

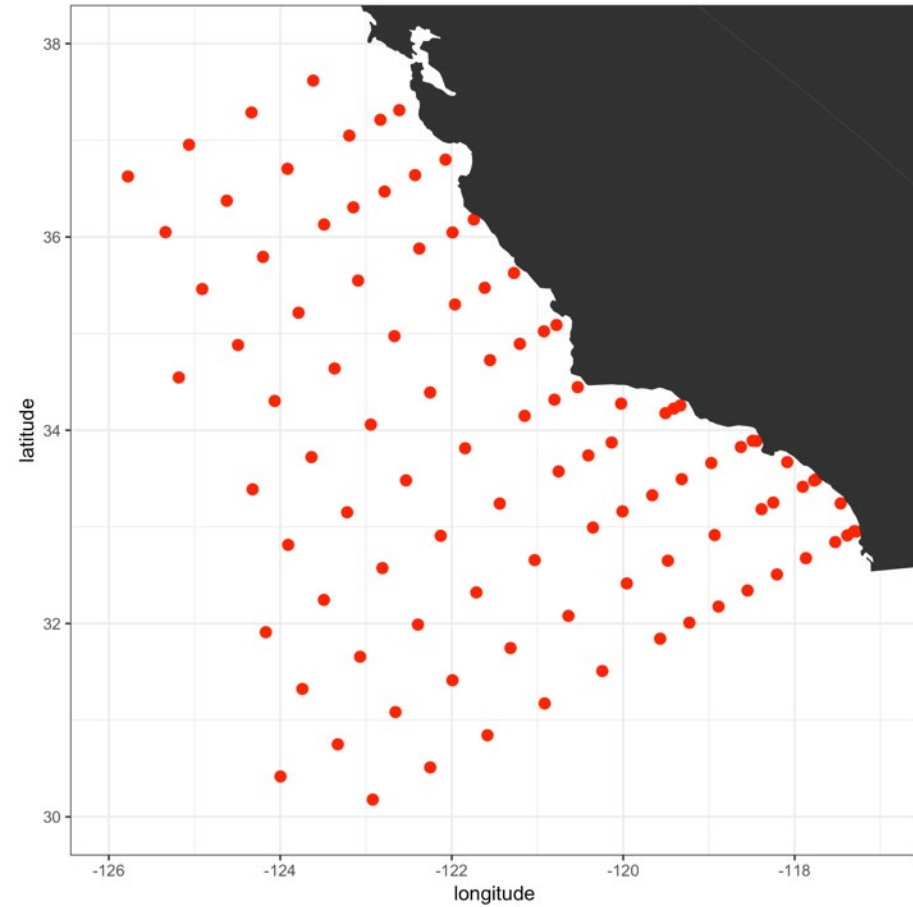
Spatial scales of dynamics in CalCOFI ichthyoplankton survey

Peter Kuriyama^{1,2}, Brice Semmens¹, George Sugihara¹, Andrew
Thompson²

¹Scripps Institution of Oceanography, UCSD

²Southwest Fisheries Science Center

CalCOFI survey



Empirical dynamic modeling (EDM)

- <https://www.youtube.com/watch?v=8DikuwwPWsY&frags=pl%2Cwn>
- One time series
 - Reconstruct shape of attractor

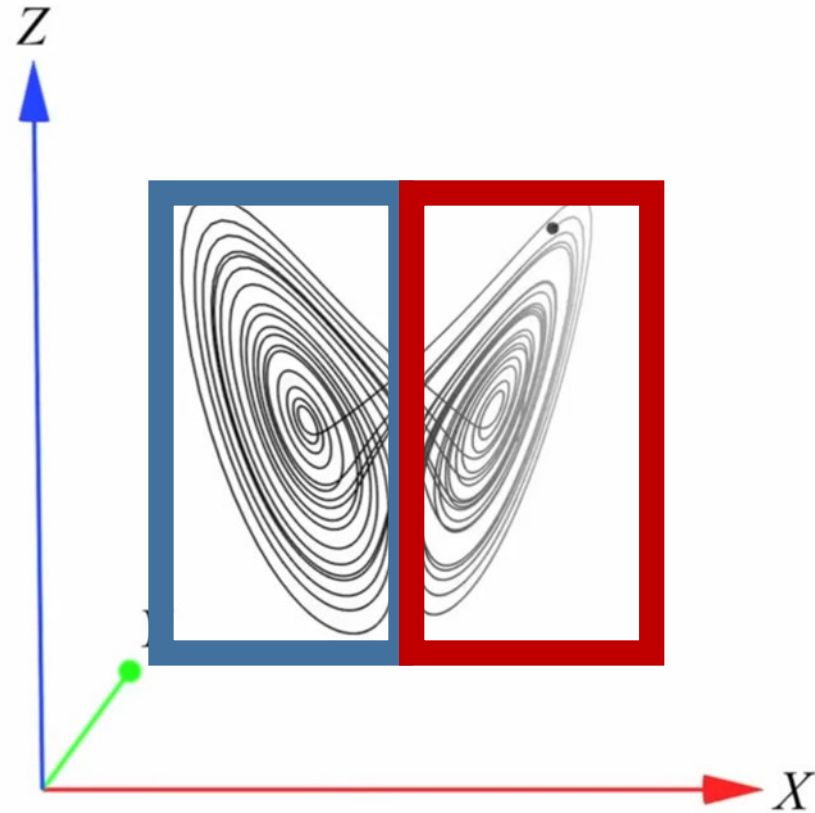
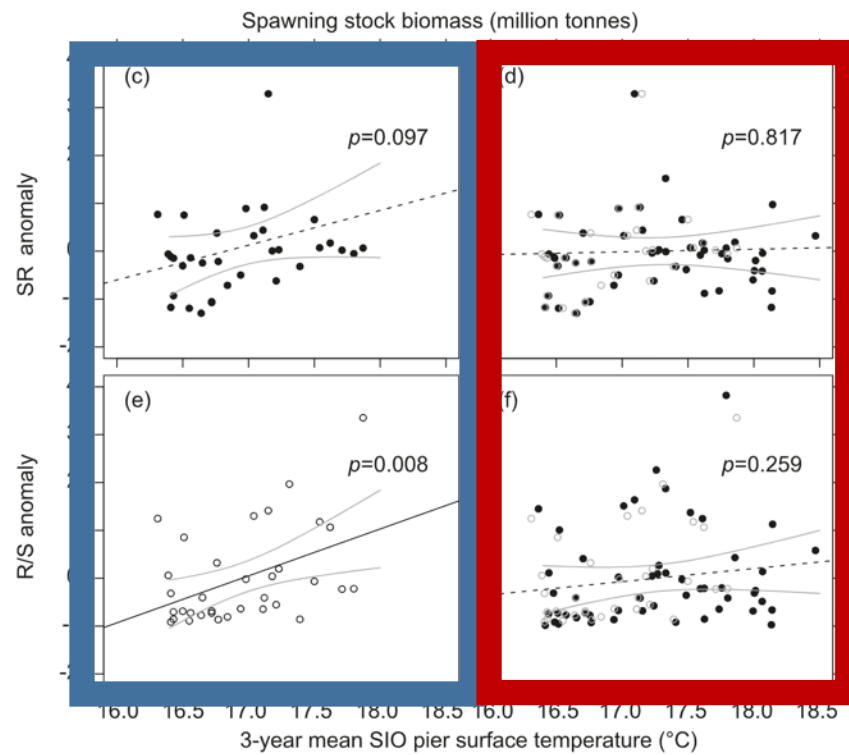
Takens' Theorem

- <https://www.youtube.com/watch?v=ctOseiJoRul>
- Evaluate reconstruction
- Can we predict?
 - Data quality
 - Representative

Shifts in system

Re-assessment of the stock–recruit and temperature–recruit relationships for Pacific sardine (*Sardinops sagax*)

Sam McClatchie, Ralf Goericke, Guillermo Auad, and Kevin Hill



CalCOFI and EDM

Distinguishing random environmental fluctuations from ecological catastrophes for the North Pacific Ocean

Chih-hao Hsieh¹, Sarah M. Glaser¹, Andrew J. Lucas¹ & George Sugihara¹

Nature, 2005

Why fishing magnifies fluctuations in fish abundance

Christian N. K. Anderson¹, Chih-hao Hsieh^{1,2,3,4}, Stuart A. Sandin¹, Roger Hewitt⁵, Anne Hollowed⁶, John Beddington⁷, Robert M. May⁸ & George Sugihara¹

Nature, 2005

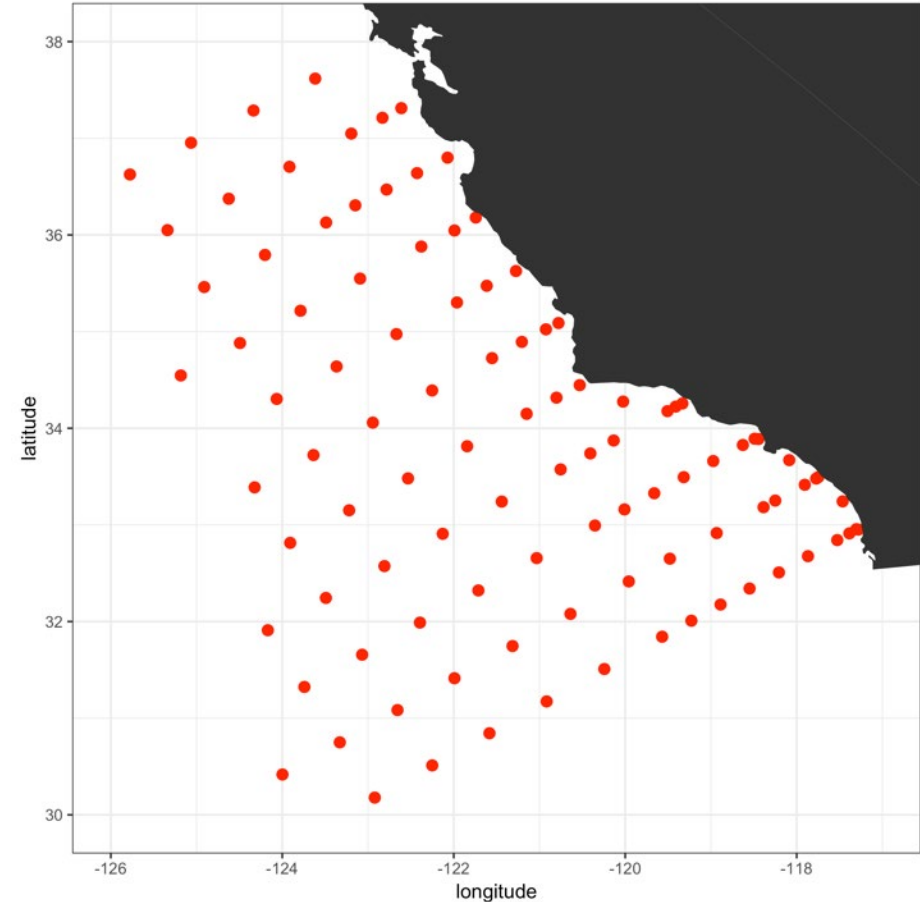
Predicting climate effects on Pacific sardine

Ethan R. Deyle^{a,1}, Michael Fogarty^b, Chih-hao Hsieh^c, Les Kaufman^{d,e}, Alec D. MacCall^f, Stephan B. Munch^f, Charles T. Perretti^a, Hao Ye^a, and George Sugihara^{a,1}

