Productivity

(or lack thereof)

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Research Institute

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Productivity Group

- Stock assessment using machine learning
- Diagnosing bias in stock assessments

Stock Assessment Goals

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- estimate current & past abundance
- estimate recruitment & mortality
- specify reference points:
  - Bmsy = biomass that produces maximum sustainable yield (MSY)
  - Fmsy = fishing mortality that produces MSY
- determine stock status
  - B<Bmsy —> overfished
  - F>Fmsy —> overfishing
- Project forward ~3 years to set quotas

Stock Assessments

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- Current approach
  - age-structured model for a particular region (stock)
  - strong dependence on trawl survey (stratified mean abundance)
  - fishery dependent data used to calculate catch

- Critiques
  - no environmental data
  - lots of data (esp. fishery dependent and human-system data) not included
  - poor performance in NE in last decade

Stock Assessments

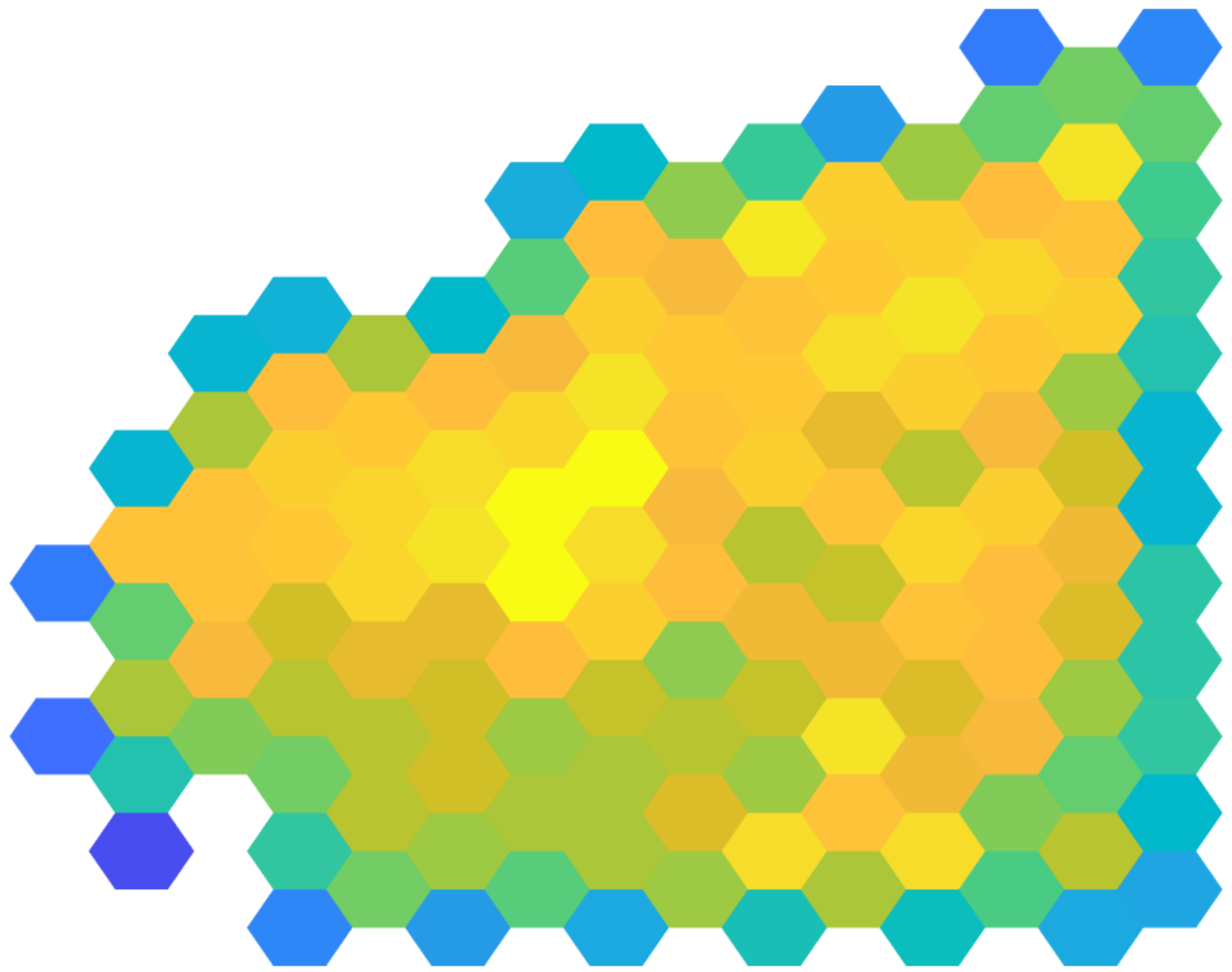
- Current approach
  - age-structured model for a particular region (stock)
  - strong dependence on trawl survey (stratified mean abundance)
  - fishery dependent da

