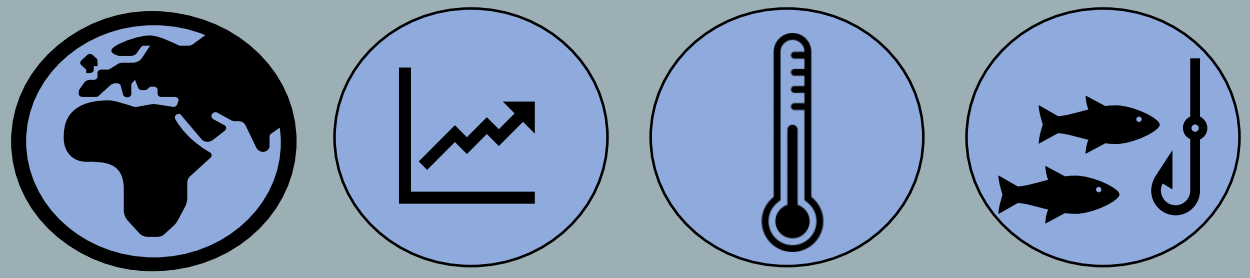
Pattern or Process: considering space, time, and the environment in species distribution models



Stephanie Brodie, Jim Thorson, Gemma Carroll, Elliott Hazen, Steven Bograd, Melissa Haltuch, Kirstin Holsman, Stan Kotwicki, Jameal Samhouri, Ellen Willis-Norton, Rebecca Selden

UNIVERSITY OF CALIFORNIA SANTA CRUZ
NOAA FISHERIES
RUTGERS THE STATE UNIVERSITY OF NEW JERSEY

Ecologists, managers, & stakeholders often ask:

How many individuals?

Why are they there?

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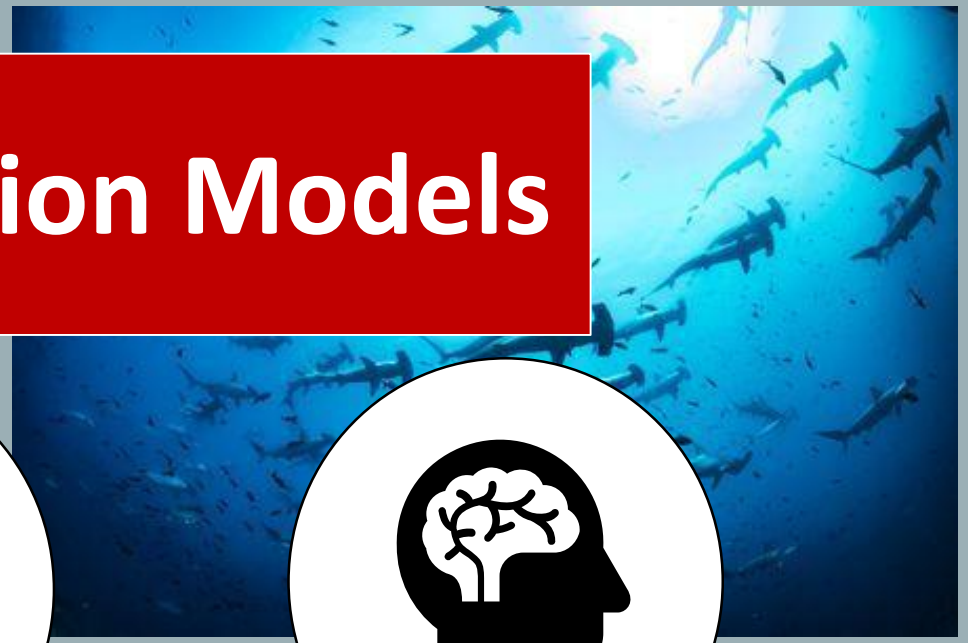
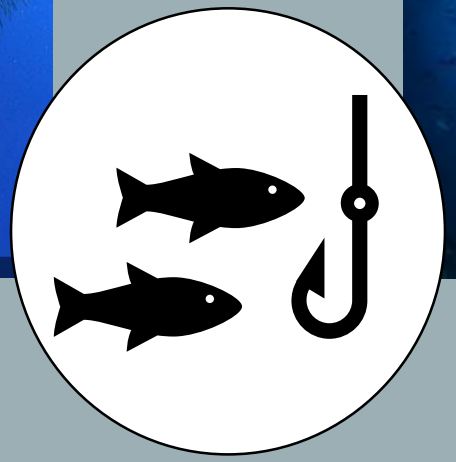


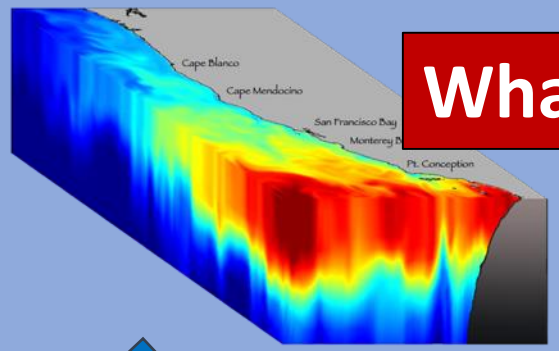
Species Distribution Models



Species Distribution Model

Species data

Covariates



What covariates?

What model is best?

Statistical or mechanistic model

Predictions

What Covariates?

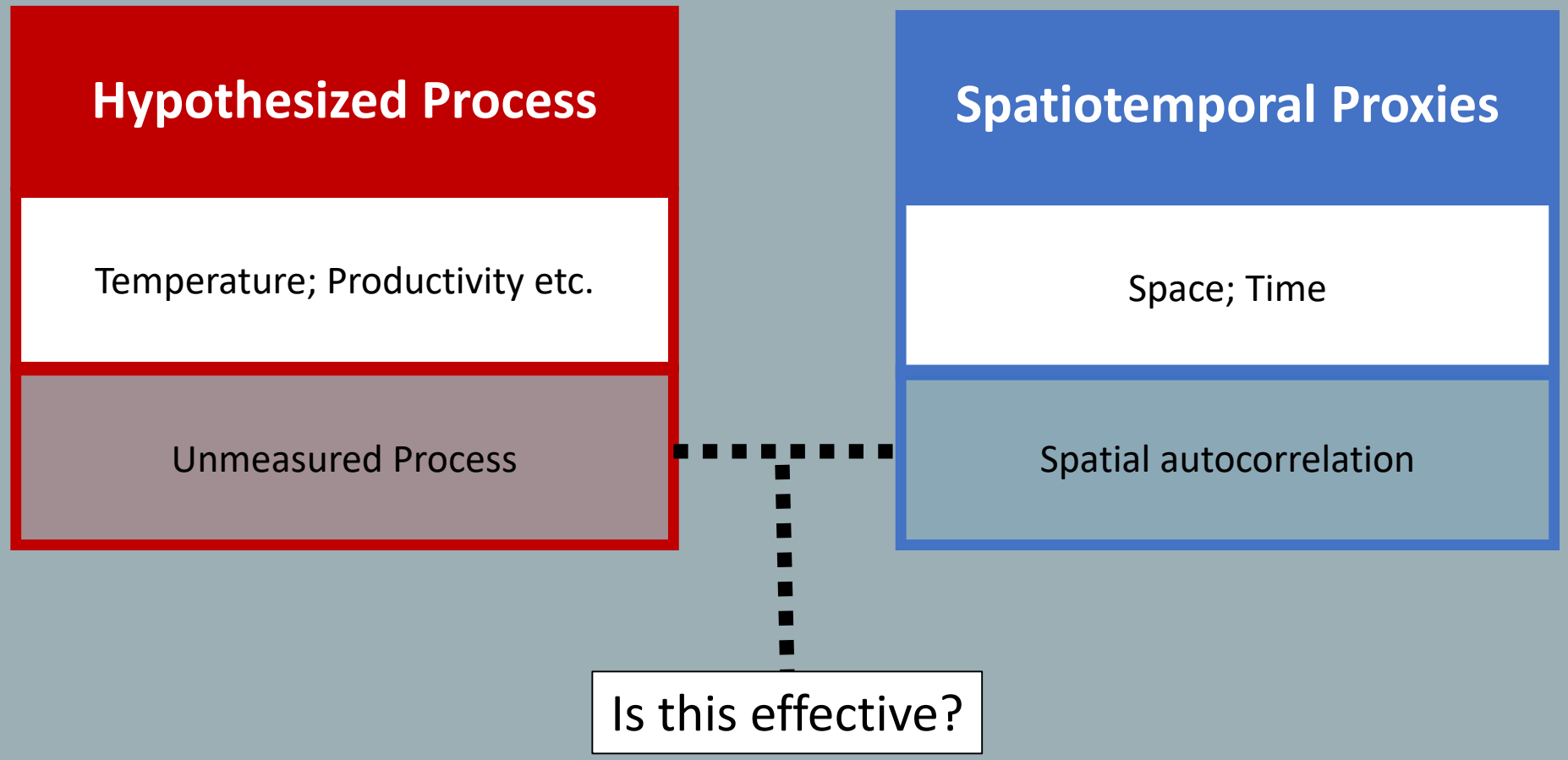
Hypothesized Process

Temperature; Productivity etc.