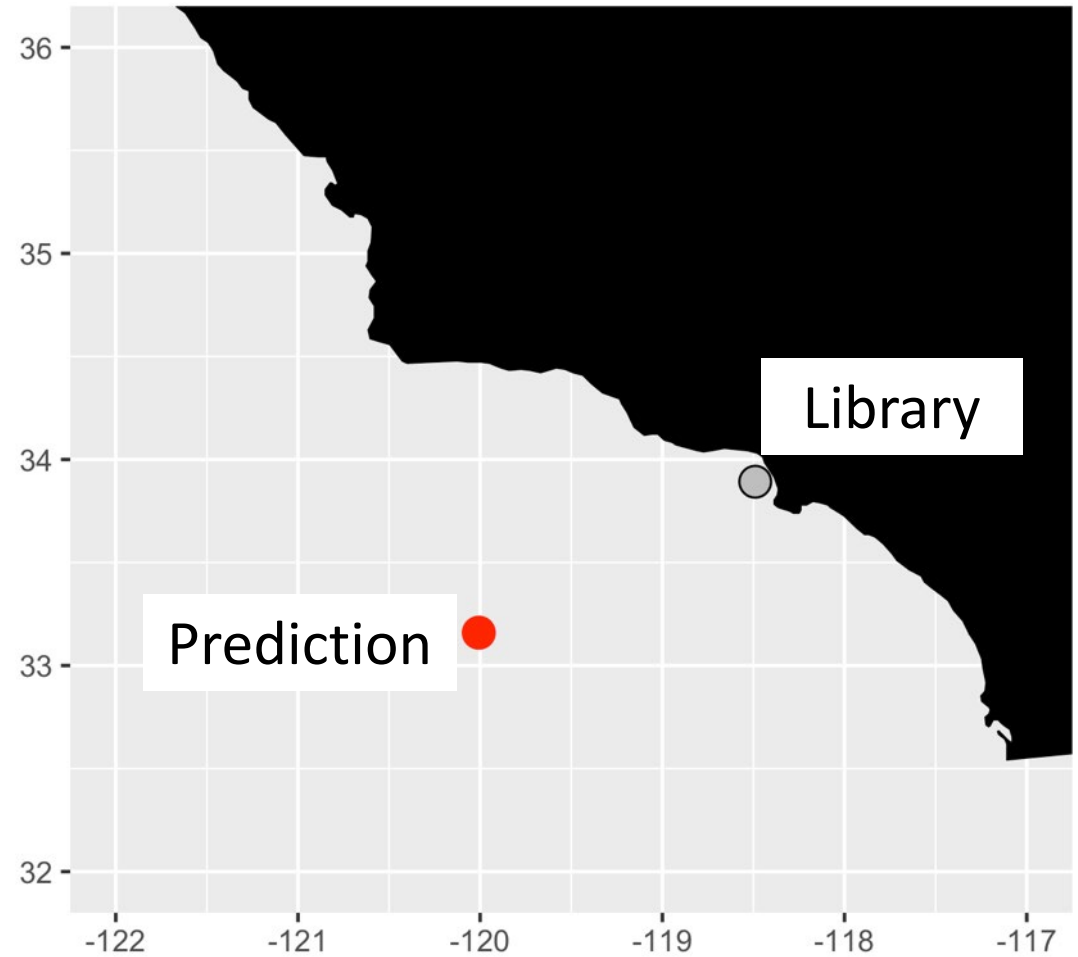
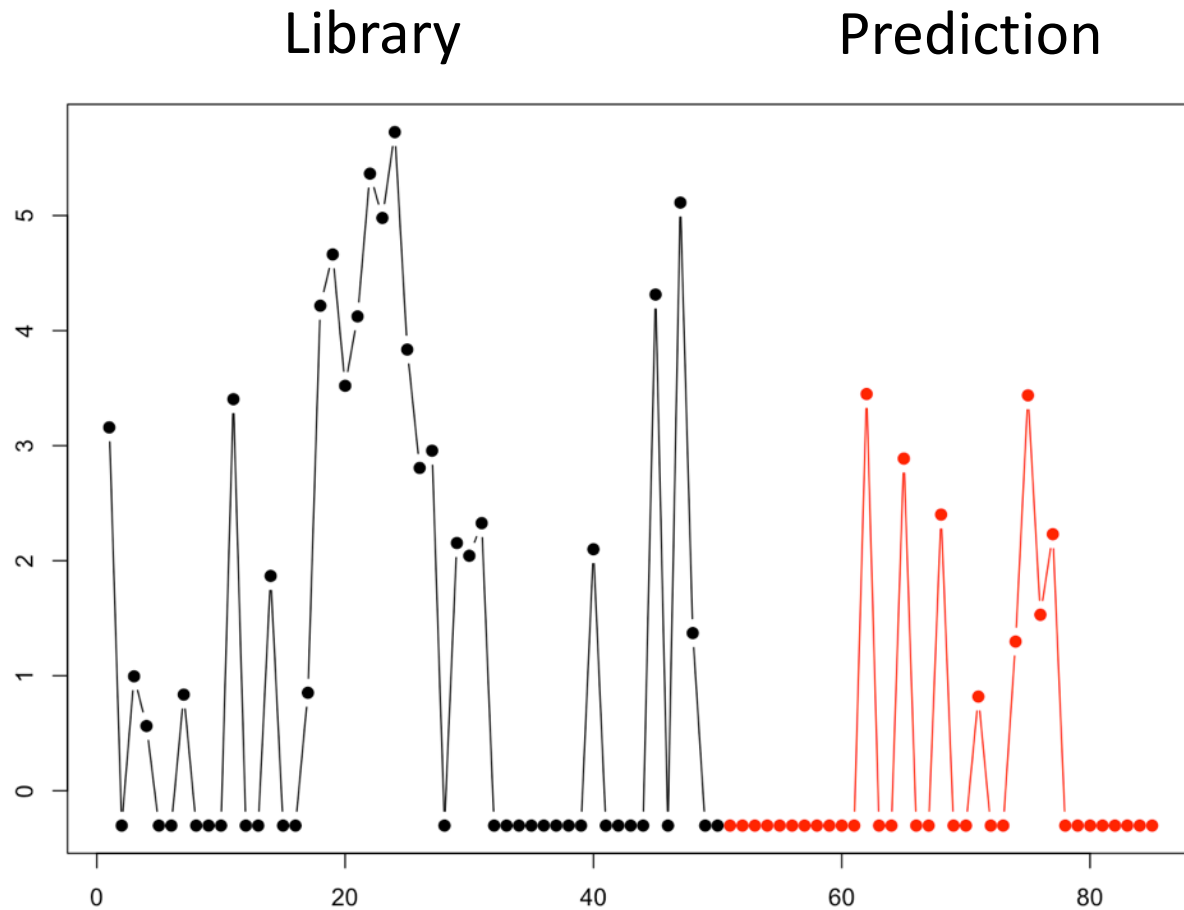
PNAS, 2013

Extensions into space and time

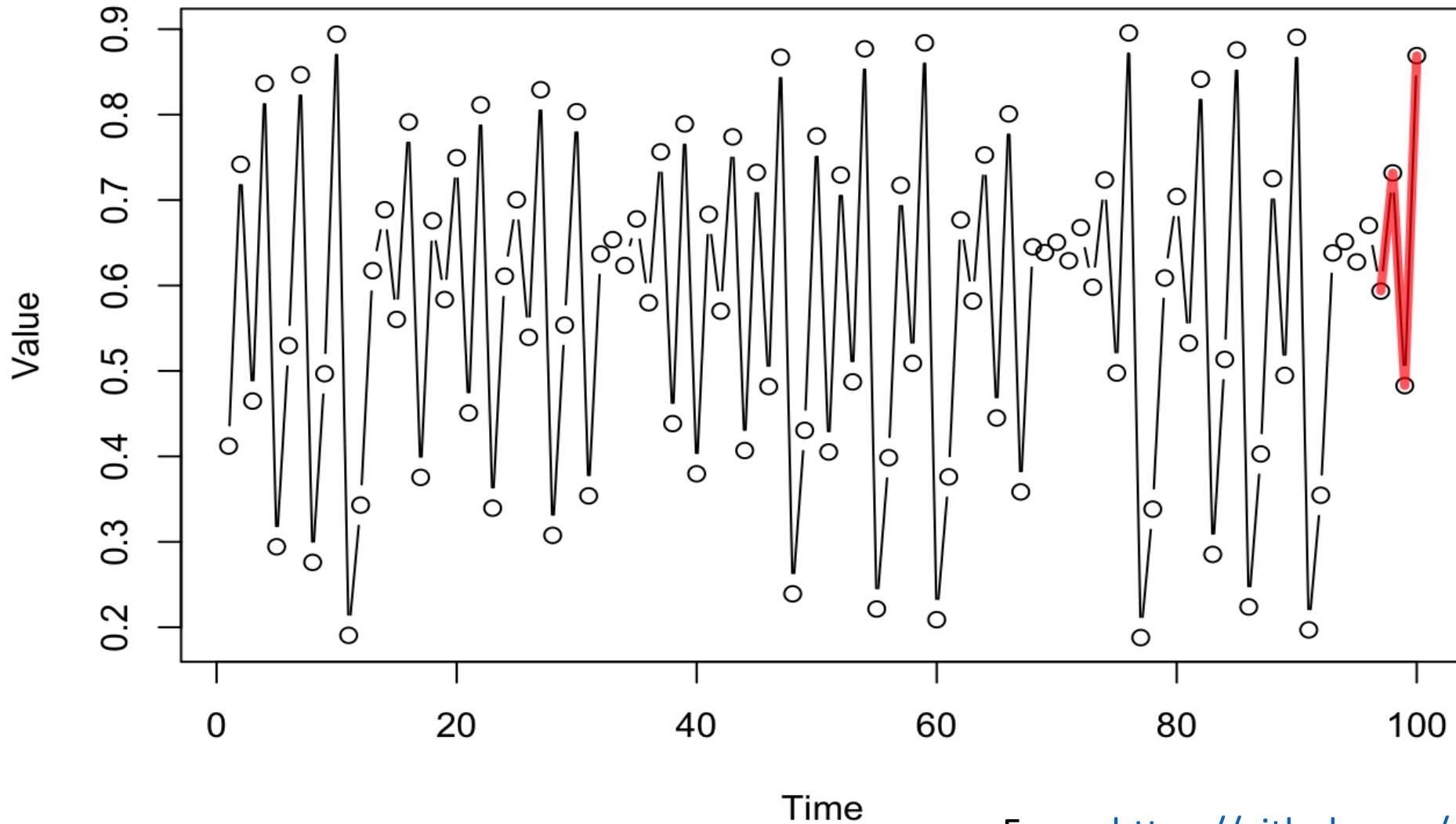
- Fish larvae
 - Annual averages, standardized
- Shared dynamics
 - Generated by same processes
 - Common response
- Where/when/which?



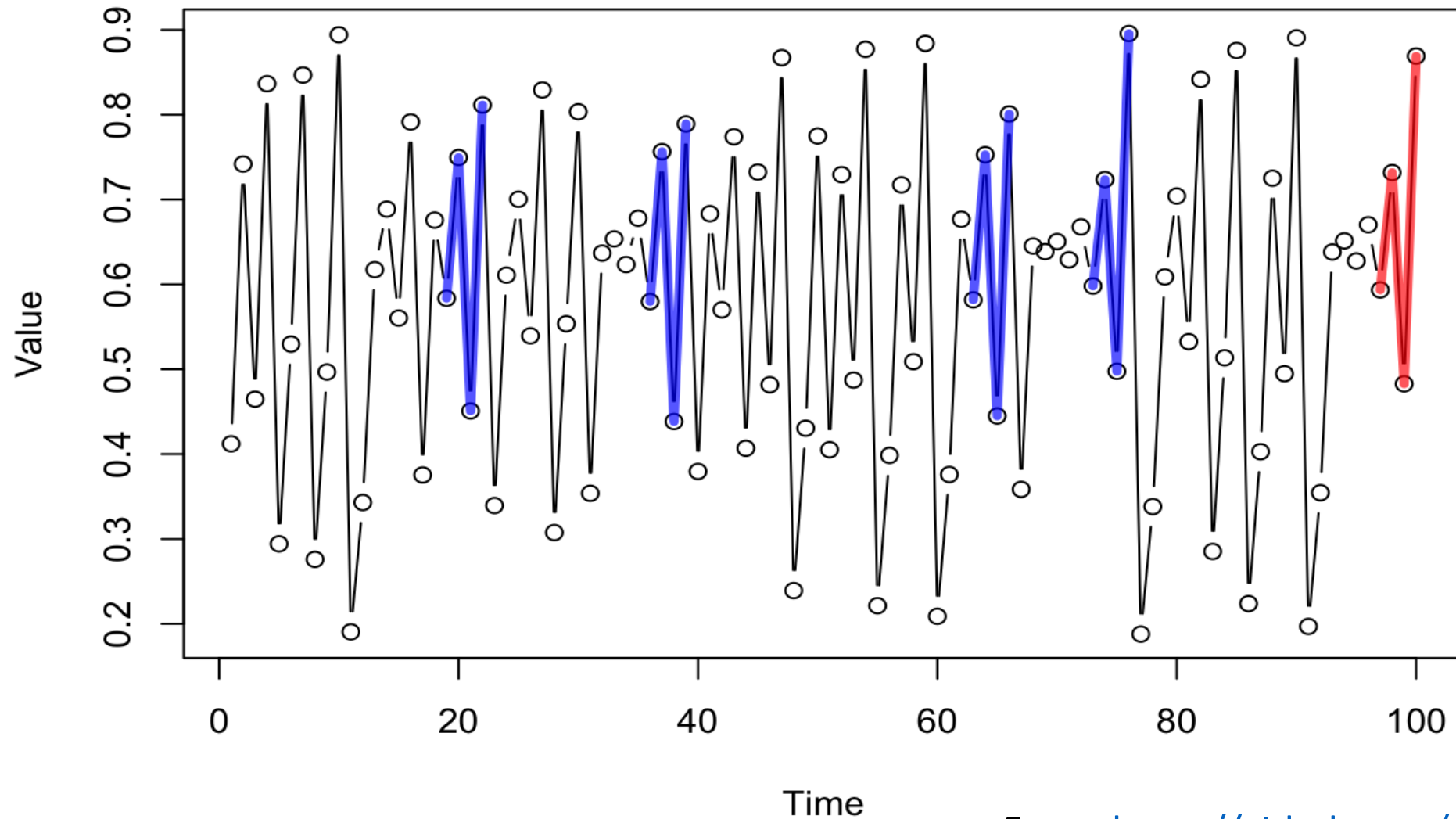
Shared dynamics (co-prediction)



