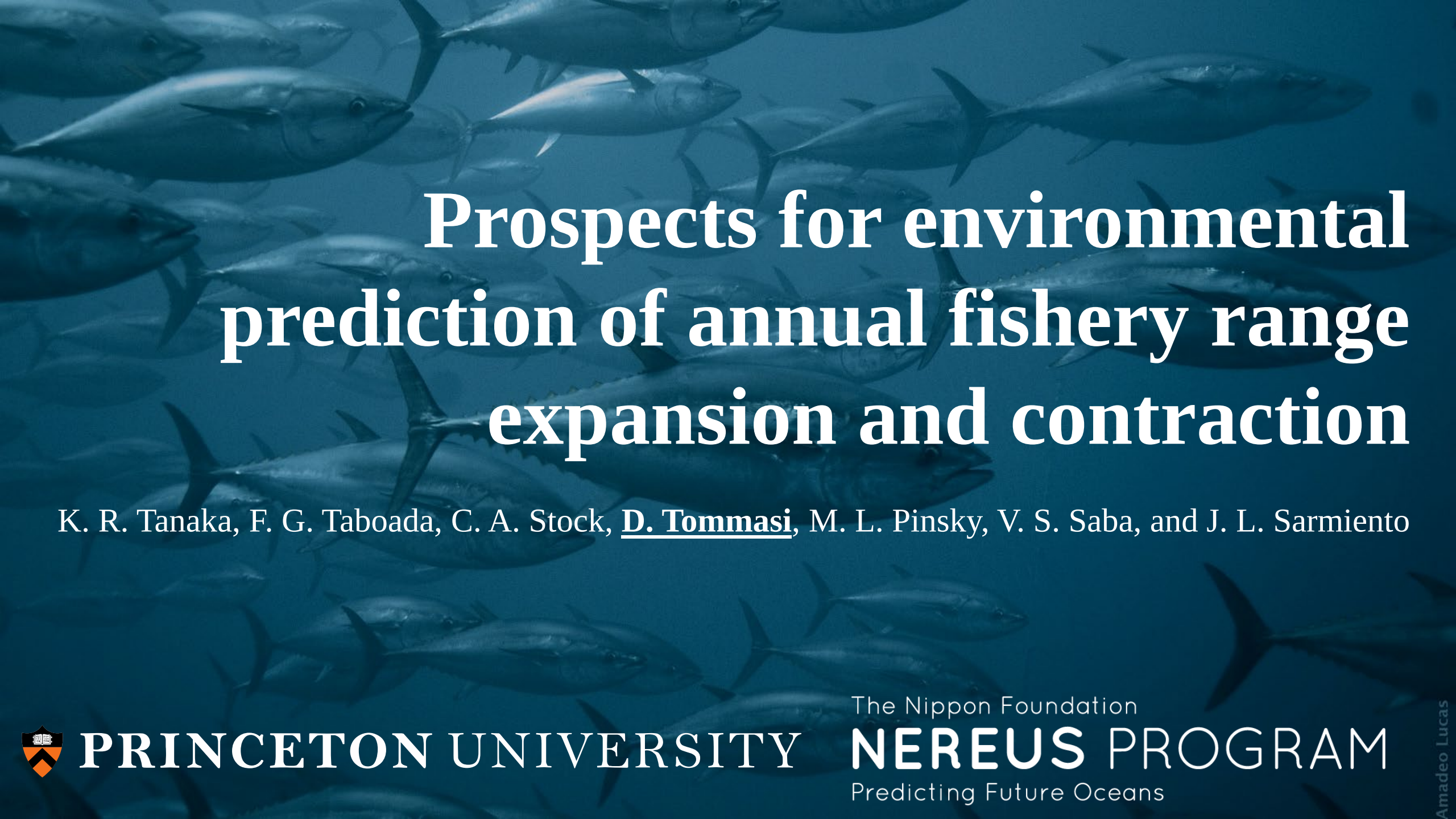


Prospects for environmental prediction of annual fishery range expansion and contraction