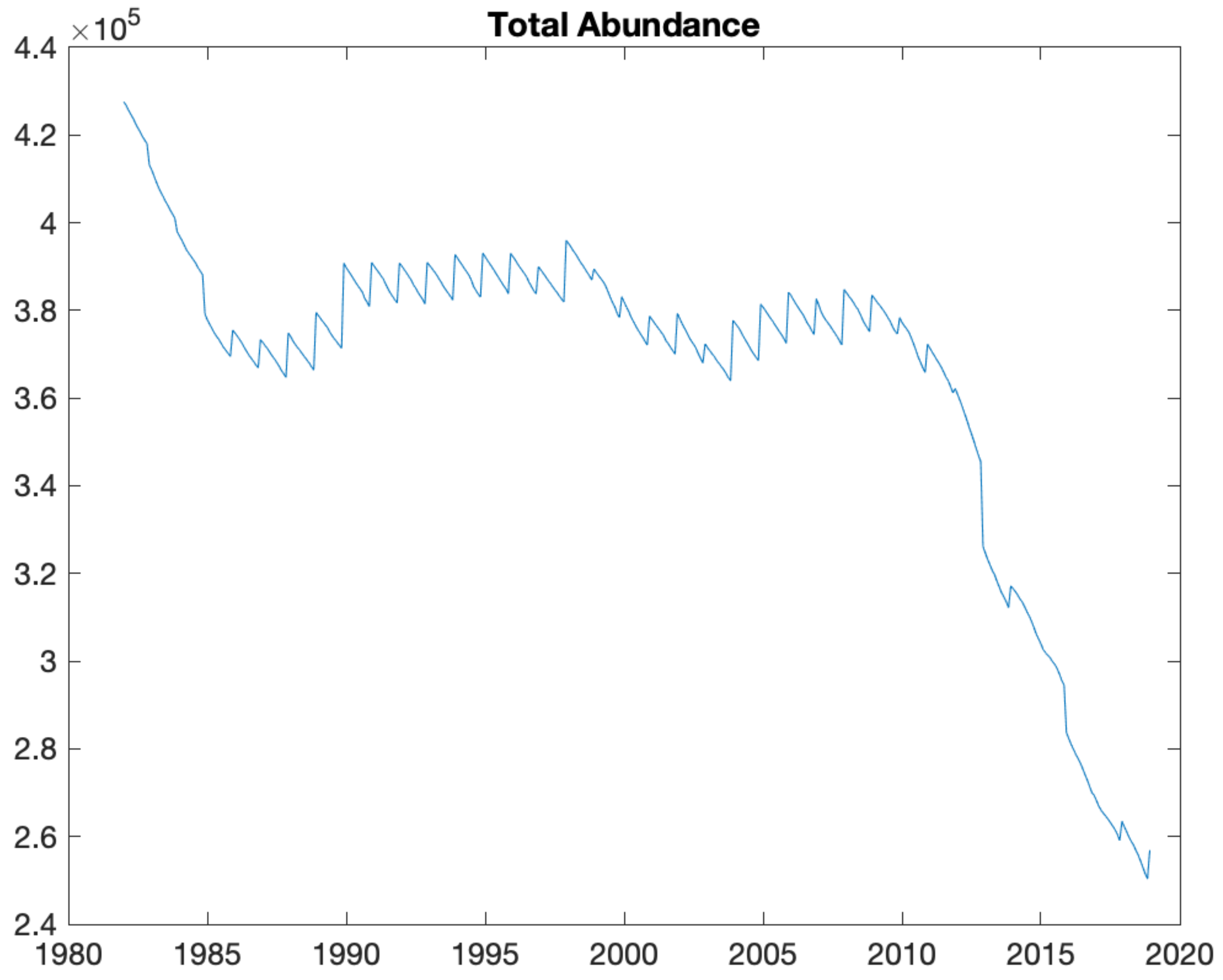
Can machine learning (e.g. neural nets) replicate stock assessments?

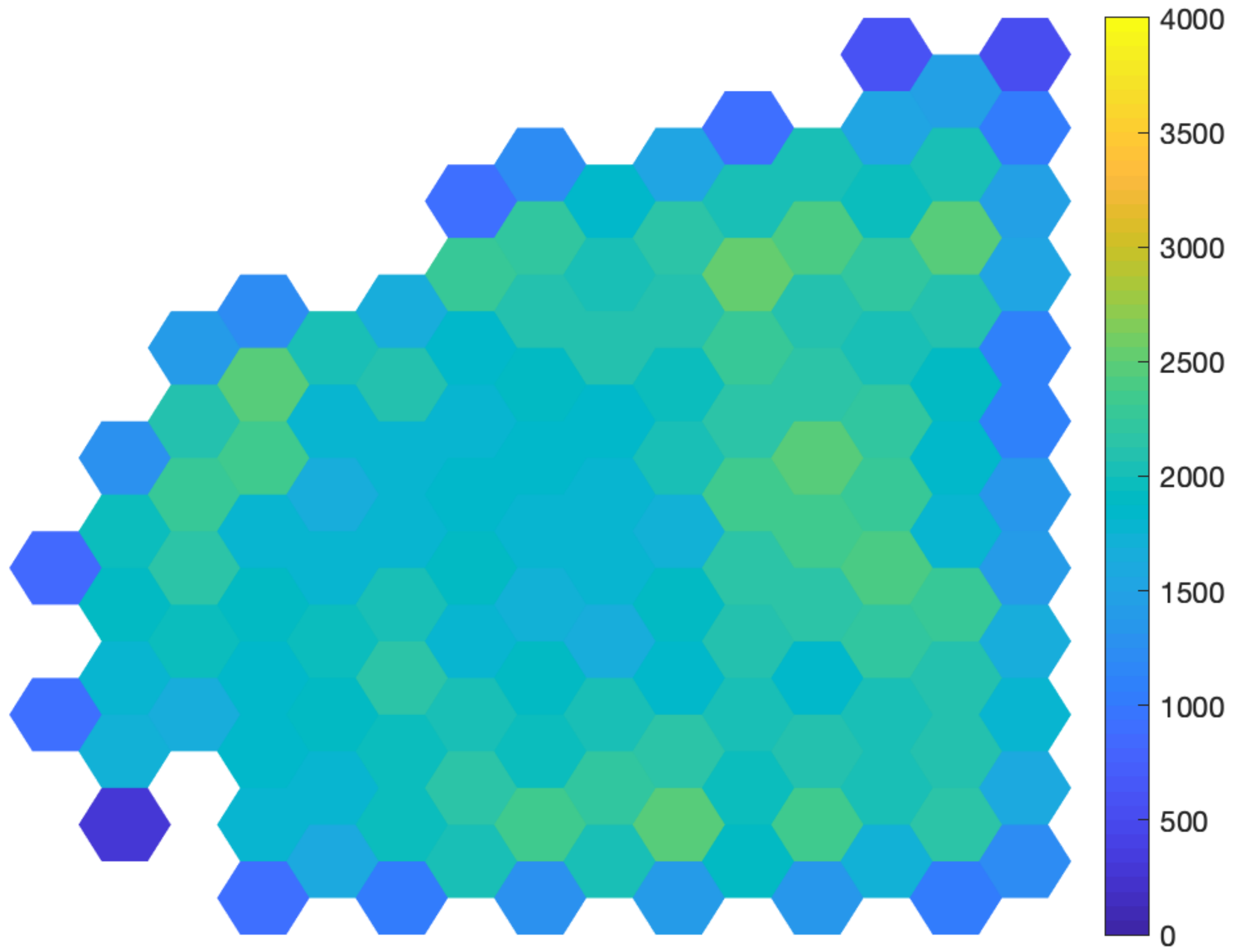
- Critiques
  - no environmental data
  - lots of data (esp. fishery dependent and human-system data) not included
  - poor performance in NE in last decade

Input data

- Forward model
  - cod like fish, 5 ages
  - temperature dependent movement
  - temperature dependent mortality & recruitment
  - monthly time step