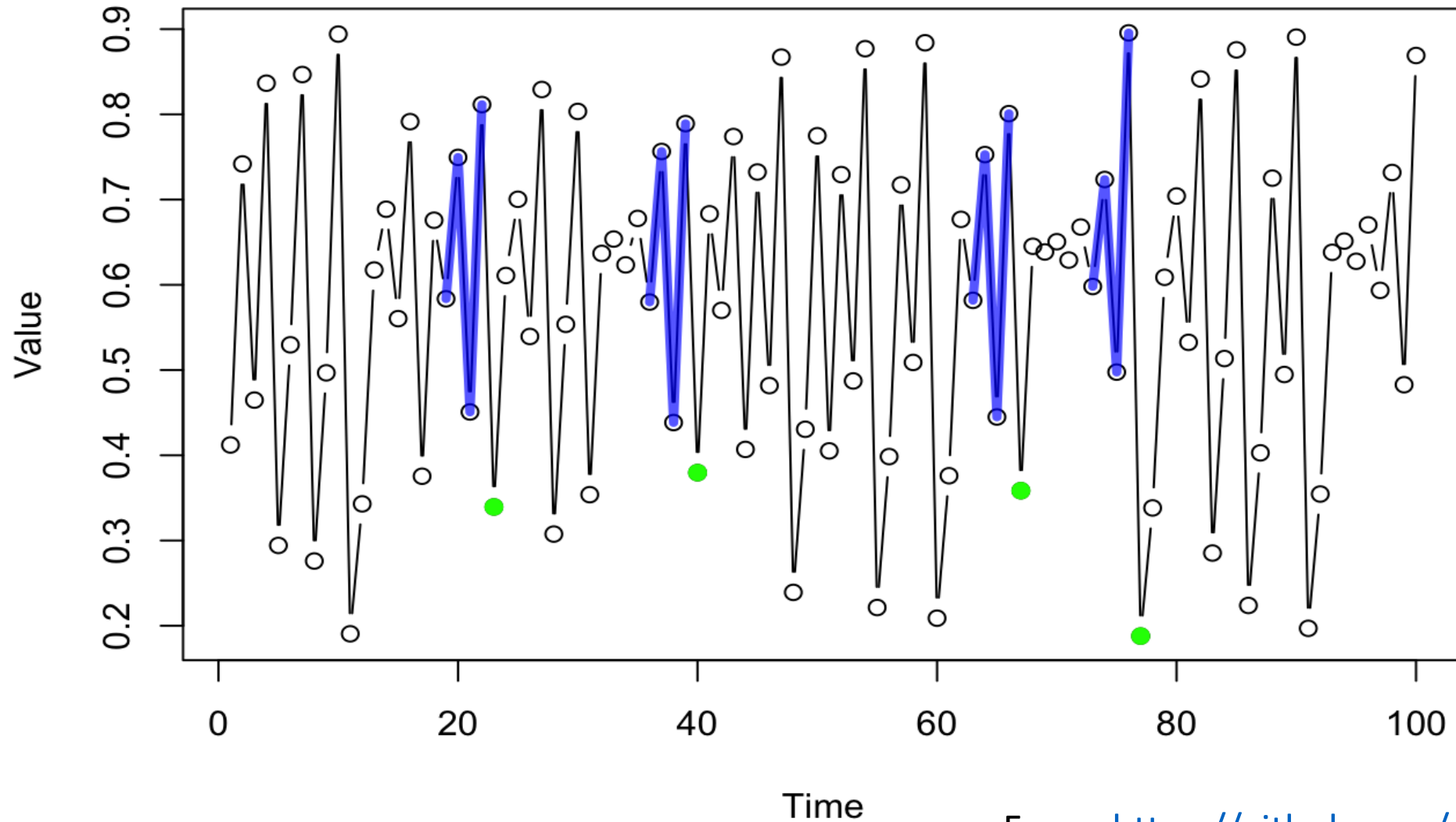
1-D Simplex (Sugihara and May 1990)



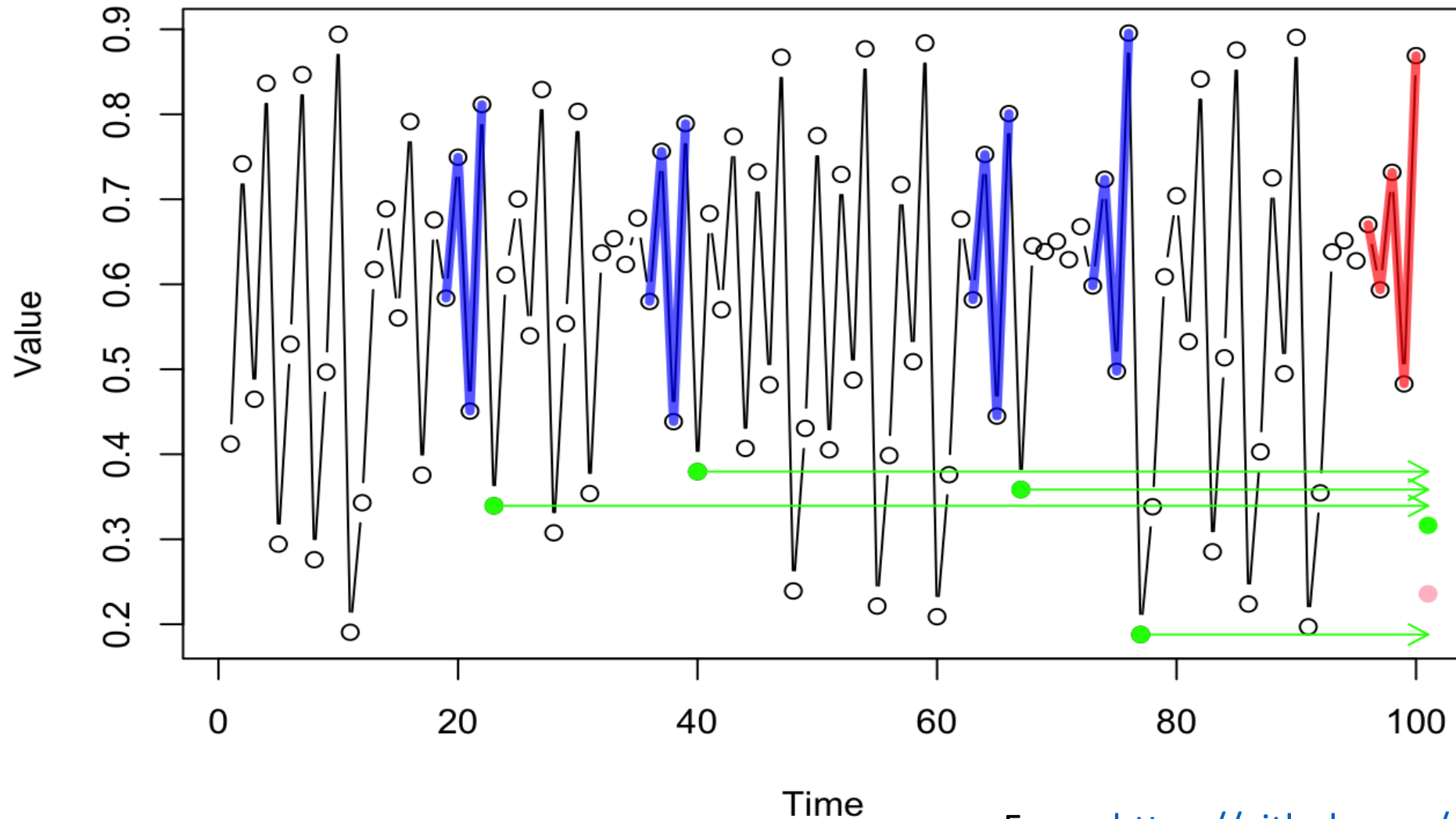
1-D Simplex (Sugihara and May 1990)



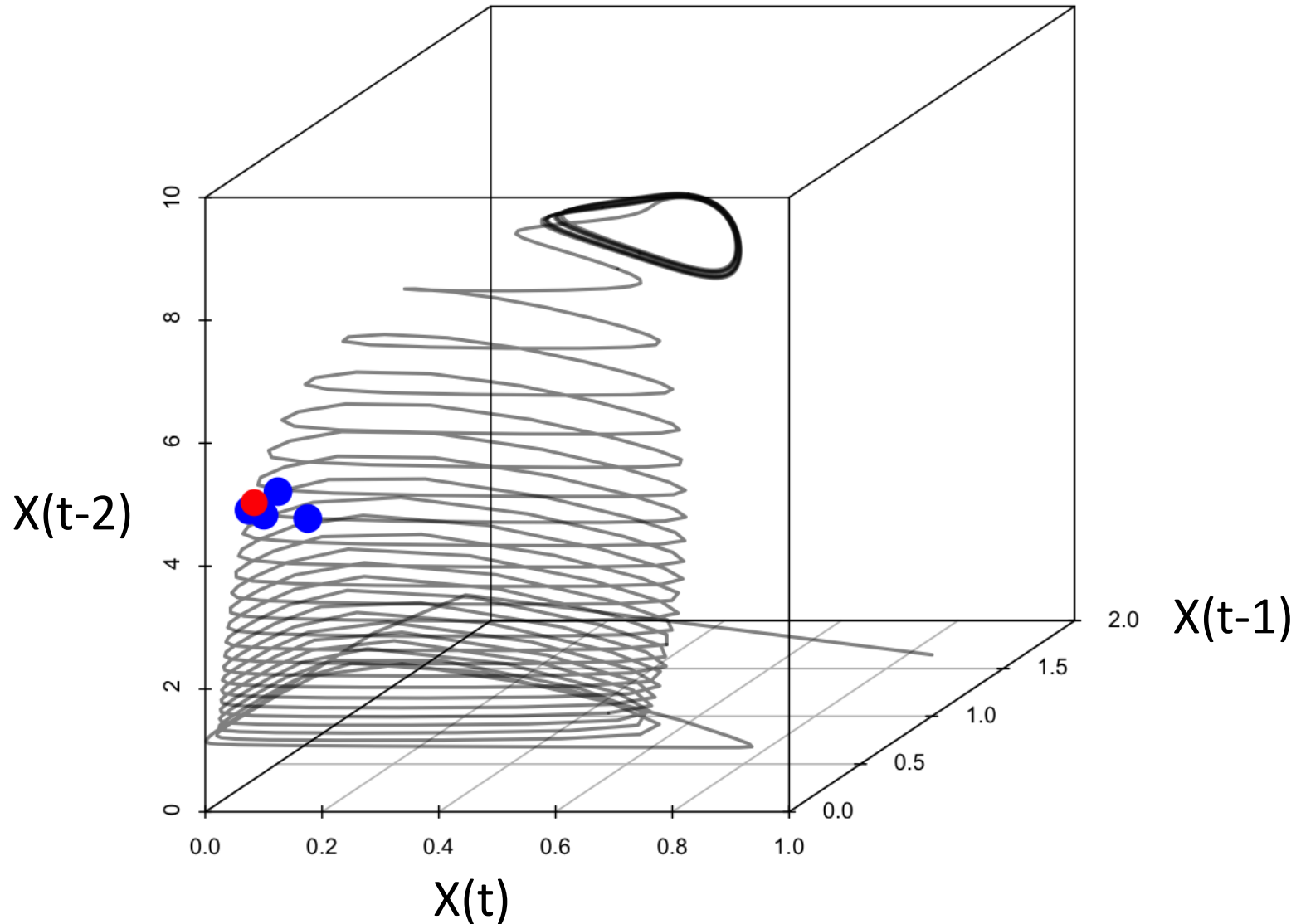
1-D Simplex (Sugihara and May 1990)



1-D Simplex (Sugihara and May 1990)