K. R. Tanaka, F. G. Taboada, C. A. Stock, **D. Tommasi**, M. L. Pinsky, V. S. Saba, and J. L. Sarmiento

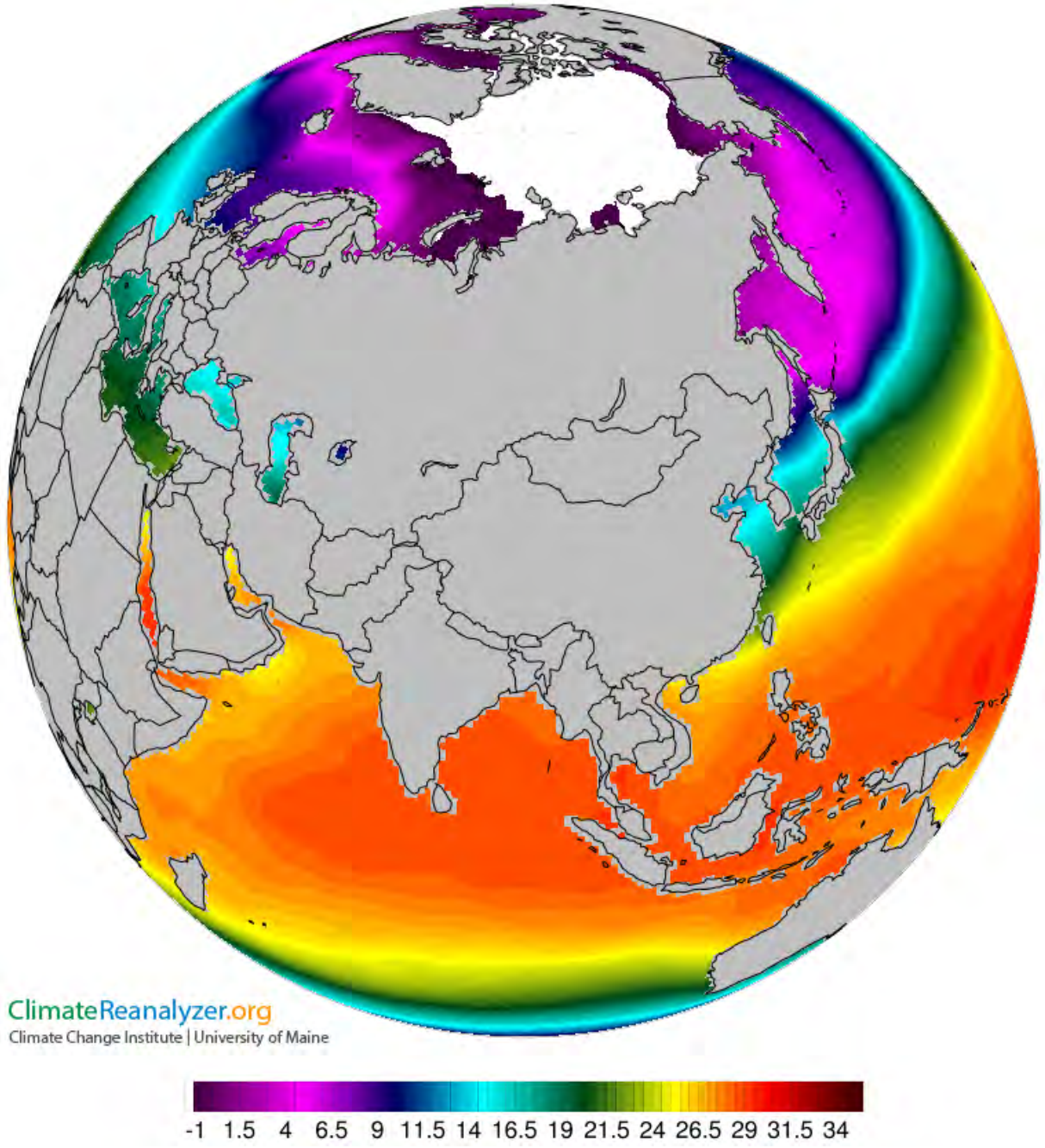
PRINCETON UNIVERSITY

The Nippon Foundation
NEREUS PROGRAM
Predicting Future Oceans

Amadeo Lucas

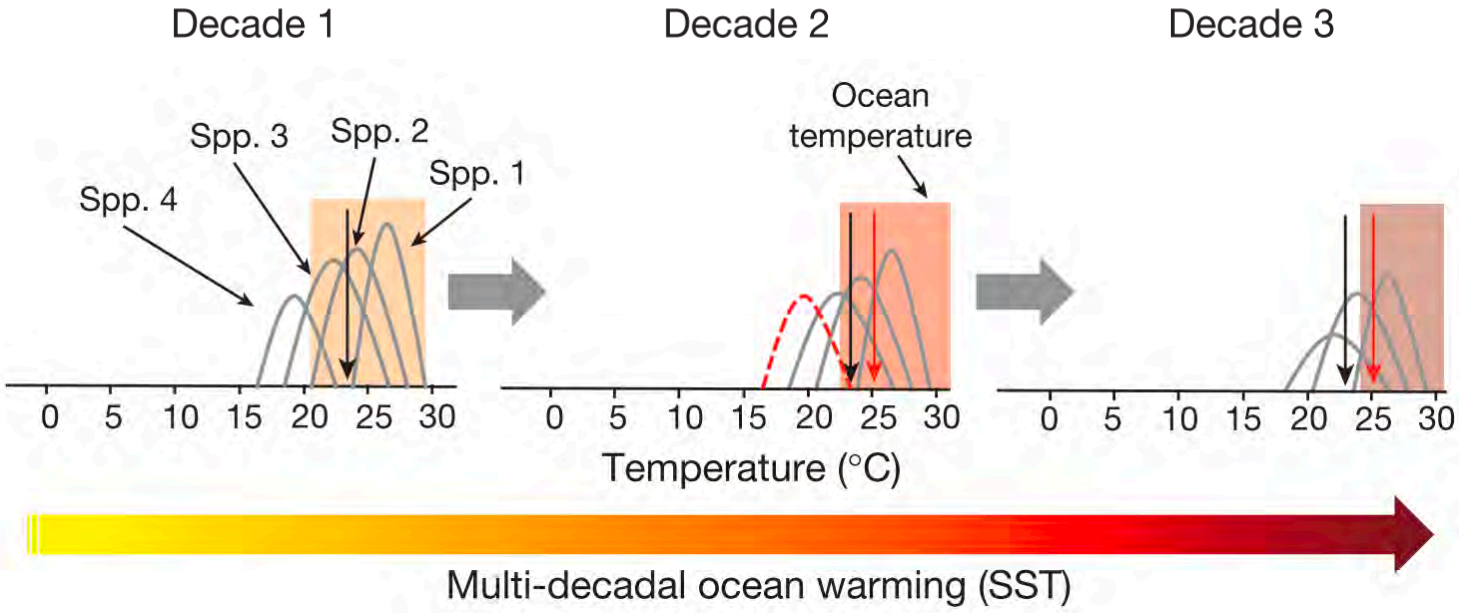
Fisheries in changing environment

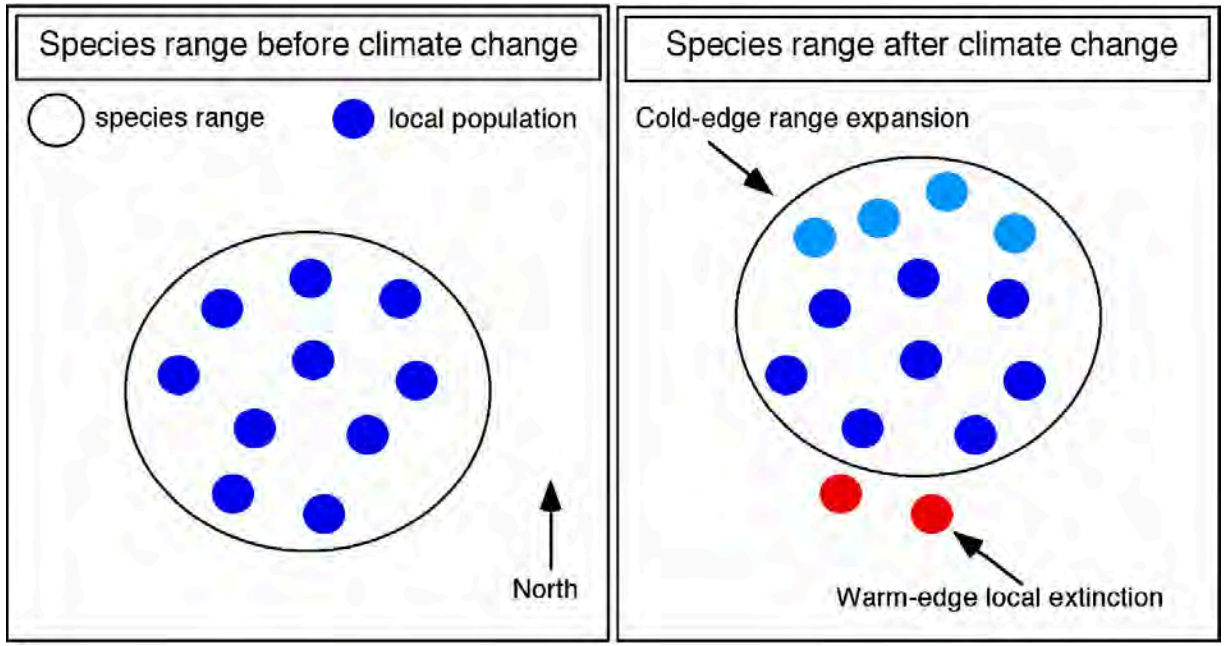
Fluctuations and trends in sea surface temperature (SST) drive major shifts in the spatial distribution of fisheries resources.



Global SST average 1979-2015 (Climate Reanalyzer 2019).

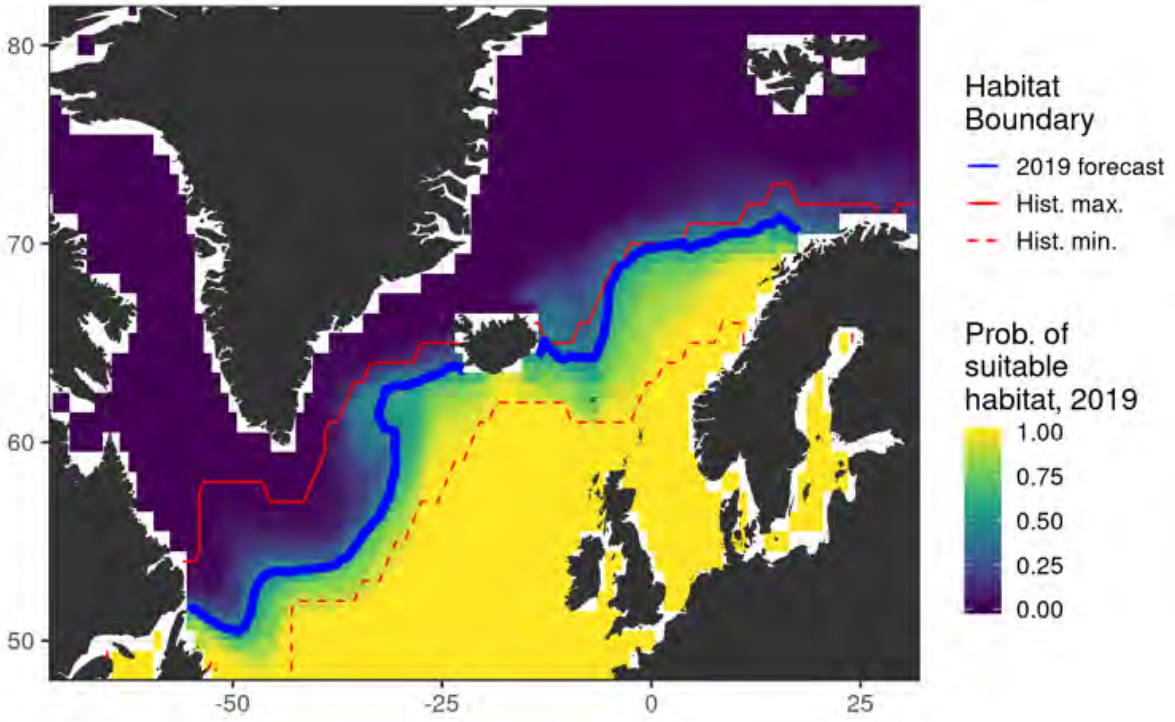
Changes in catch species composition in relation to ocean warming (Cheung et al. 2013)