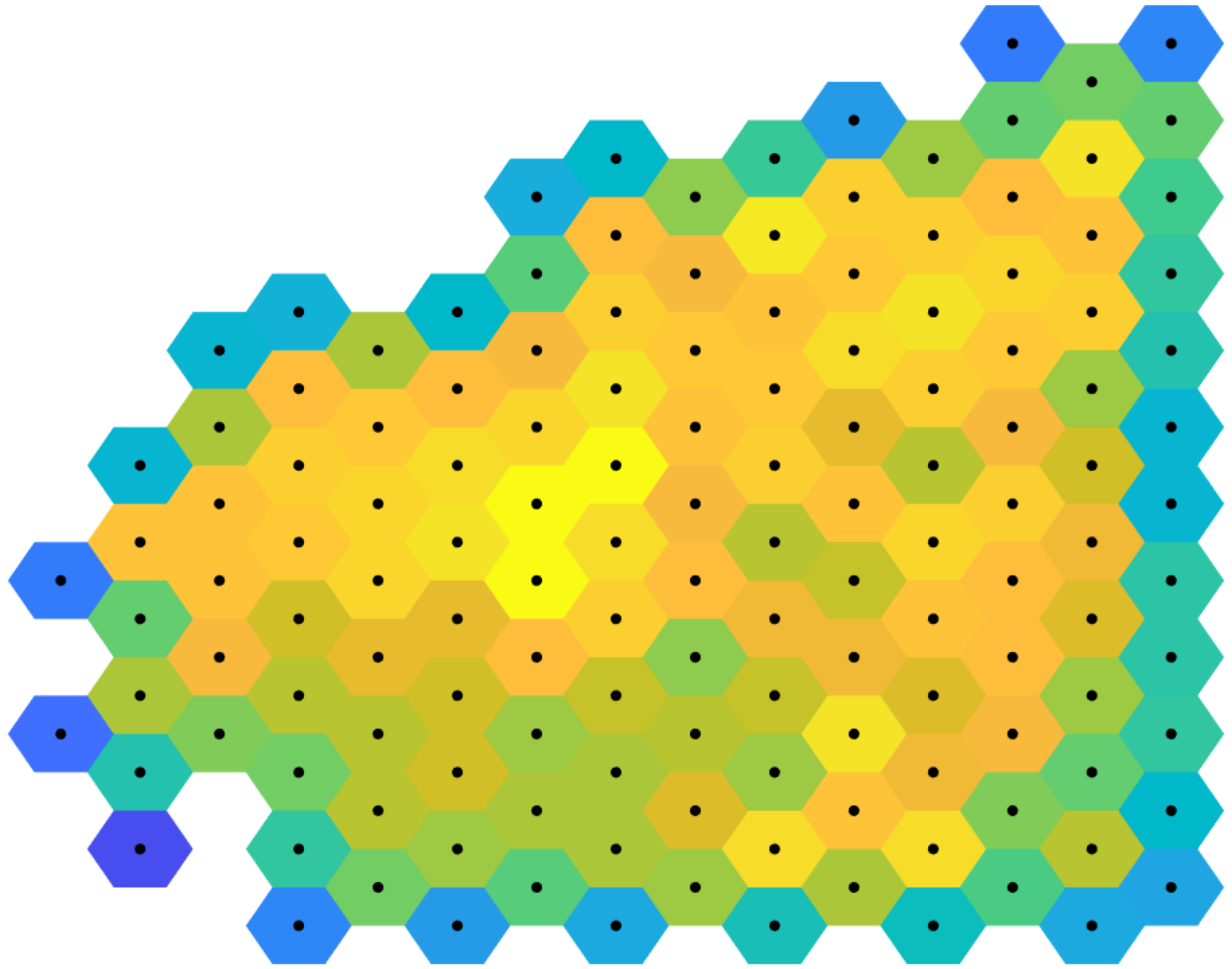


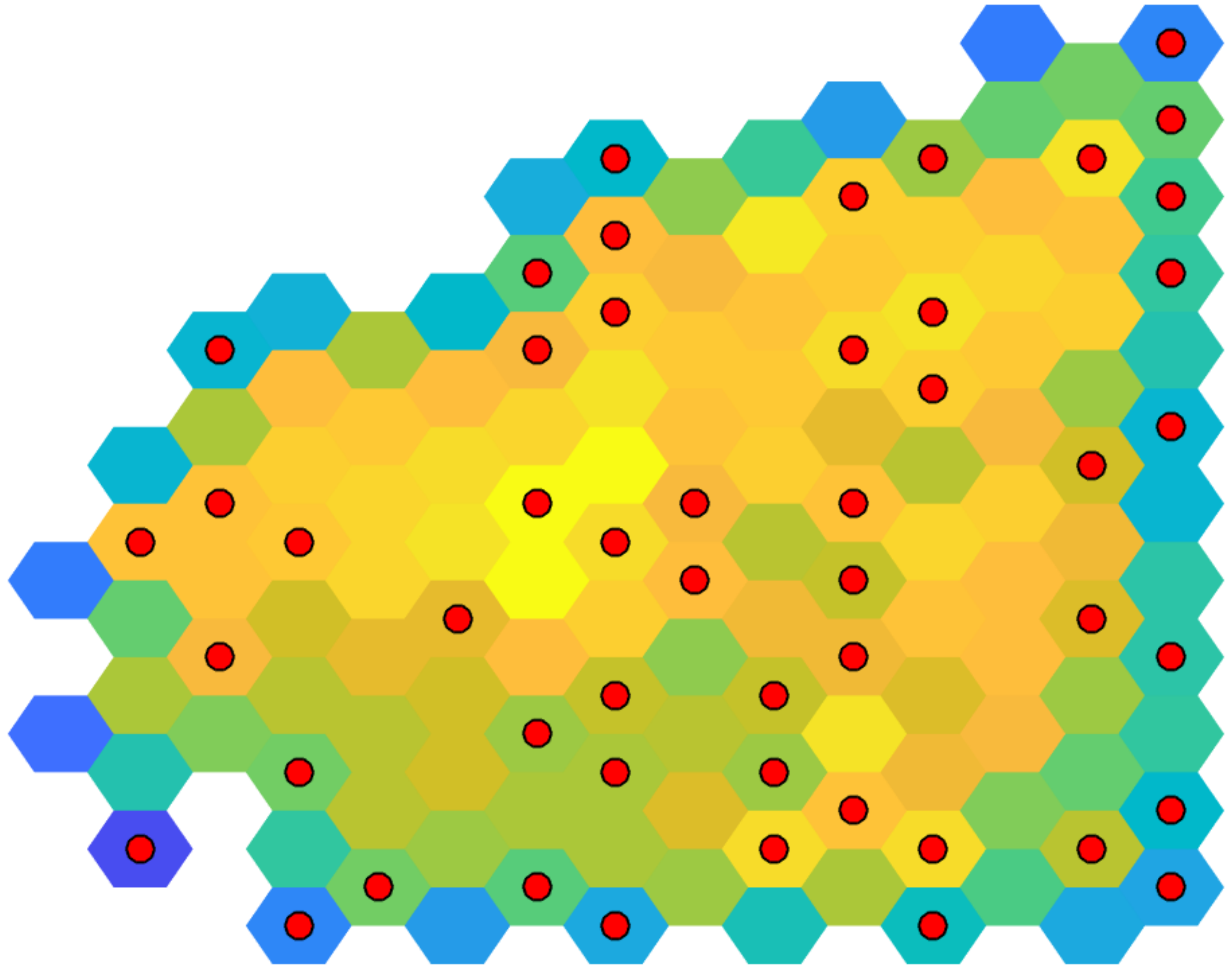




Input data

- Sampling
  - Survey: samples each cell twice per year
  - Fishery: randomly samples 100 cells each month





