Physiological Impacts of Climate Change Using Remote Sensing

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Species Distribution Modeling

- Correlative niche models
- Mechanistic niche models

- These models assume that mechanisms and patterns found in one geographic region or epoch can be used to predict distribution in another. This is the concept of niche conservatism or model stationarity.

Can physiology inform species distribution models?

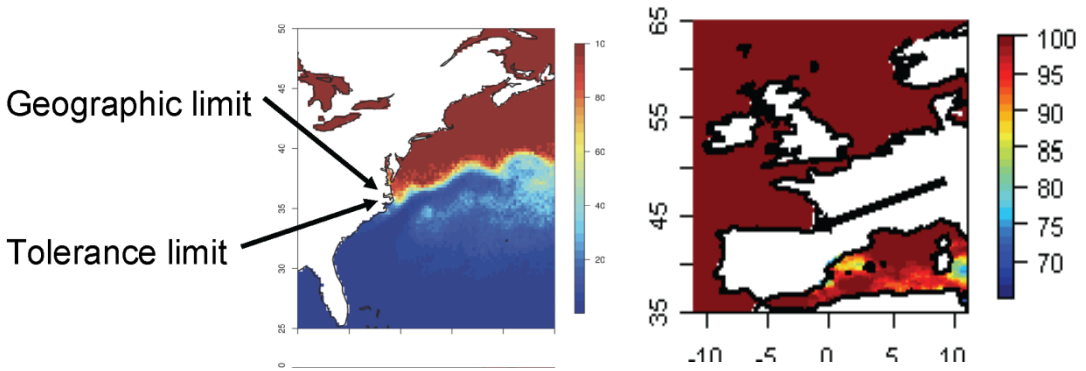
- Examine difference between lethal vs performance limits
    - Thermal death vs scope for growth / energy budget
- Commercially important shellfish
    - Extensive physiology, production, biogeography data

- Extremely important to find reasons for failure of assumption of niche conservatism in species distribution models that work in one geographic region but fail to make correct predictions elsewhere.

Marine mussel
Mytilus edulis
Distribution
Model
Validated for
US East Coast

Fails utterly in
Europe

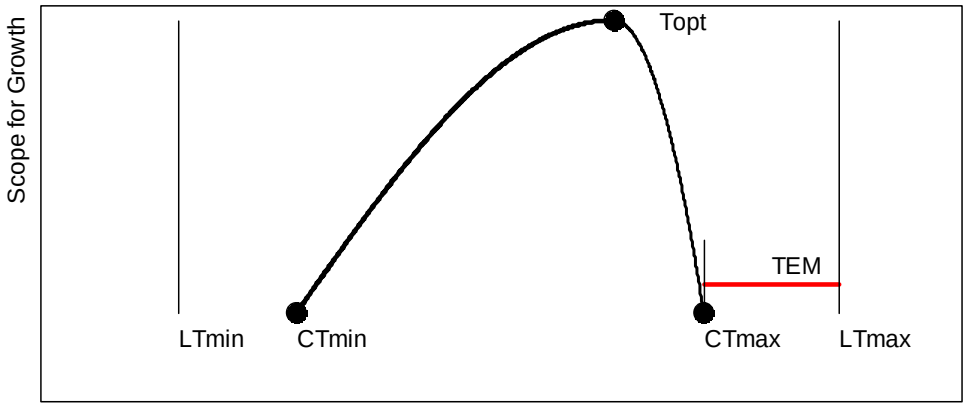
Species Distribution Model Based On Thermal Tolerance