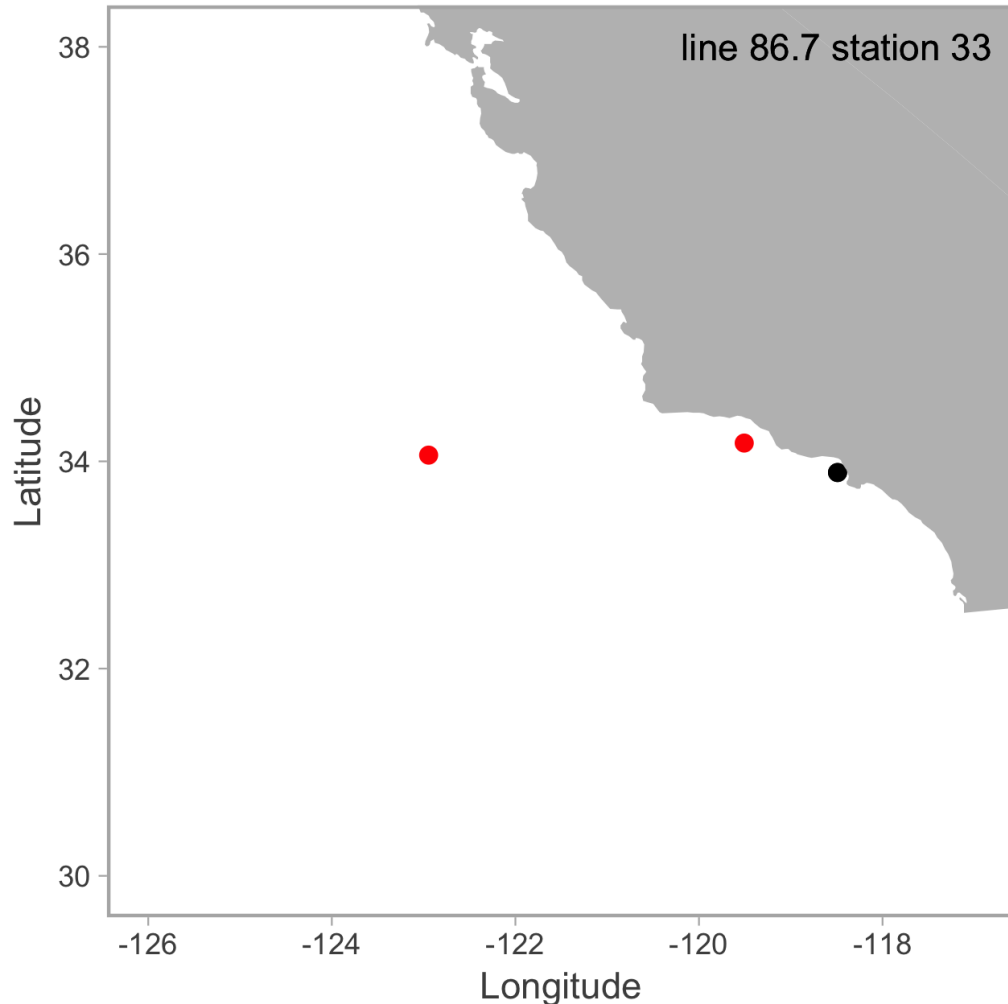


3-D Simplex (Sugihara and May 1990)



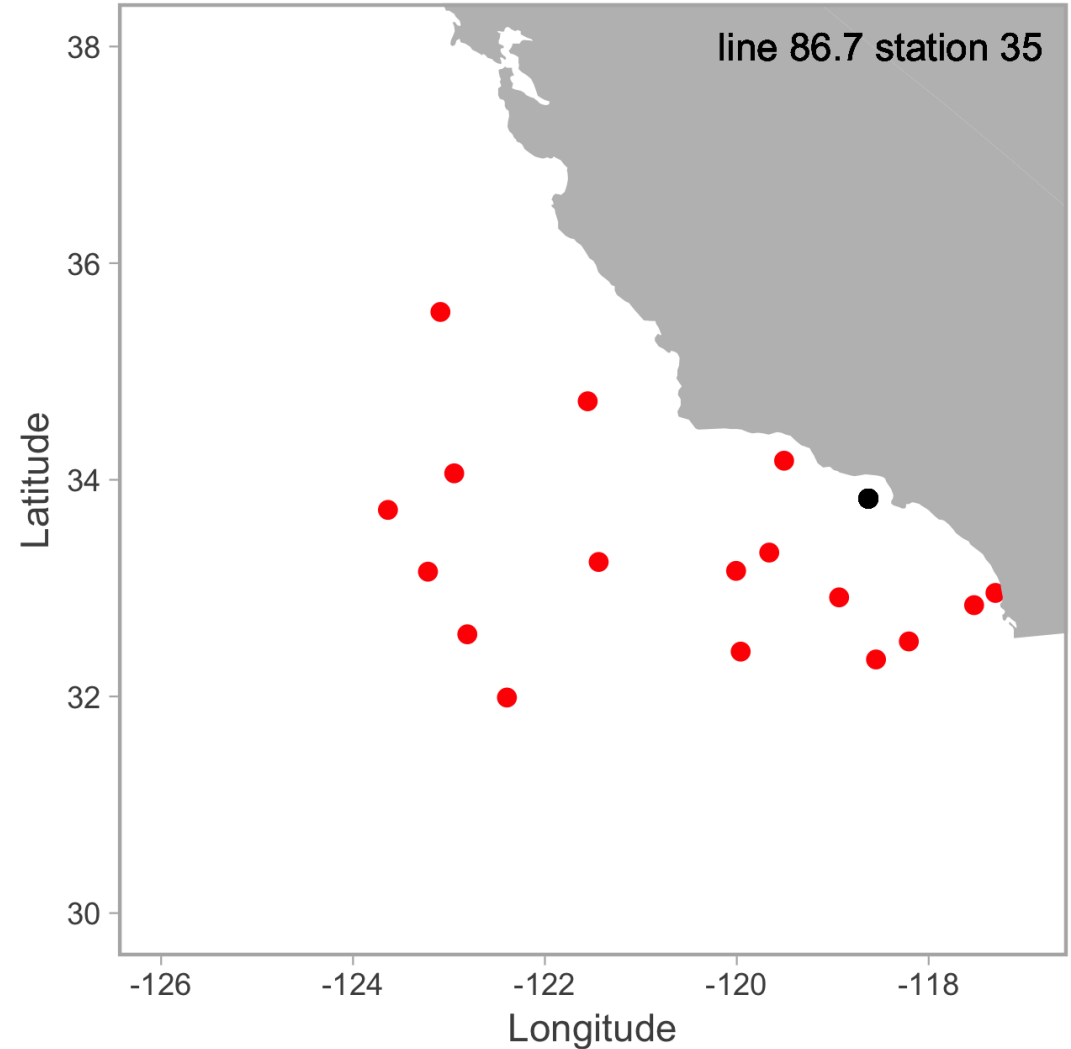
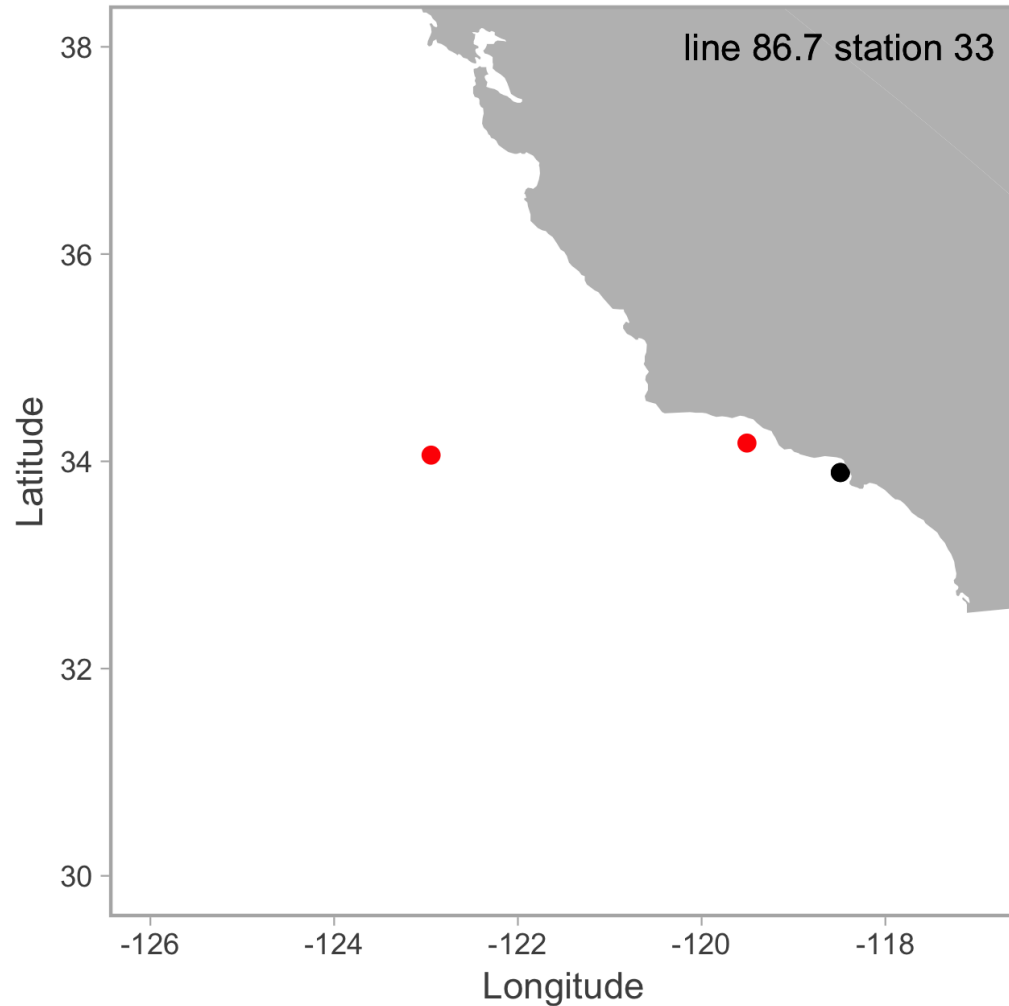
- Estimate dimension
- Nearest neighbors
- Compare predictions to observations