Spatiotemporal Proxies

Space; Time

What Covariates?



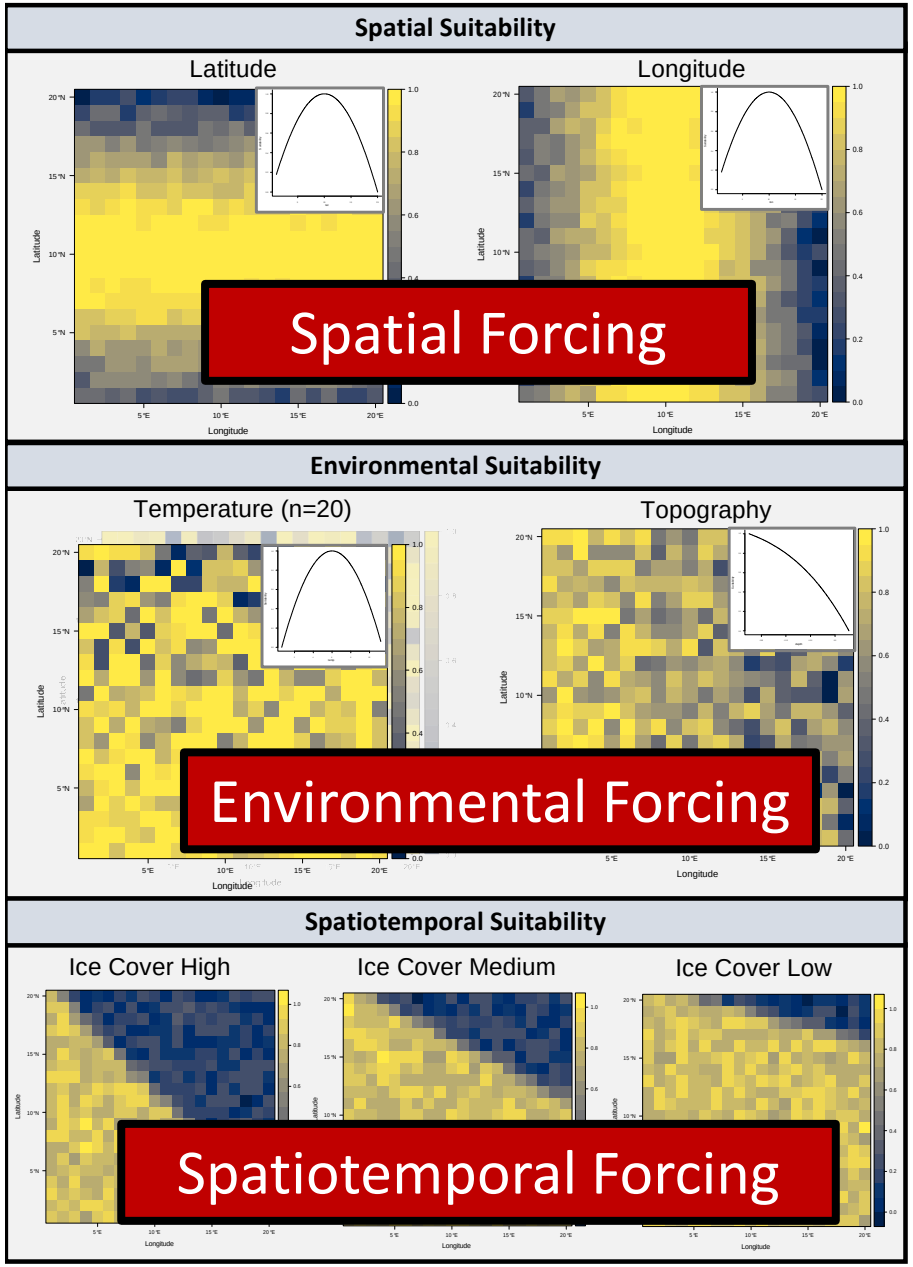
Goal

Evaluate SDM performance and parametrization of spatiotemporal and environmental covariates

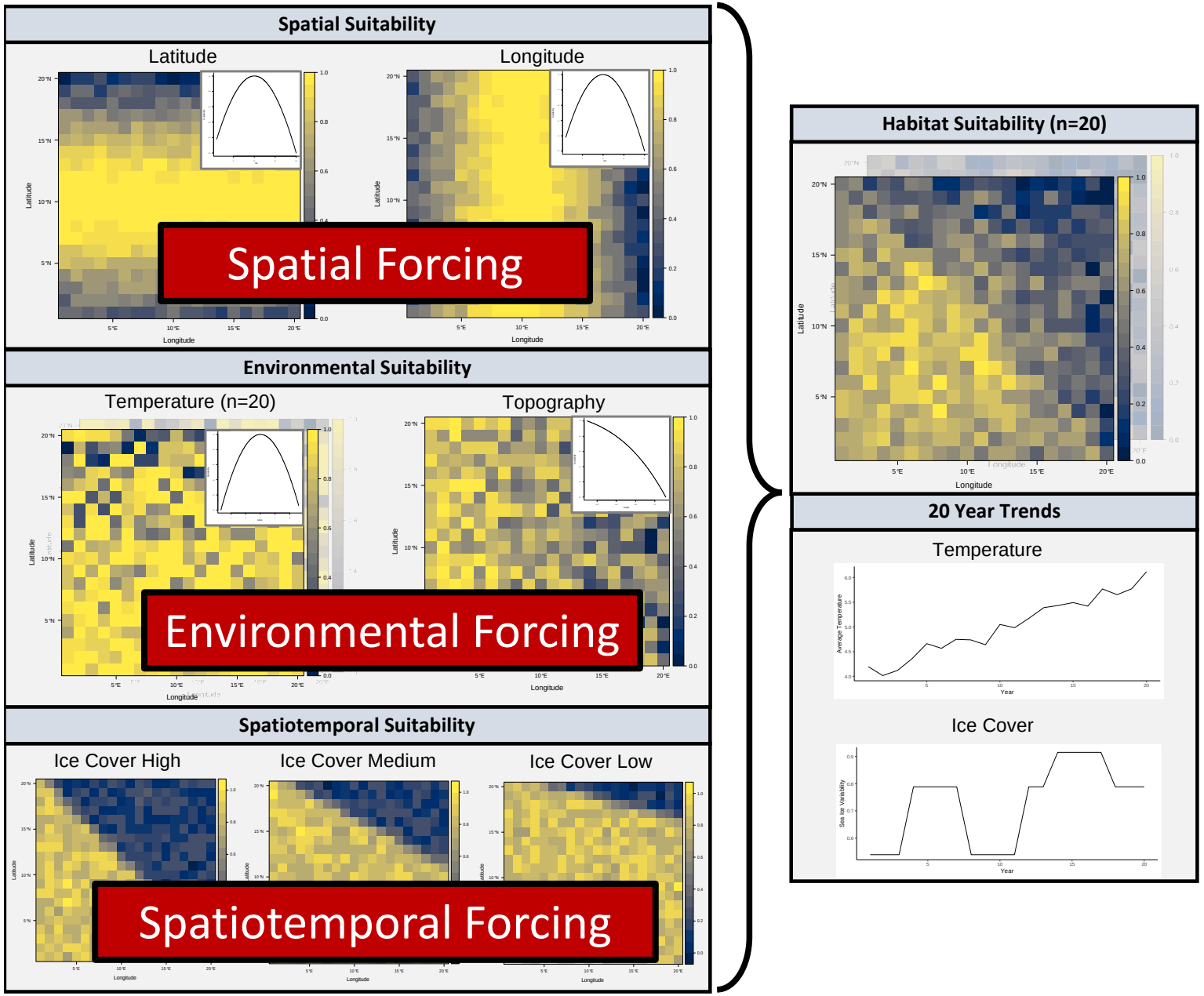
Simulated Data

Fisheries Case study

Simulated Data



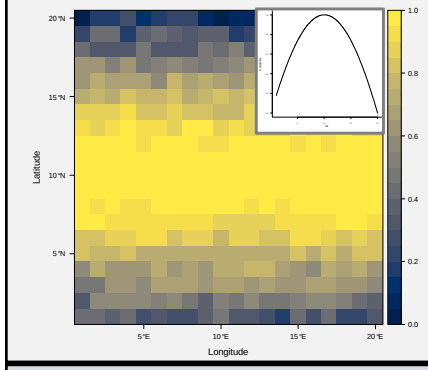
Simulated Data



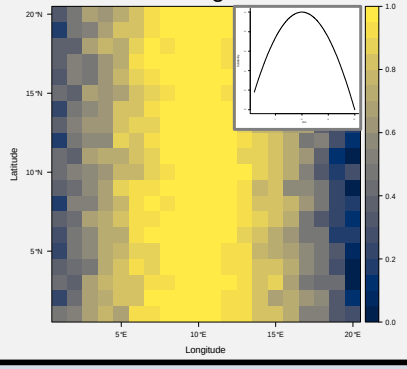
Simulated Data

Spatial Suitability

Latitude

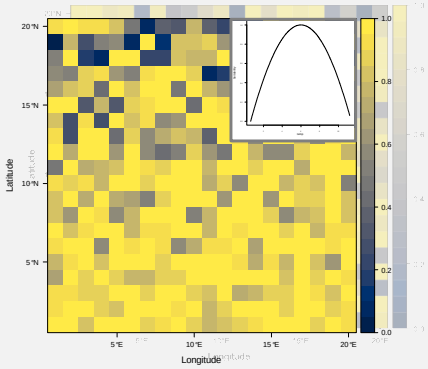


Longitude

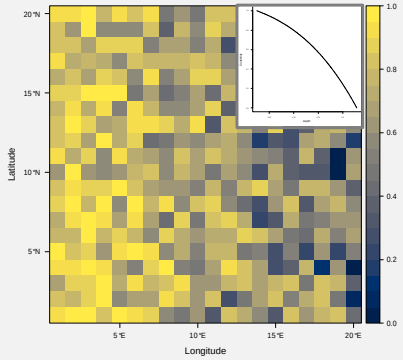


Environmental Suitability

Temperature (n=20)