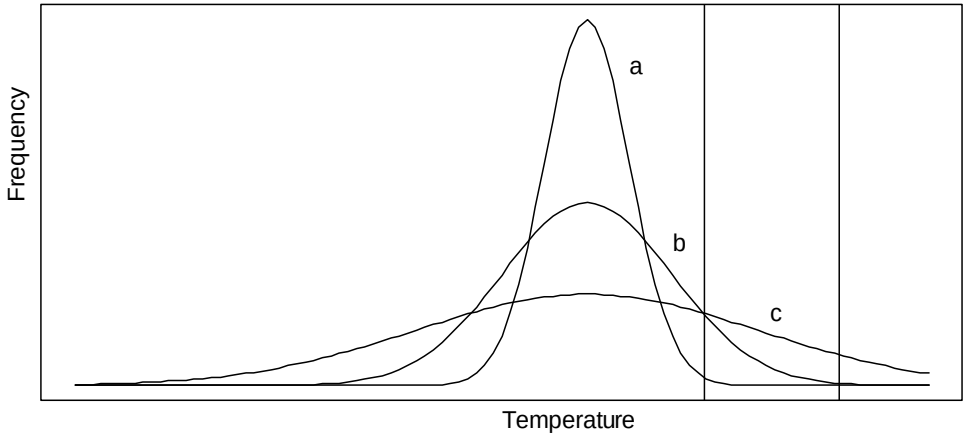


Jones & Wethey

Transient Event Margin

May explain failure of niche conservatism and biogeographic model stationarity

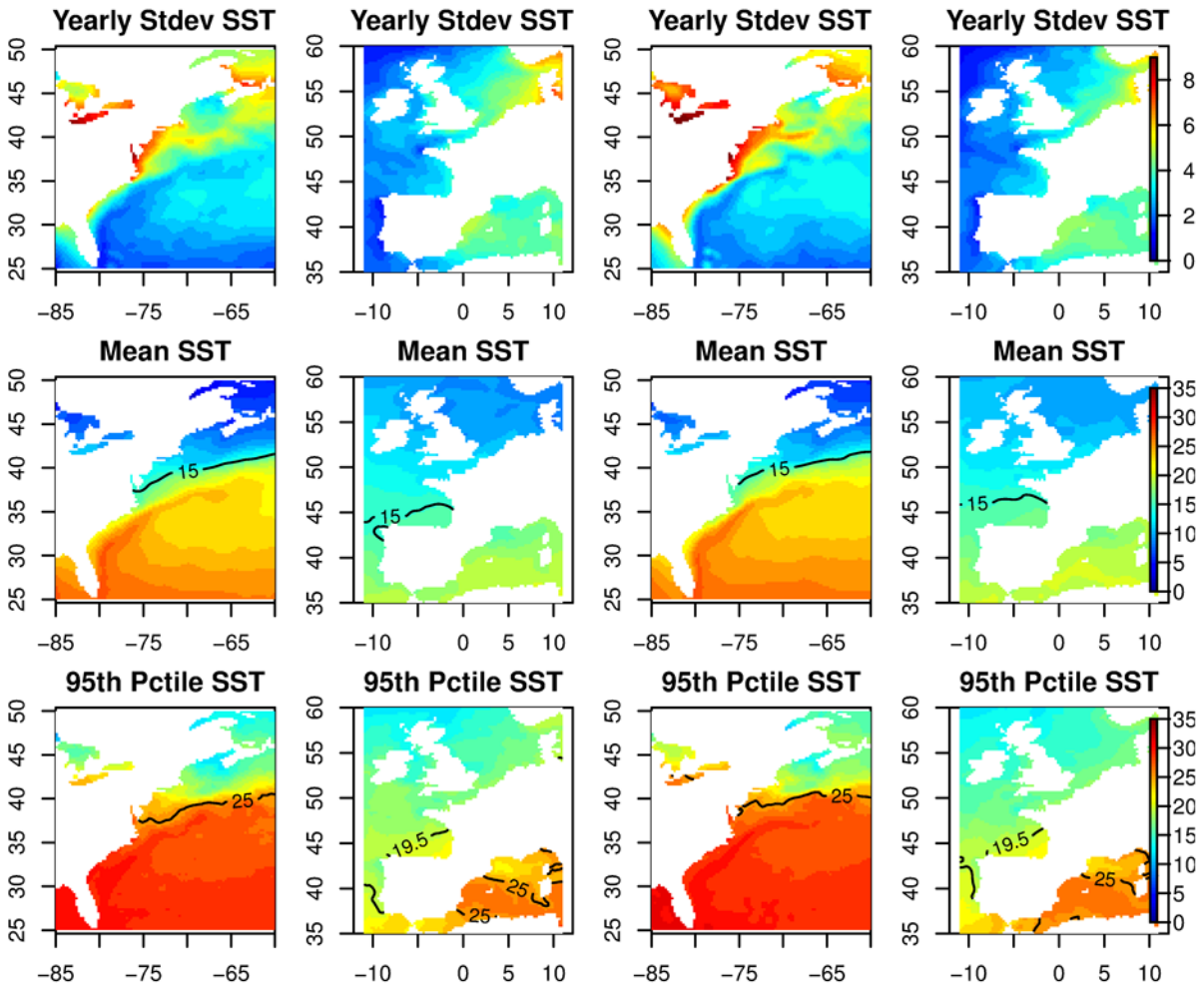




Woodin et al. Ecology and Evolution

Environmental Variance on opposite sides of Atlantic

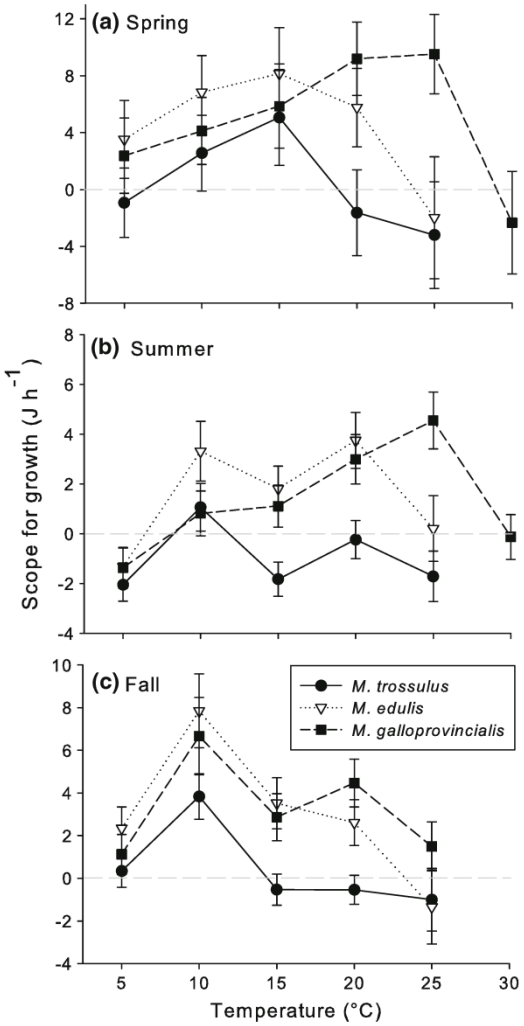
1982 2011



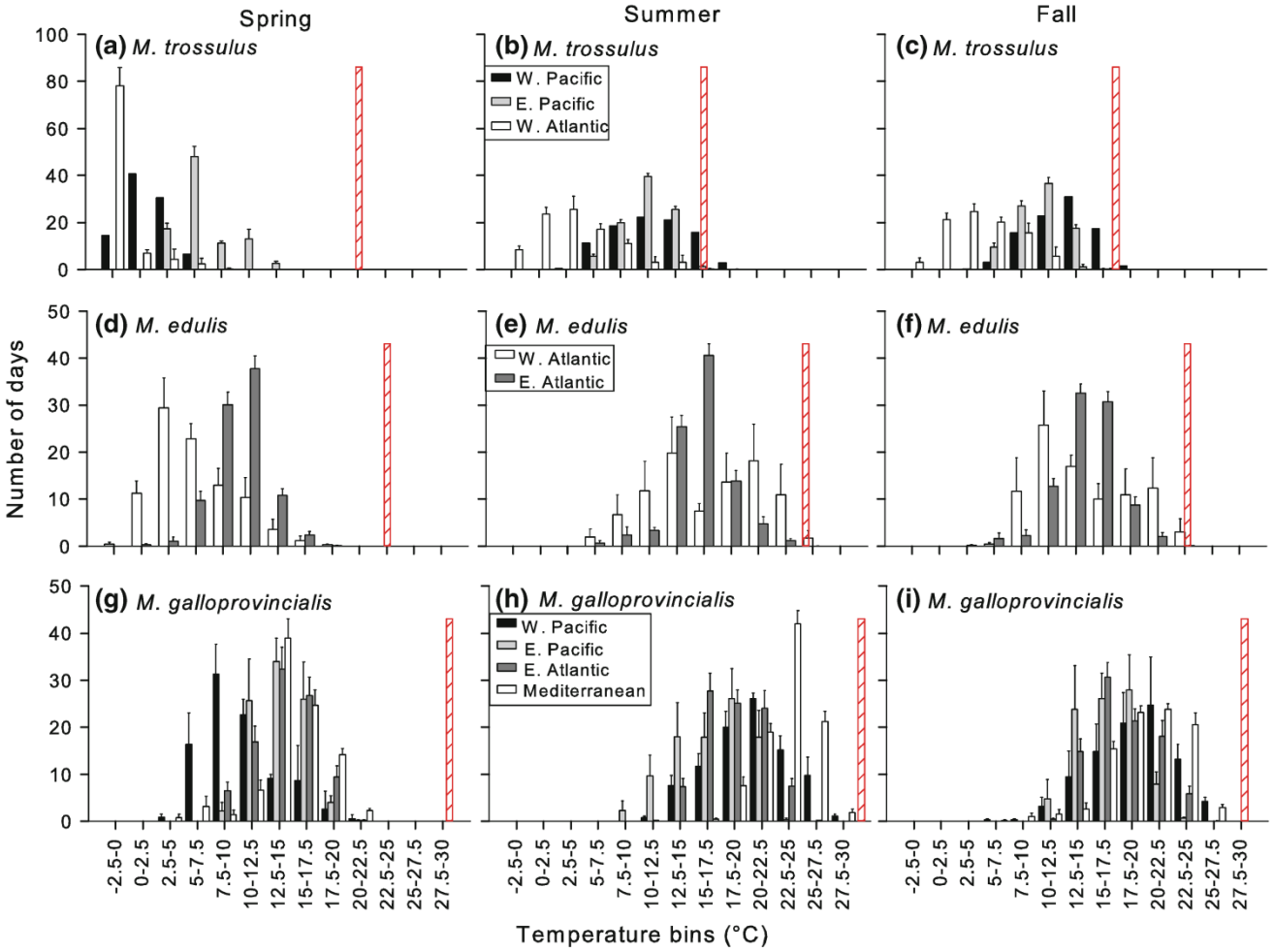
Woodin et al. 2013

