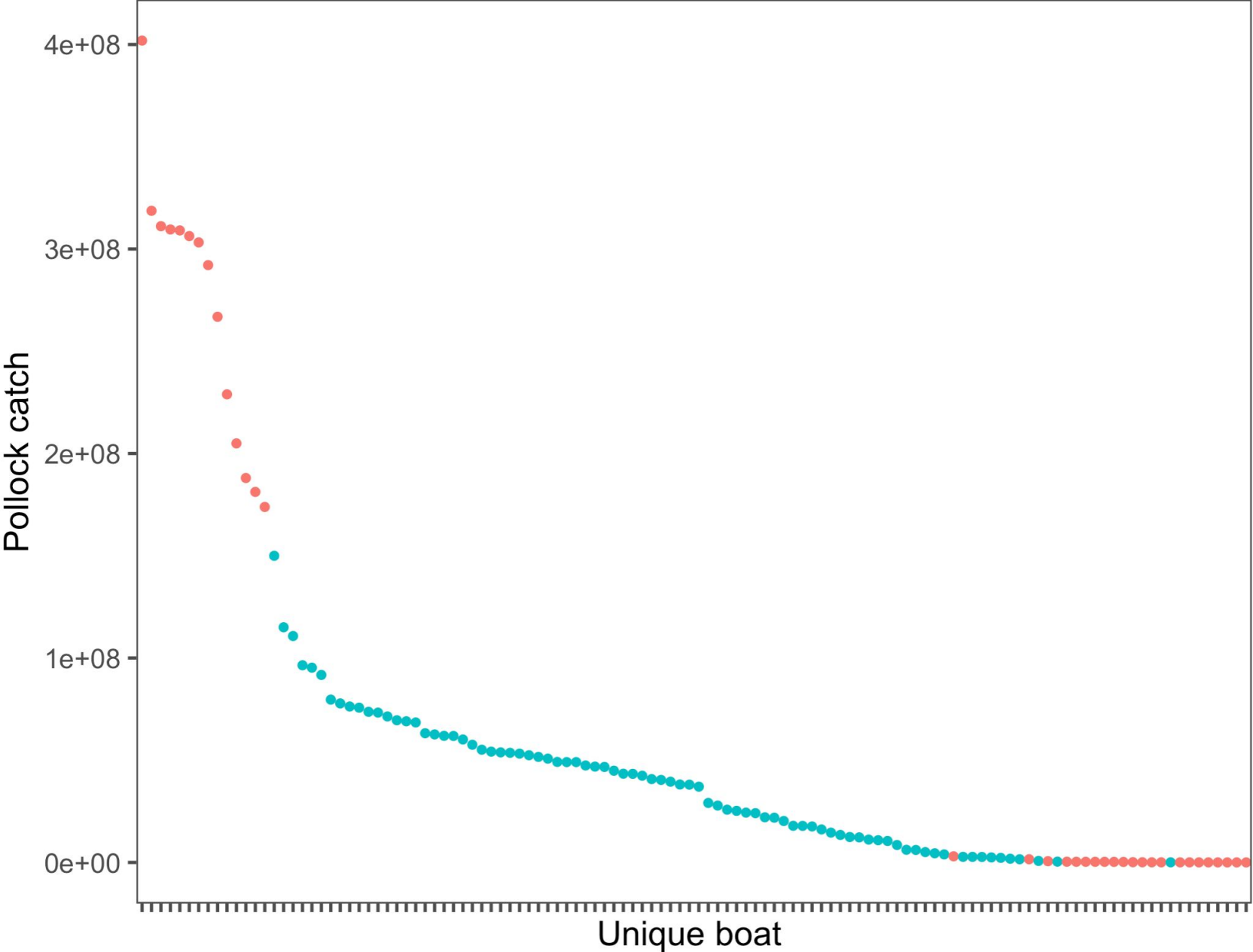


B-season

Tow-by-tow mean
weight frequency
by week



B-season catch patterns



Catcher-vessels

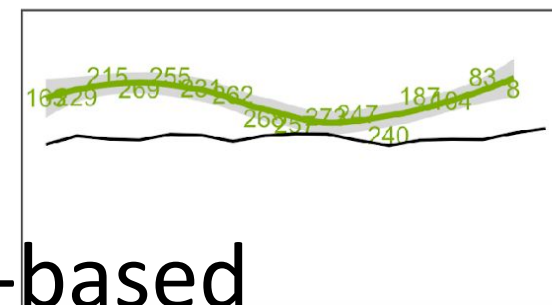
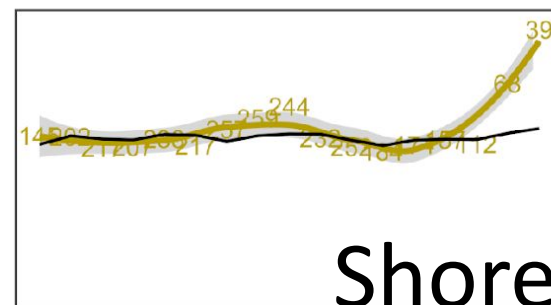
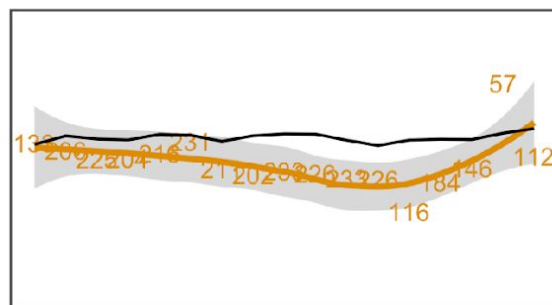
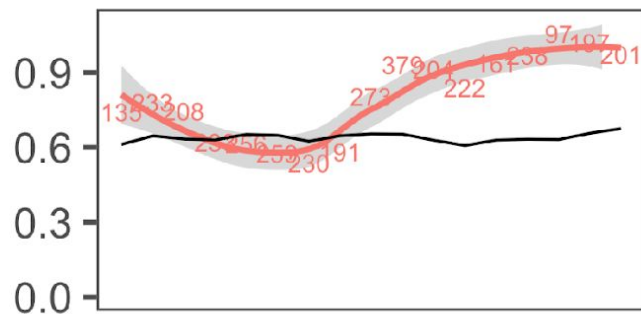
B-season catch patterns

2011

2012

2013

2014



Shore-based

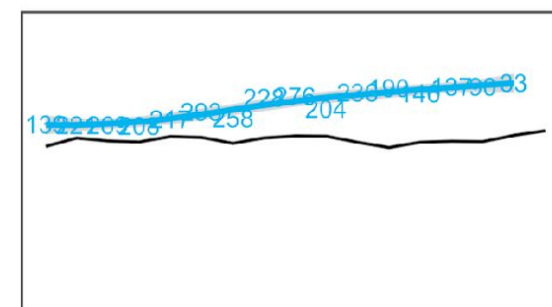
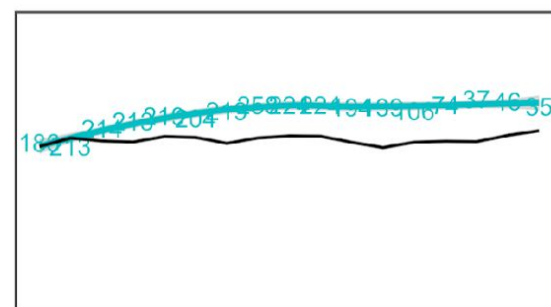
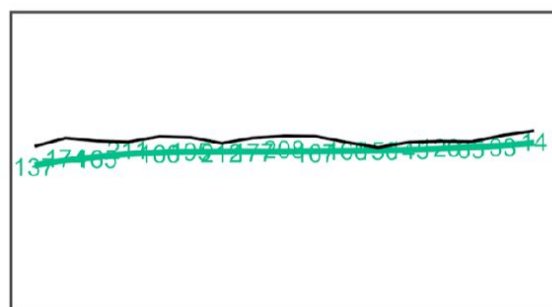
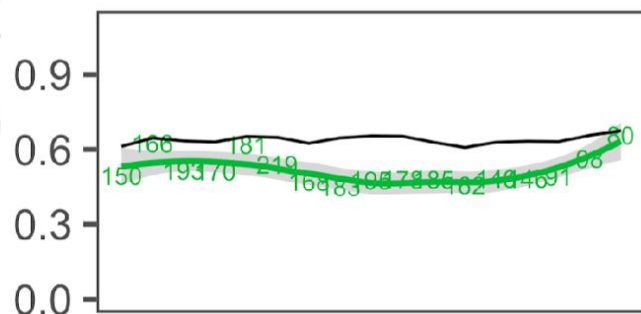
2015

2016

2017

2018

Mean weight (kg)

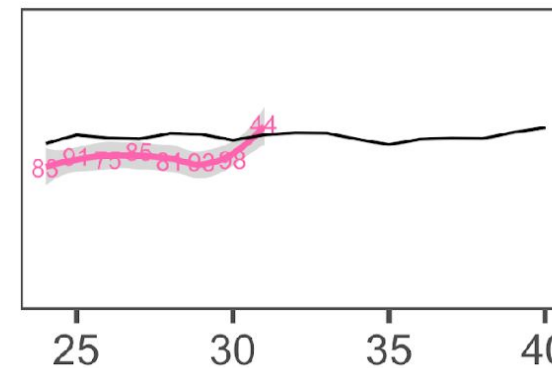
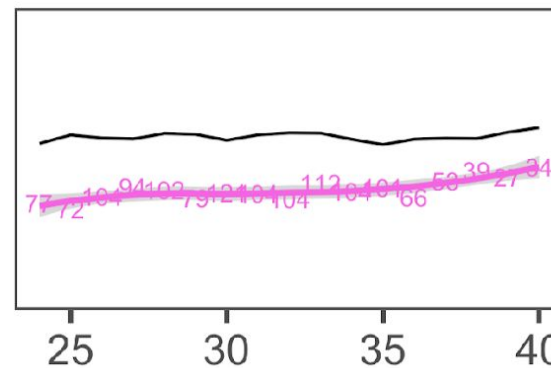
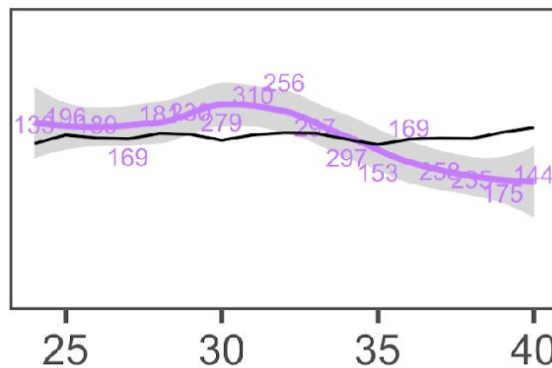
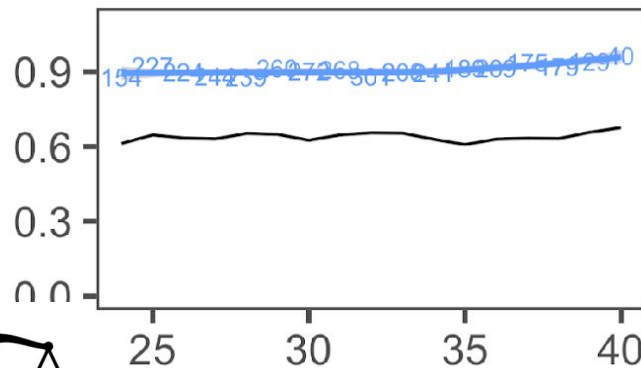