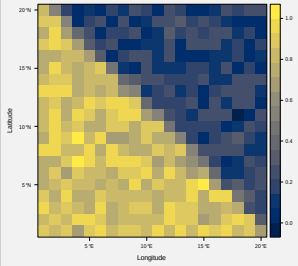


Topography

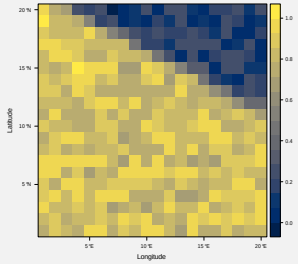


Spatiotemporal Suitability

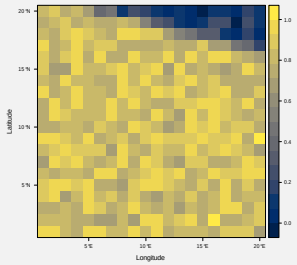
Ice Cover High



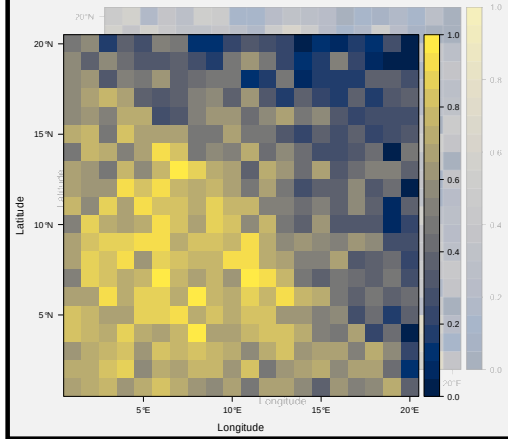
Ice Cover Medium



Ice Cover Low

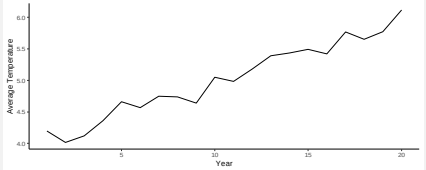


Habitat Suitability (n=20)

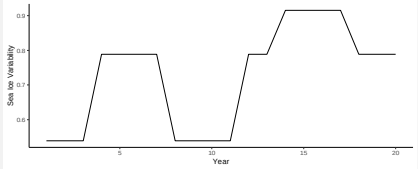


20 Year Trends

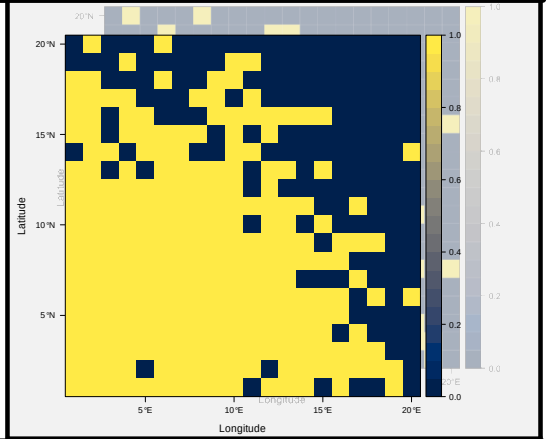
Temperature



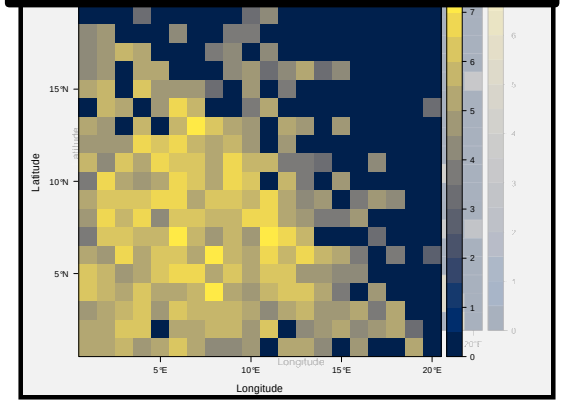
Ice Cover



Species Presence



Species Abundance



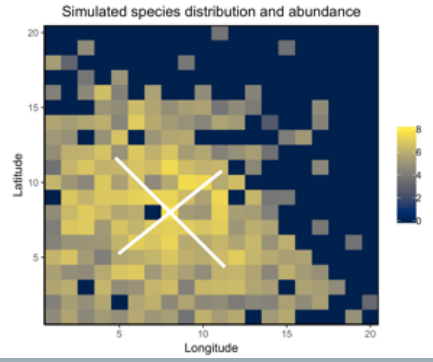
Model Comparison

3x3 factorial design

3 Models	3 Covariate configurations
Boosted Regression Tree (BRT)	Spatiotemporal
Generalised Additive Model (GAM)	Environmental
Vector Autoregressive Spatiotemporal model (VAST)	Spatiotemporal & Environmental