Mussel Physiological Energetics and Biogeography

Scope for Growth



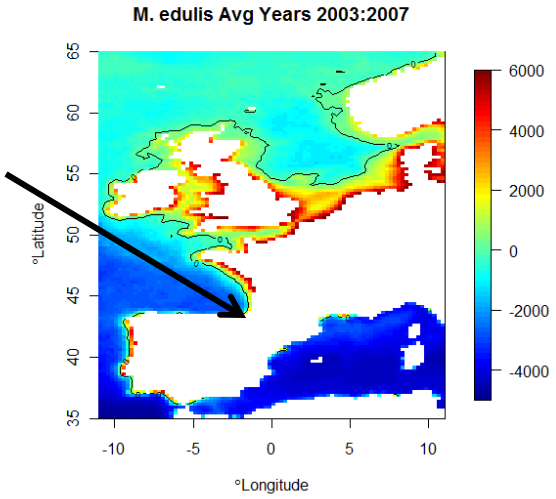
Geographic Distribution vs Seasonal Temperature

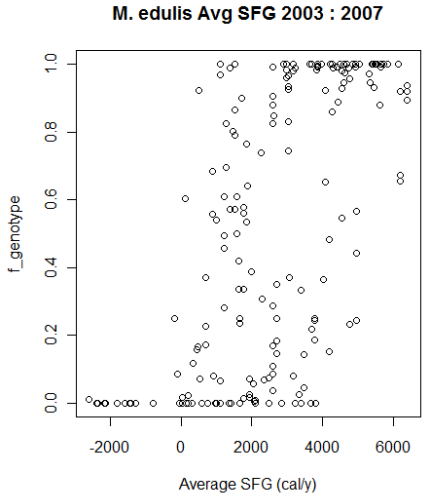


Fly & Hilbish 2013 Oecologia 172: 35-46

Mussel Physiological Energetics and Biogeography

Geographic Limit





Scope for Growth in European mussels

SFG = FeedingRate * AssimEff – Resp

Feeding Rate = Fmax * Chl/(k + Chl)