Stock Assessment with Machine Learning

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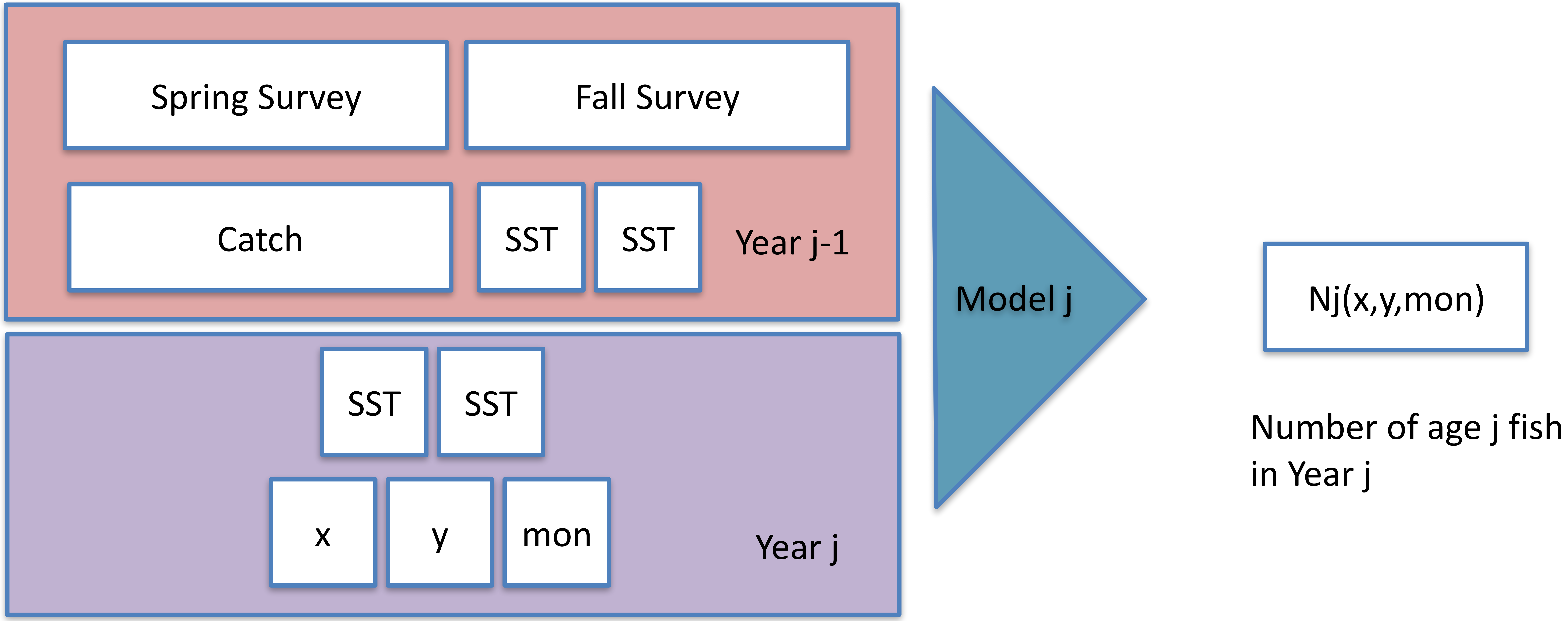
- Machine-learning model
  - Feed-forward neural net



Stock Assessment with Machine Learning

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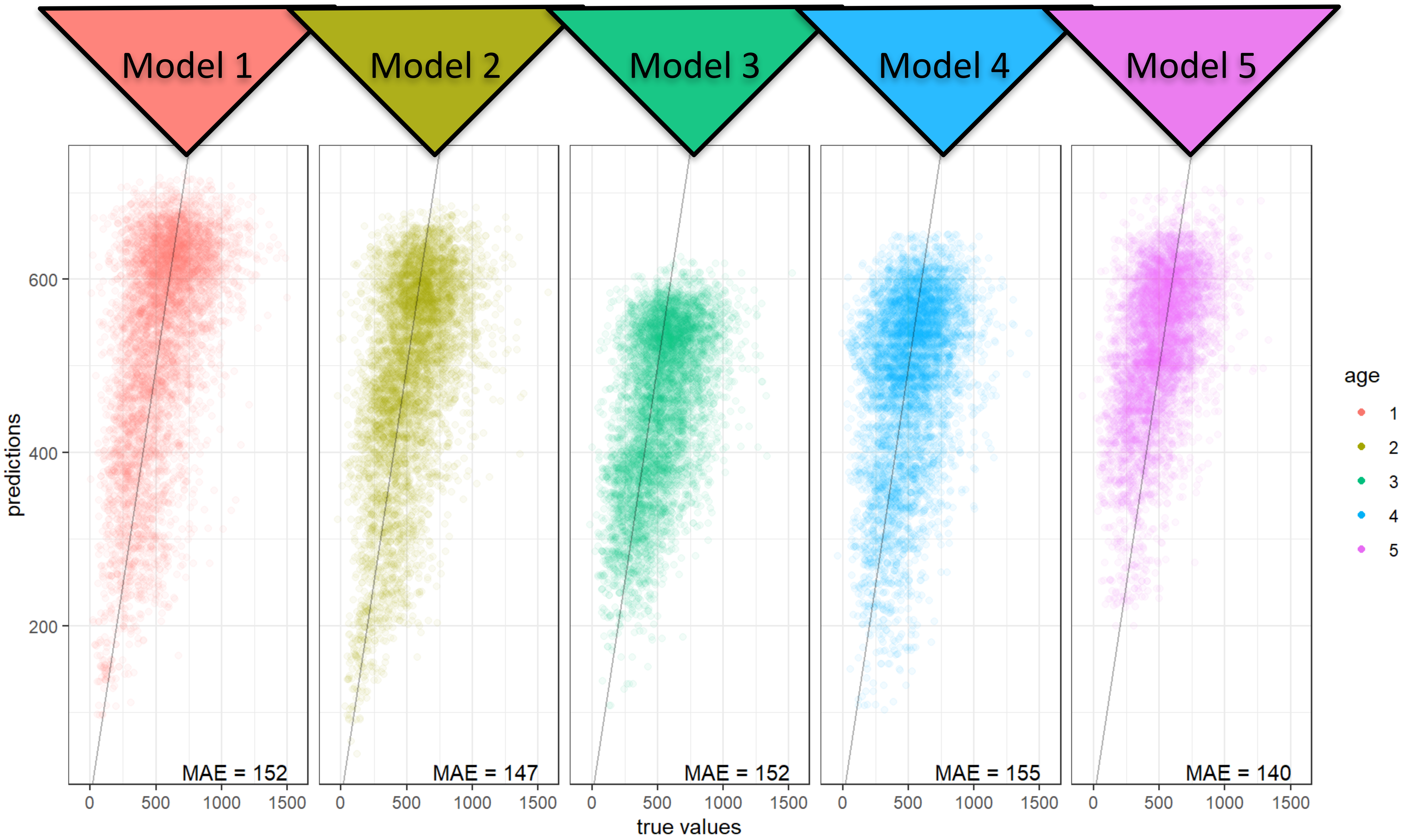