Results:
Spatial Predictions

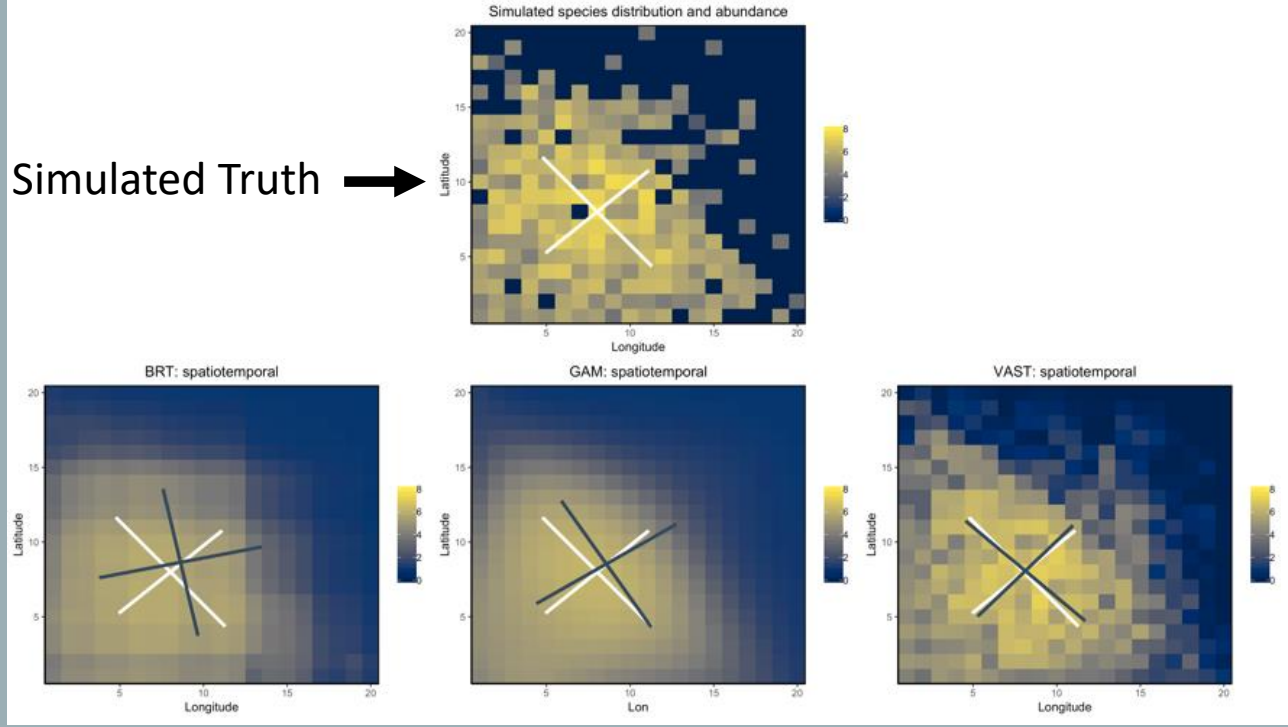
Simulated Truth



Results: Spatial Predictions

Simulated Truth →

Environment is missing →

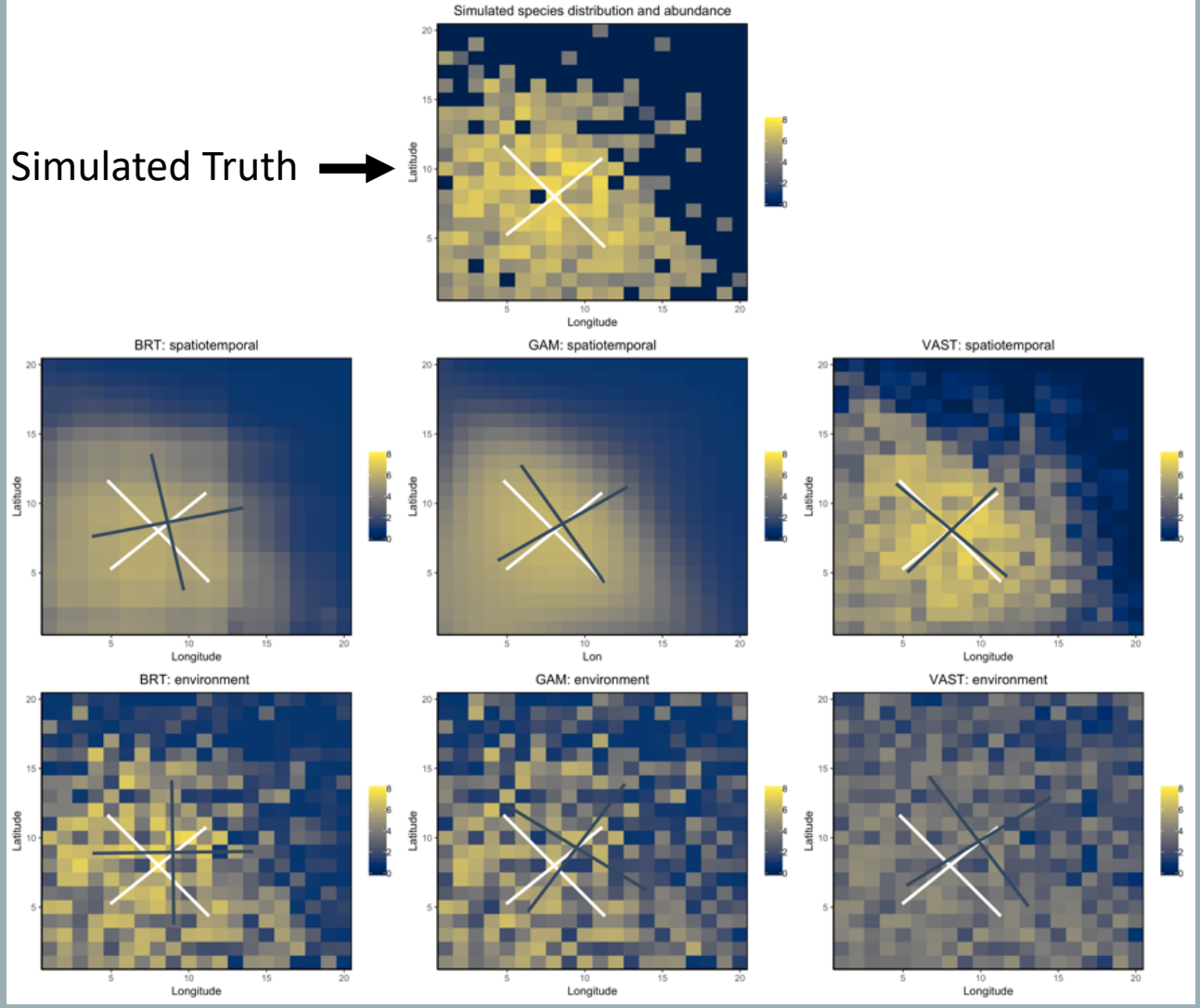


Results: Spatial Predictions

Simulated Truth →

Environment is missing →

Space & time is missing →



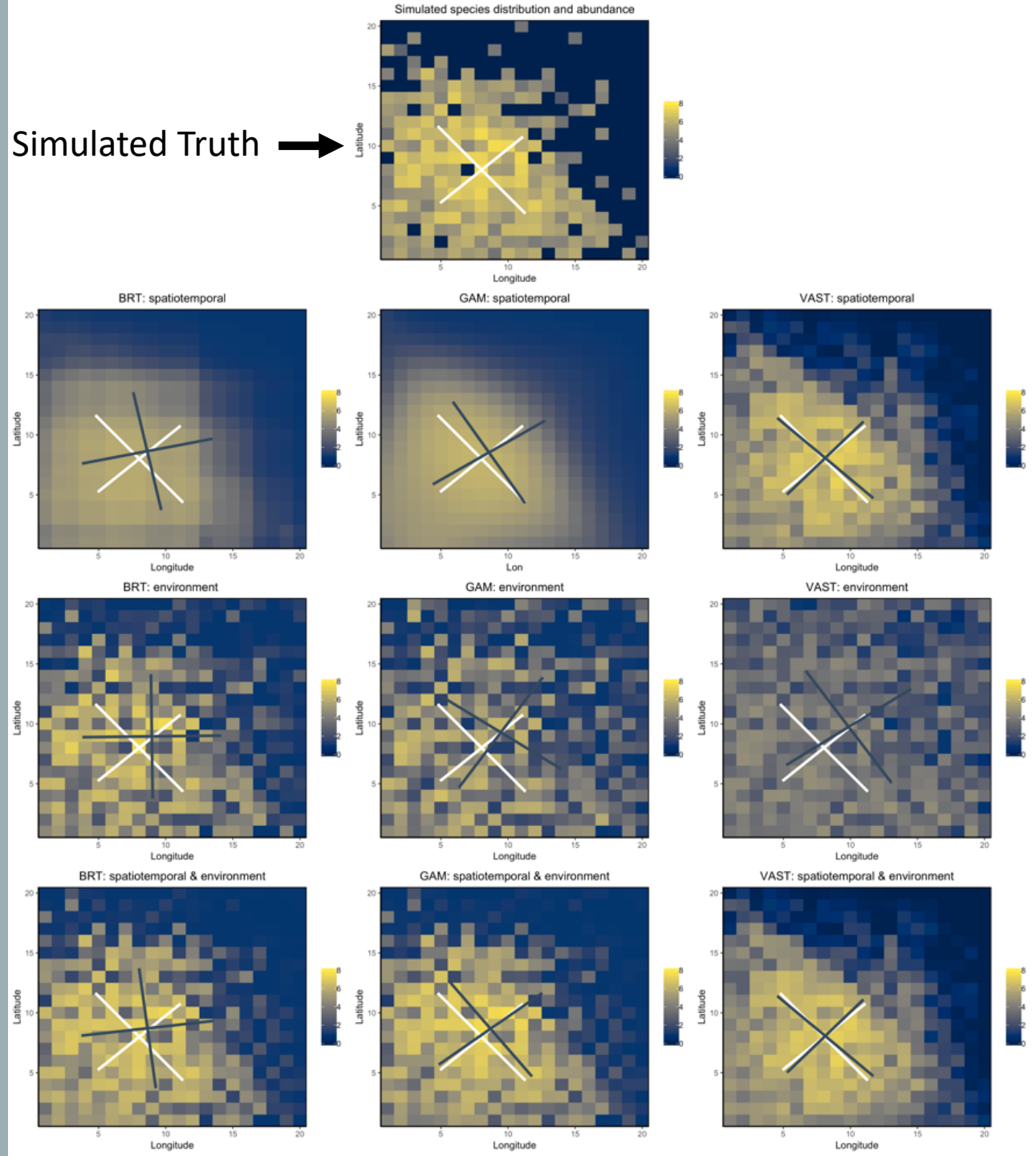
Results: Spatial Predictions

Simulated Truth →

Environment is missing →

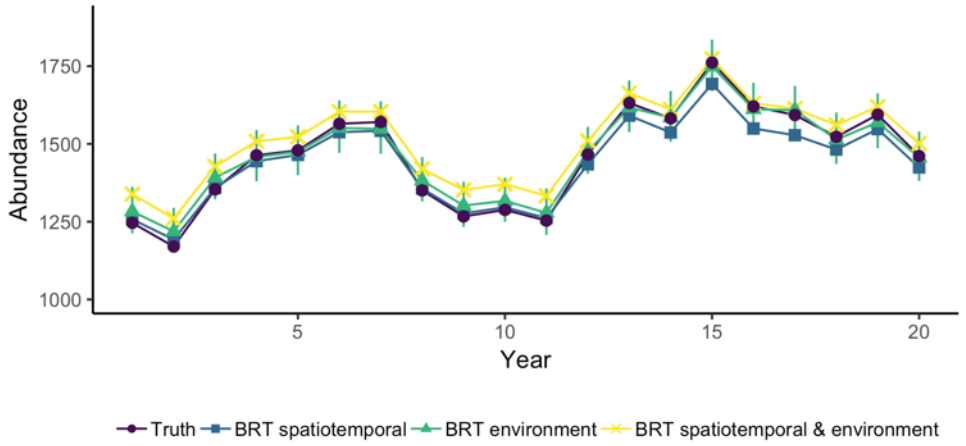