Chlorophyll from oceancolor.nasa.gov

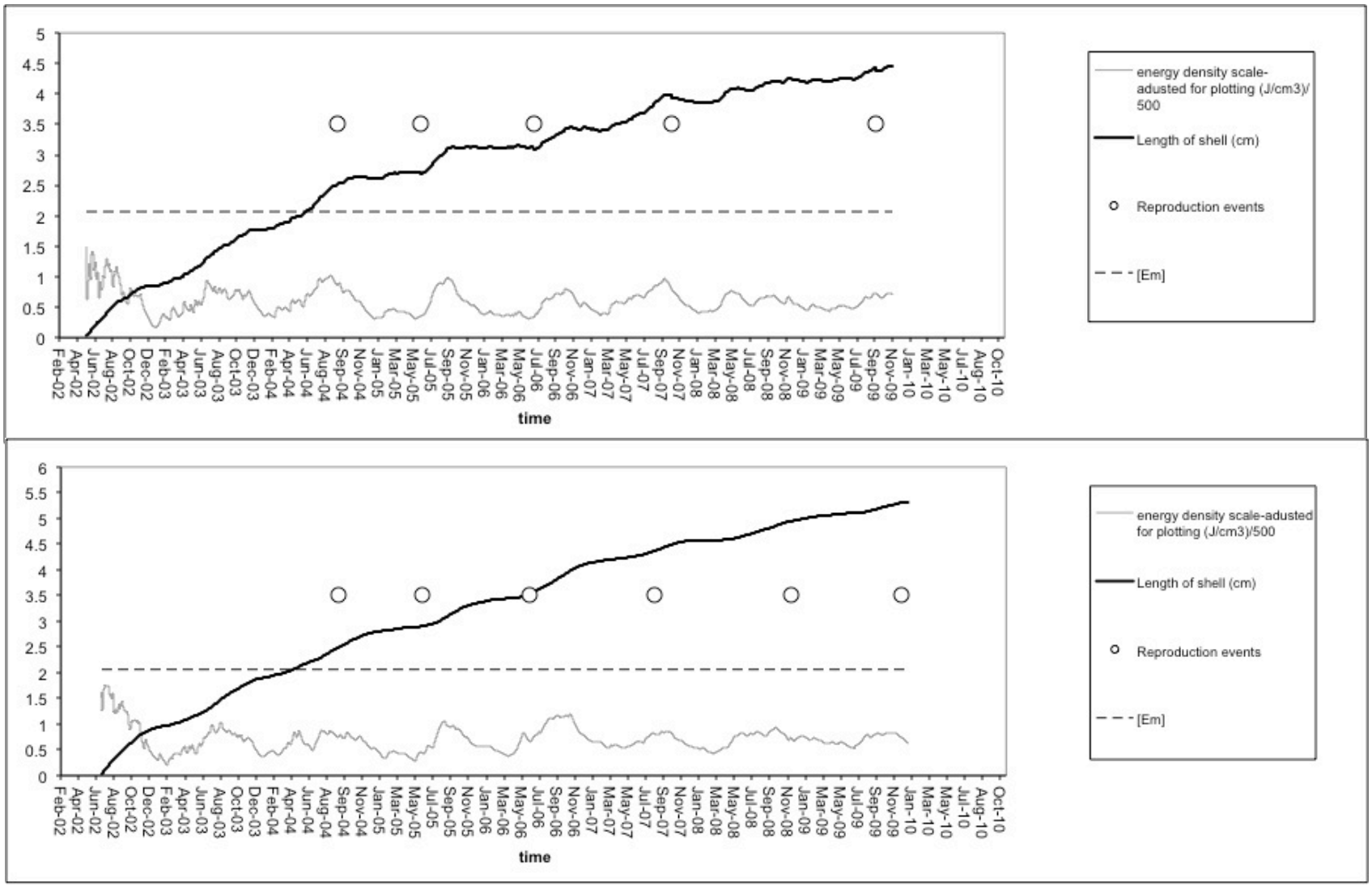
Daily temperature from Reynolds AVHRR OISST

Bottom Line:

Physiology informs the species distribution model and generates a prediction much closer to reality than the thermal mortality model.

Fly, Jones, Wethey, Hilbish

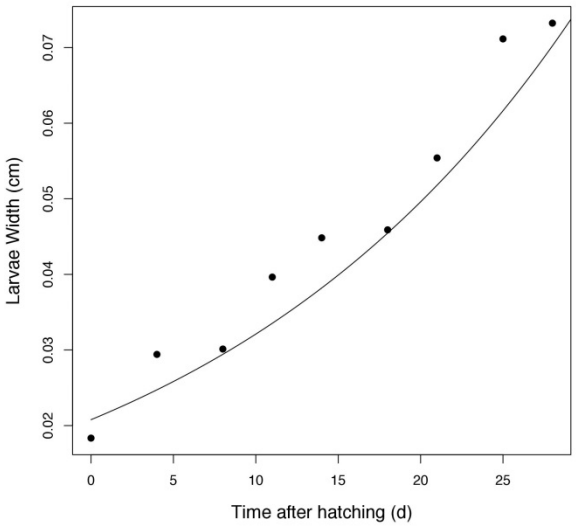
Dynamic Energy Budget Models for California Mussels



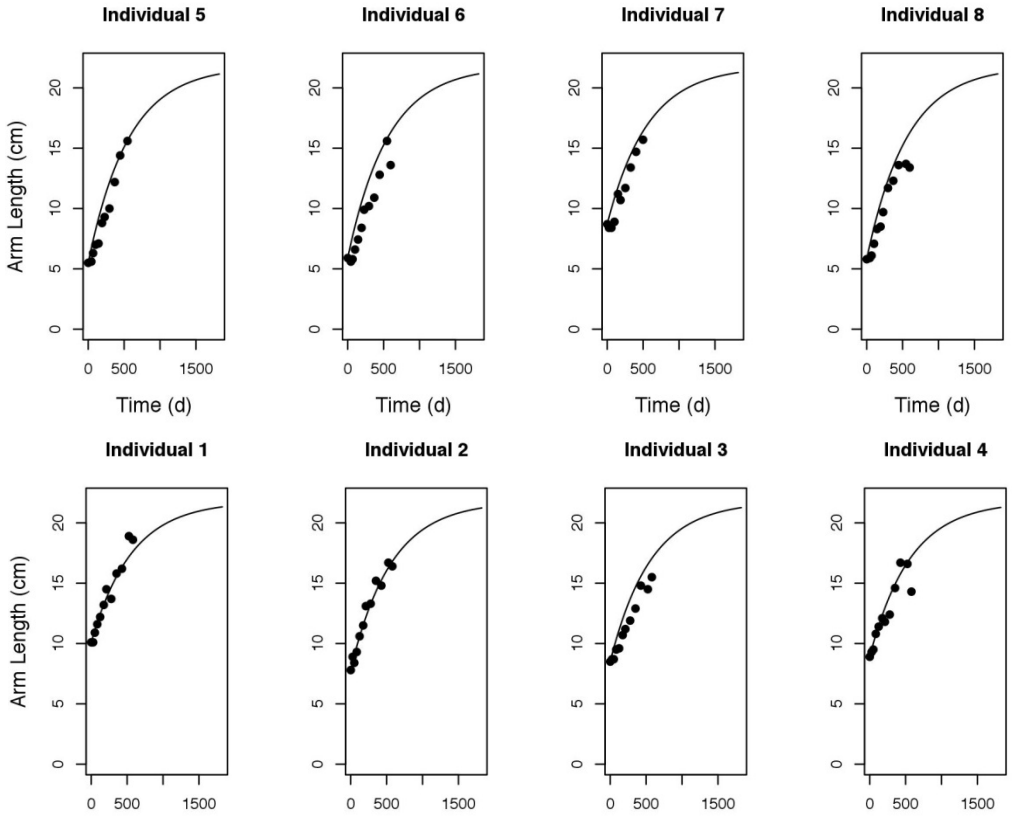
Zippay et al.