2019

2020

2021

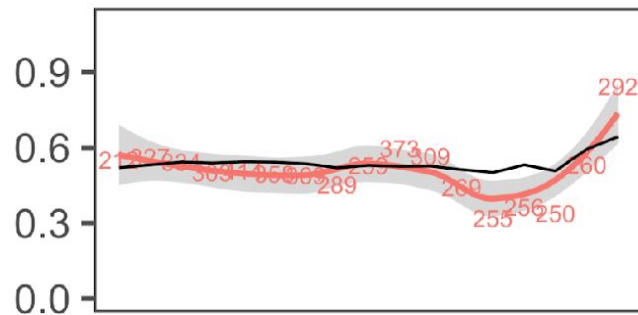
2022



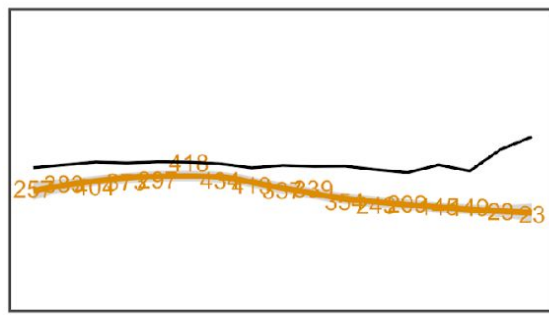
week

Catcher-processors

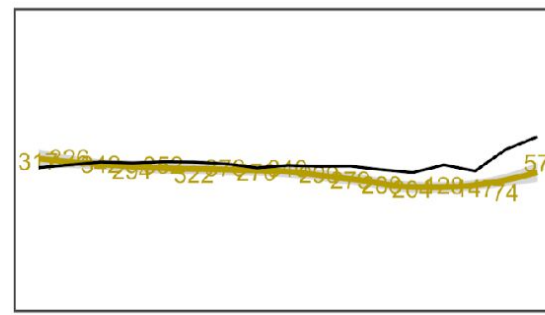
2011



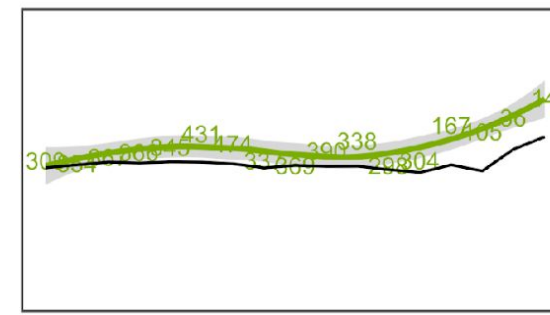
2012



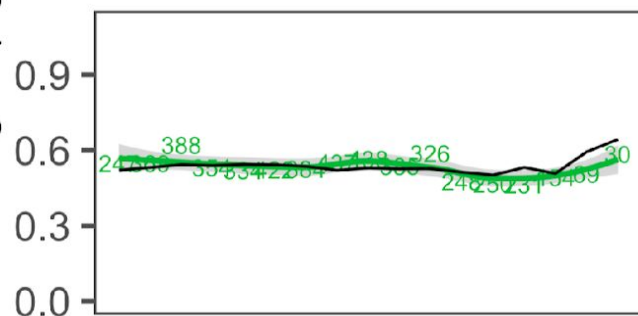
2013



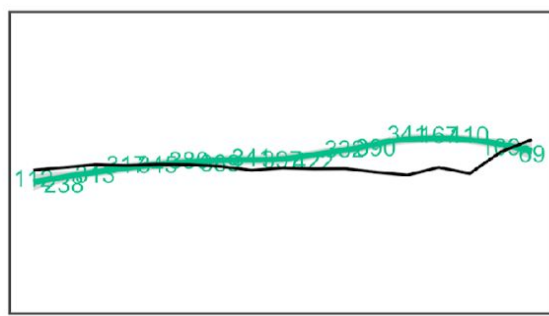
2014



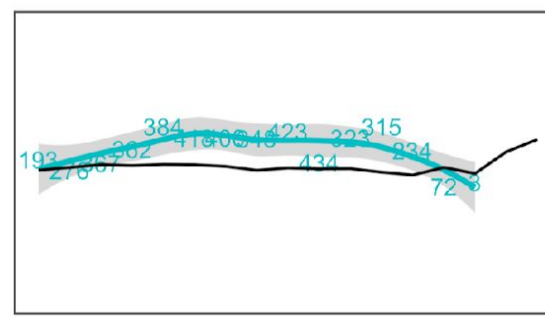
2015



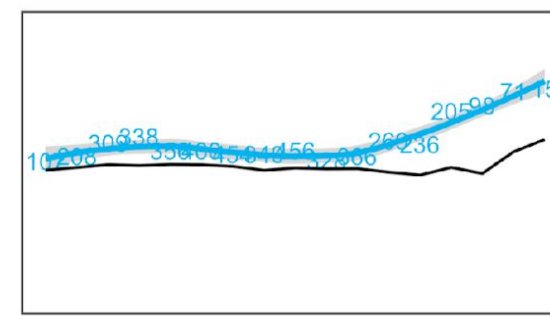
2016



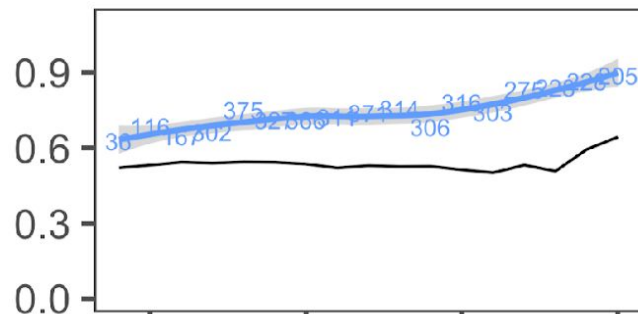
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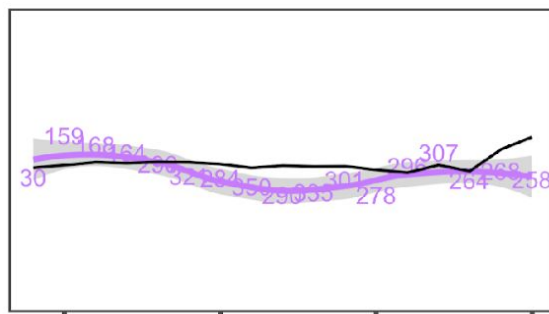
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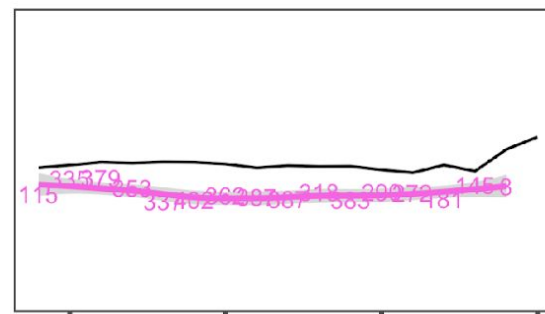
2019



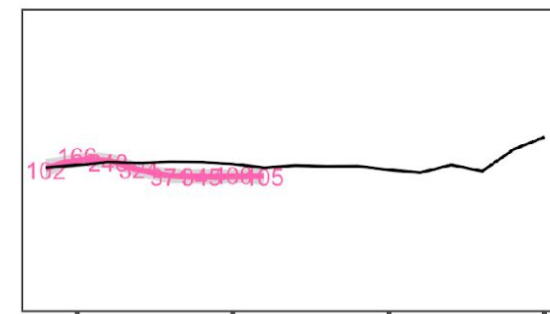
2020



2021

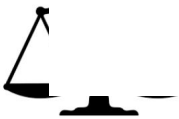



2022



Mean weight (kg)

week

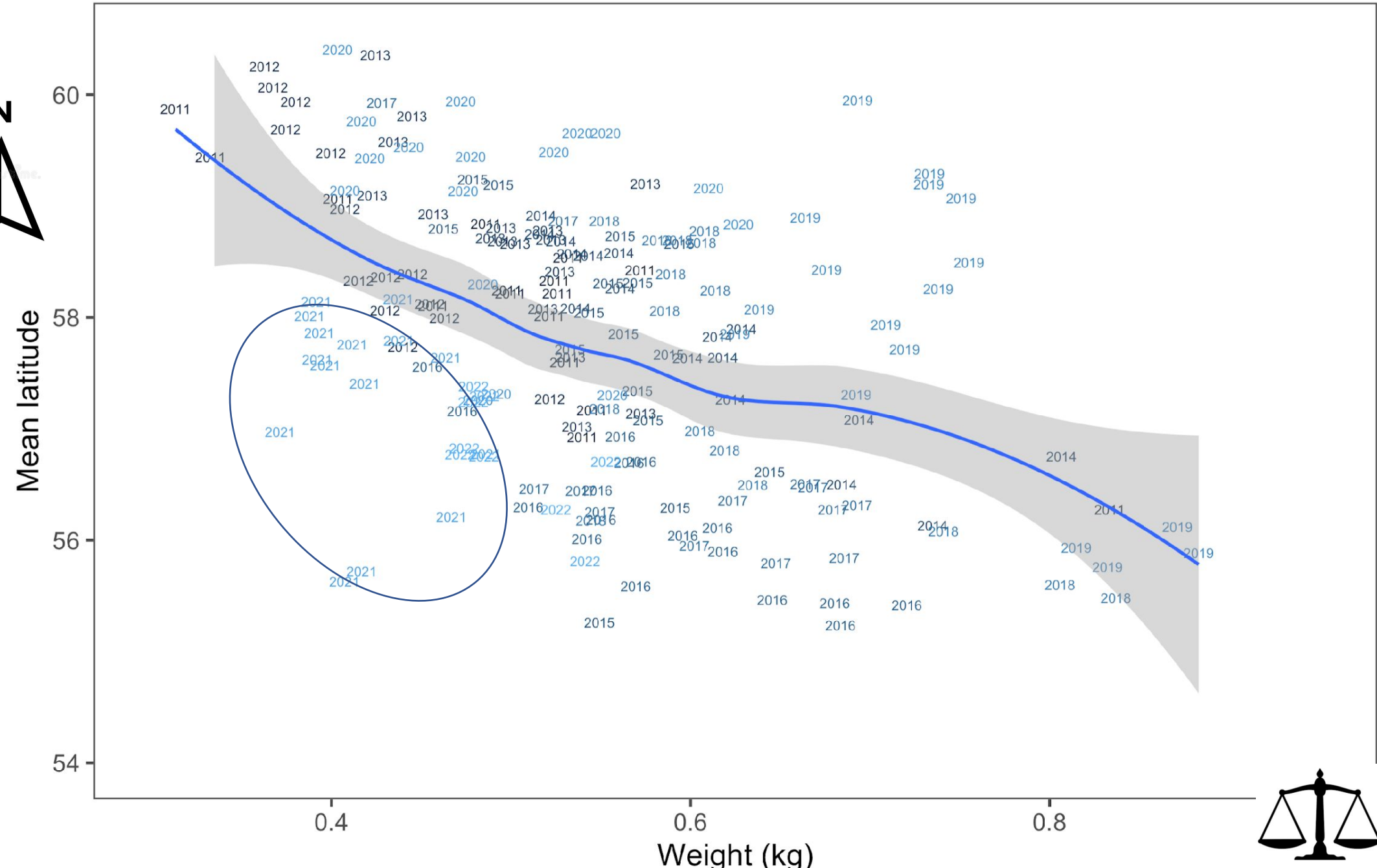




How much is
due to
shifted pattern
of fishing?