Space & time is missing →

All covariates included →

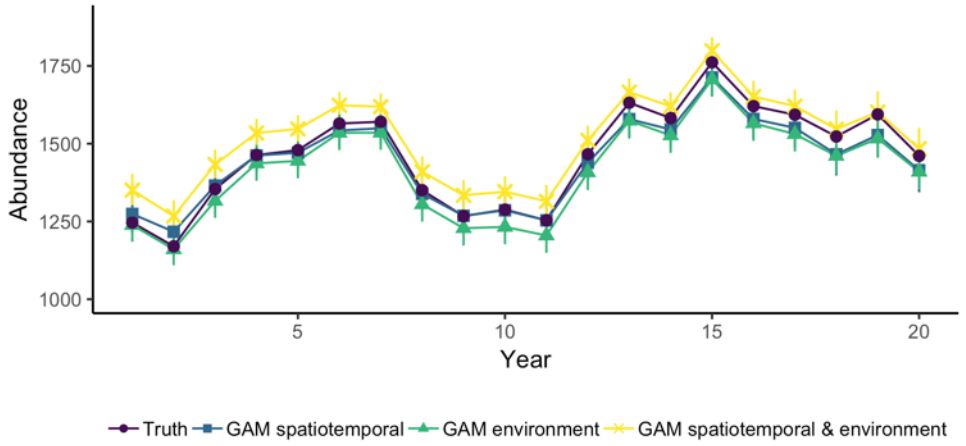


Results:
Time-series of abundance

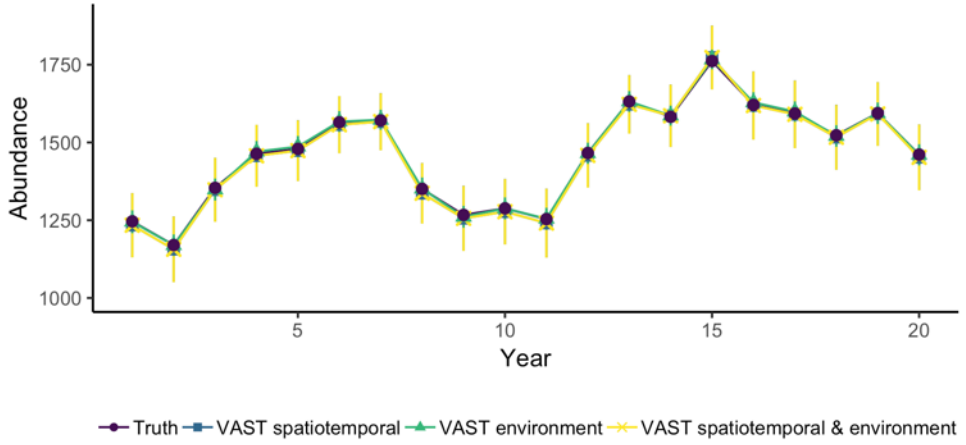
BRT models



GAM models



All models do well but VAST is best



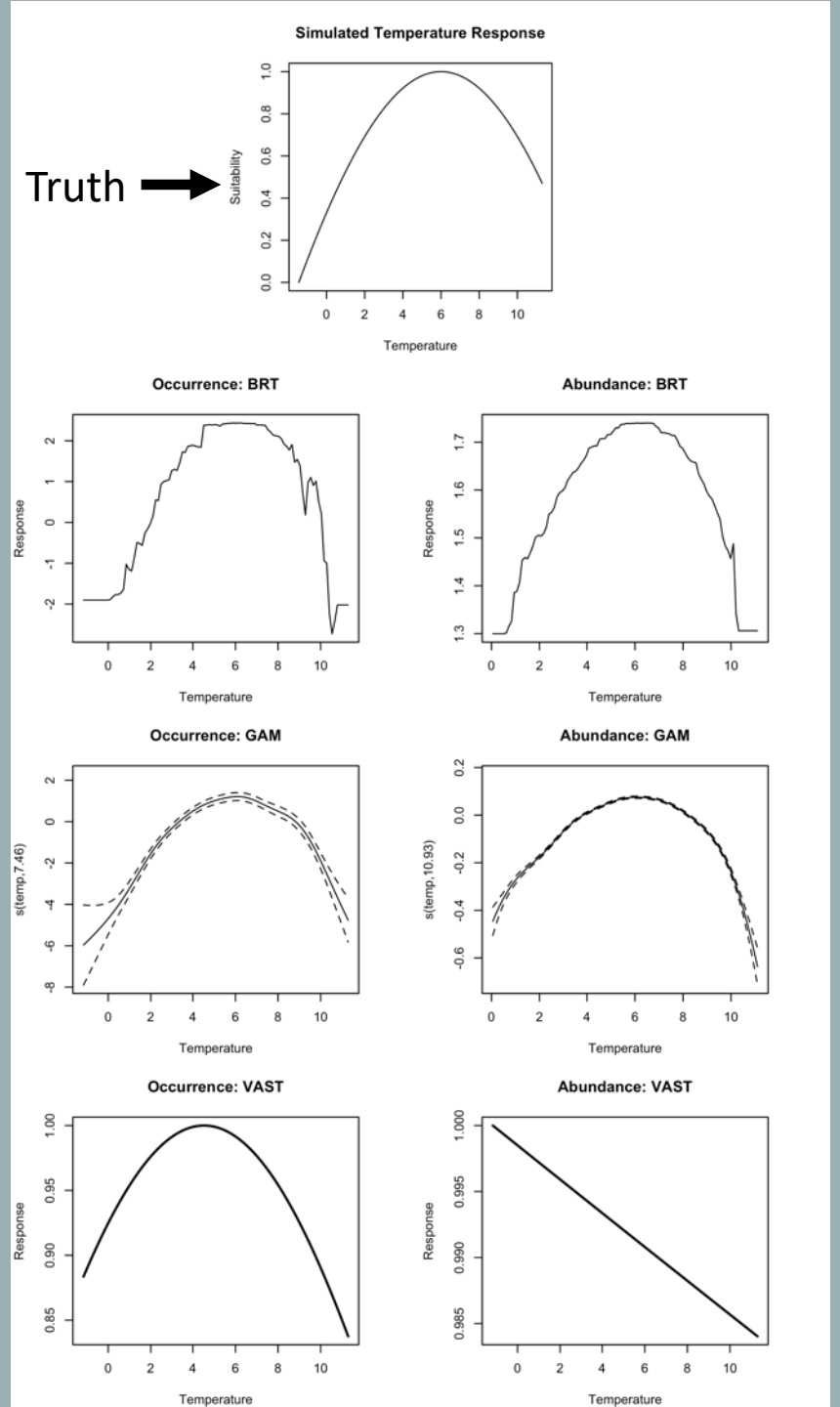
Results:
Model response curves

Truth →

BRT models:
regression tree splits →

GAM models:
spline smoother →

VAST models:
quadratic functions →



Simulation Summary

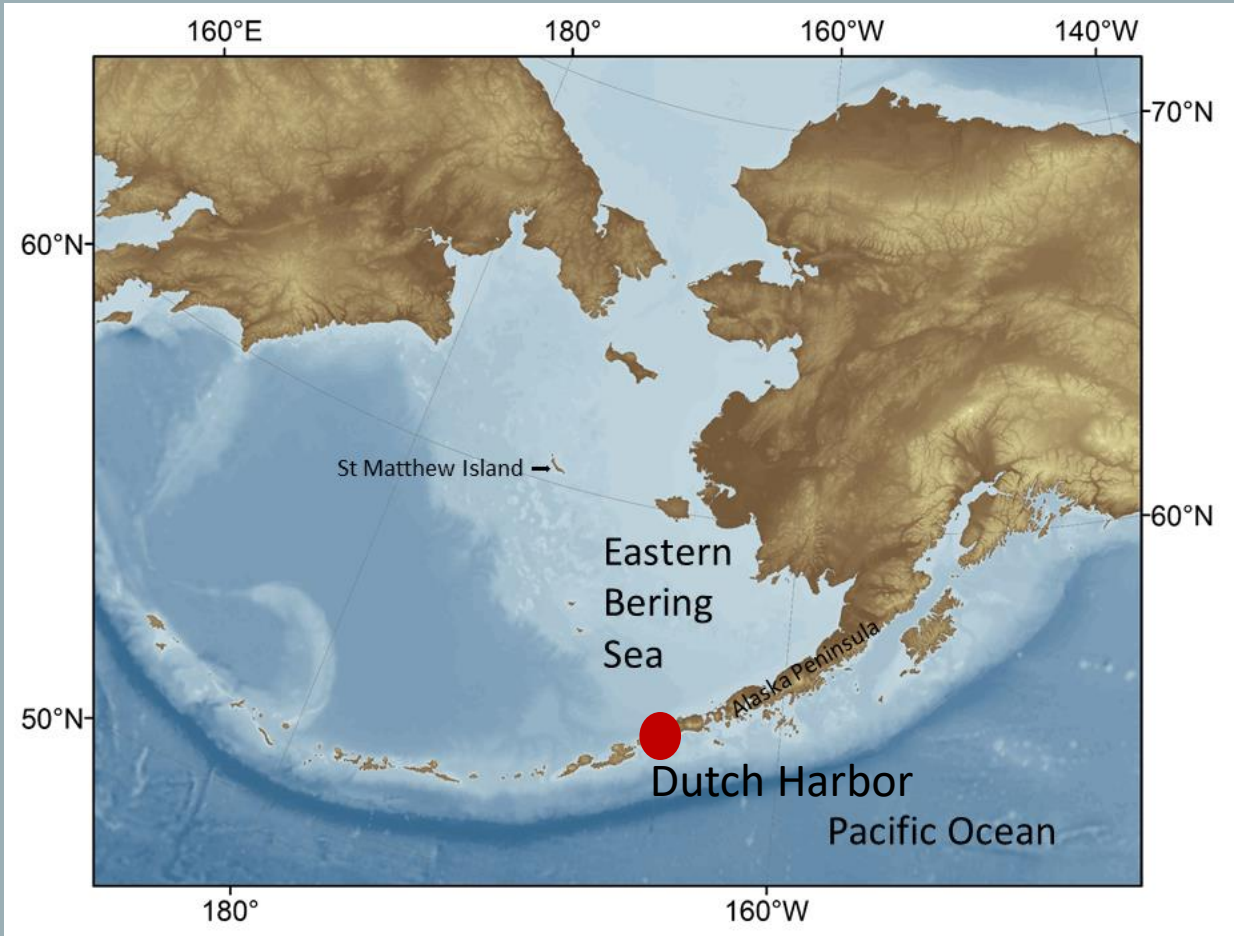