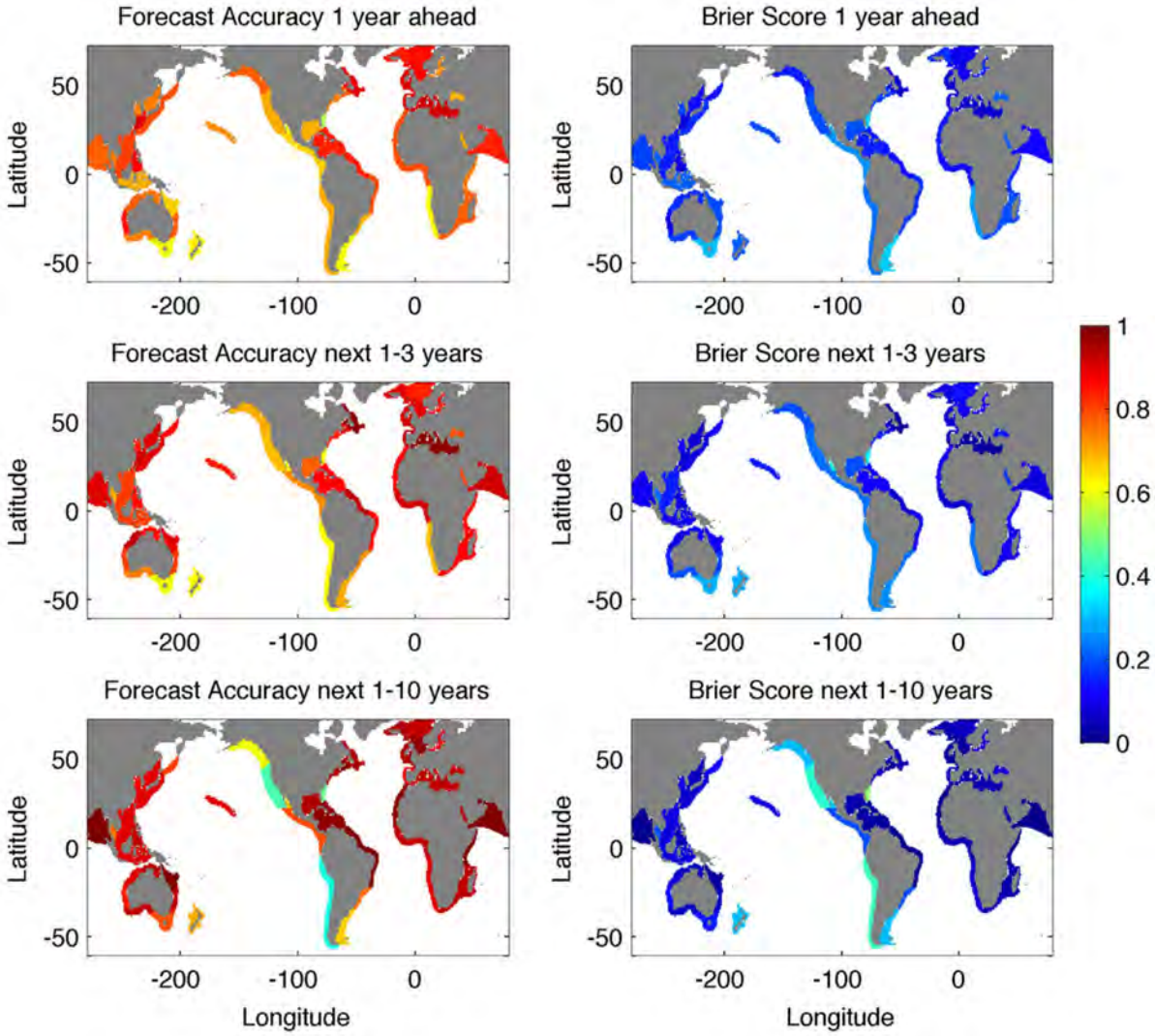


Hypothetical example illustrating the two components of a geographic range shift associated with climate change. (Wiens 2016)

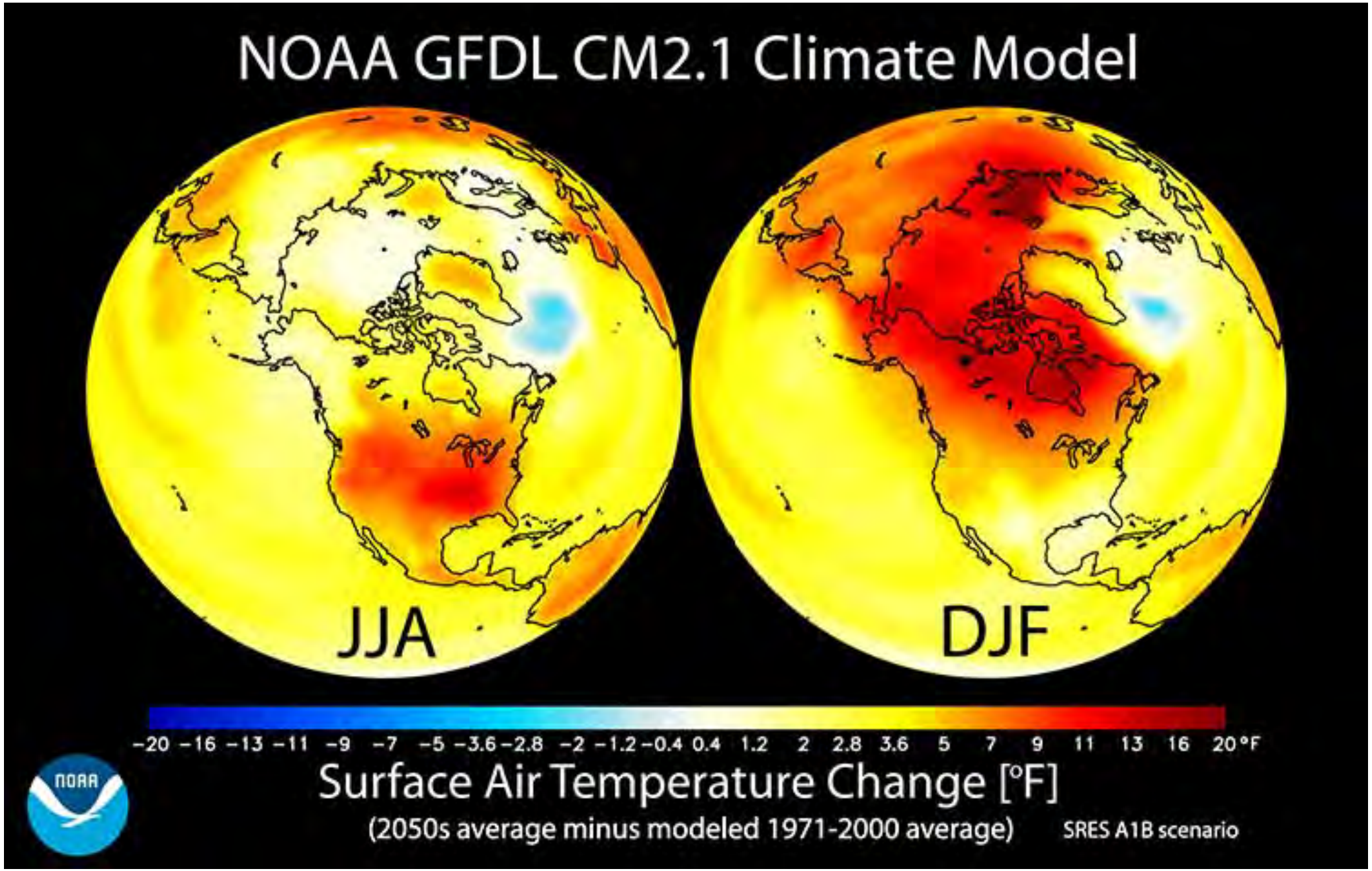
Skillful forecasts improve fisheries planning and decision making



Bluefin Tuna Feeding Habitat Forecast.
Payne 2019. http://www.fishforecasts.dtu.dk/