Dynamic Energy Budget for Pisaster Starfish
Growth Trajectories vs Data

Larvae

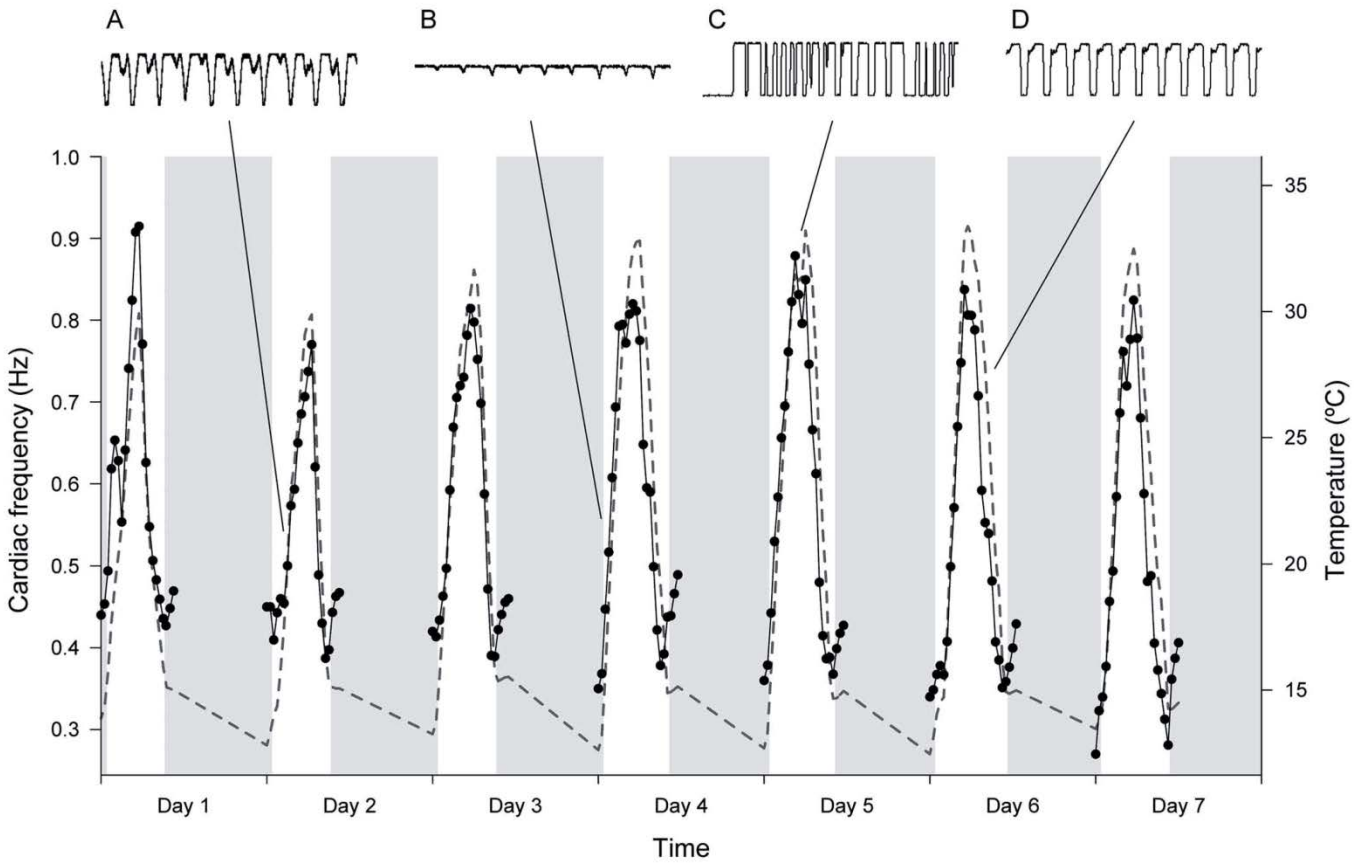


Adults



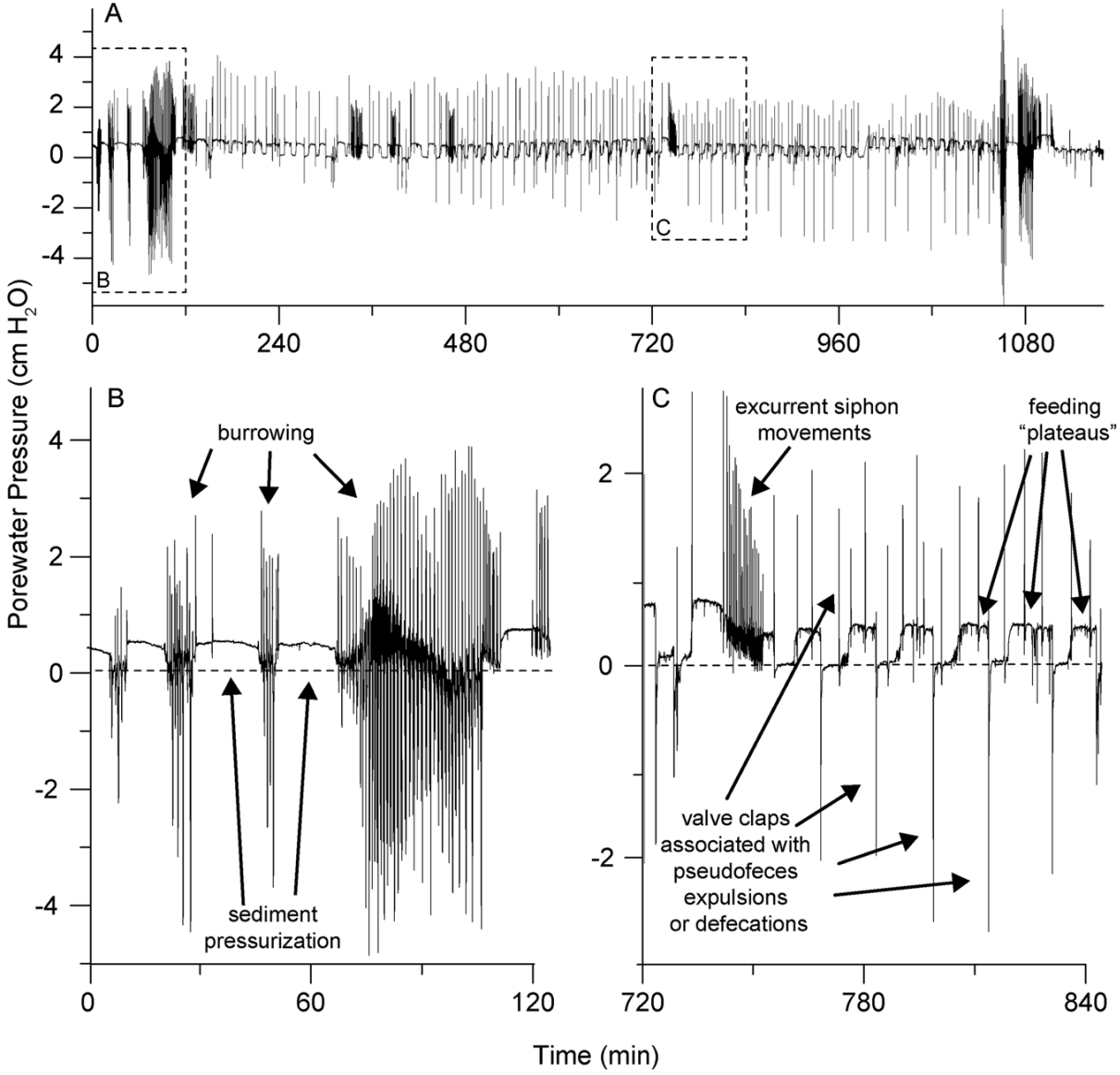
Monaco et al.

Effects of Temperature on Heart Rate
Non-invasive IR Transducer