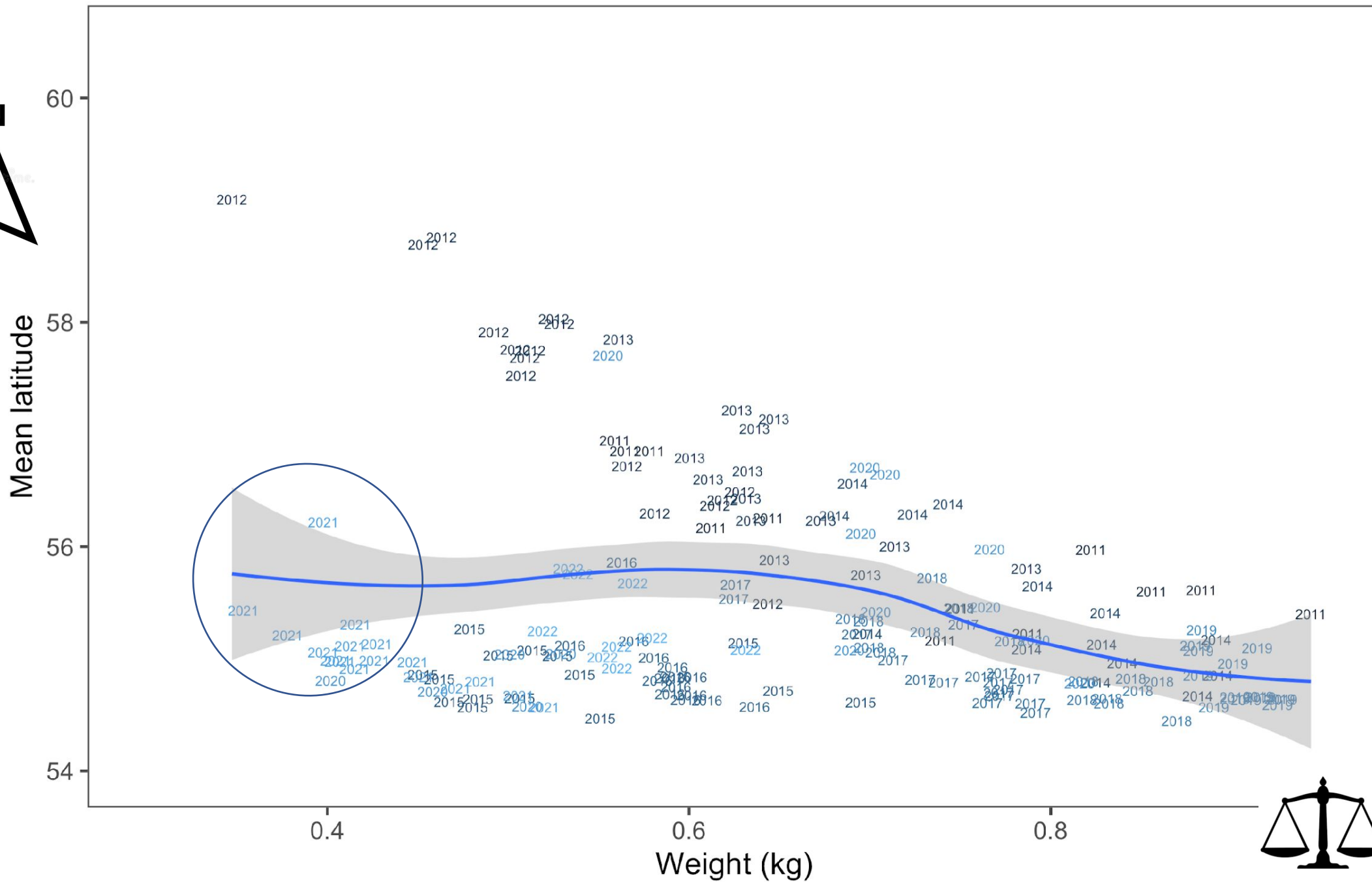
Catcher-processors

B-season catch patterns



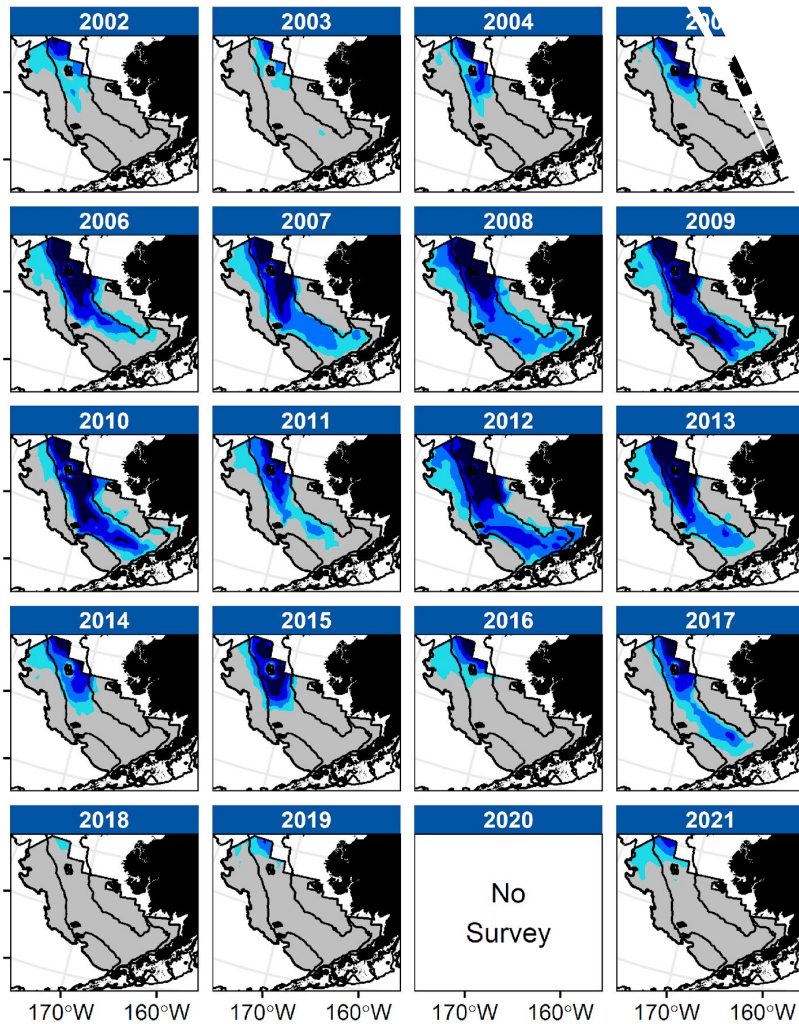
Catcher-vessels

B-season catch patterns



How does it compare to fishery data?

Another survey product: Bottom Temperature

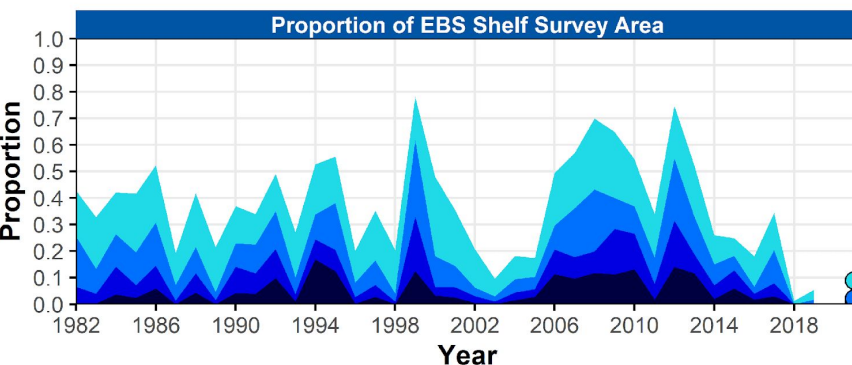


Bo.
Tem.