Multi-year SST forecast
Tommasi et al. 2017

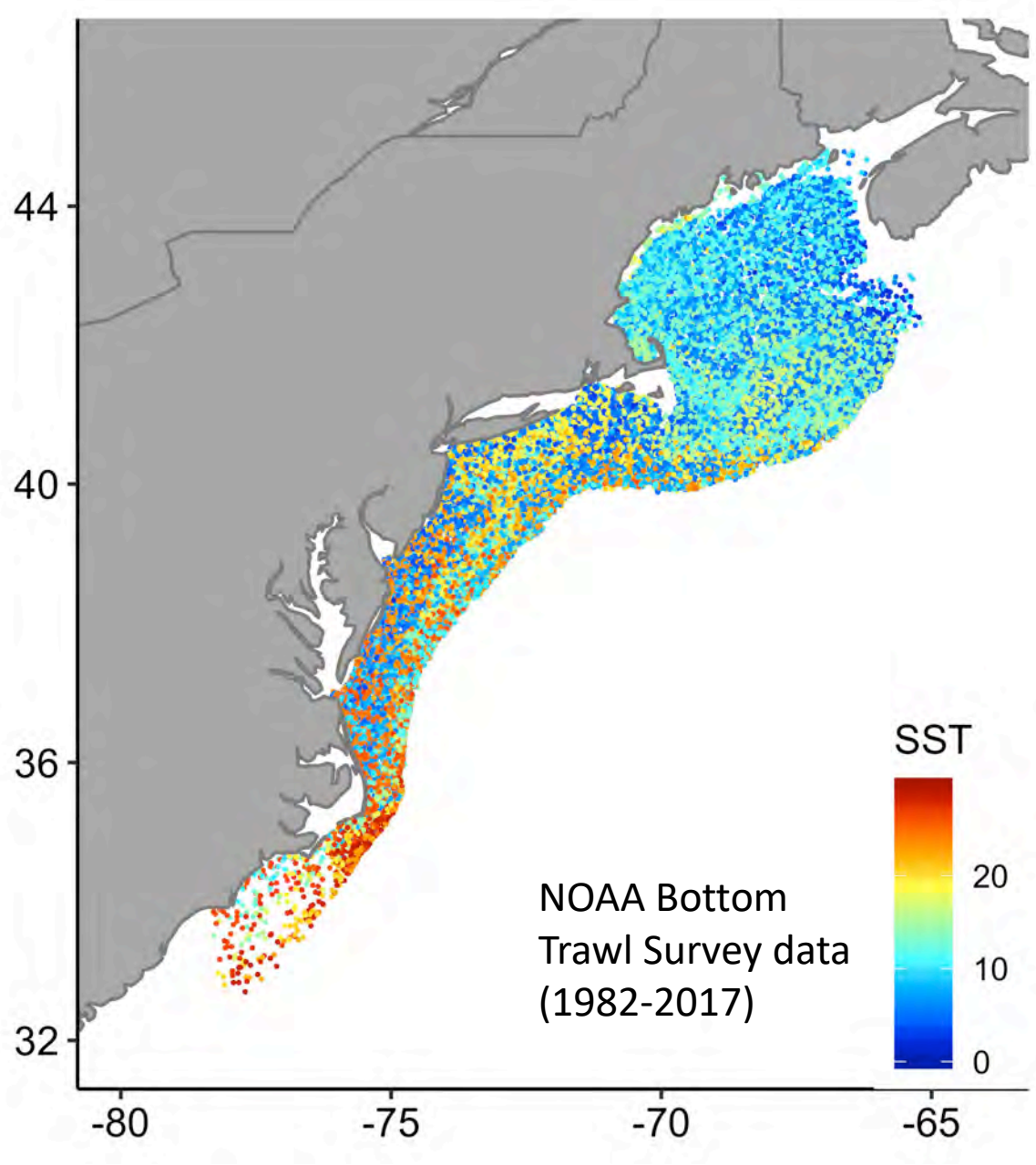

NOAA GFDL CM2.1 Climate Model
JJA
DJF
−20 −16 −13 −11 −9 −7 −5 −3.6 −2.8 −2 −1.2 −0.4 0.4 1.2 2 2.8 3.6 5 7 9 11 13 16 20 °F
Surface Air Temperature Change [°F]
(2050s average minus modeled 1971-2000 average)
SRES A1B scenario
NOAA

Objectives

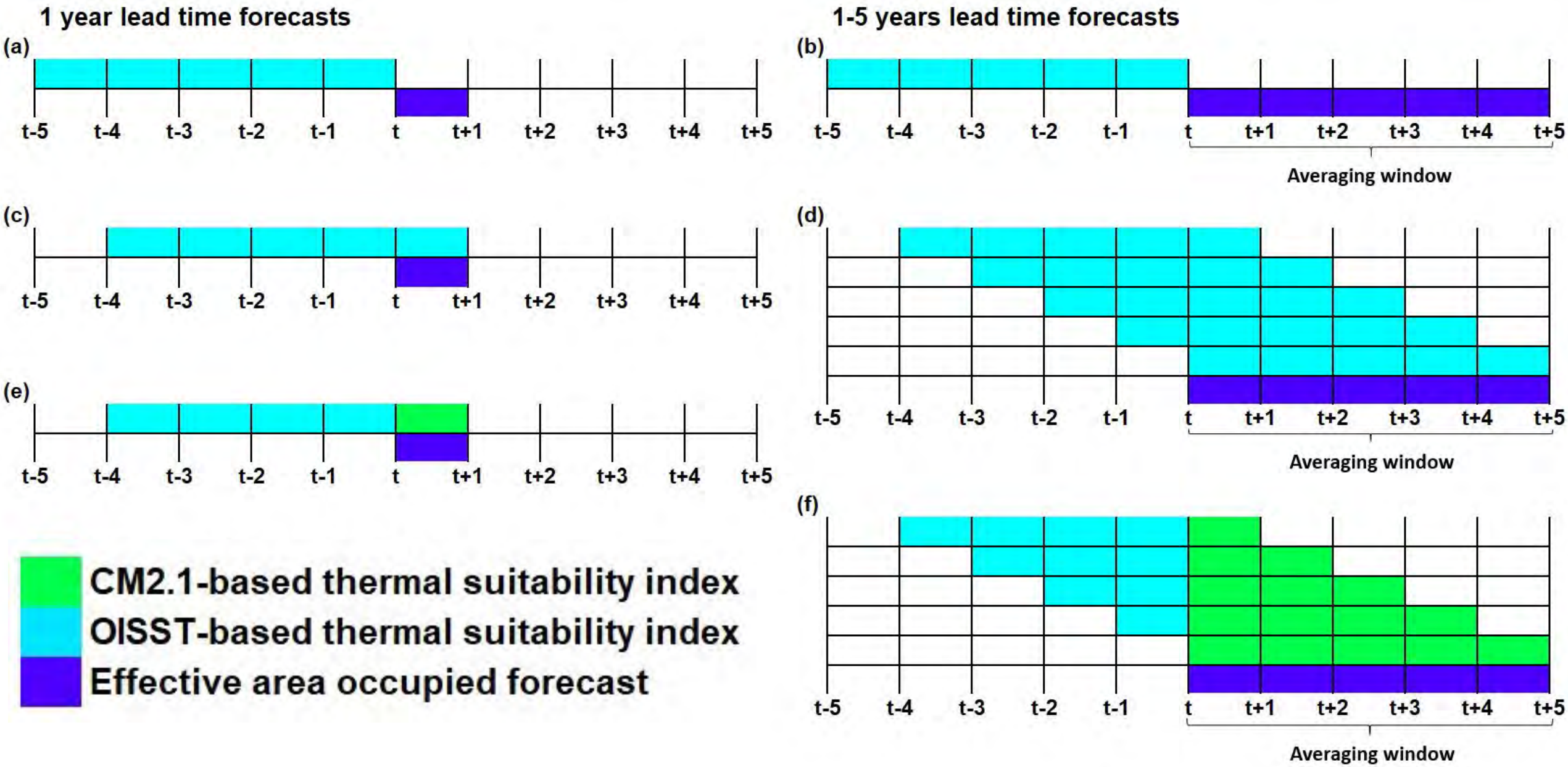
1. Demonstrate utility of a global SST prediction system in near-term (1 and 1-5 year) forecasts of the expansion and contraction of the range of commercially important species.

2. Perform a series of retrospective forecasts experiments to determine how well past and future SST can predict a specie's range.