Stock Assessment with Machine Learning

- Machine-learning model
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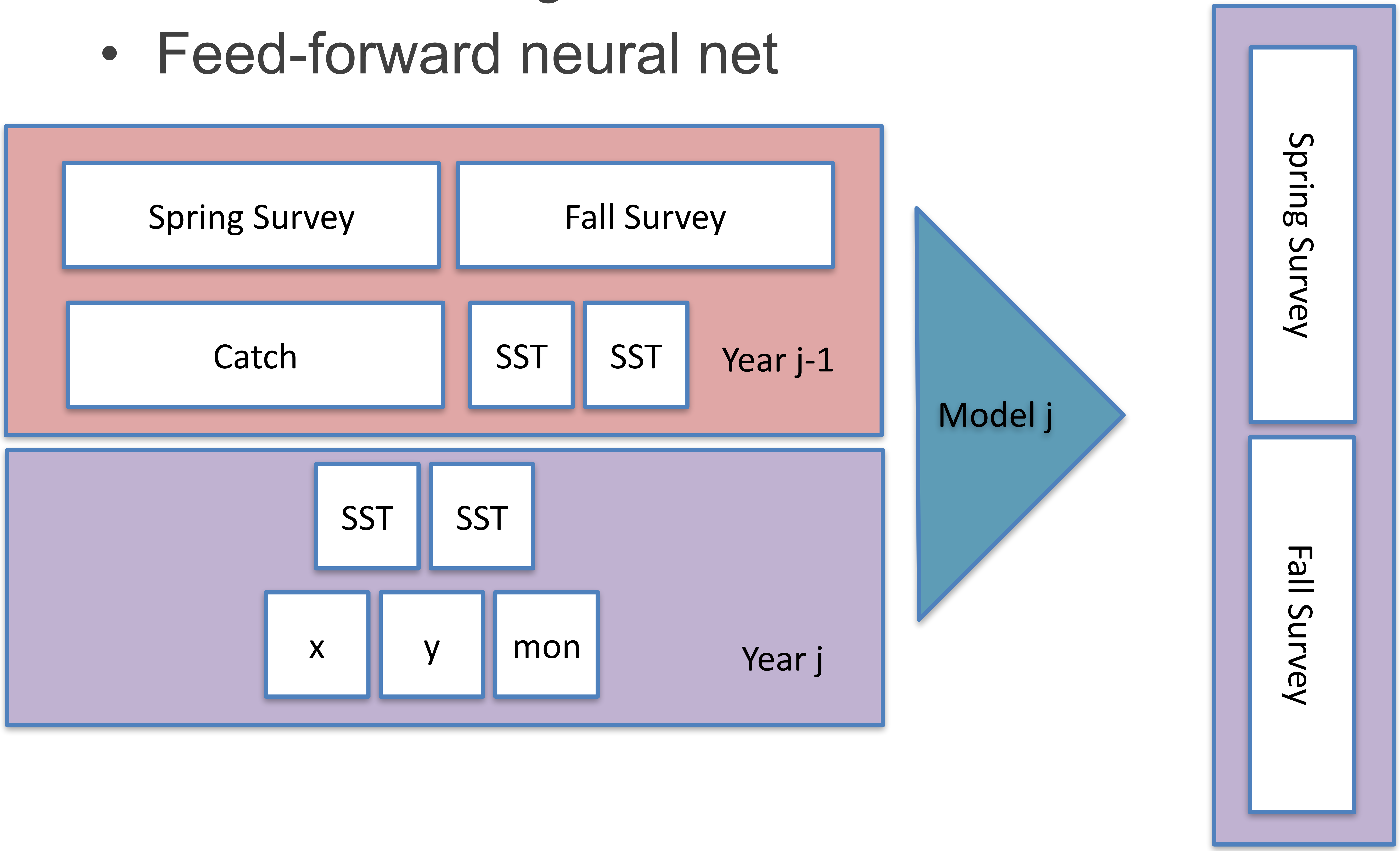
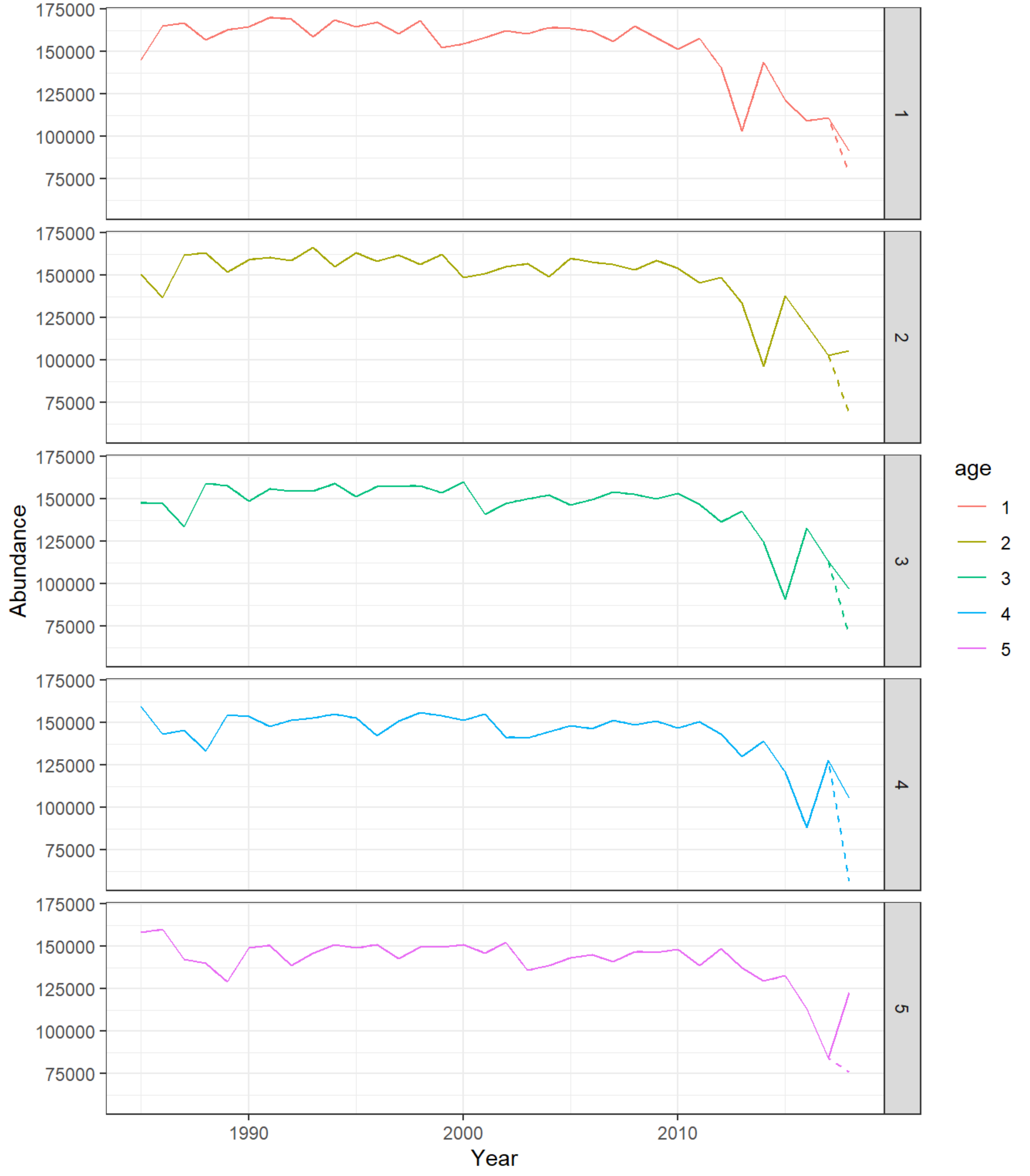