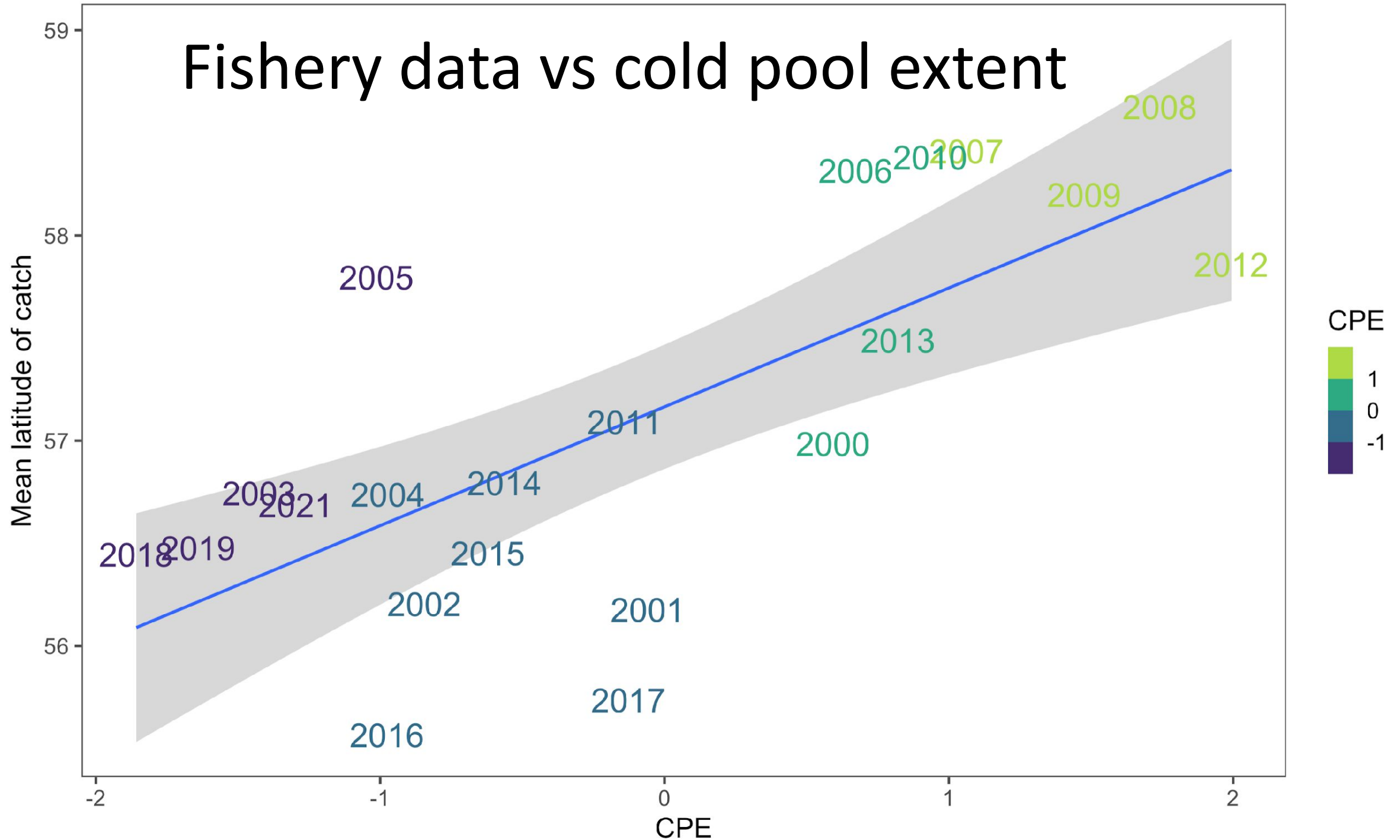
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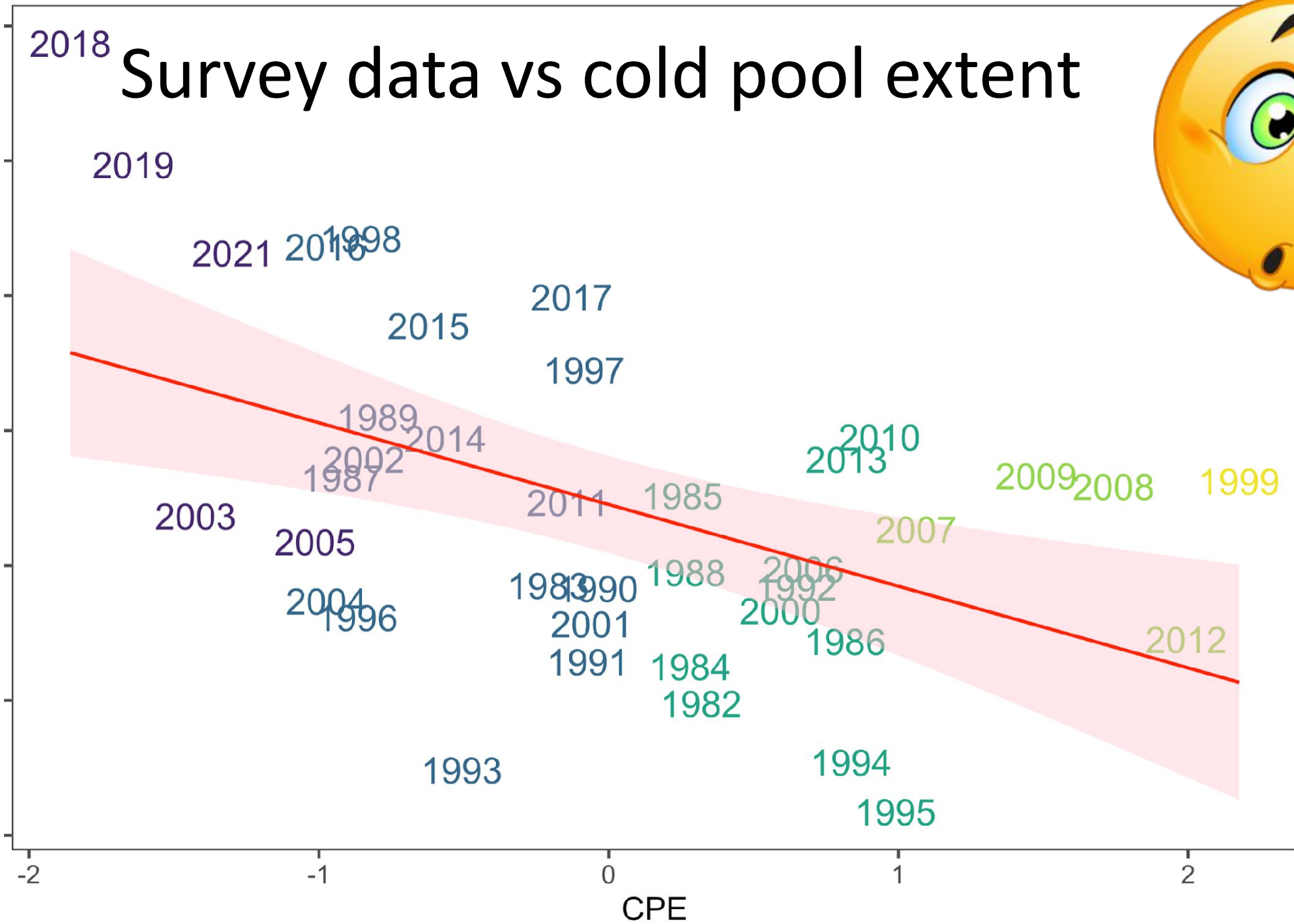
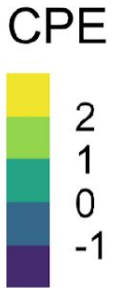


Fishery data vs cold pool extent



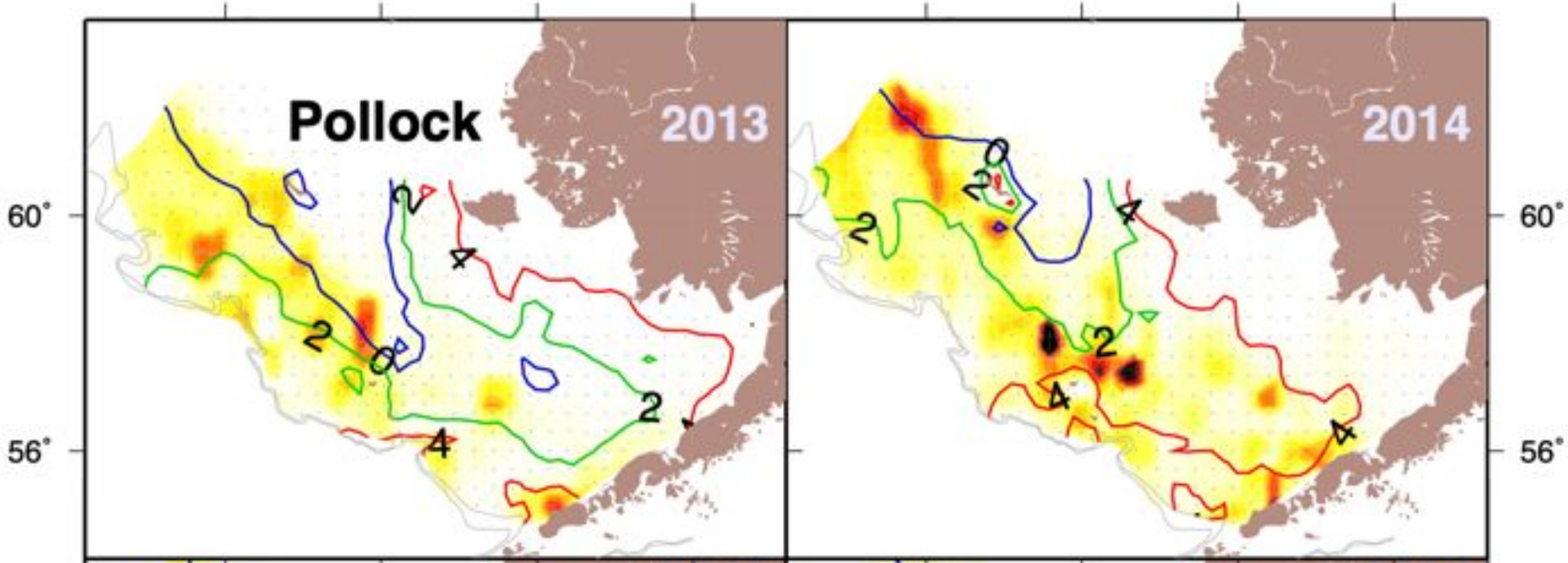
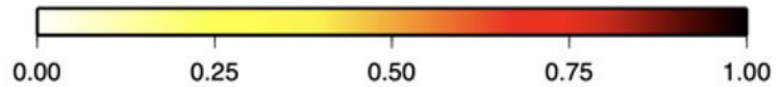
Survey data vs cold pool extent

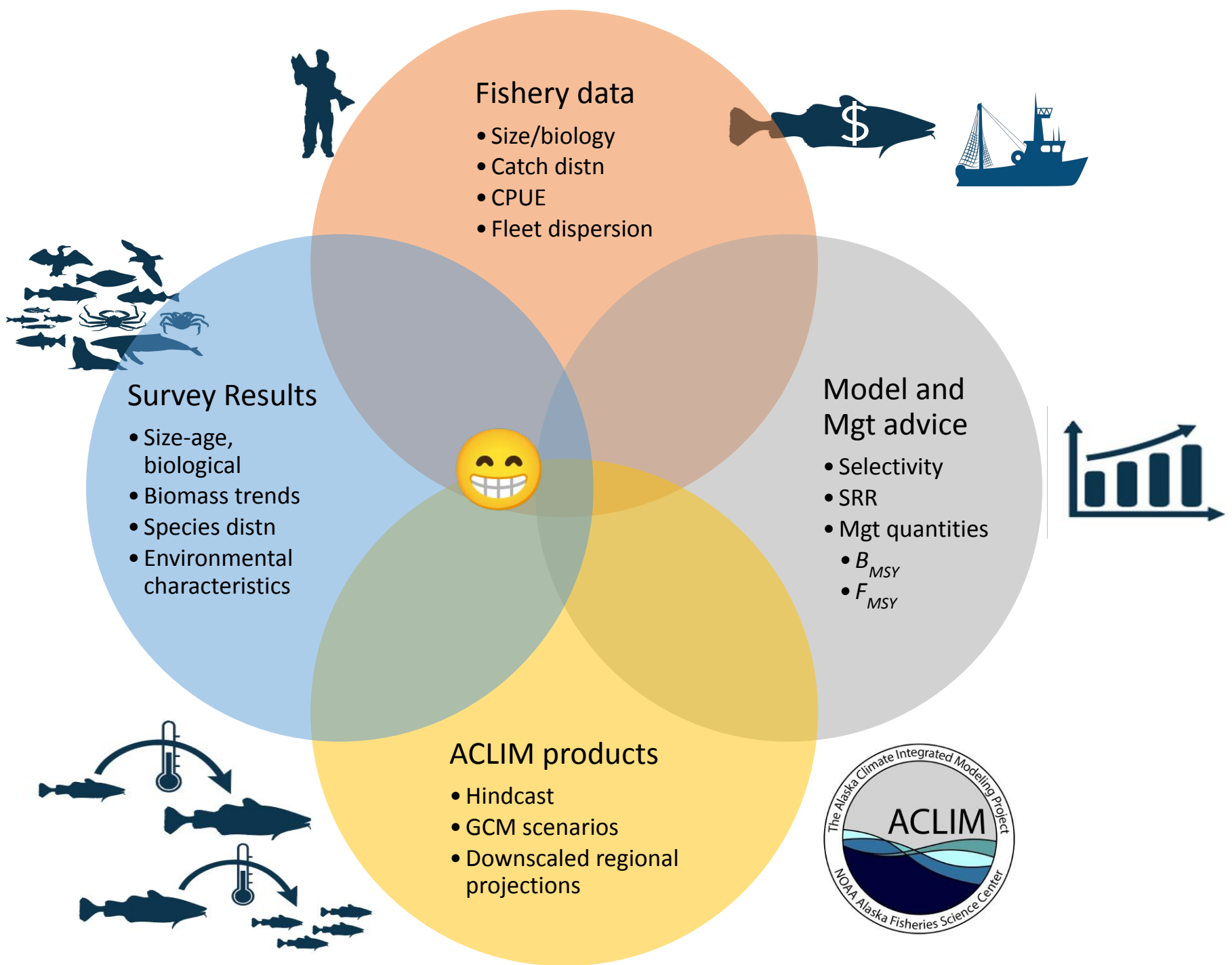
Center of gravity (Northing)