3. A case study with 20 commercial stocks within the Northeast U.S. Shelf Large Marine Ecosystem.

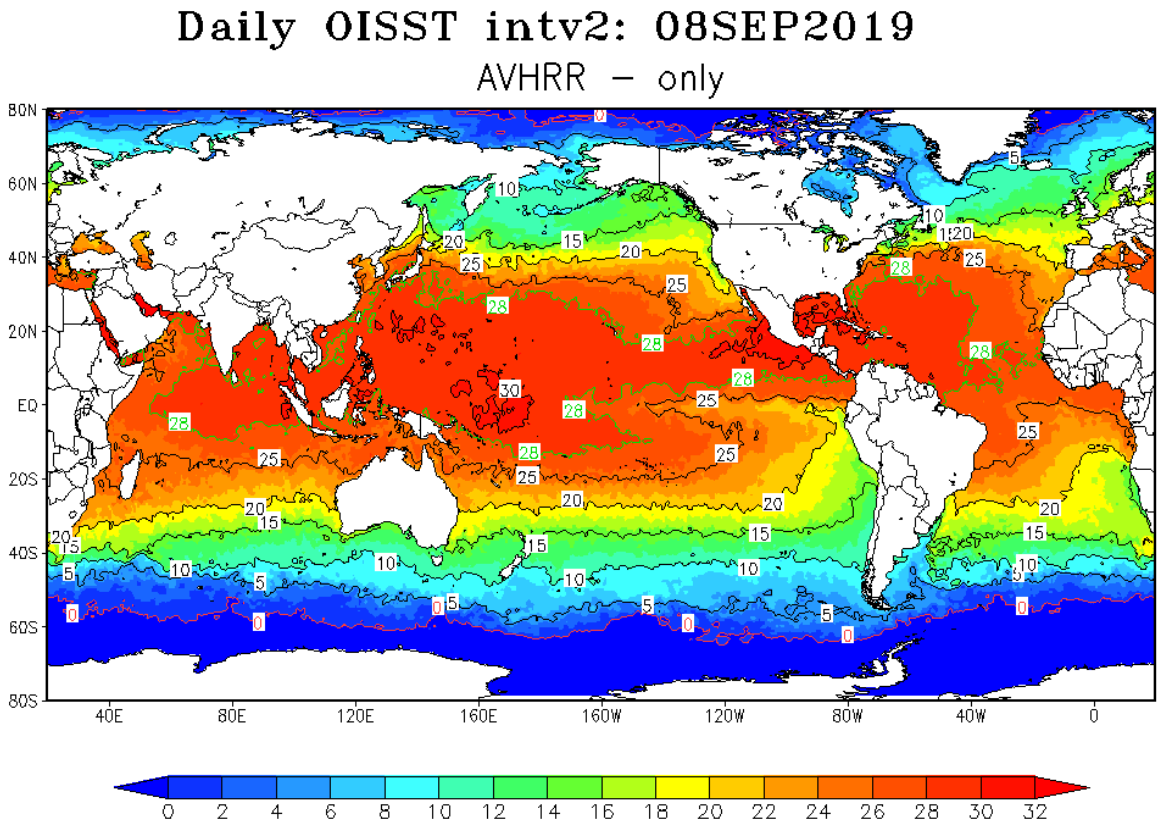


Retrospective forecast verification experiments



“Perfect” SST data

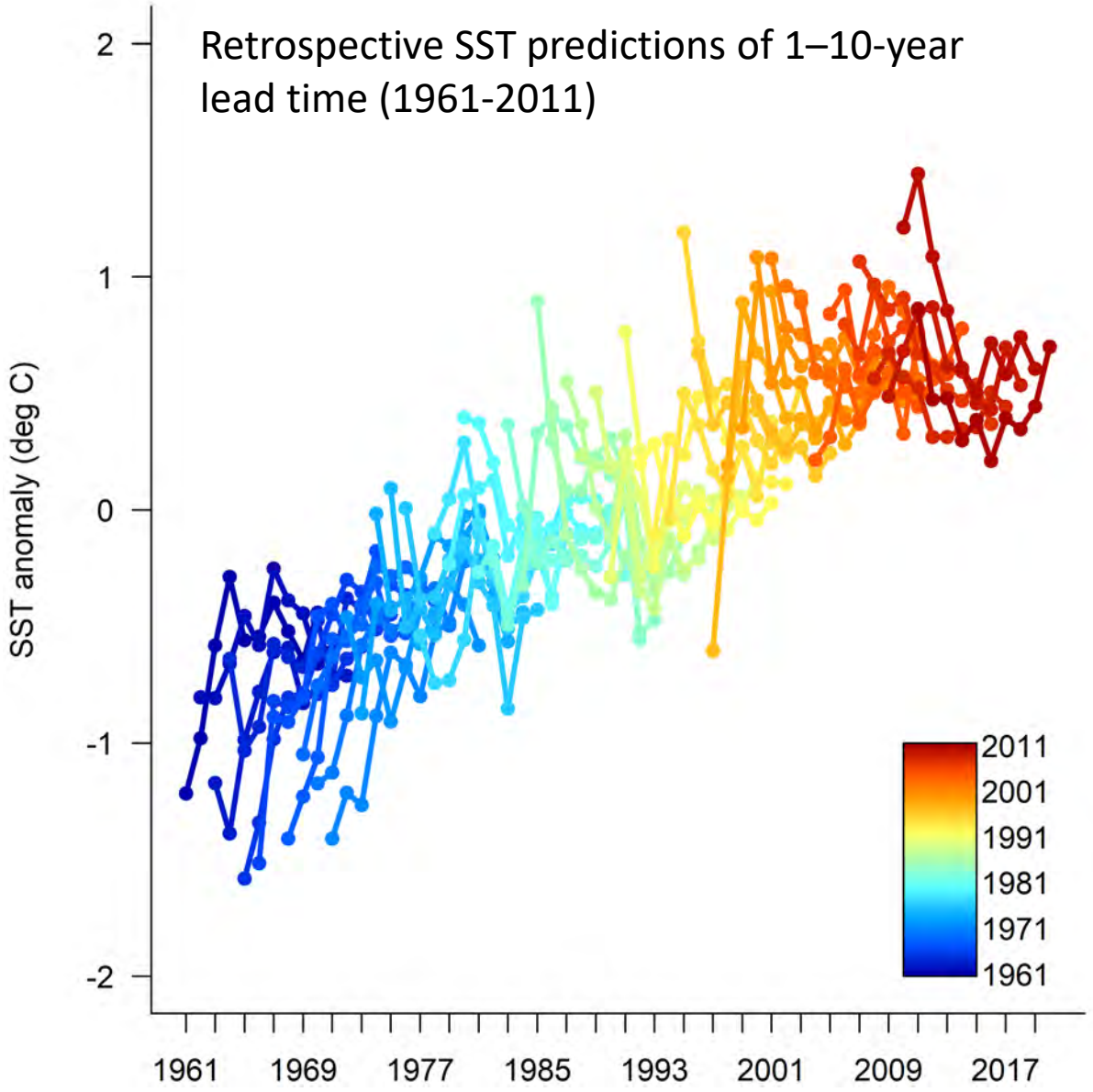
Optimum Interpolation Sea Surface Temperature (OISST)



Reynold 1993, Tommasi et al. 2017

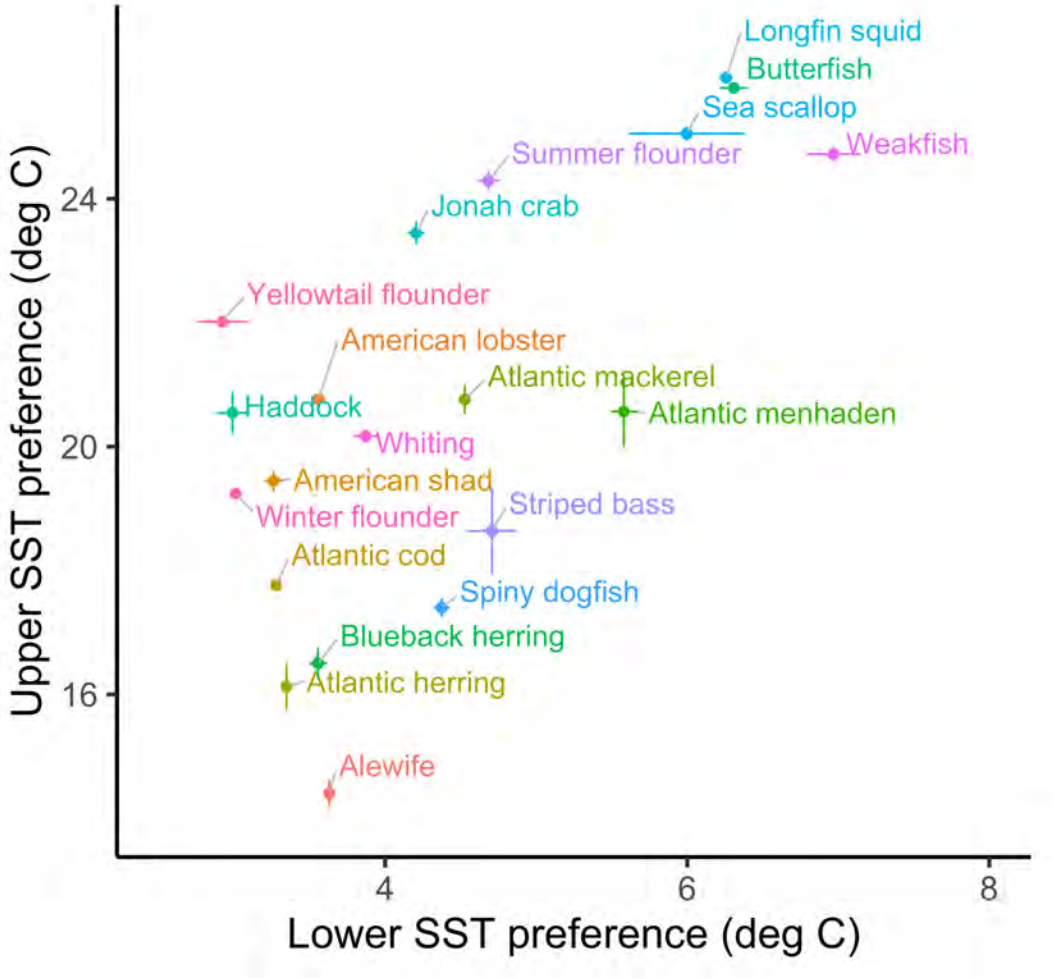
“Realized” SST data

NOAA GFDL CM 2.1 SST prediction system



Thermal Suitability Index (TSI)

A simple metric to assess interannual variations in the species thermal suitability



Species SST preferences (1982-2017)