Synchrony results: sardine, one location

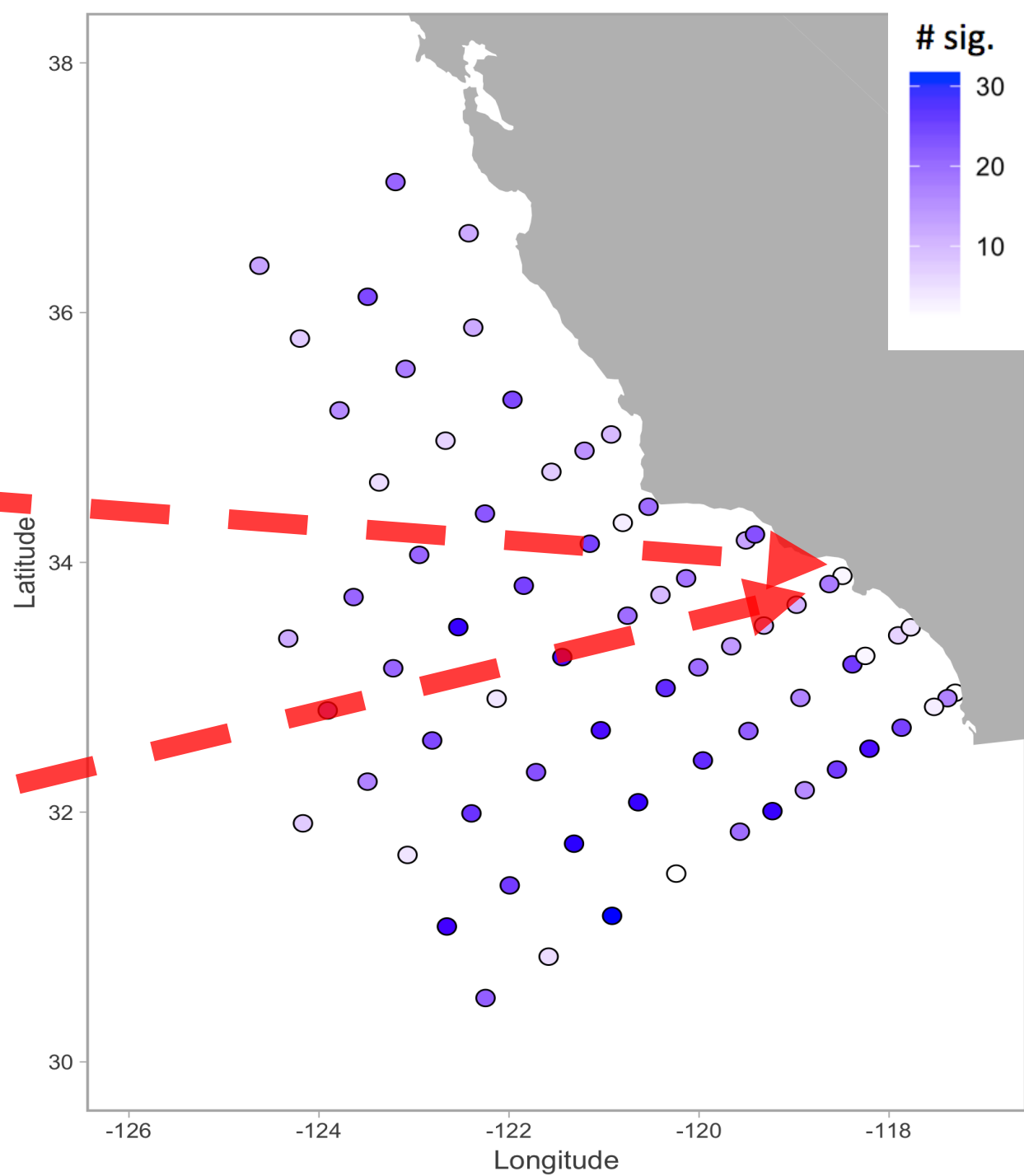
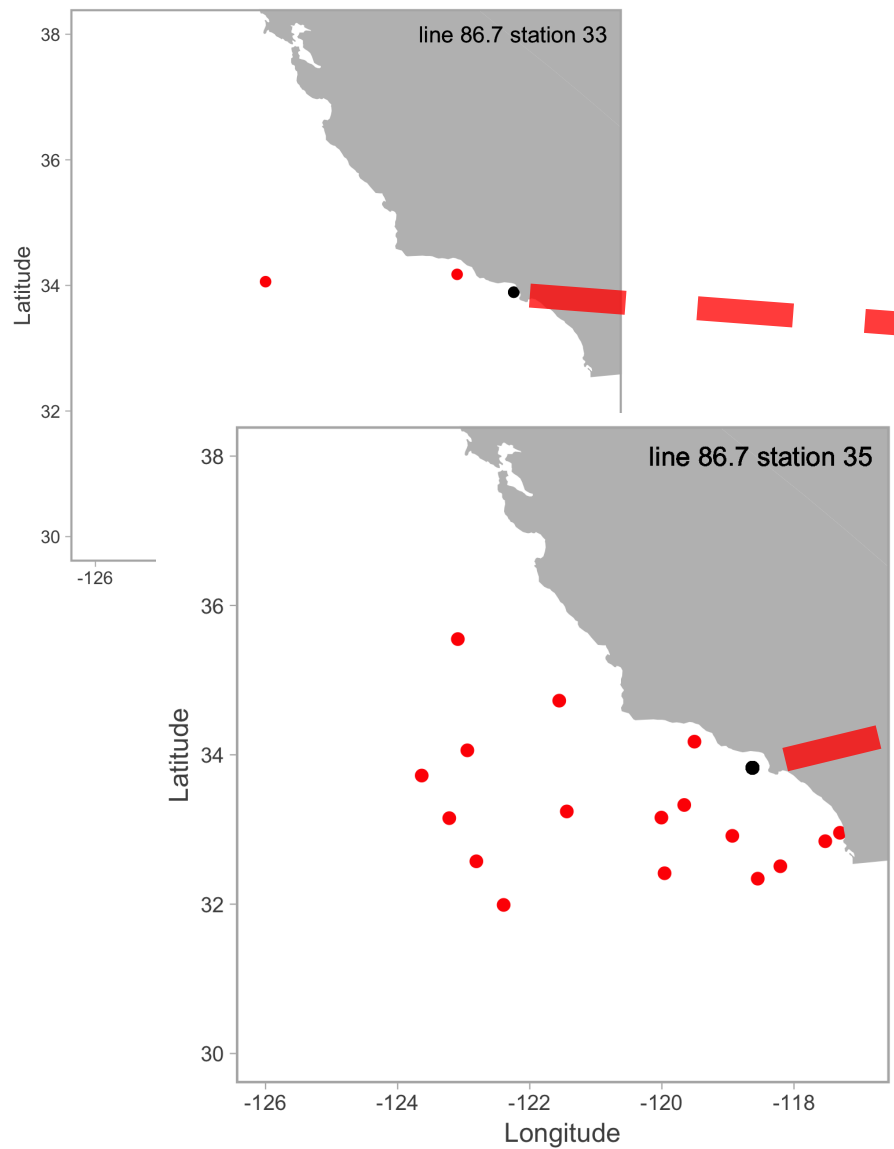


- Pairwise predictions
- Significance:
 - Spearman's rho ($p < .05$)
 - Better than naïve prediction?
 - Less than 75% zeroes
- Here 2 significant sites
- 1951-2017

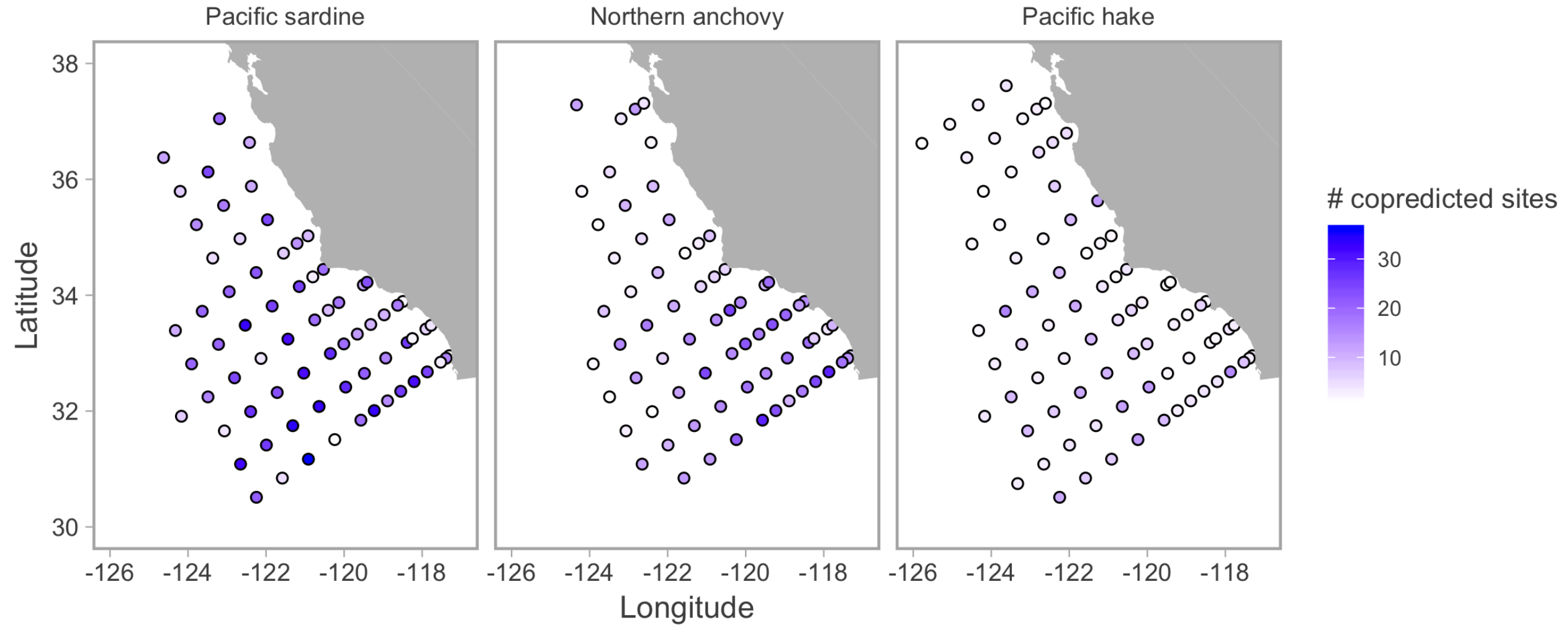
Synchrony results: sardine, two locations



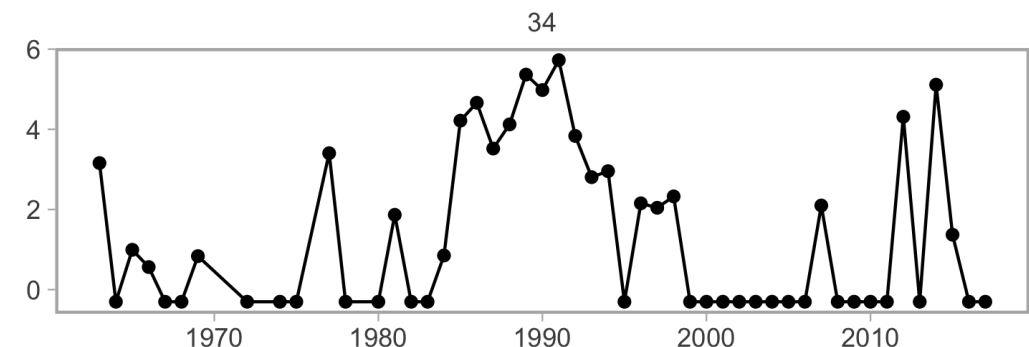
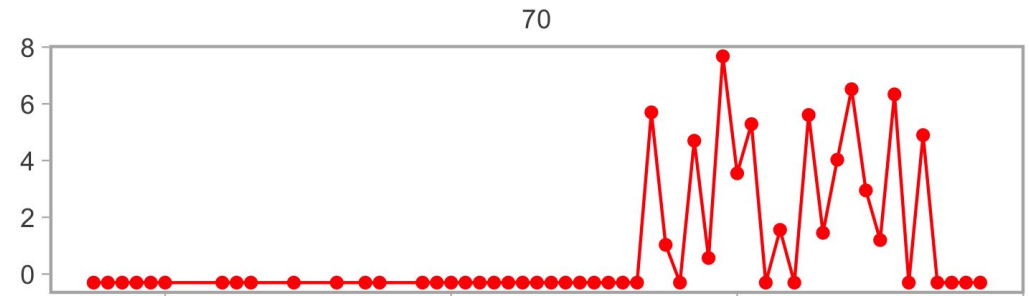
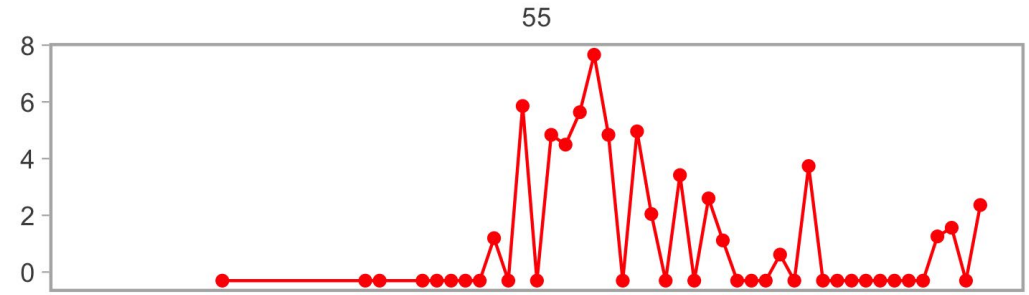
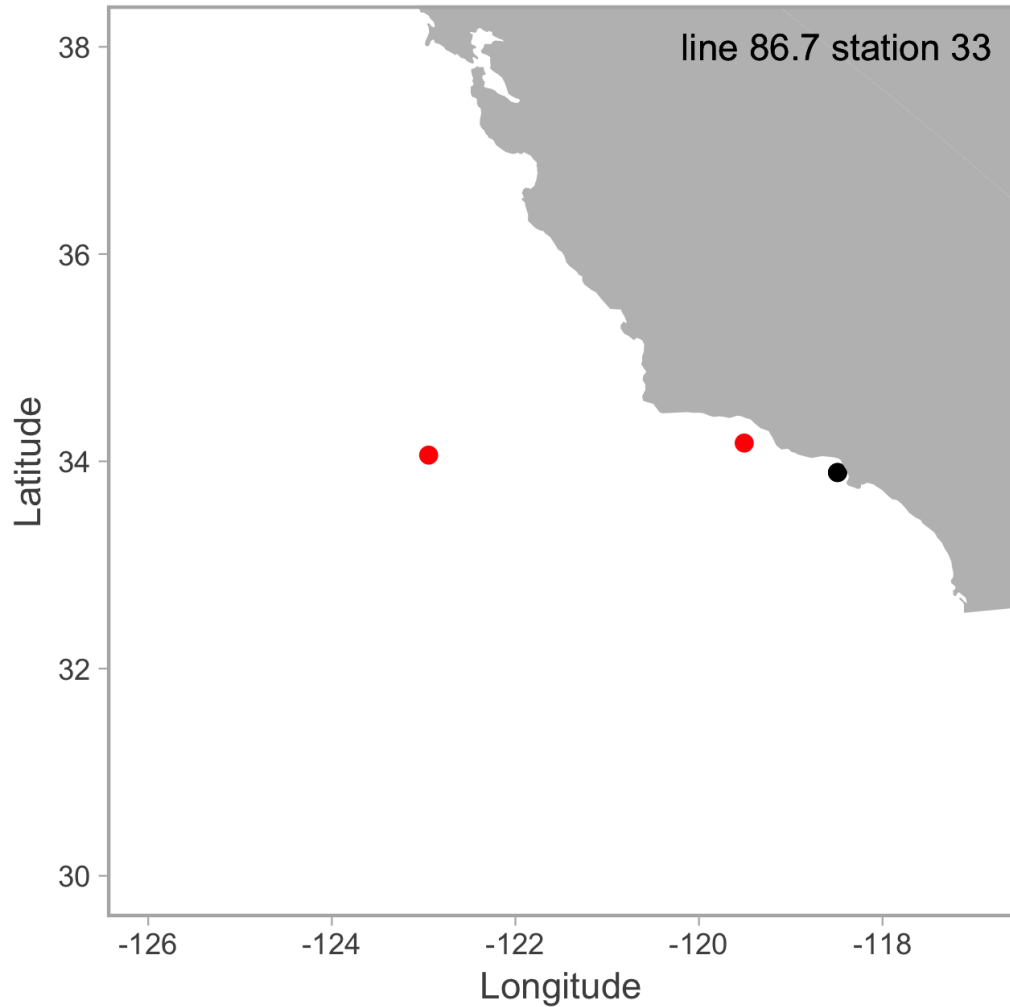
Sentinel sites