Number of age j fish in Year j

Simulating a survey

2001 from 2000

2018 from 2017



Hot takes

- Seems like it's working (more or less)
- ML is more flexible than standard methods
  - fitting takes only a few minutes
  - includes space
  - not clear if adding fishery-dependent data is helping

- Improvements:
  - log-transform data, ditch x,y
  - more interesting catch time series
  - single model for all ages

Diagnosing Bias in Fish Stock Assessment

- **Problem:** Retrospective patterns represent a large source of uncertainty in the assessment of Northeast groundfish stock. These patterns can lead to unintentional overfishing that undermines efforts to sustainably manage fisheries or to underutilization of the resource that can impact profitability of the fishery.
- **Goal:** Explore potential drivers of bias in a suite of Northeast groundfish on Georges Bank.
- We anticipate candidate drivers will include:

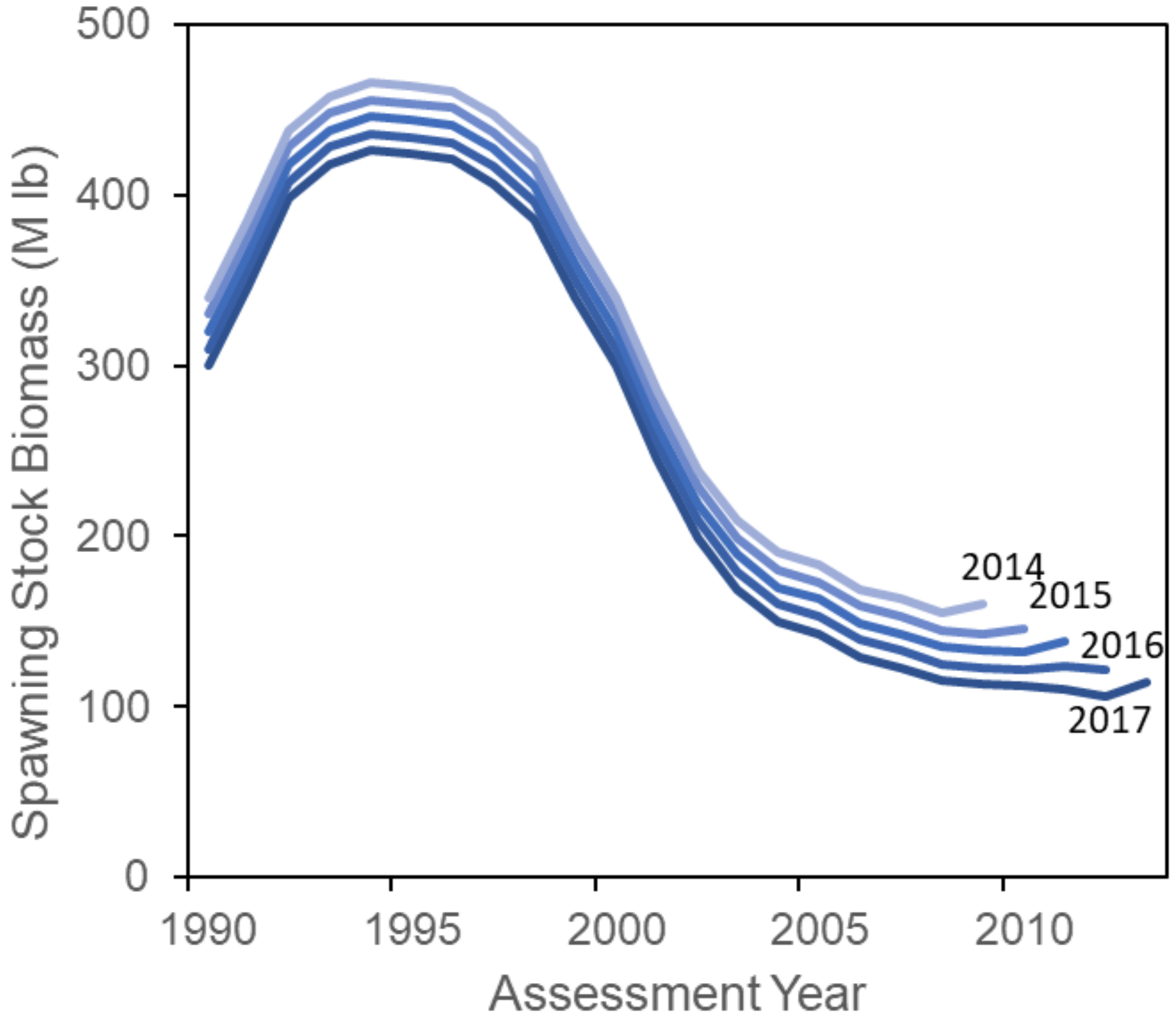
  1) Changes in the ecosystem that impact fish population dynamics,