Relative survey CPUE





2011 Stock assessment

- EBS pollock

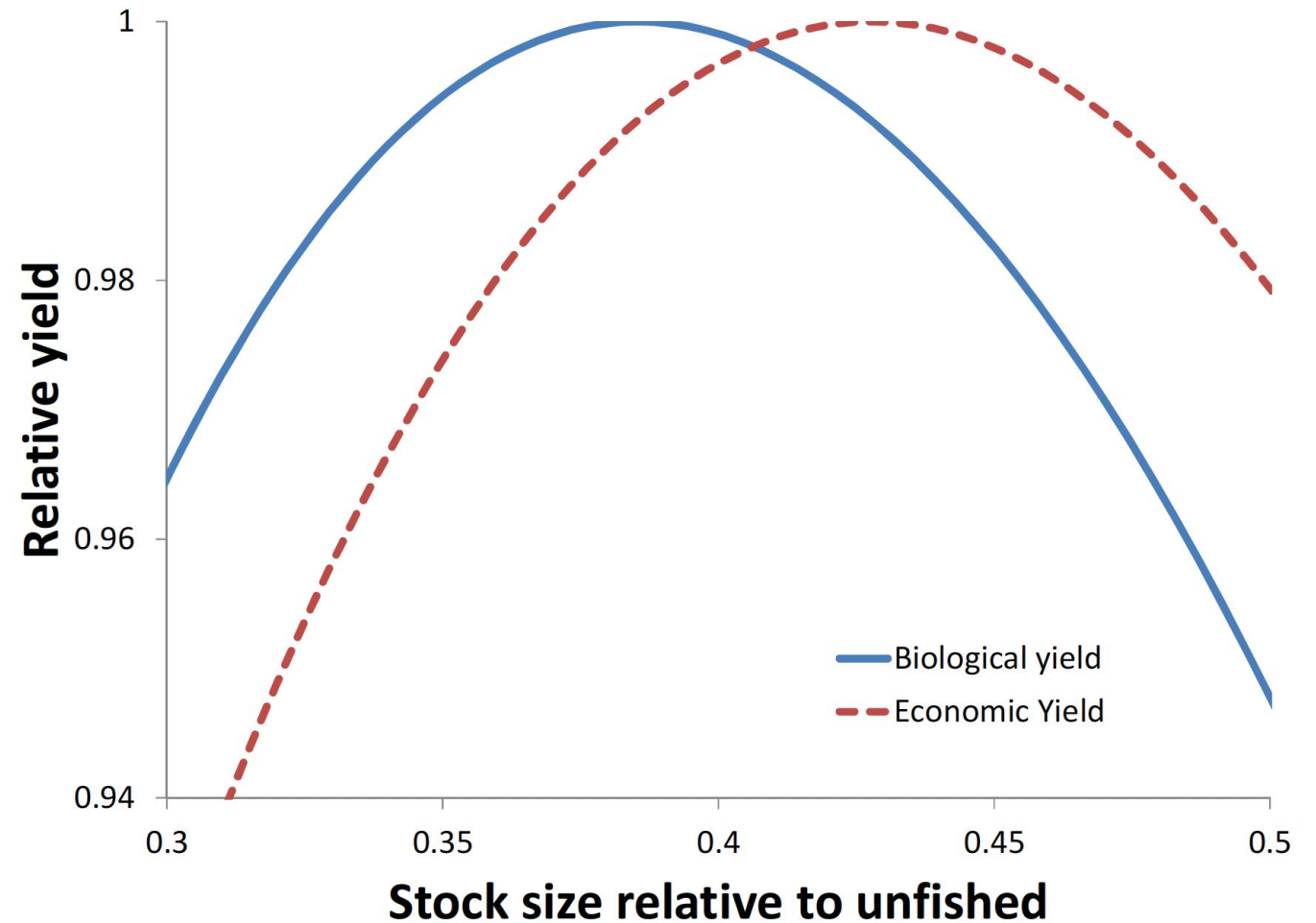
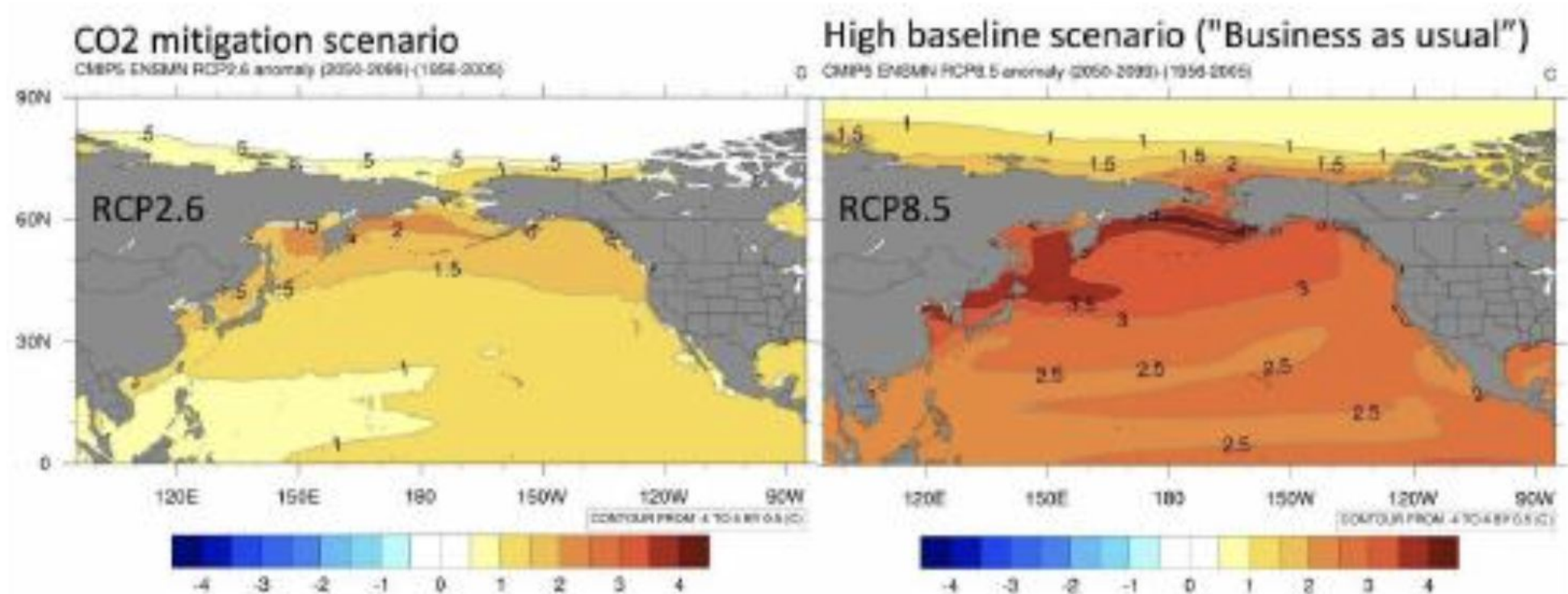
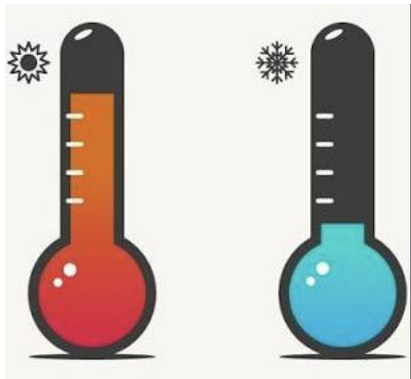


Figure 1.36. Population-level estimated yield curves normalized for biomass (solid line) and economic yield (dashed line). The economic curve uses age-specific with relationship between relative effort (distance) required for capture with a 60-40 weighting and an example age-specific value for ex-vessel landings (slope parameter equal to 0.1).