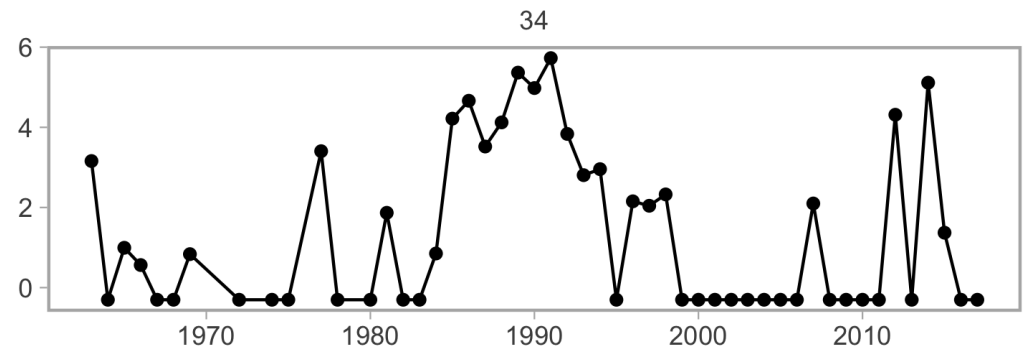
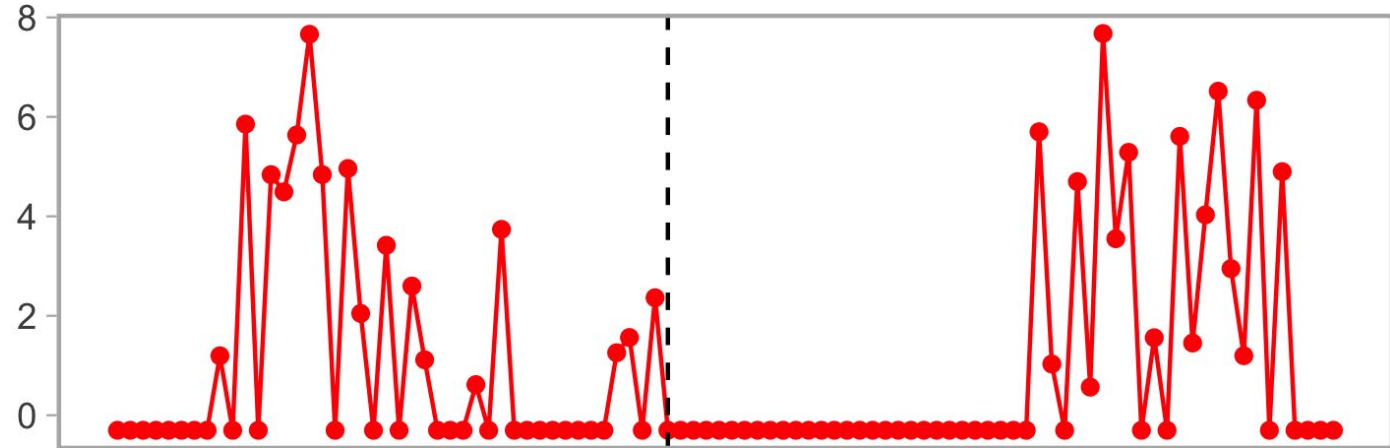
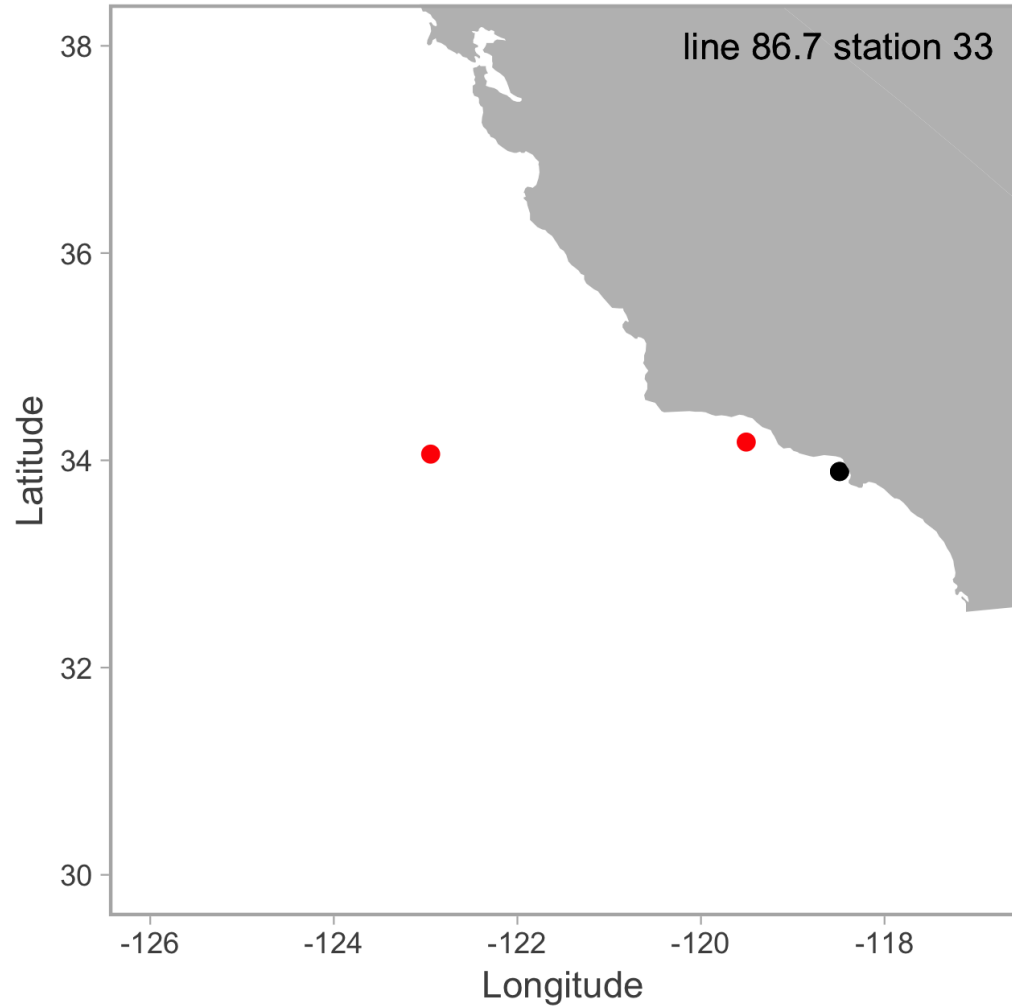
Sentinel sites



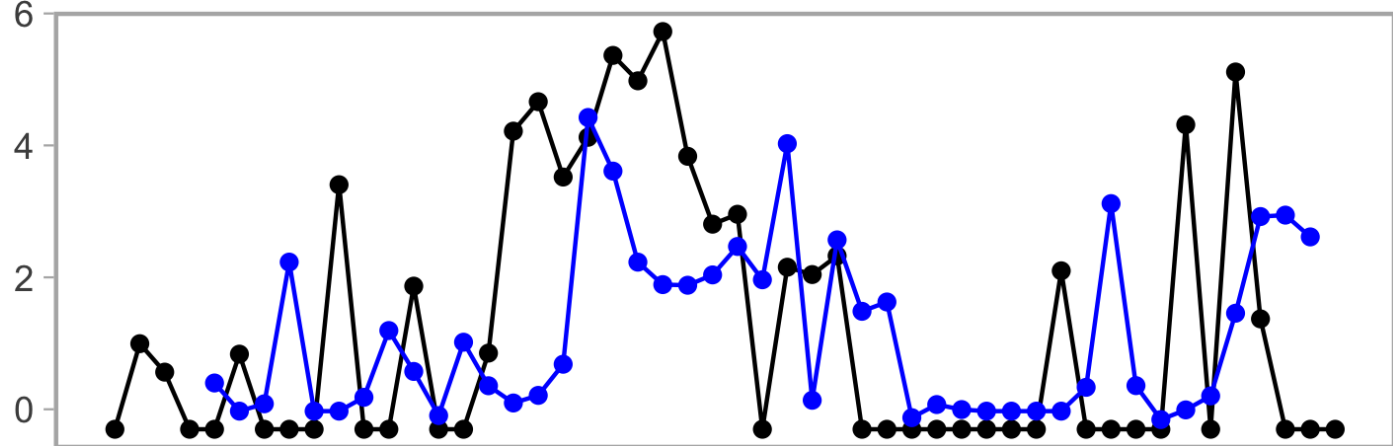
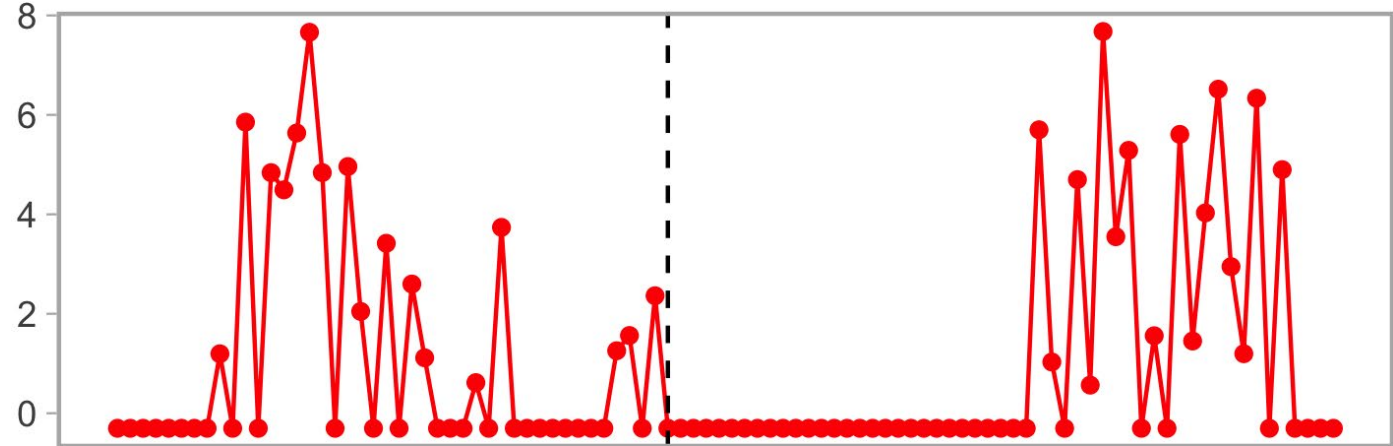
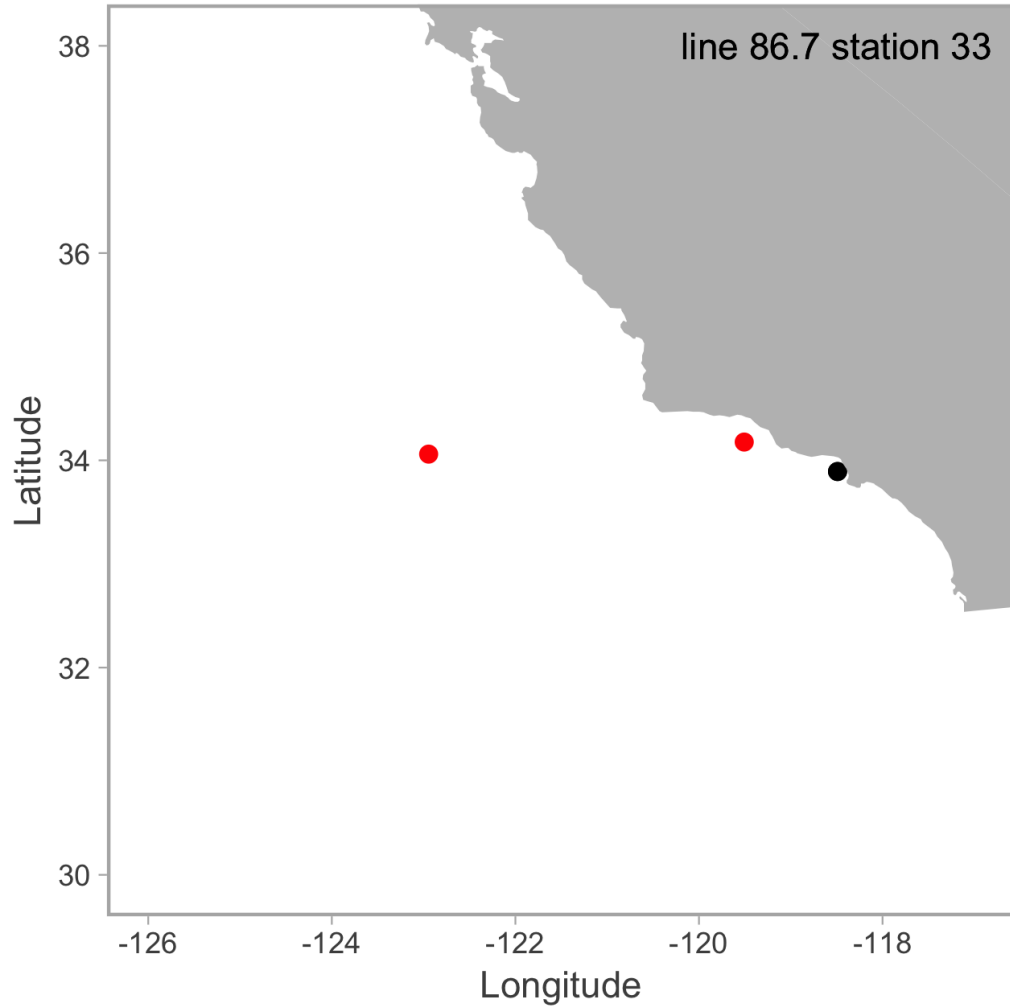
Synchrony to predict time series