- VAST was best for estimating abundance
- Non-linear models can accurately represent environmental relationships
- Models including both environmental and spatiotemporal covariates are best

Limitation: Ecological Forecasting

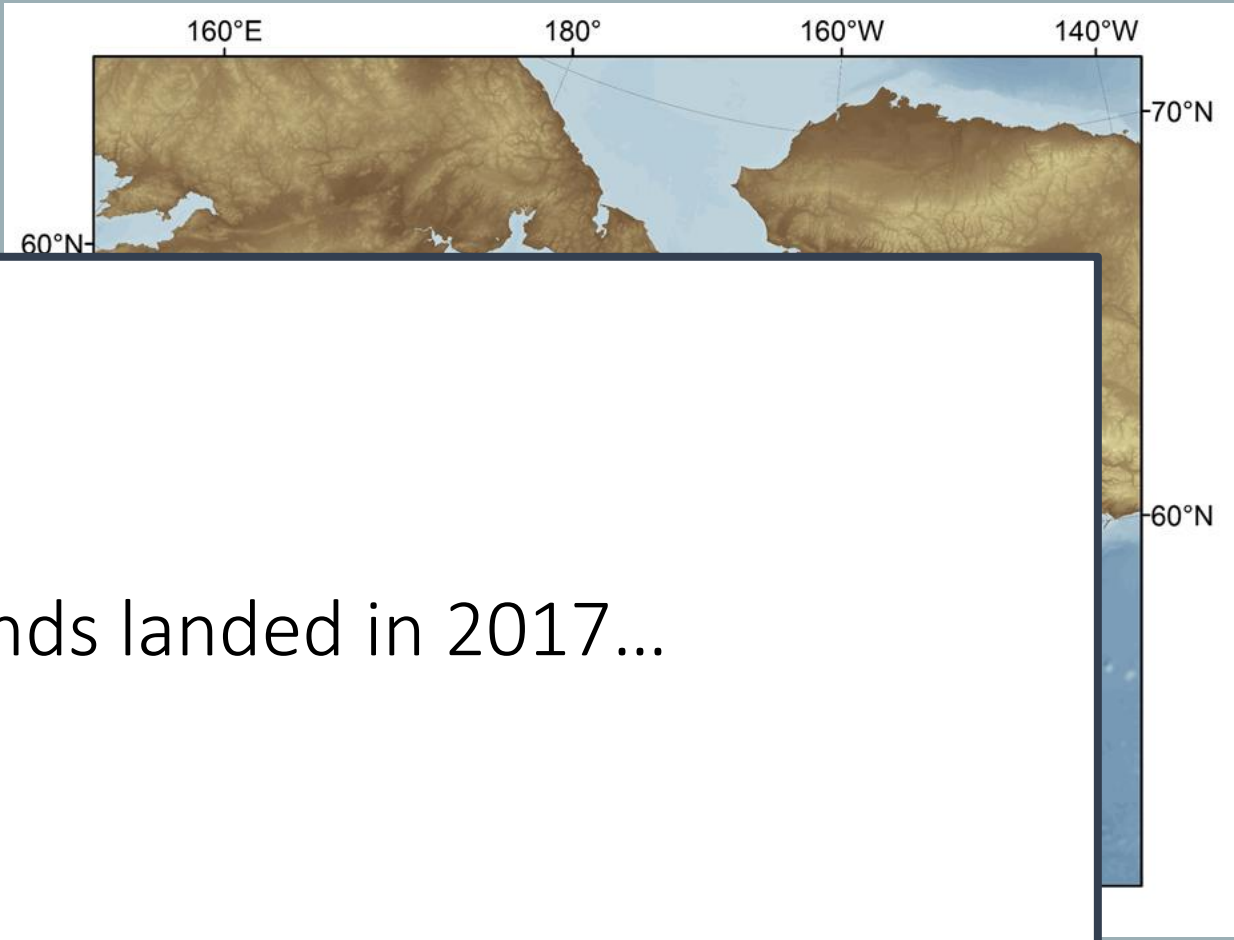
Brodie et al., in review

Fisheries Case Study

- Fisheries-independent trawl surveys
- 1982-2016
- Accurately estimating abundance is critical
- Contains US port with highest landings for 21 consecutive years