How may temperatures affect fishing patterns

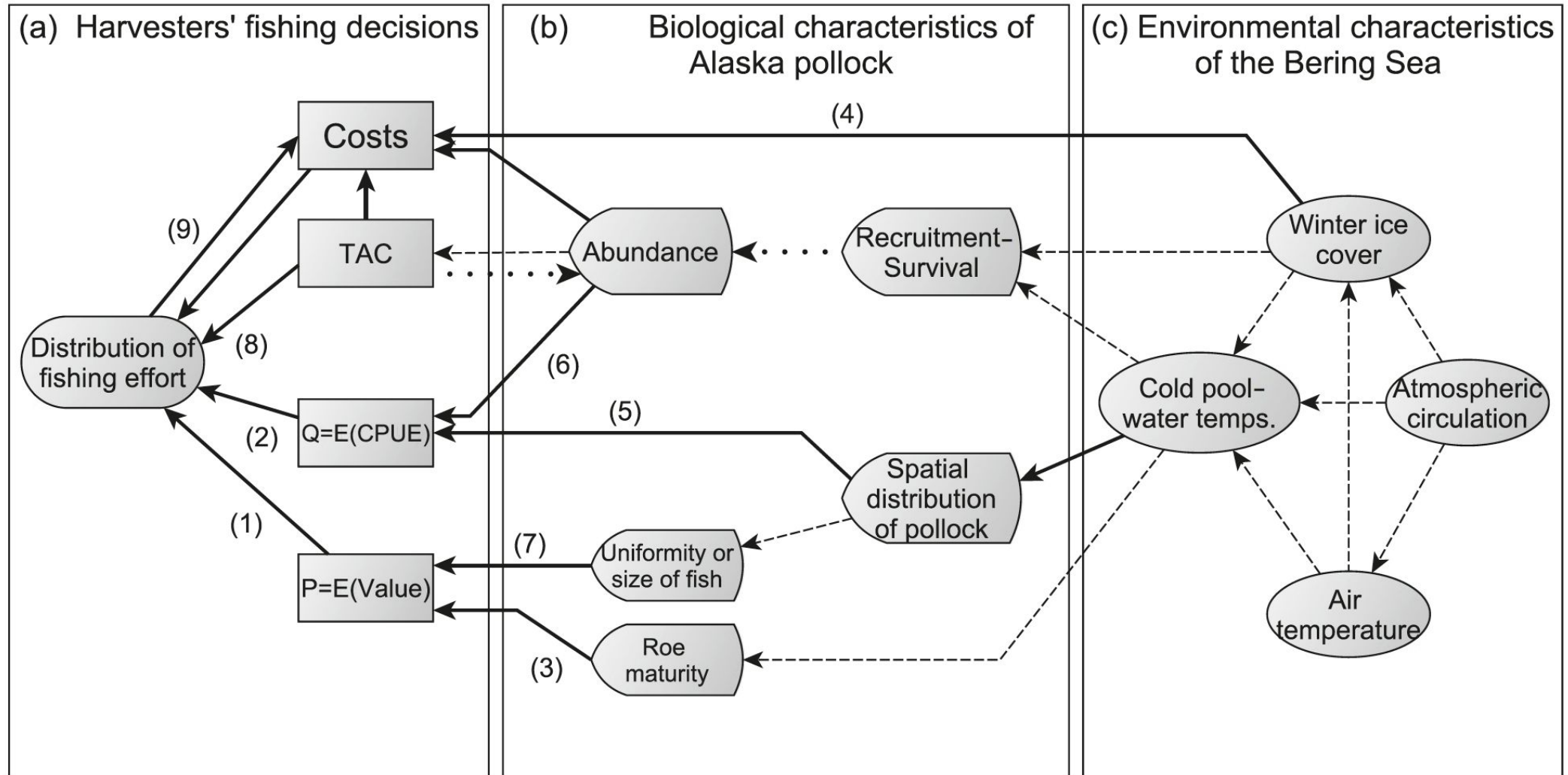
- And stock characteristics



Projection data from CMIP5 (Taylor et al., 2012) avail. at: www.esrl.noaa.gov/psd/ipcc/ocn

Climatic and economic drivers of the Bering Sea walleye pollock (*Theragra chalcogramma*) fishery: implications for the future

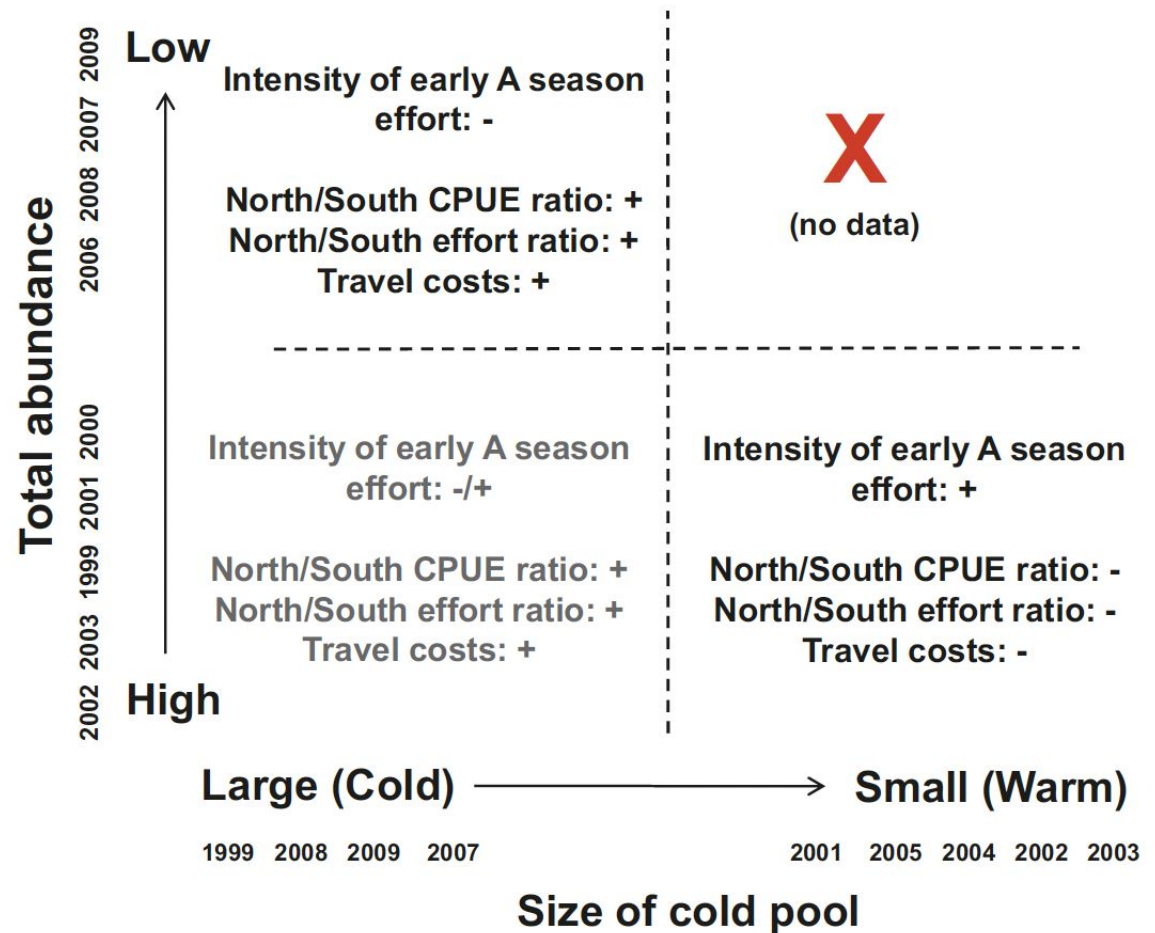
Alan C. Haynie and Lisa Pfeiffer

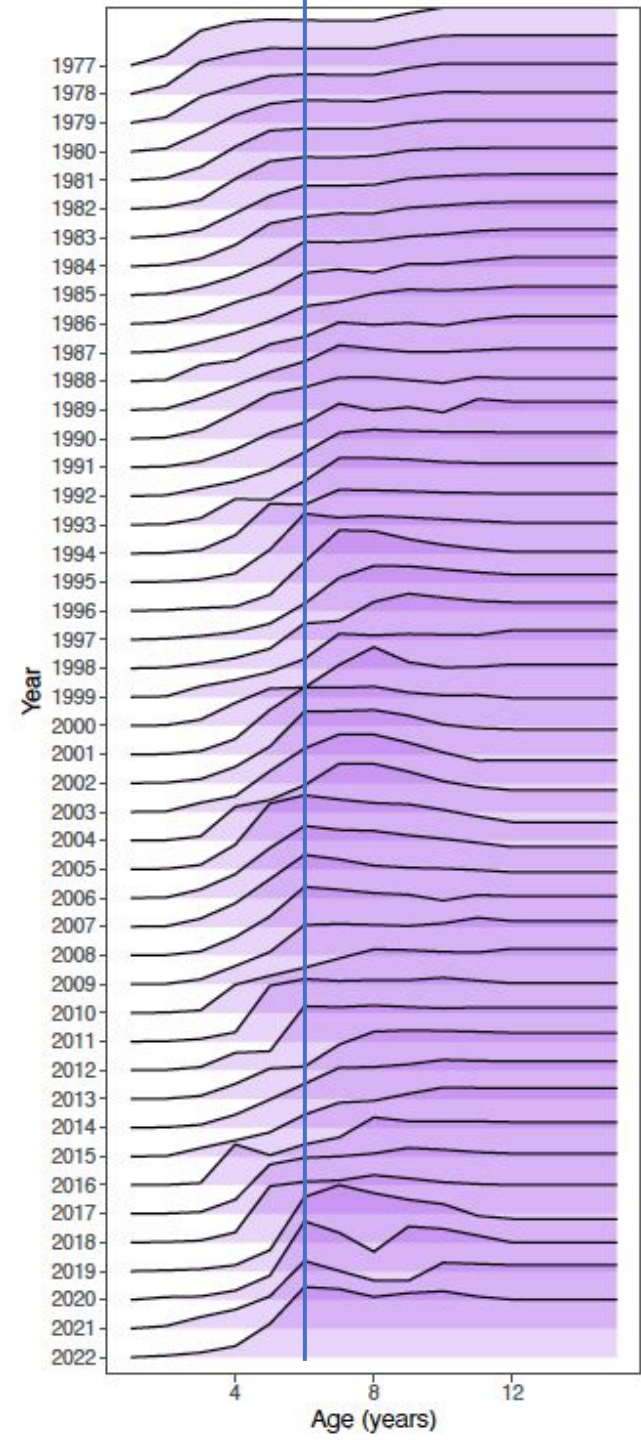
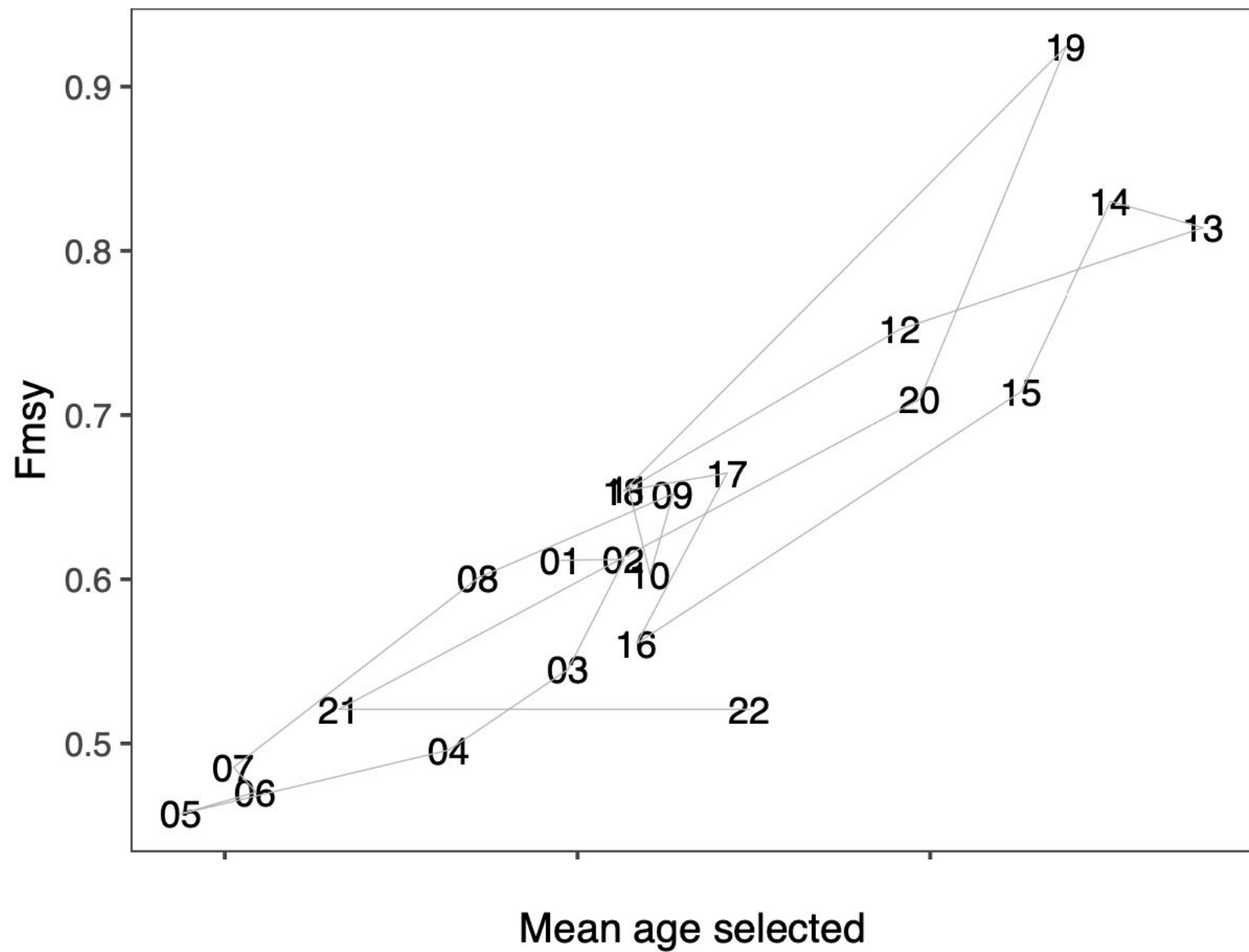