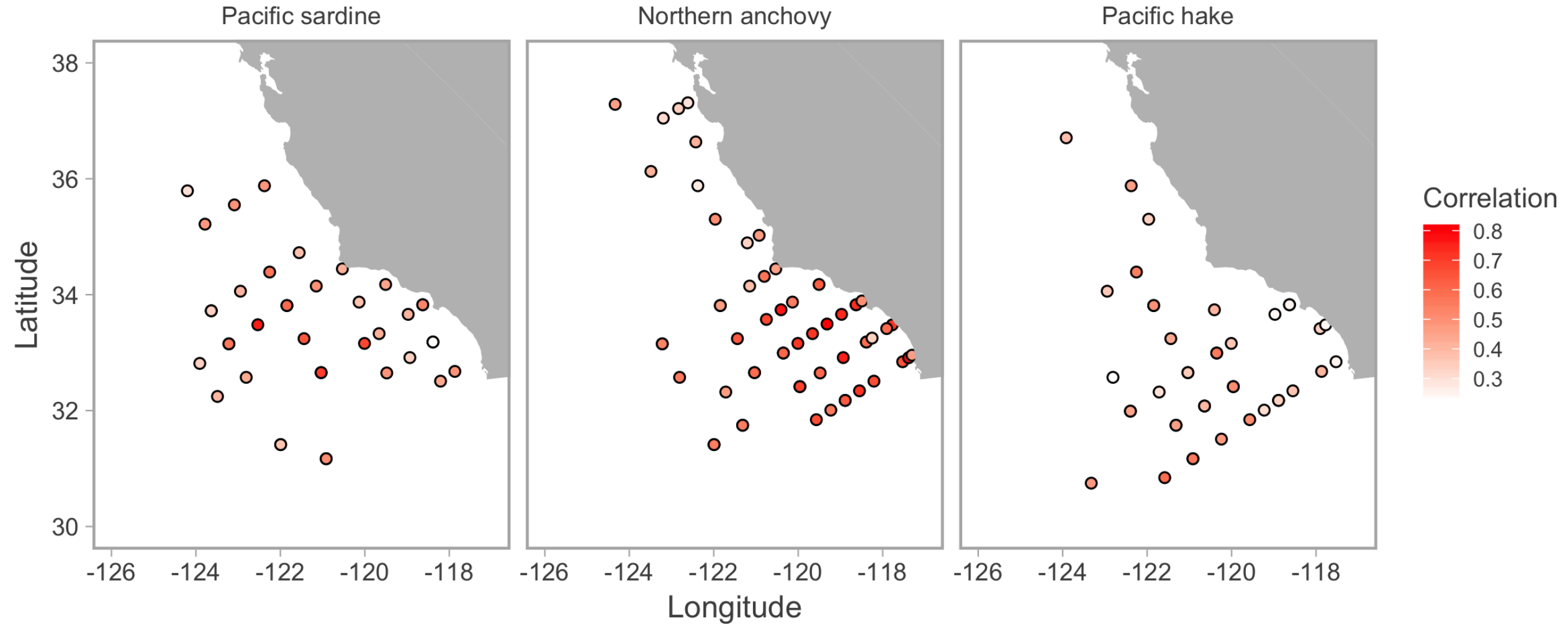
Composite library



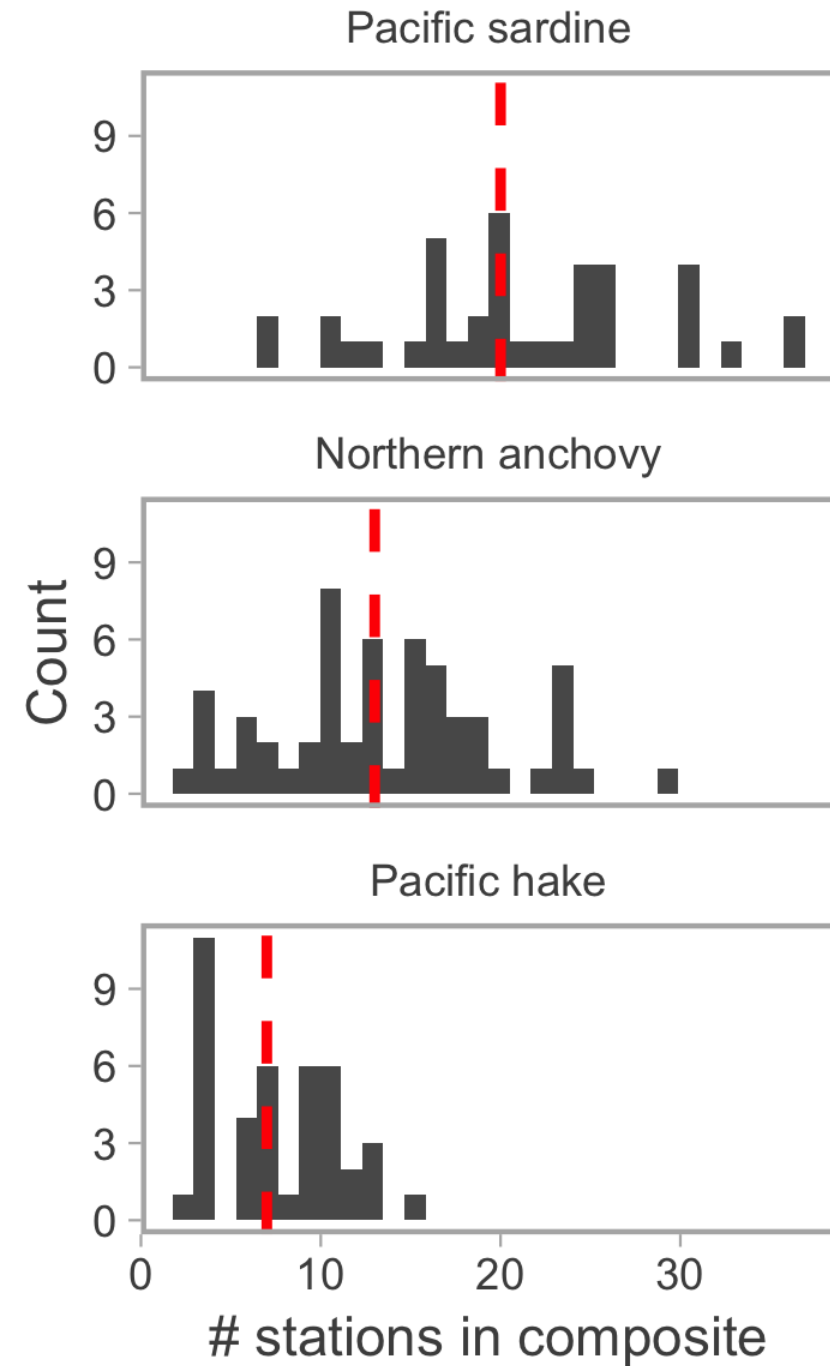
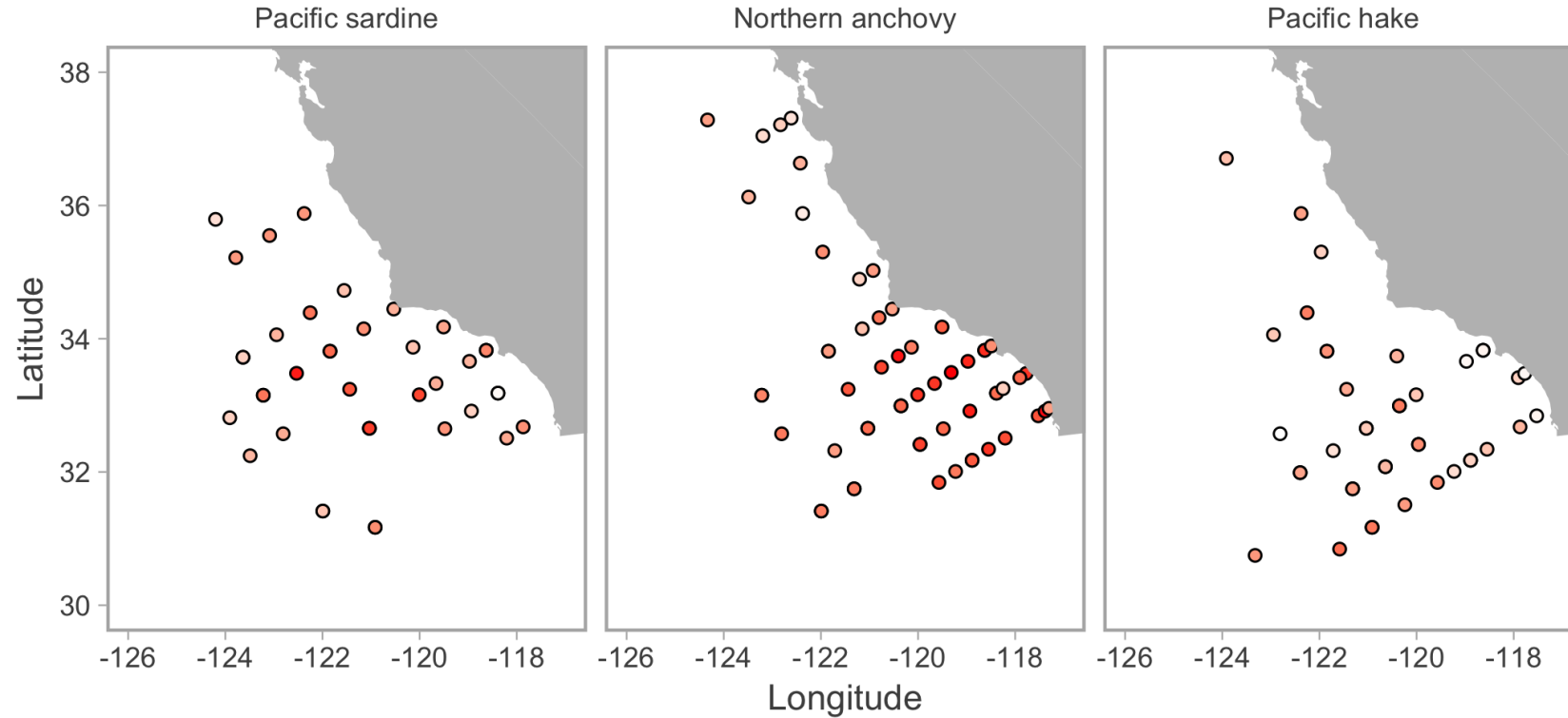
Prediction from composite library