  2) Changes in fishing behavior, management, and reporting of catch, and

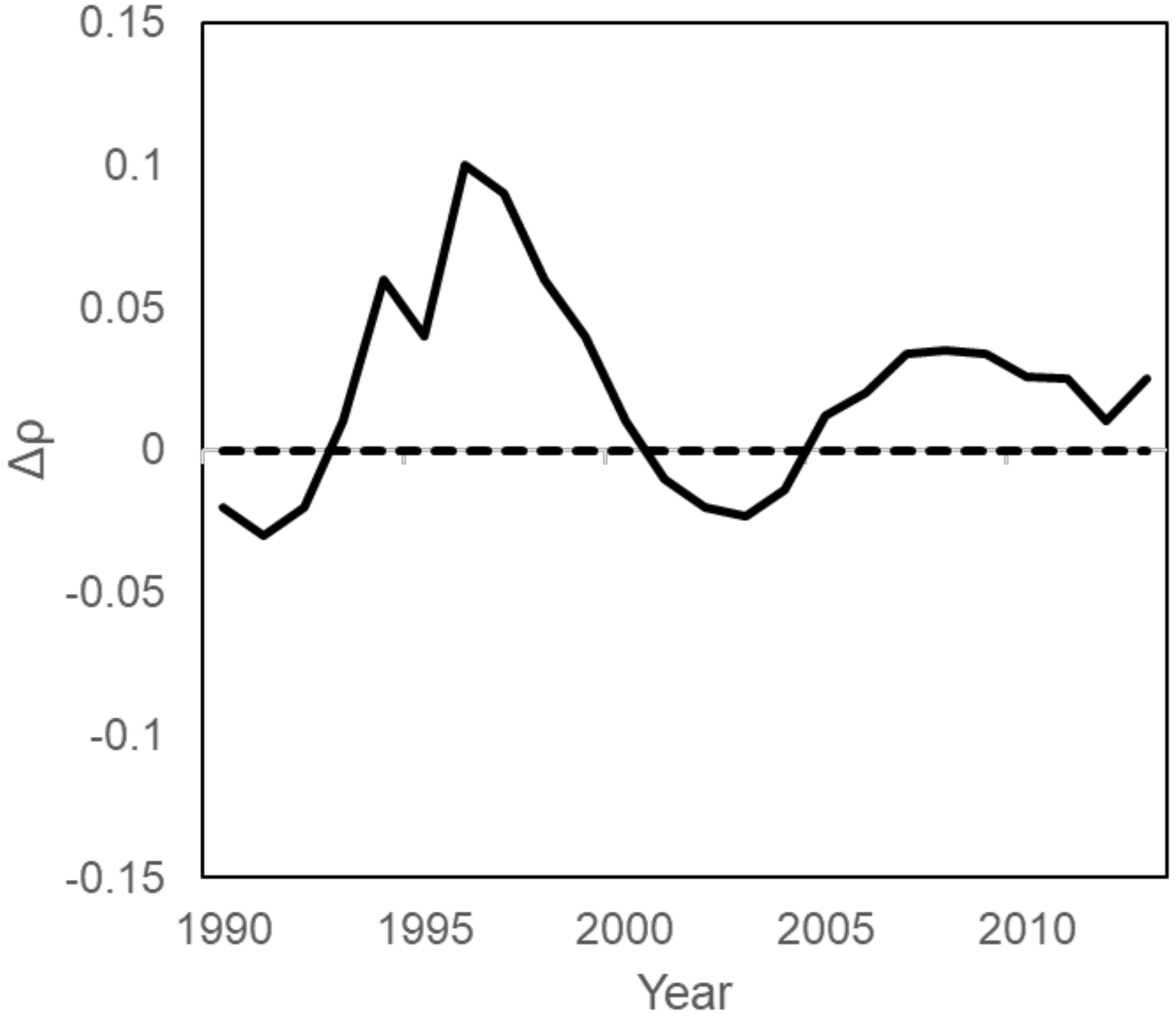
  3) Changes in survey or fishery catchability.
- **Approach:** Evaluate associations between model diagnostics and time series data for candidate drivers using:
  - Machine learning approaches: neural networks
  - Non-linear models: generalized additive models or generalized additive mixed models.

Diagnosing Bias in Fish Stock Assessment

Retrospective peels conducted to characterize bias in assessment,



Moving window time series of bias metric(Mohn's rho).



Potential Drivers to Investigate

THIS WOULD BE A LOT EASIER WITH AN OKN

Type of Driver	Potential Driver	Hypothetical Impact	Time series	Source
Ecosystem	Decadal-scale climate variability	Recruitment, growth and/ or natural mortality	Climate indices such as NAO, AMO, and Gulf Stream Index	NOAA National Centers for Environmental Information
Ecosystem	Climate warming trend	Recruitment, growth and/ or natural mortality	Sea surface or bottom temperature anomaly	Modeled SST< bottom temp. (ROMs)
Ecosystem	Unaccounted for predation	Time-varying natural mortality	Predator abundance time series (e.g., spiny dogfish) or diet information	NOAA stock assessment output, NOAA food habits database
Ecosystem	Fish distribution shift	Time-varying catchability in survey or fishery	Sea surface or bottom temperature anomaly for region	NASA Optimum Interpolation Sea Surface Temp. (OISST) or FVCOM (bottom temperature)
Fishery	Misreporting of catch	Bias/error in reported catch	Catch reporting error	Catch-area reporting errors (Palmer 2017), Catch reporting error (Groundfish Plan Development Team. 2018); Revised recreational data (NOAA MRIP)
Fishery	Misreporting of catch	Underestimated discards	Time series of stock utilization rate or constraining “choke” stocks trajectories)	NEFMC time series of ACL utilization rates, time series of TAC for choke species.
Survey	Changes in survey catchability	Time-varying catchability	Change in survey catchability that has not been accounted for through standardization.	Break-point transition between NOAA survey vessels Albatross and Bigelow