Included CPUE

- Updated

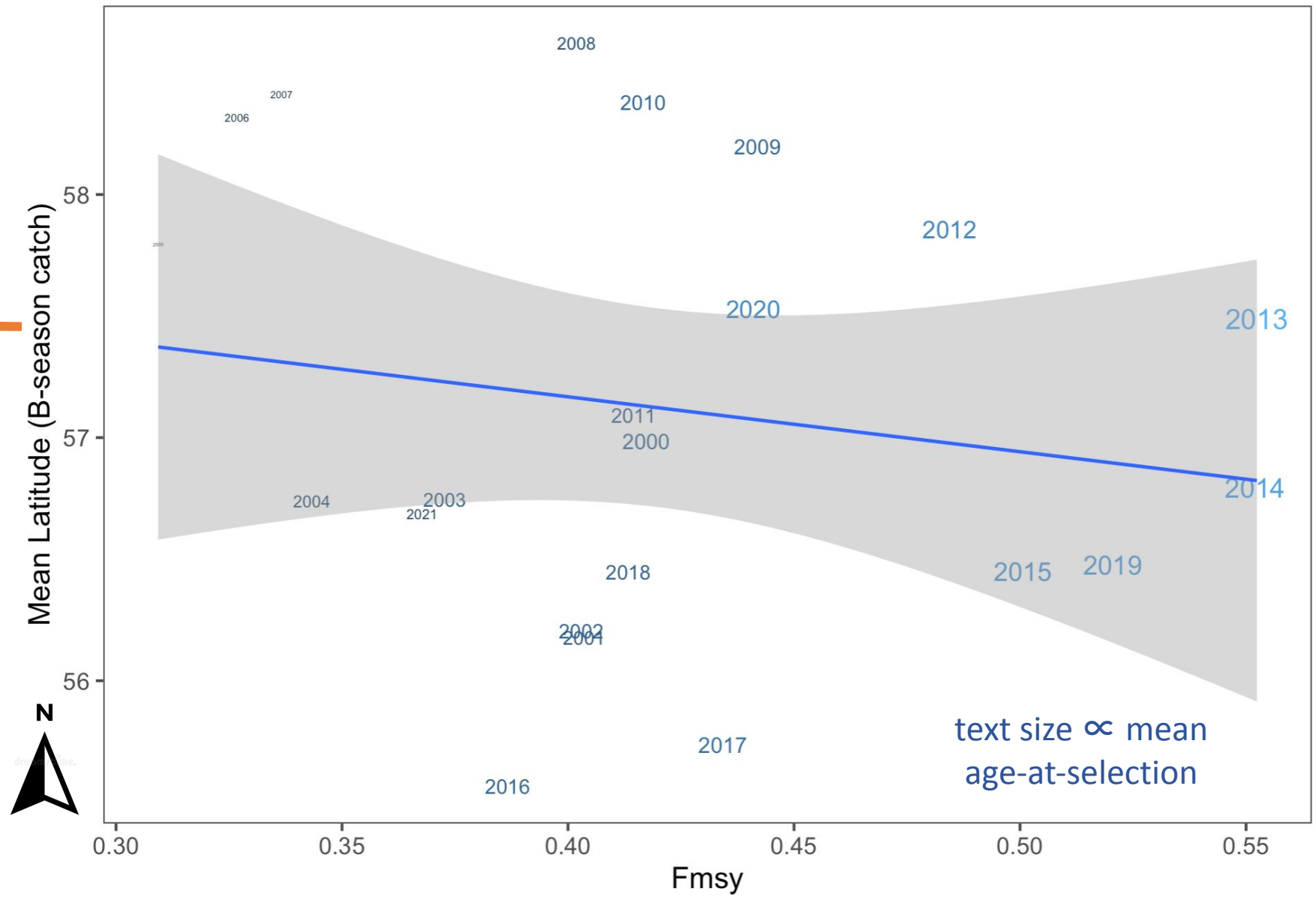
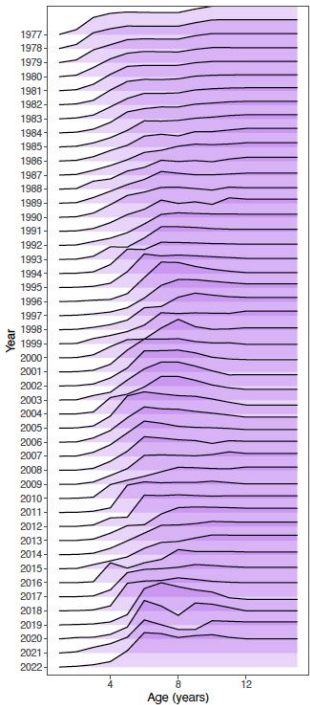
Fig. 7. Summary of the effects of the size of the cold pool and total walleye pollock abundance on the intensity of early A-season (winter season) effort, B-season (summer season) CPUE, B-season effort, and B-season travel costs. Years in the sample characterized by varying abundance and cold pool levels are listed on the horizontal and vertical axes.





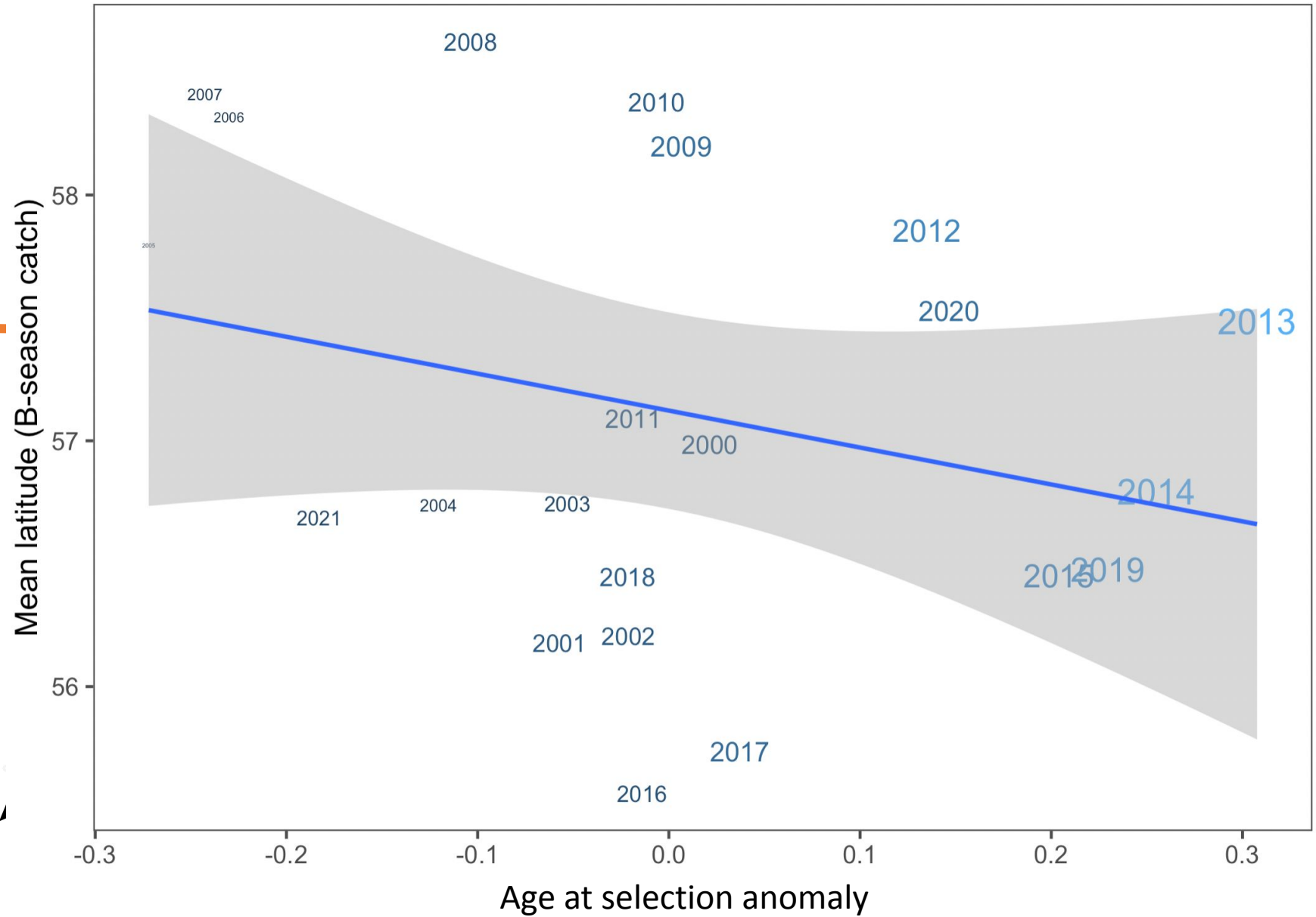
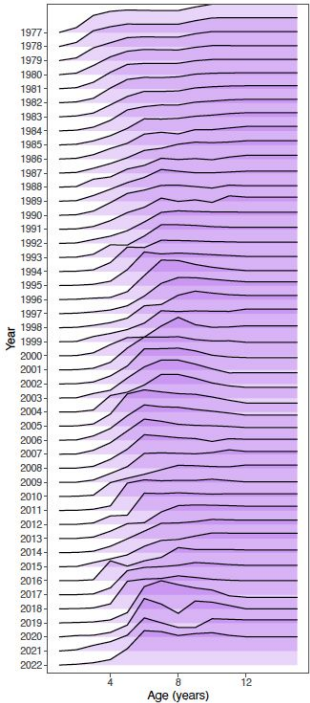
F_{MSY}