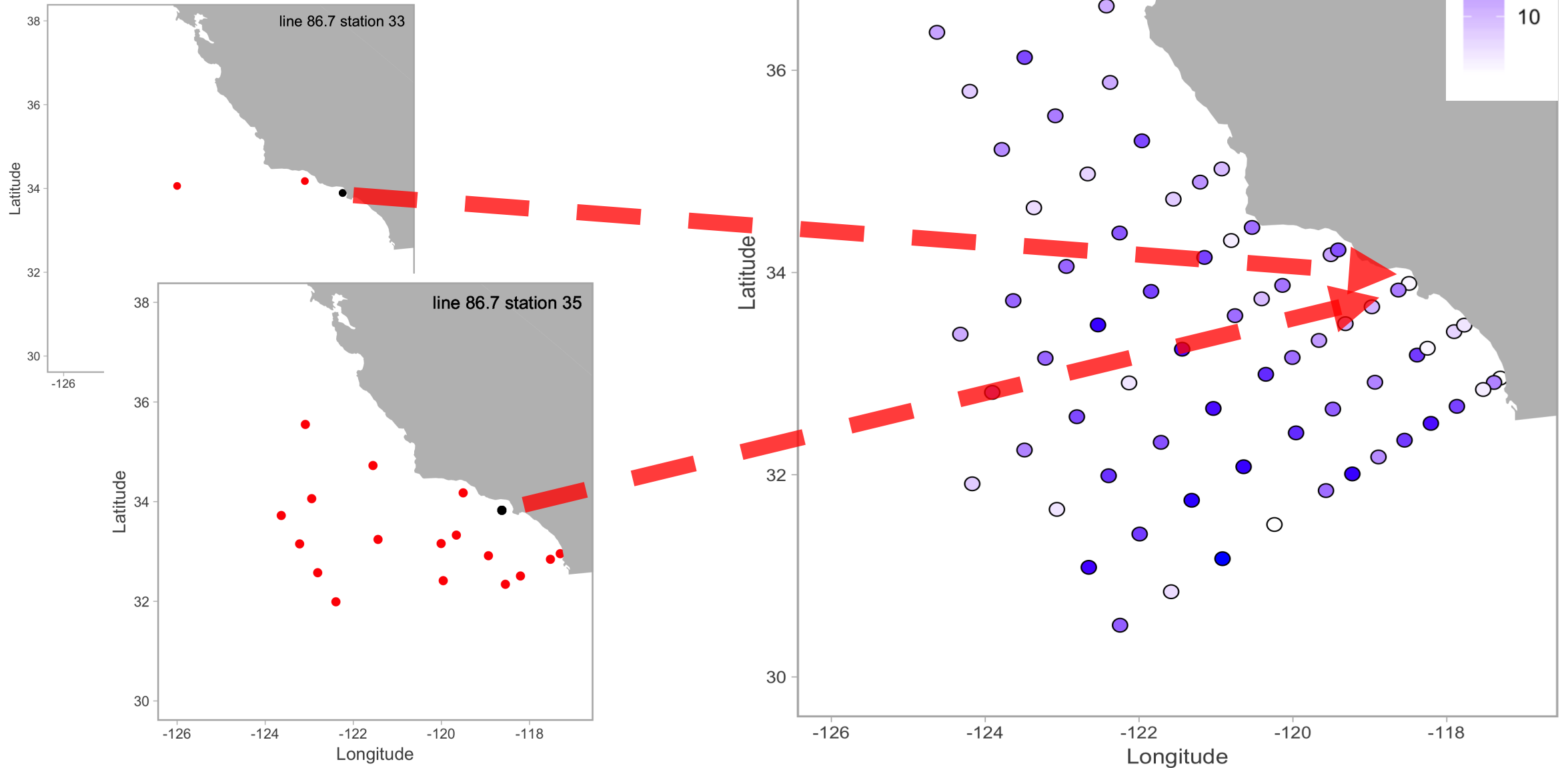
Where do we predict well?



Scales of dynamics



Sentinel sites *through time*



1951-1963

1951-1975

1951-1982

1951-1989

1951-2010

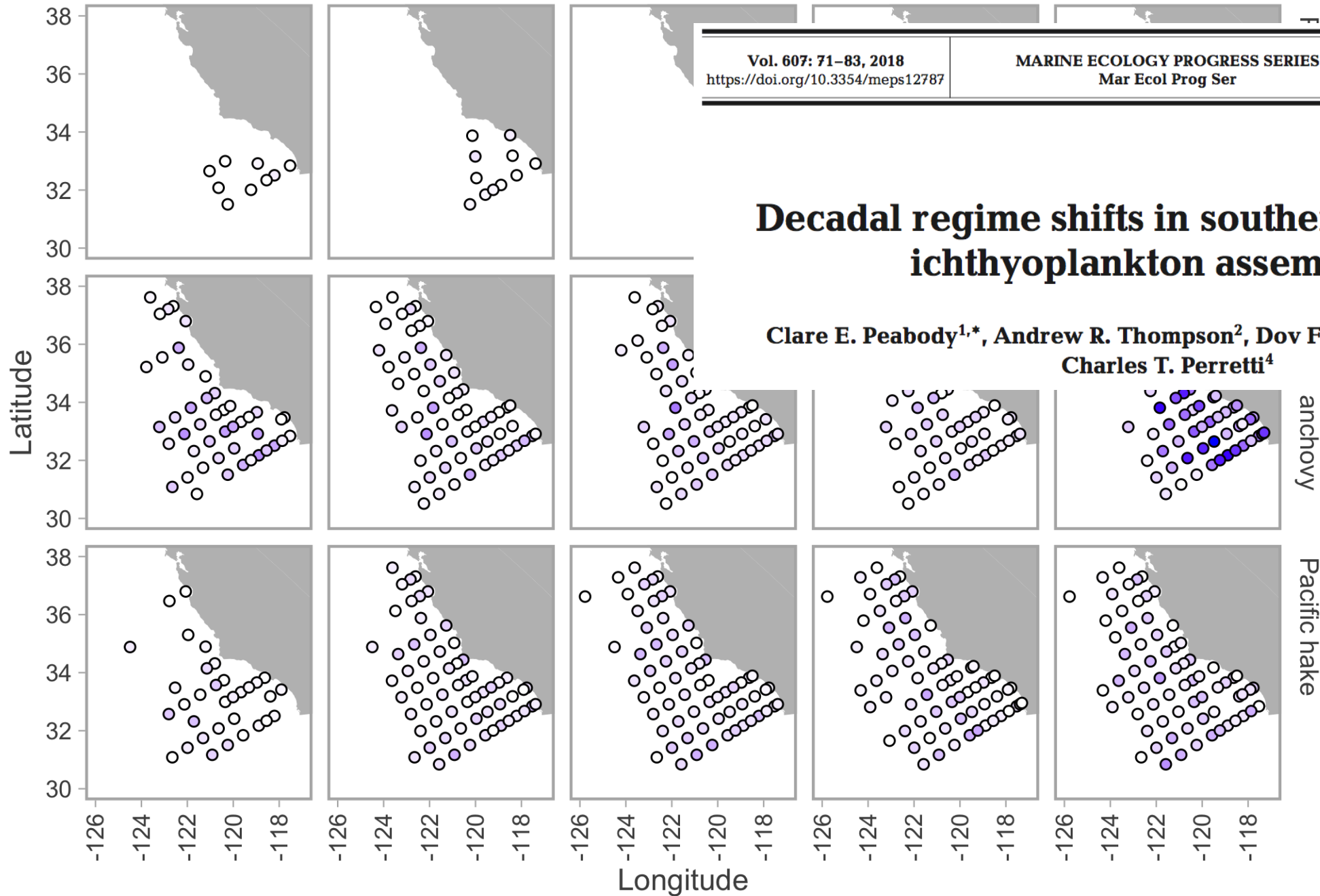
Vol. 607: 71-83, 2018
<https://doi.org/10.3354/meps12787>

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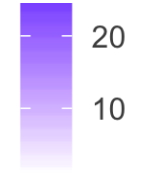
Decadal regime shifts in southern California's ichthyoplankton assemblage

Clare E. Peabody^{1,*}, Andrew R. Thompson², Dov F. Sax¹, Ryan E. Morse³,
Charles T. Perretti⁴



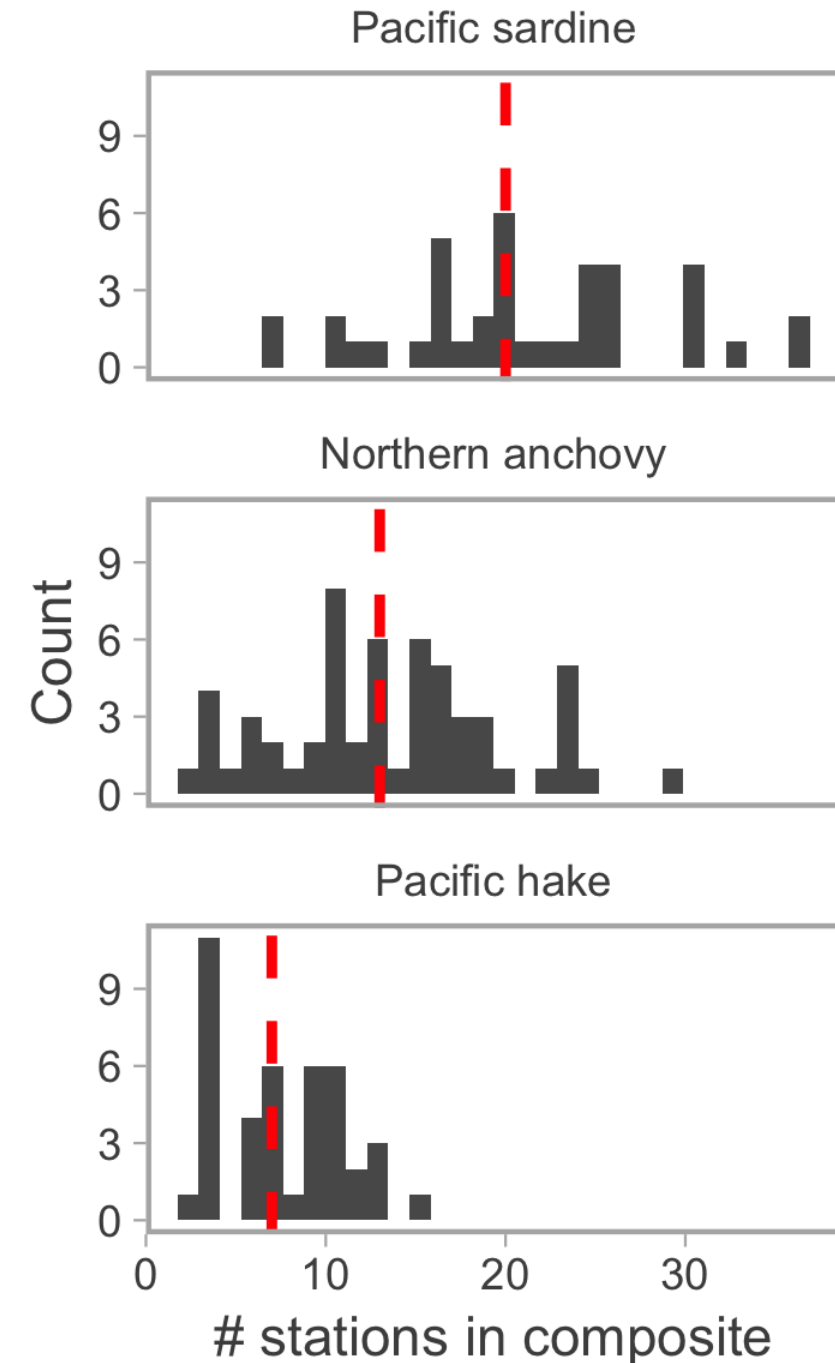
anchovy

Pacific hake



Extensions into space and time

- Shared spatial dynamics
 - Sentinel sites
 - Improve predictability
- Shared dynamics improve predictability
 - (Better defined attractor)
- Identification of causal relationships



Thanks

- CalCOFI ship crews and sorters



**Southwest
Fisheries
Science
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