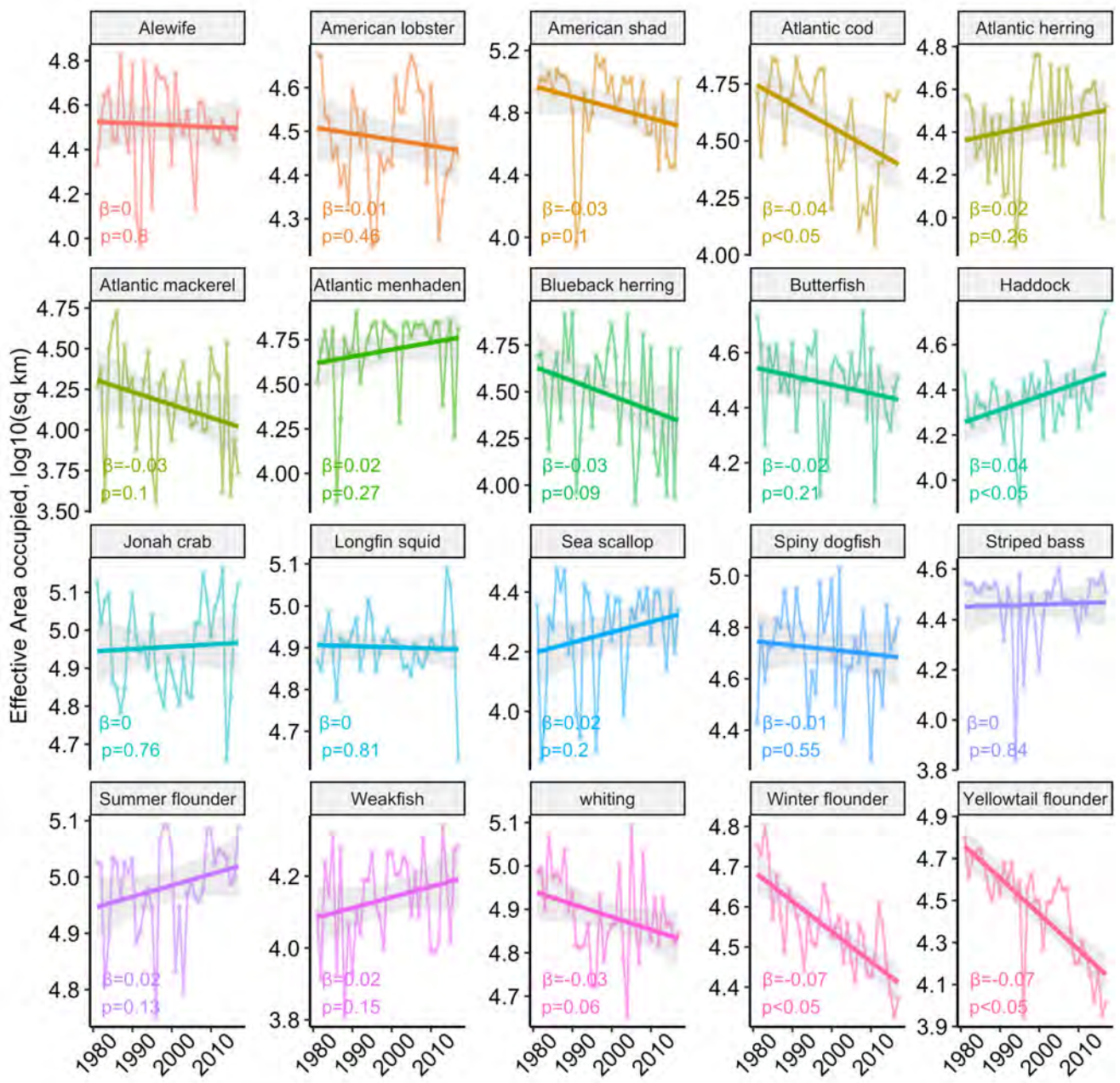
$$TSI(y) = \frac{\int_{m=1}^{12} A(m,y)dt}{12 \times A_{tot}}$$

- **A(m,y): area falling within species lower and upper SST preferences**
- **A_tot: total area**
- **m: month**
- **y: year**

Historical effective area occupied

- estimated from from the survey data using delta-generalized linear mixed model
- corresponds to/is defined as the area that can contain a population at its average density.
- Changes in effective area occupied indicate either range expansion or contraction of a species in a given space.
- a species range metric we hope to forecast.

(Thorson et al. 2016; Thorson 2019)

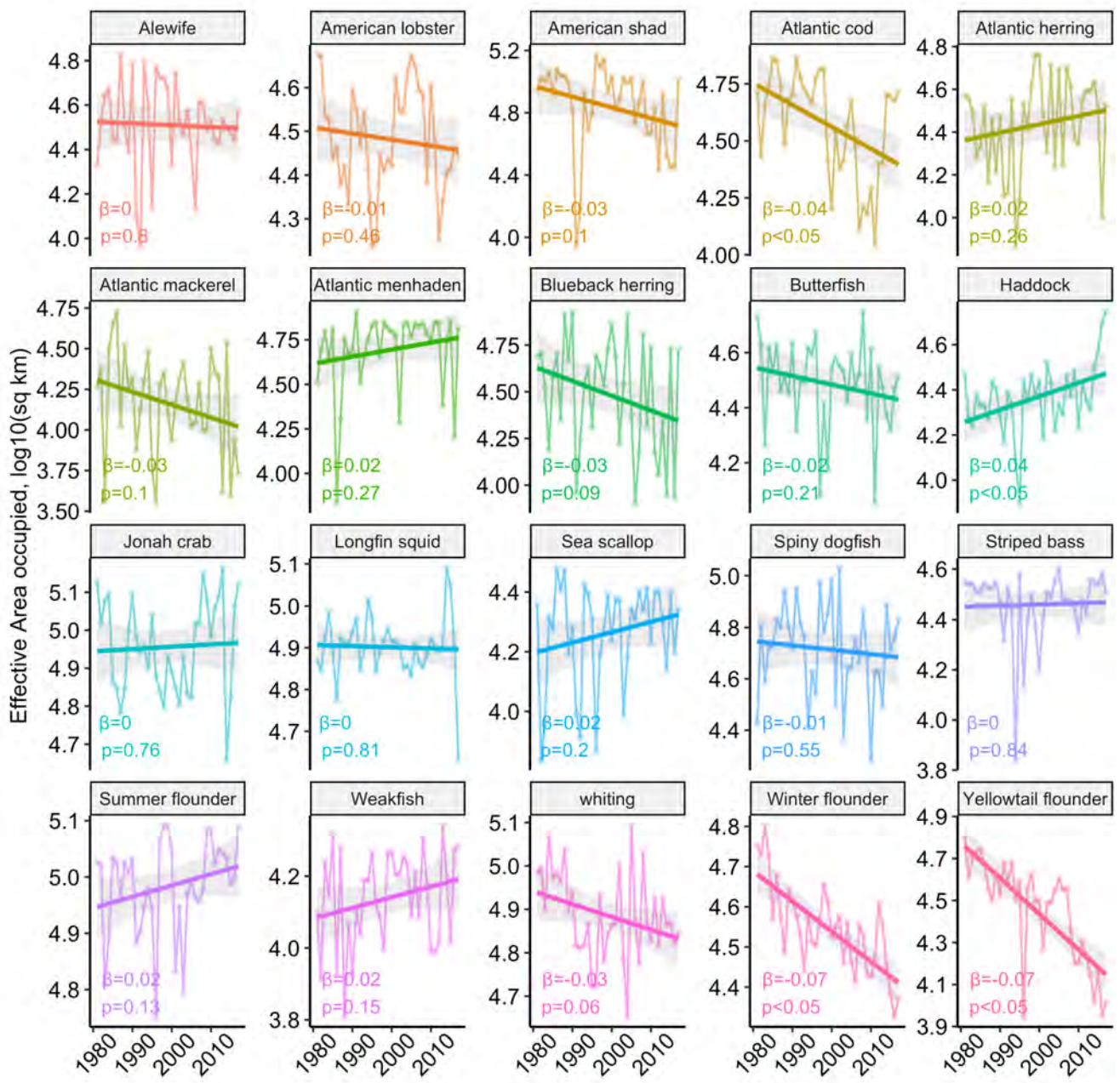


Interannual variations in species effective area occupied (1982-2017)

Forecast effective area occupied

- We then linked changes in TSI values to the species' area occupied (i.e., a species range
- metric we hope wanted to forecast).
- Past and predicted TSI variations were used to forecast the effective area occupied.
- The TSI was linked to effective area occupied using a Gaussian generalized additive model (GAM; R package "mgcv"; Wood, 2014)
- In forecast mode, the TSI-effective area model is developed only using available data