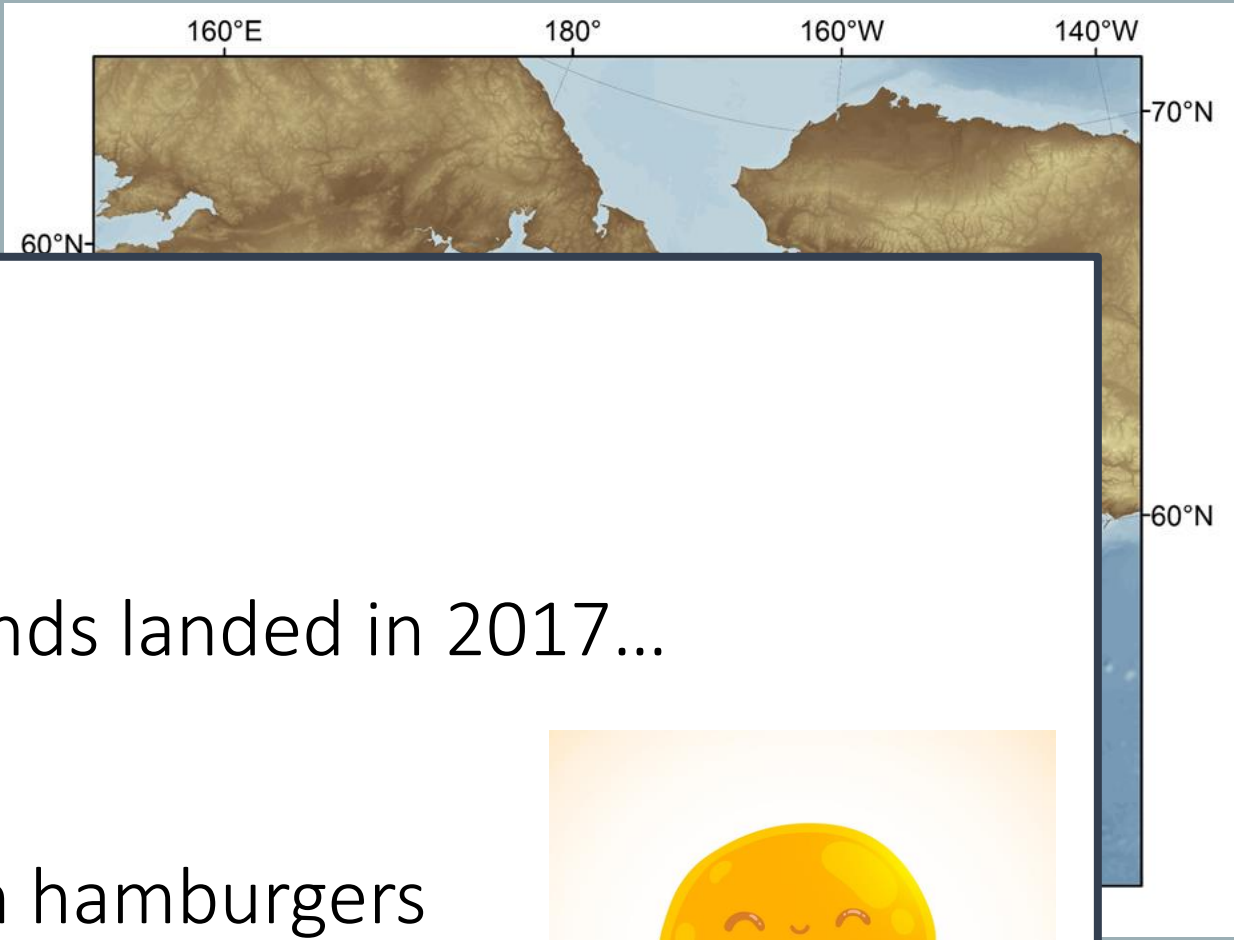
Fisheries Case Study



- Fisherie
- 1982-20
- Accurat
  critical
- Port wit
  21 cons

769 million pounds landed in 2017…

Fisheries Case Study



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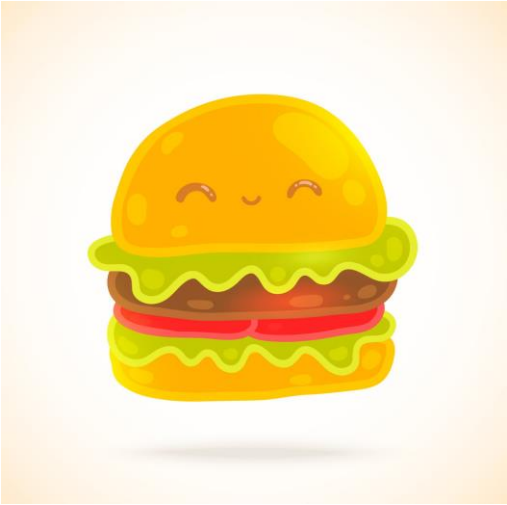
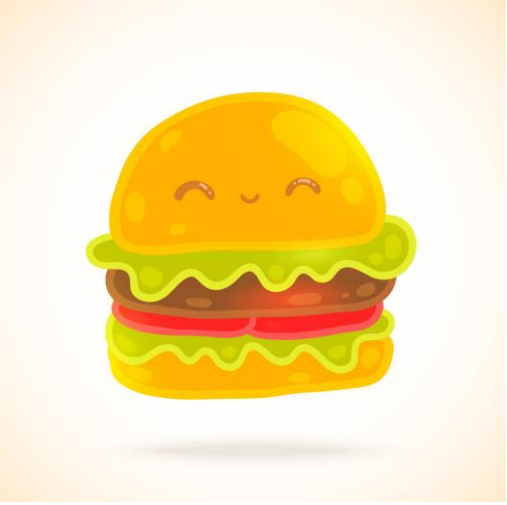


12 billion hamburgers



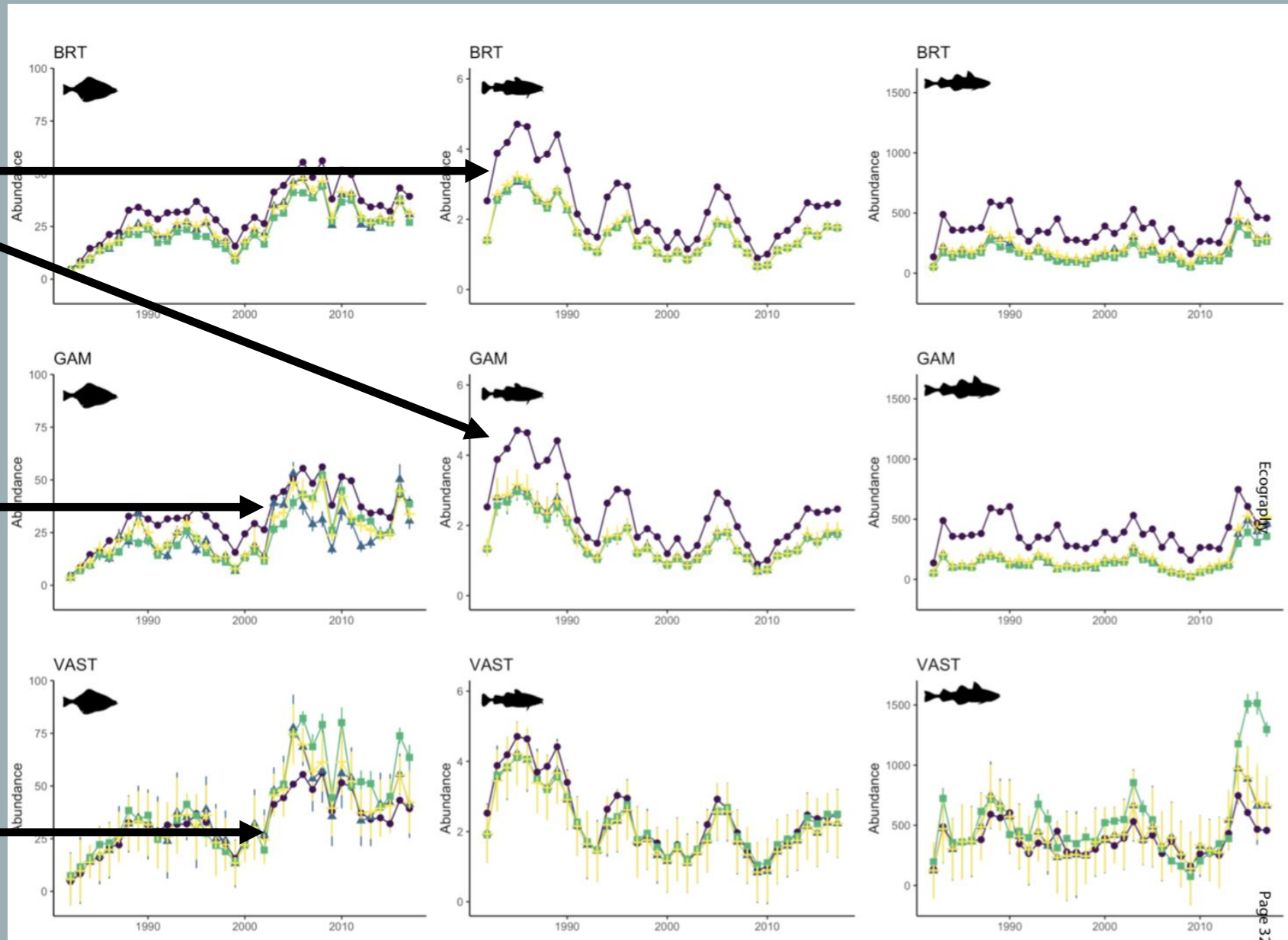
Case Study matches the simulation

BRT & GAMS likely to under predict

Species specific differences (flounder model was noisy)