Burnett et al. 2013. Limnology & Oceanography Methods 11: 91-100

Non invasive behavioral activity monitoring of sediment dwellers: Porewater pressure waveforms indicate clam activity



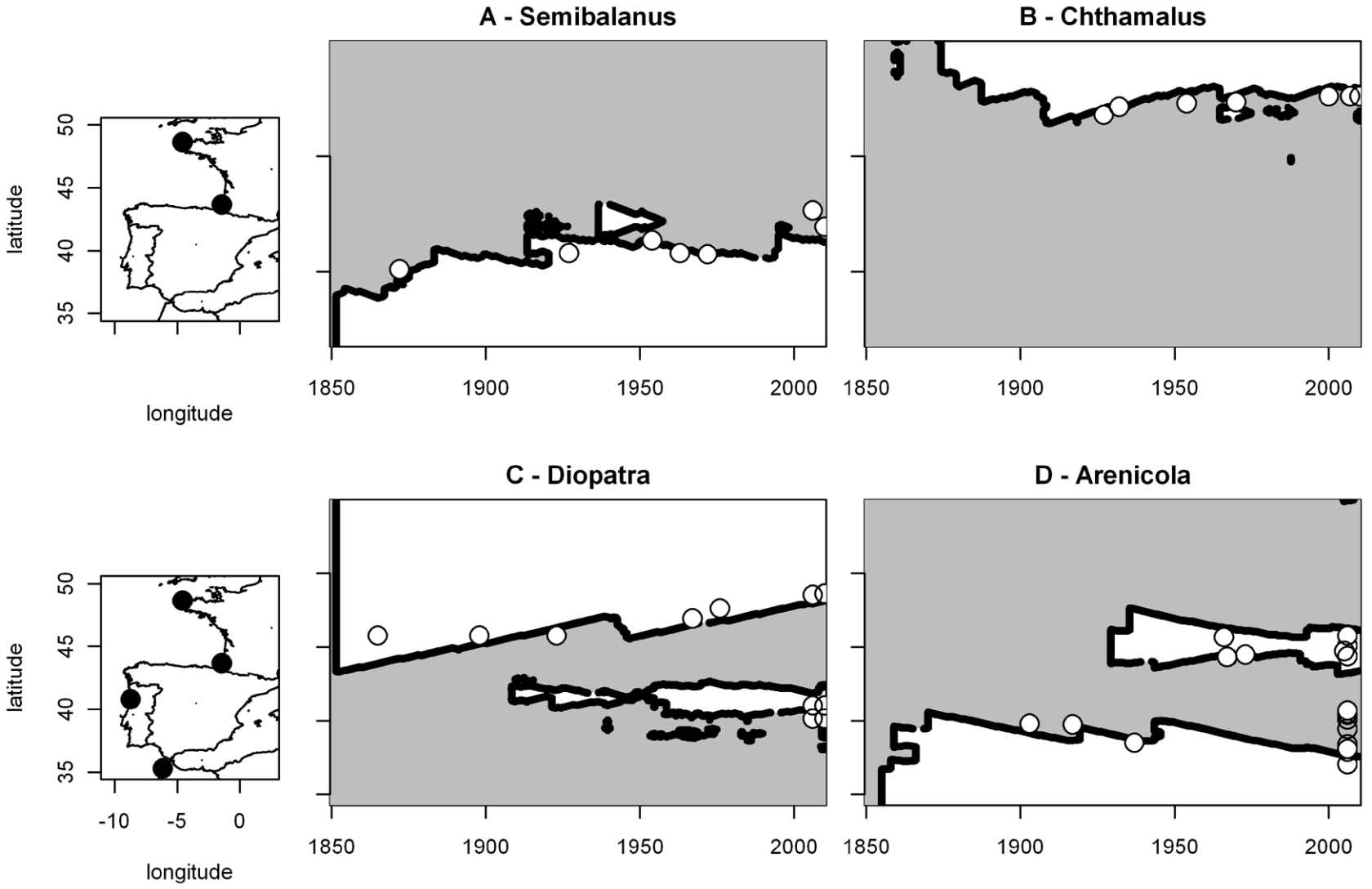
Volkenborn et al. 2013 Journal of Marine Research (in press)