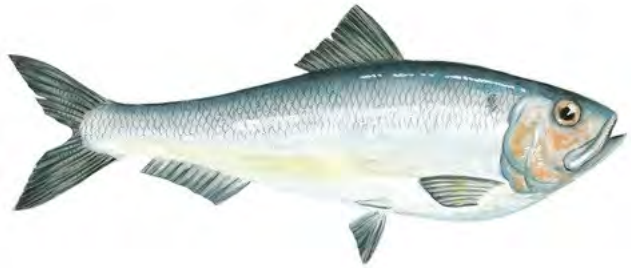
(Thorson et al. 2016; Thorson 2019)

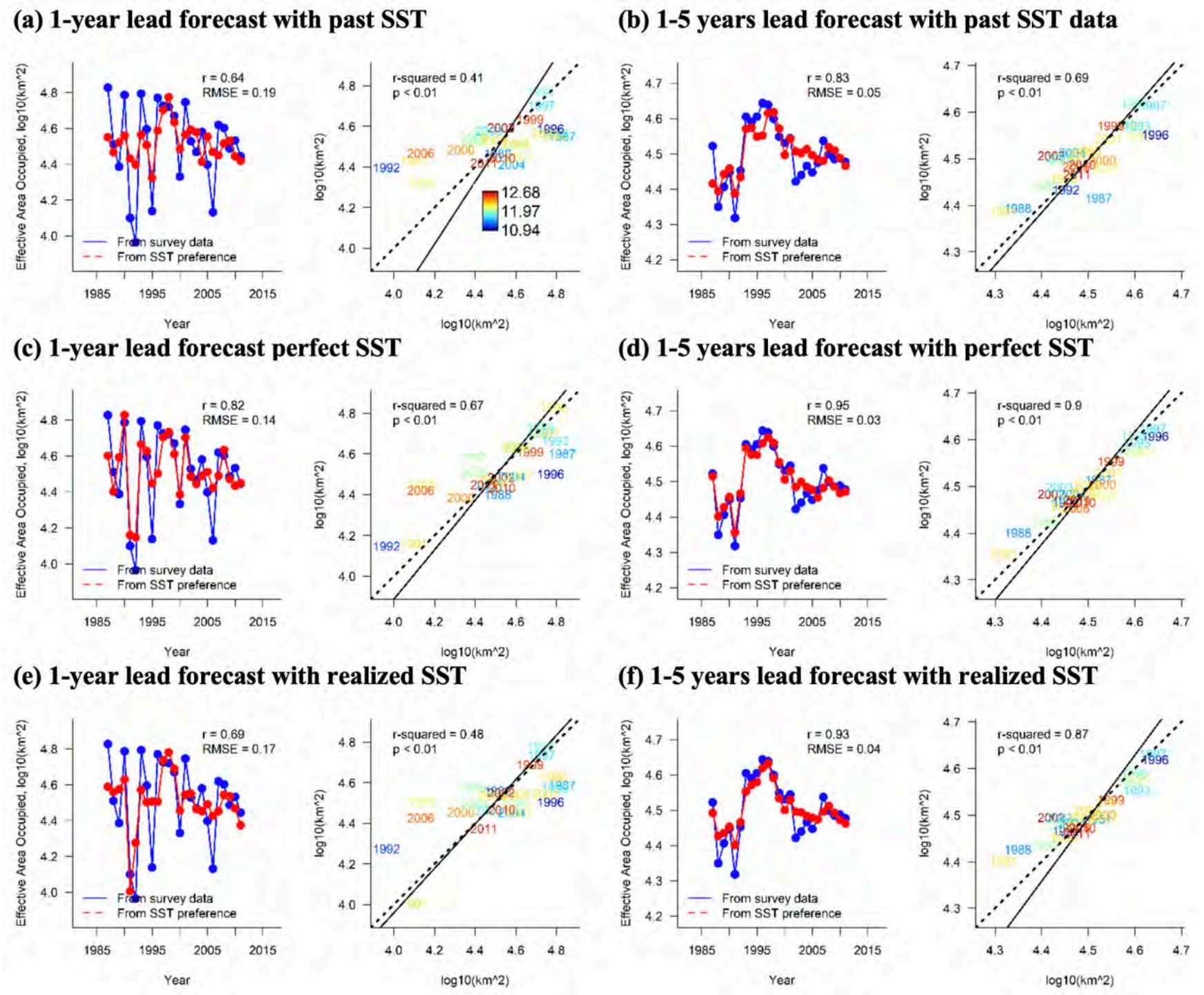


Interannual variations in species effective area occupied (1982-2017)

Retrospective forecasts of the effective area occupied by alewife (*Alosa pseudoharengus*)

- from survey data
- from SST data.

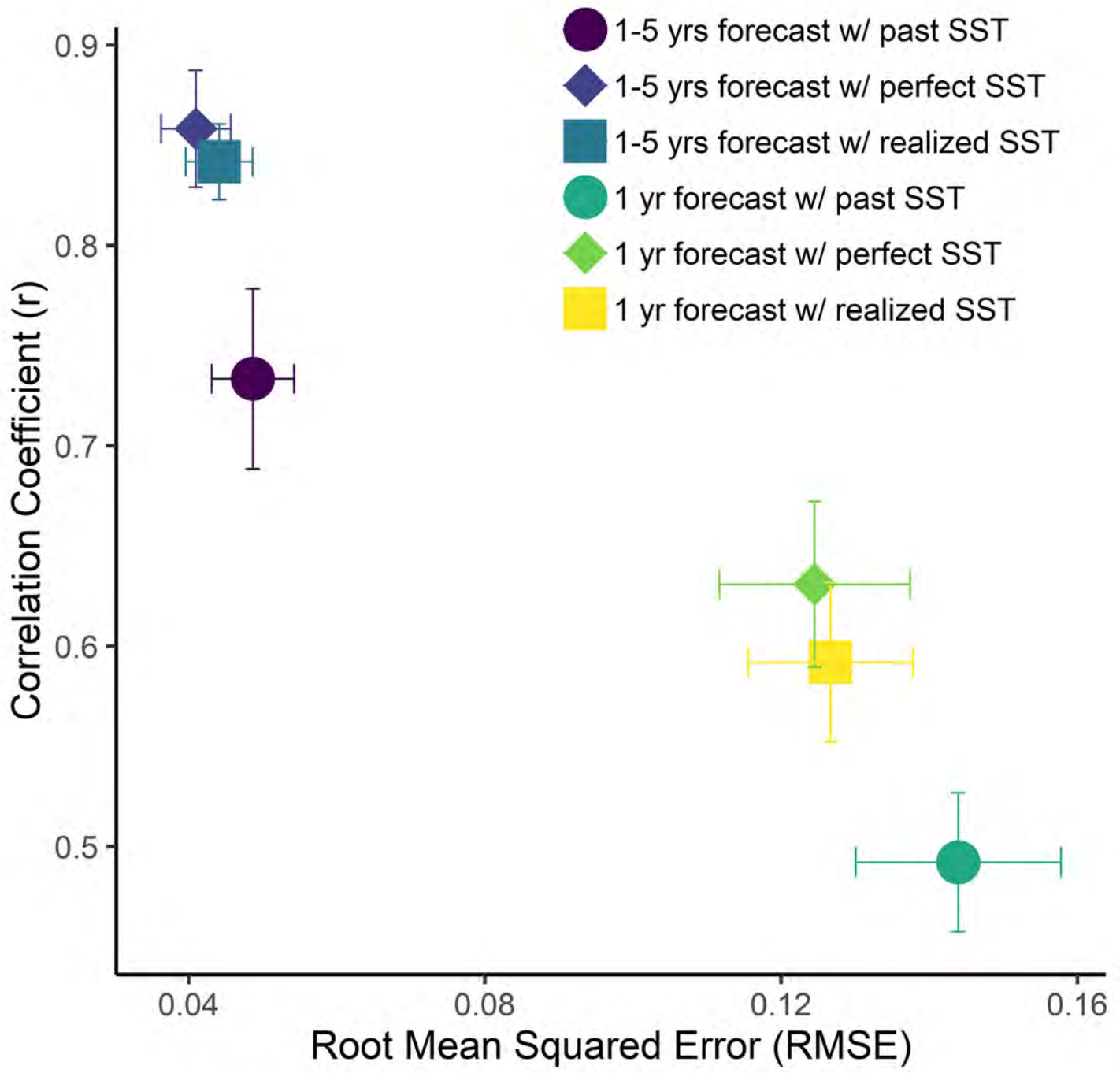




Comparisons of forecast skills across verification experiments using correlation coefficients (r) and root mean squared error (RMSE).