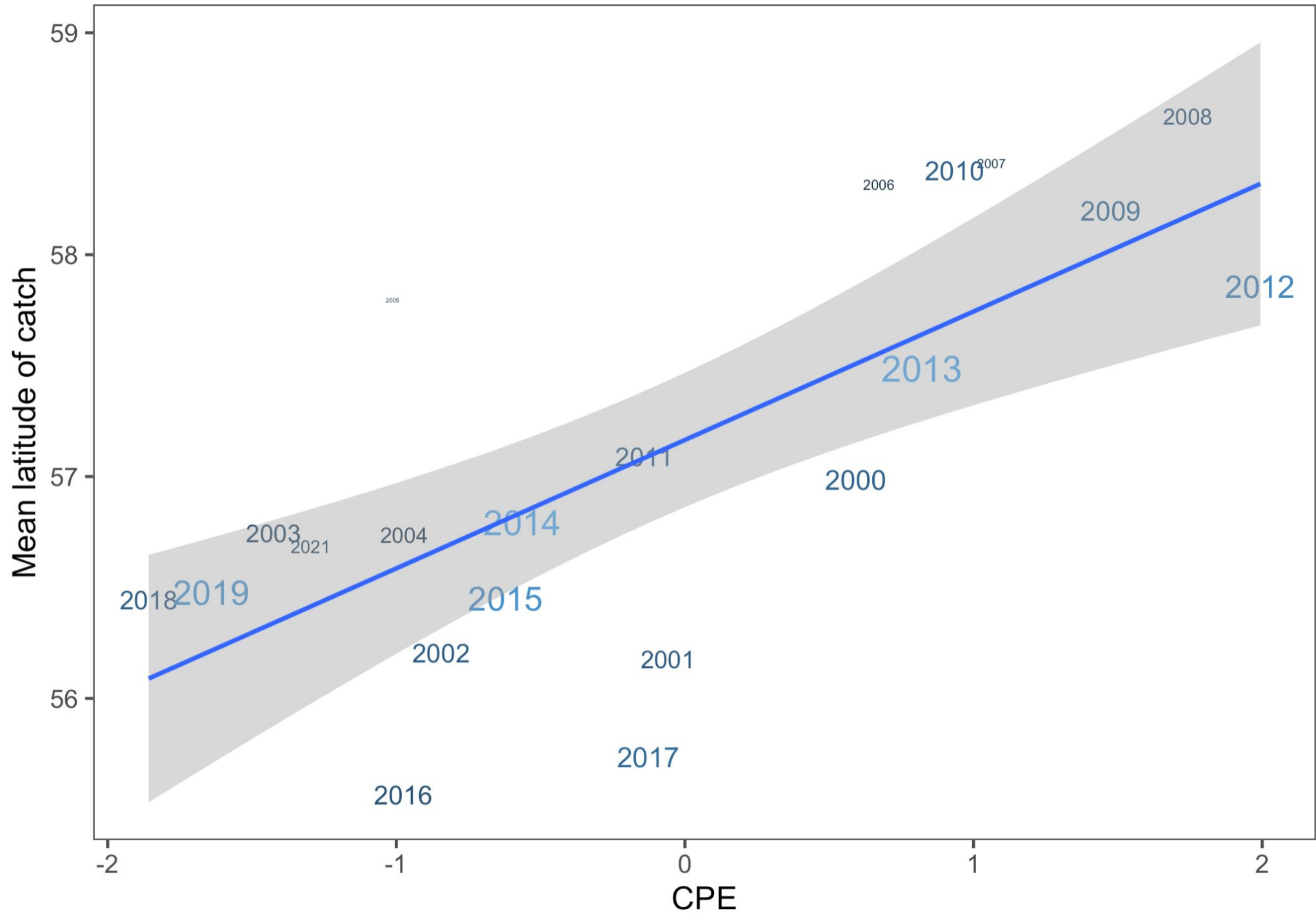
- By year and latitude (and F_{MSY})

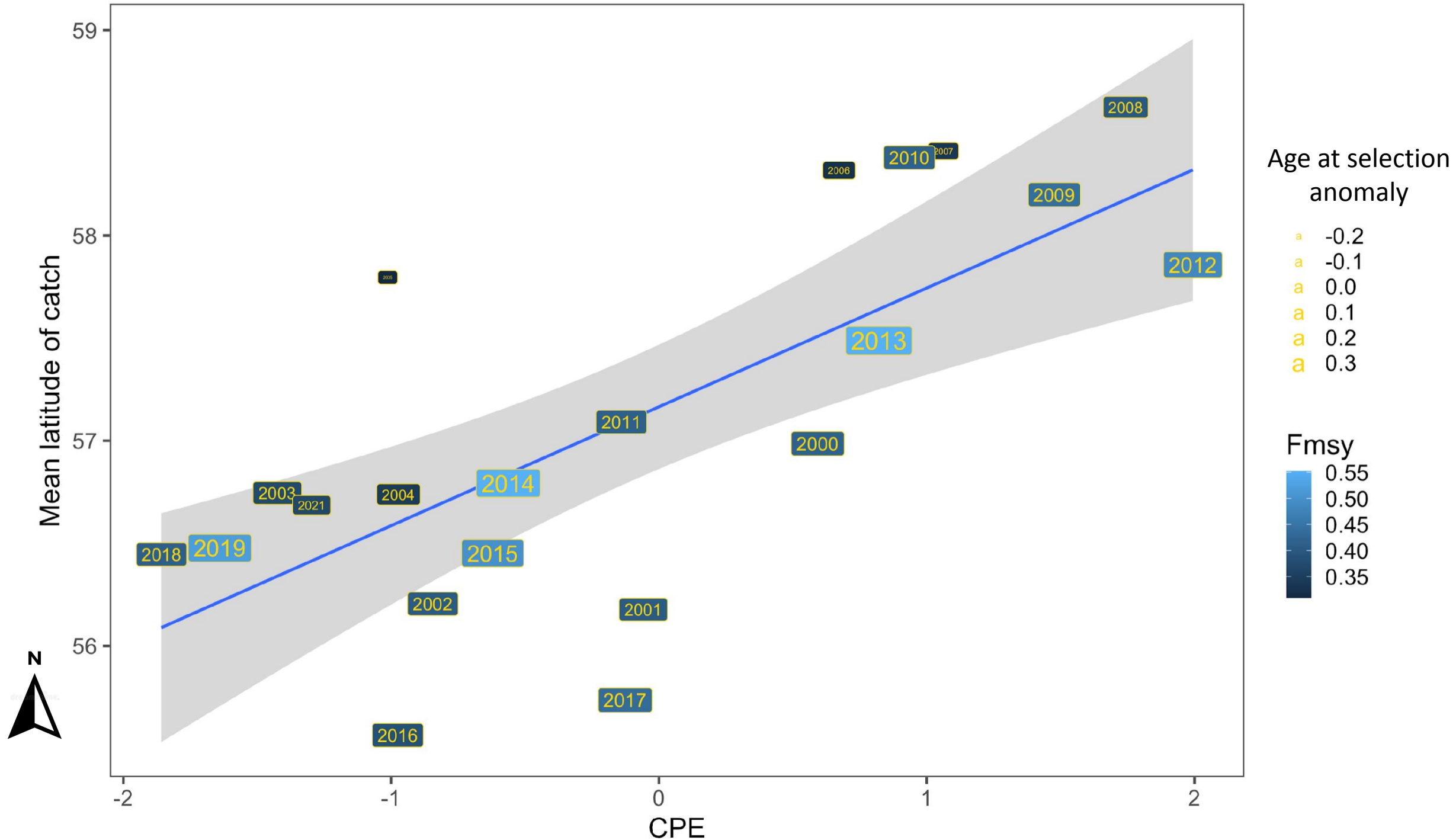


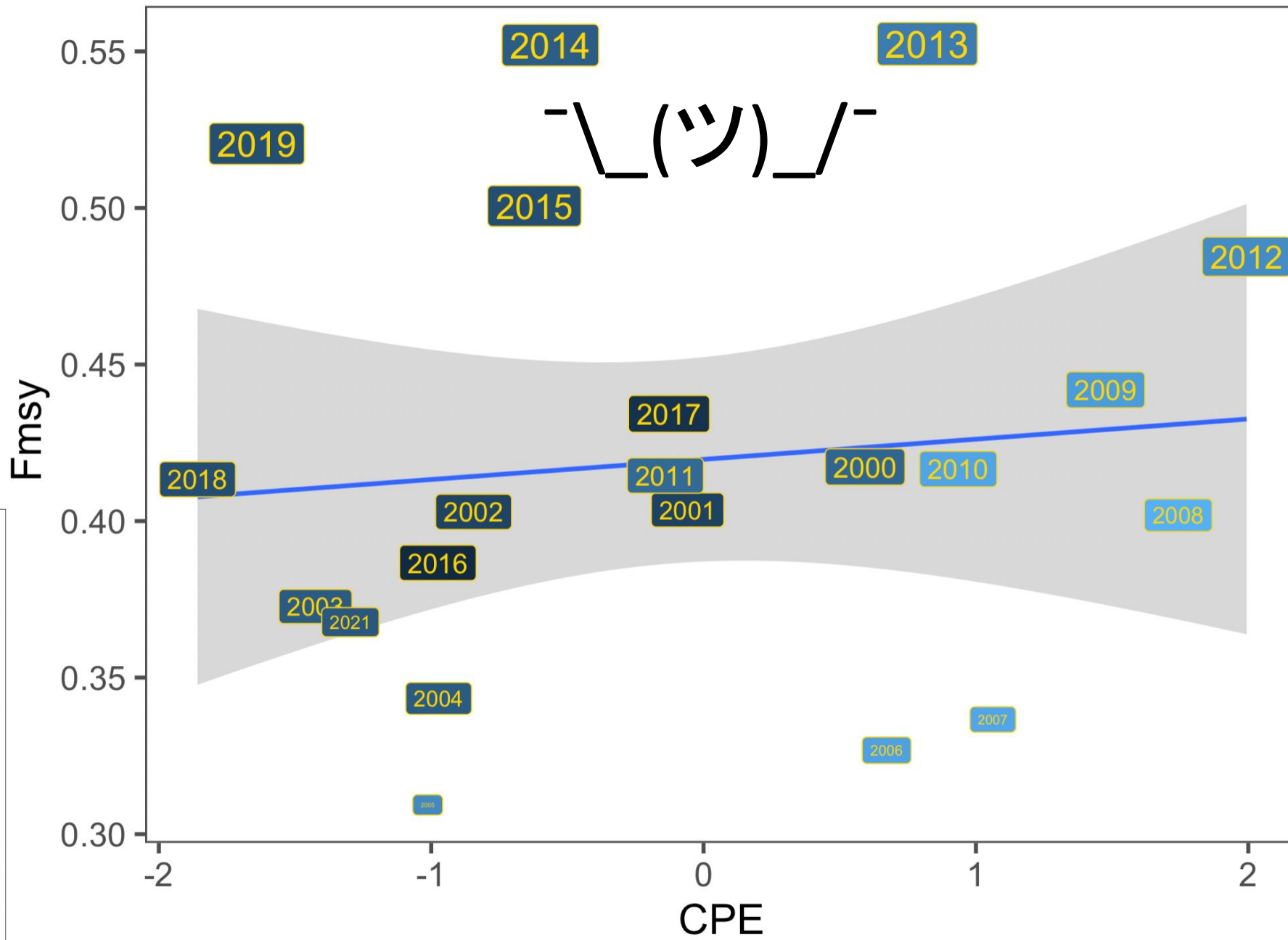
F_{MSY}

- By year and latitude
(and mean selected age)









Age at selection anomaly

- a -0.2
- a -0.1
- a 0.0
- a 0.1
- a 0.2
- a 0.3

MeanLat