Linking Physiological Models to Biogeography
Metapopulation Modeling

- Local population dynamics controlled by physiology (SFG, mortality)
  - Intertidal temperature, SST, SSS, ocean color, ocean turbidity
- Planktonic larvae broadcast into the plankton
- Connectivity among local populations estimated from surface velocity fields in regional ocean models

- Preliminary models developed using nearest neighbor connectivity
- Testing regional ocean model predictions by comparing results from 7 different operational ocean models
  - US Navy, IFREMER, UK Met Office, Puertos del Estado
- Field tests using recruitment variations on European coast

Hindcasts of Geographic Limits (lines) and Historical Records of Limits (dots)



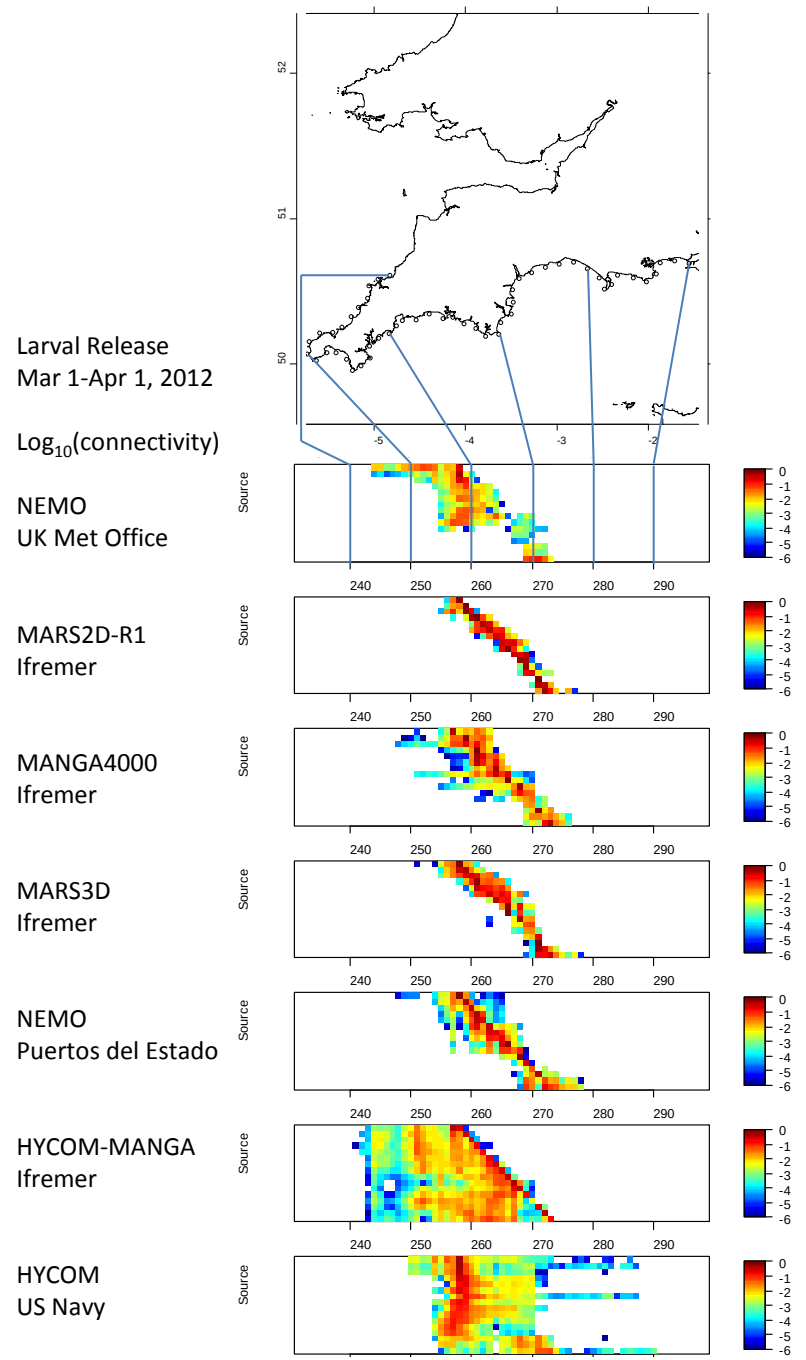
Wethey et al. 2011. J Exp Mar Biol Ecol 400:132-144