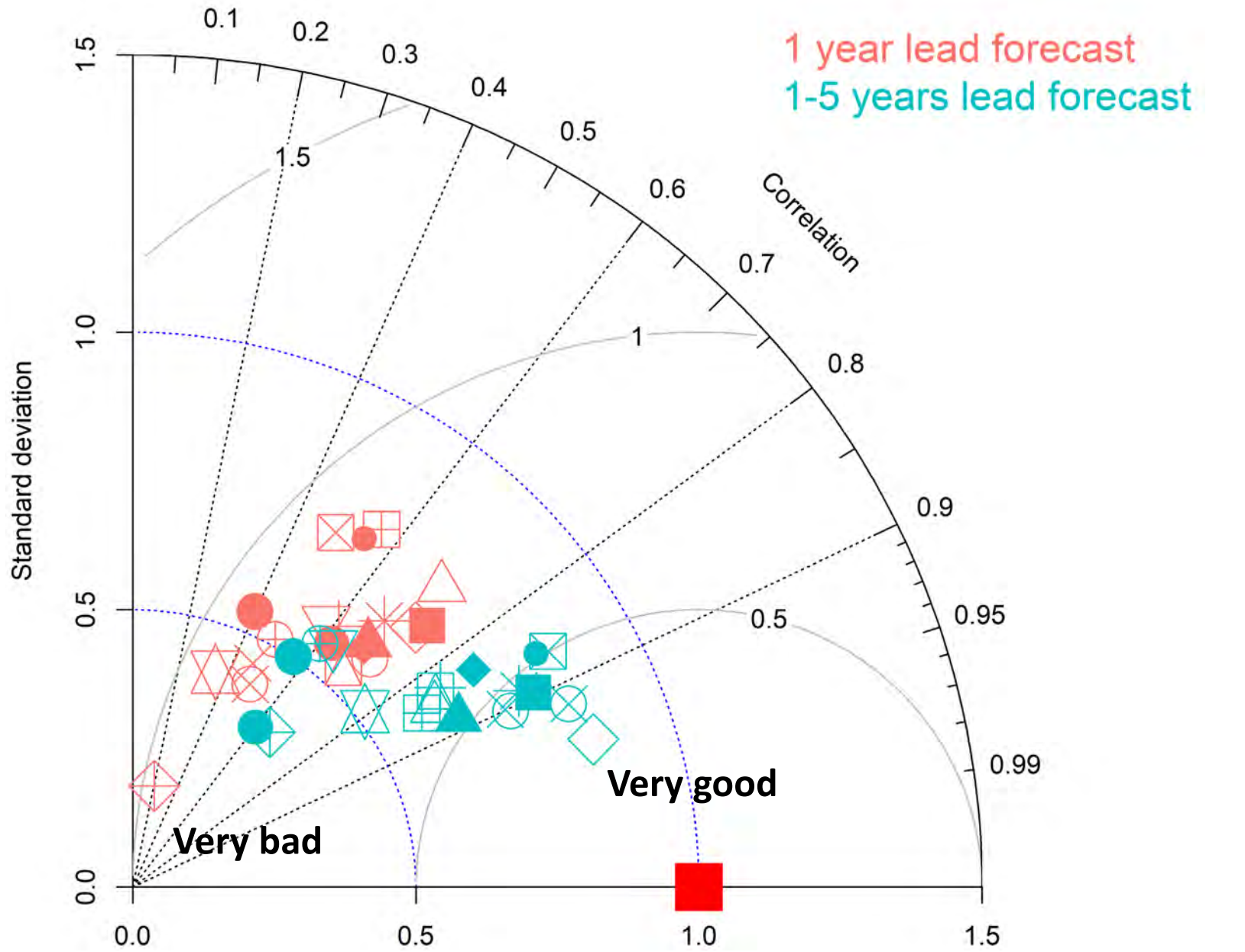
Higher *r* = a better prediction skill

Lower RMSE = a reduced mean error.

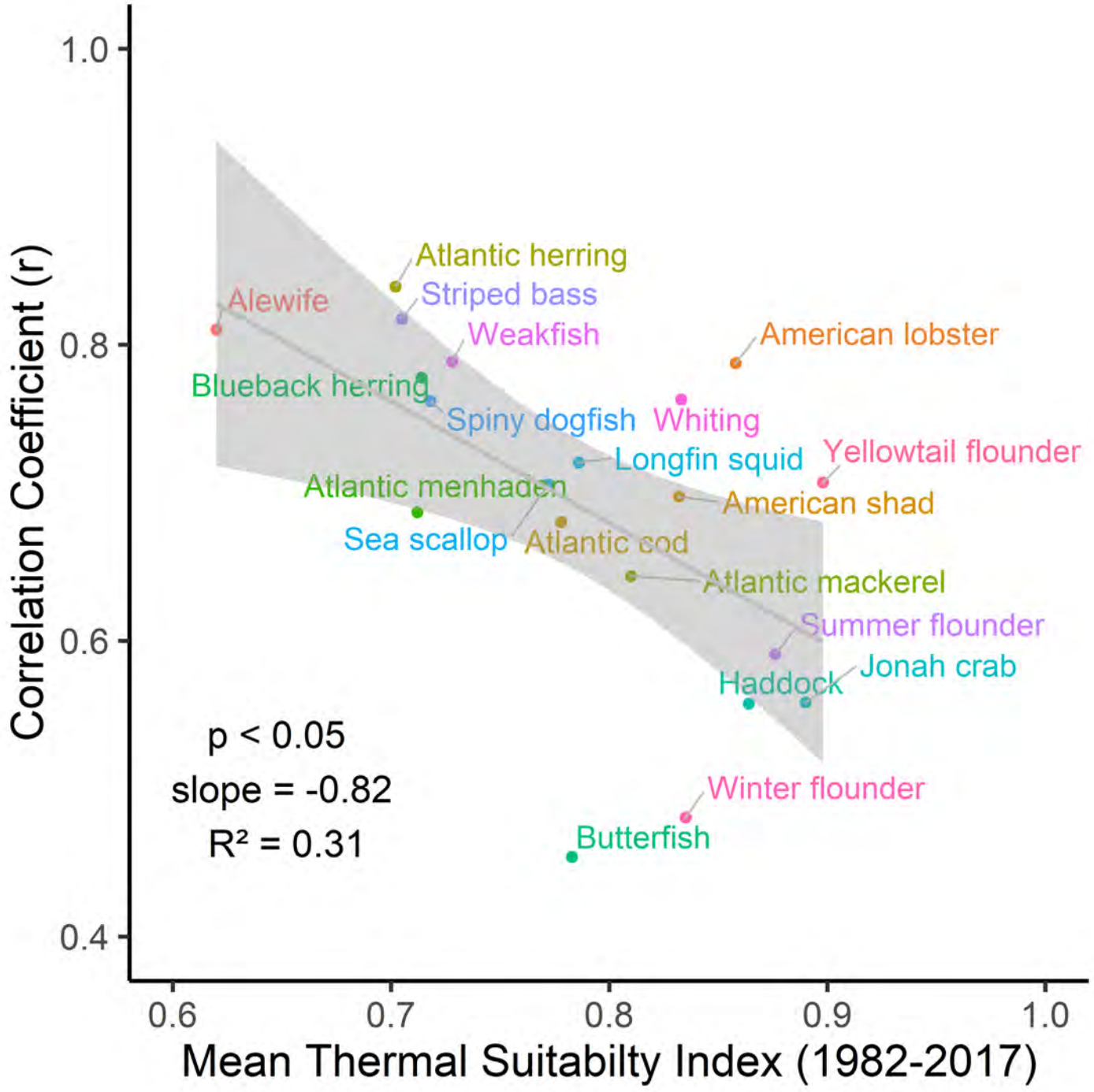


Standardized Taylor diagrams for forecasts with realized future SST data for each species.

- Alewife
- American lobster
- American shad
- Atlantic cod
- Atlantic herring
- Atlantic mackerel
- Atlantic menhaden
- Blueback herring
- Butterfish
- Haddock
- Jonah crab
- Longfin squid
- Sea scallop
- Spiny dogfish
- Striped bass
- Summer flounder
- Weakfish
- Whiting
- Winter flounder
- Yellowtail flounder



Forecasts were particularly skillful for species at the edges of the thermal ranges



Take away

Our analysis supports the potential strategic utility of multi-year SST forecasts for the proactive fisheries management.

Acknowledgement

- Andrew Ross & Elizabeth Drenkard (NOAA GFDL)
- NOAA NEFSC (bottom trawl survey data)
- Tom Delworth Research Team (CM 2.1, NOAA GFDL)
- James Thorson (VAST, NOAA Alaska Fisheries Science Center)
- NOAA NESDIS & NCDC (OISST-AVHRR)

Questions

kiseit@princeton.edu
ktanaka@mbayaq.org

PRINCETON UNIVERSITY

The Nippon Foundation
NEREUS PROGRAM
Predicting Future Oceans

Amadeo Lucas