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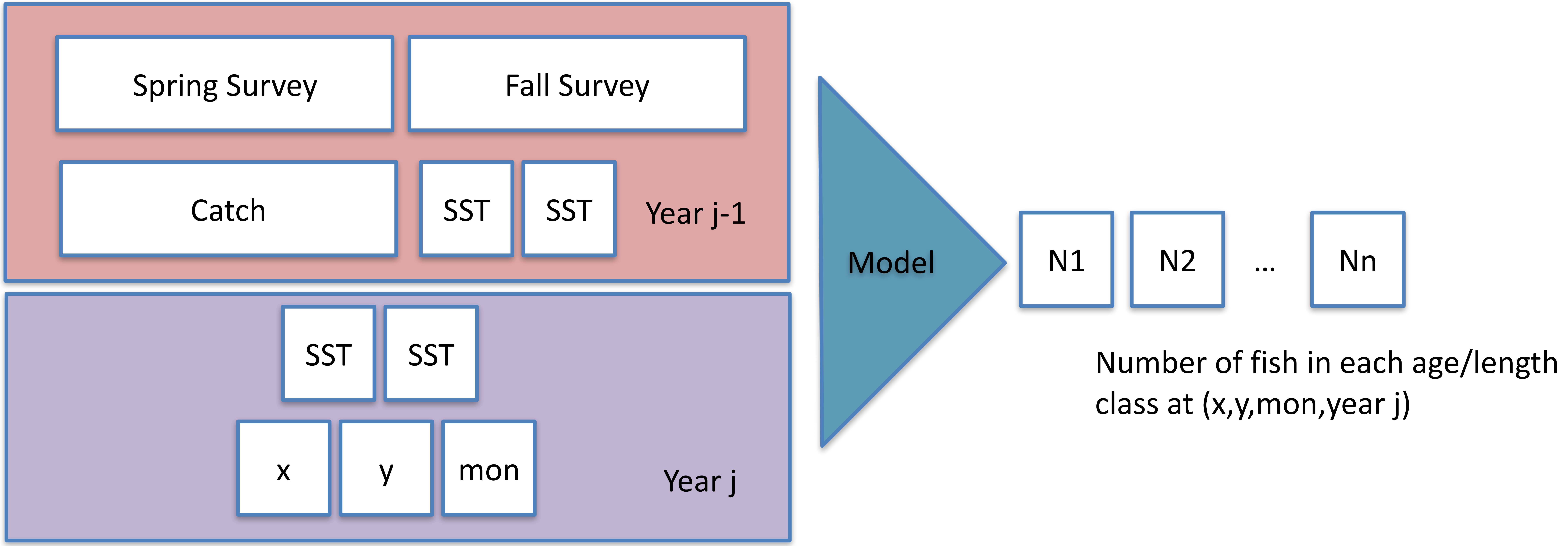

Two Stock Model

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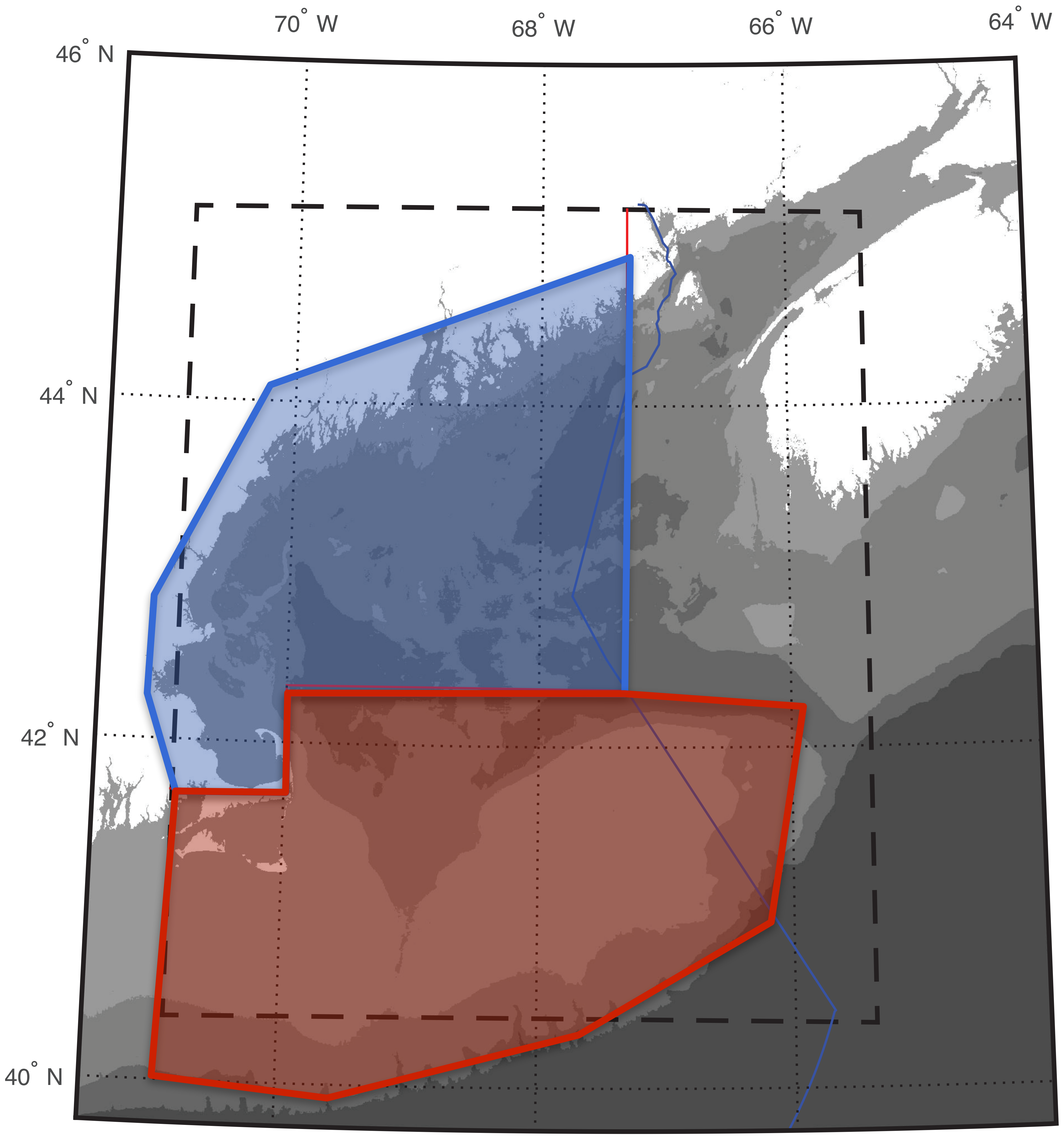

- Two stocks: GoM (blue), GB (red)
- Assume stocks correspond (roughly) to reproductive units
  - catch and prior abundance (survey) particular to a stock
- But, assume fish are essentially the same
  - expect similar relationships with environment (T, depth) regardless of area

Two stock area model

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N1 N2 … Nn ~ In_Area 1 | In_Area 2 | Depth (x,y) | m | SST (x,y,m,j) | SST (A1,m-1,j) | SST (A1,j-1) | SST (A2,m-1,j) | SST (A2,j-1)

Number of fish in each age/length class at (x,y,month=m,year=j)

1 if sample from stock area A, 0 if not (one-hot)

SST at location & time, averaged over stock area, and averaged over area and year

C1 (1,j-1) | C2 (1,j-1) | … | Cn (1,j-1)

Catch of fish in each age/length class in stock area A=1

C1 (2,j-1) | C2 (2,j-1) | … | Cn (2,j-1)

Catch of fish in each age/length class in stock area A=2

S1 (s,j-1) | S2 (s,j-1) | … | Sn (s,j-1)

Sample of fish in each age/length class from survey cell s

for s=1: number of survey cells