Estimating Coastal Population Connectivity – Barnacles in SW England

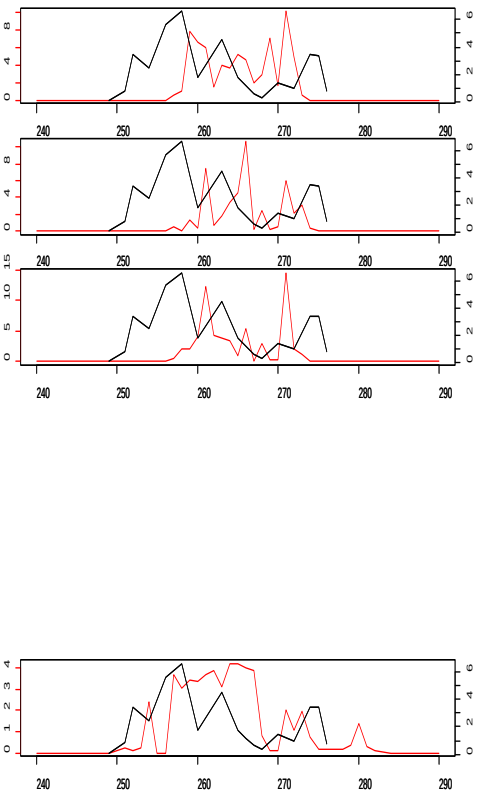
Lagrangian particle tracking in velocity fields from operational ocean models

Each day during larval transport season, at sites spaced by 10 km, 500 particles released 5 km offshore in velocity fields from 7 different ocean models.

Wethey, Rognstad, Oliver



Population wave of new recruits moving west after severe winters of 2010 & 2011
Black- obs; Red- model



Forecasting and Hindcasting Connectivity

Categorize weekly connectivity patterns

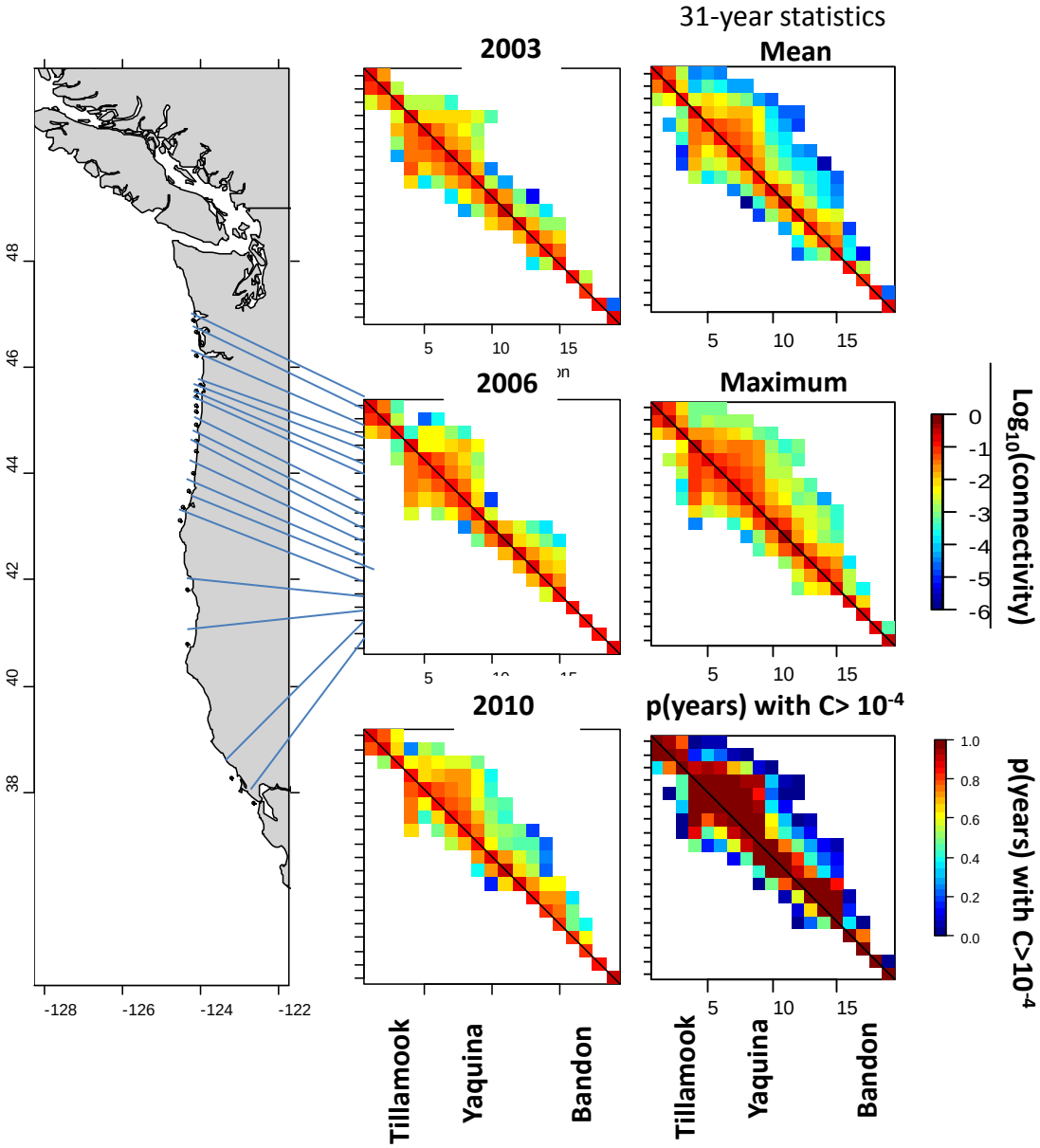
- Multiple years & ocean models
- K-means clustering
- Self Organizing Maps

Correlate clusters with winds

- R=0.6 between wind & cluster ID

Forecasts and Hindcasts

- Downscaling necessary
- IPCC AR5 wind scenarios
- Reanalysis winds



- Physiological performance metrics are important additions to species distribution models.
- The Transient Event Margin in relation to environmental variance may be a good predictor of model stationarity.
- Metapopulation models based on physiological performance work well in predicting and hindcasting the effects of climate change on biogeography.
- We need to be very careful in selection of environmental forcing in development of species distribution models and models of the effects of climate change. Each model is an hypothesis, and *a priori* one cannot necessarily know whether to trust a particular model or not. Using a single environmental model is risky.

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- Funding – NASA, NSF
- Website: www.coastalwarming.com

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