VAST models are most accurate with large errors

Including spatiotemporal and environmental covariates best



Trade-offs

Species abundance

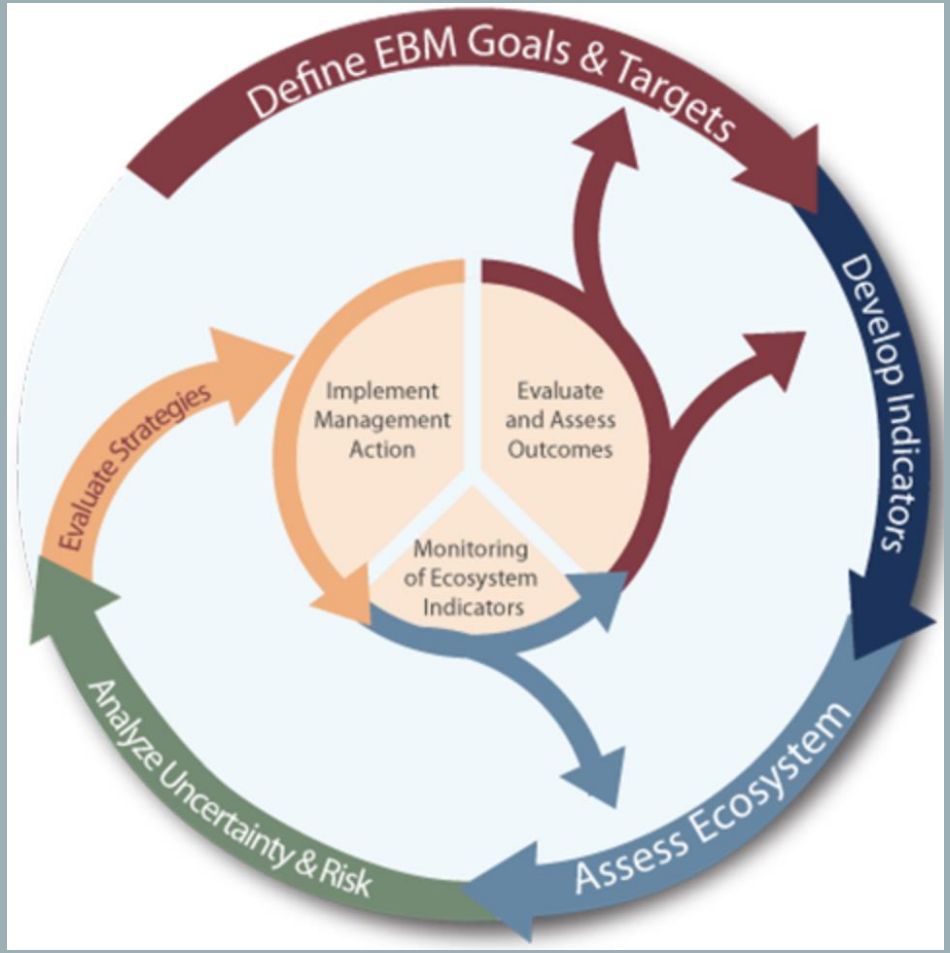
Spatial patterns

Underlying mechanisms

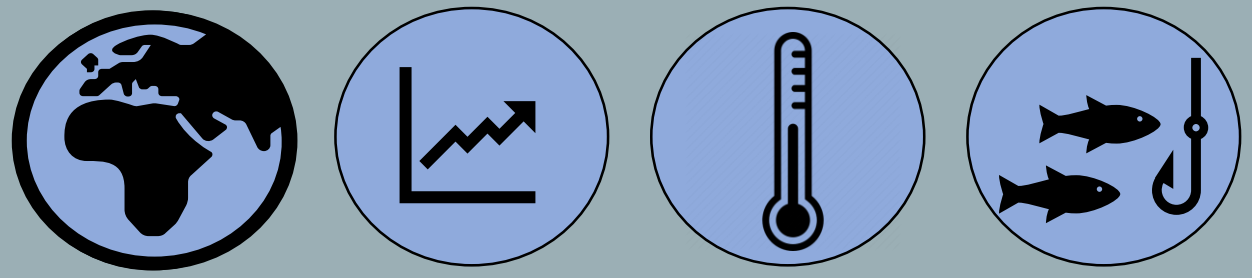
Brodie et al., in review

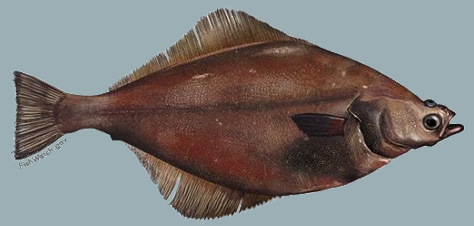
Why does this matter?

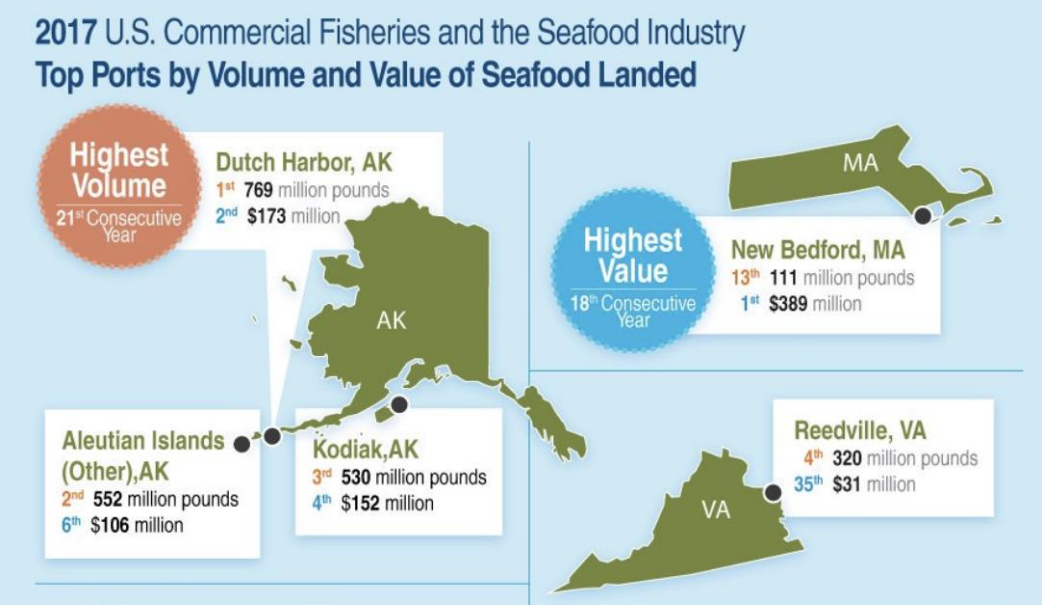
- Managers & policy makers use these models:
  - Accurate distribution and abundance is a key requirement
  - Accurate estimates form baseline of strategic plans that seek to conserve resources and improve resilience to future change
- Time-series of metrics can form part of integrated ecosystem assessments

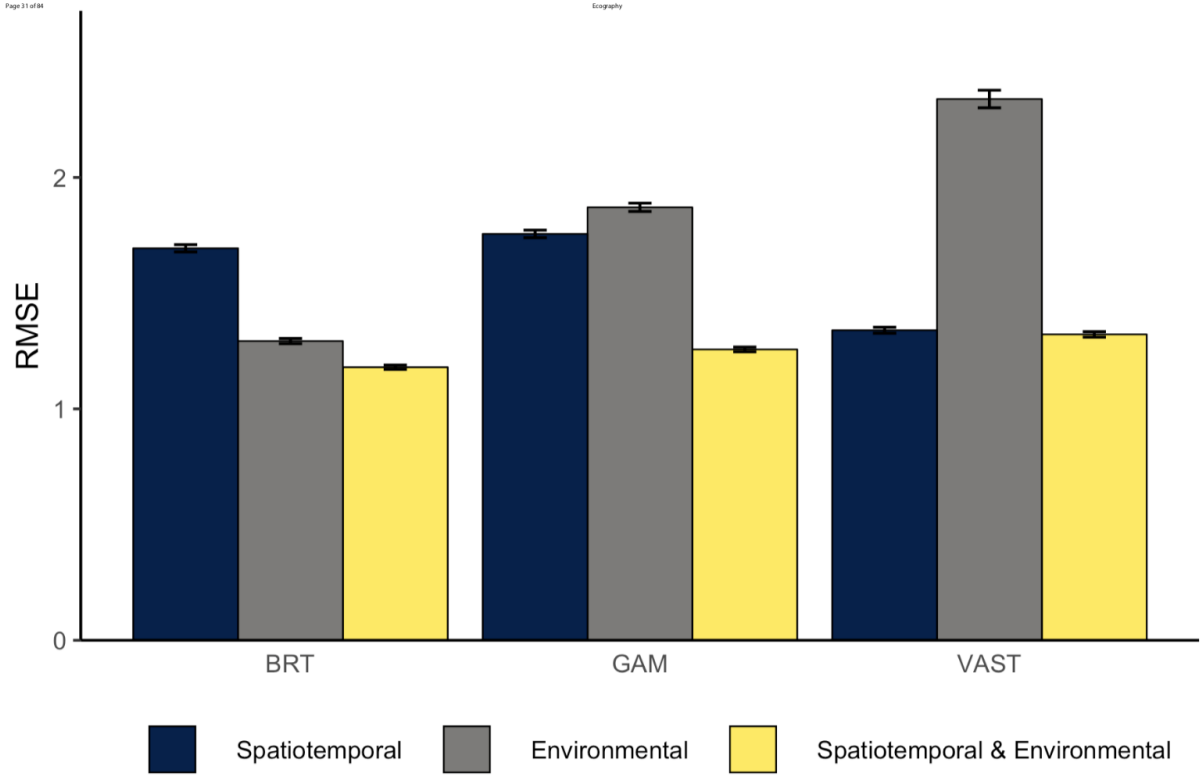


Thanks for listening






2017 U.S. Commercial Fisheries and the Seafood Industry
Top Ports by Volume and Value of Seafood Landed
Highest Volume
21st Consecutive Year
Dutch Harbor, AK
1st 769 million pounds
2nd $173 million
AK
Aleutian Islands (Other),AK
2nd 552 million pounds
6th $106 million
Kodiak,AK
3rd 530 million pounds
4th $152 million
MA
Highest Value
18th Consecutive Year
New Bedford, MA
13th 111 million pounds
1st $389 million
VA
Reedville, VA
4th 320 million pounds
35th $31 million


RMSE
0
1
2
BRT
GAM
VAST
Spatiotemporal
Environmental
Spatiotemporal & Environmental