A spatial bioeconomic model for MPA network design

Oceanography Workshop

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Why models help inform good decisions

- MLPA modeling team: What are ecological and economic consequences of a given MPA network?

- Bioeconomic model being developed and tuned to So Cal data to predict spatial effects of MPA networks
  - Economic and ecological criteria for a range of target species/fleets

- Larval dispersal is a critical component of model
  - How are patches “connected” across space?
  - Do connections differ among species?
  - What is temporal variability of connections?
  - Do larvae exhibit behavior or are they passive?

Model inputs/outputs

- Inputs: Current MPAs, Spatially-explicit habitat data, MPA locations, larval dispersal kernels, adult home range, dynamic biomass model, fleet model of fishing effort

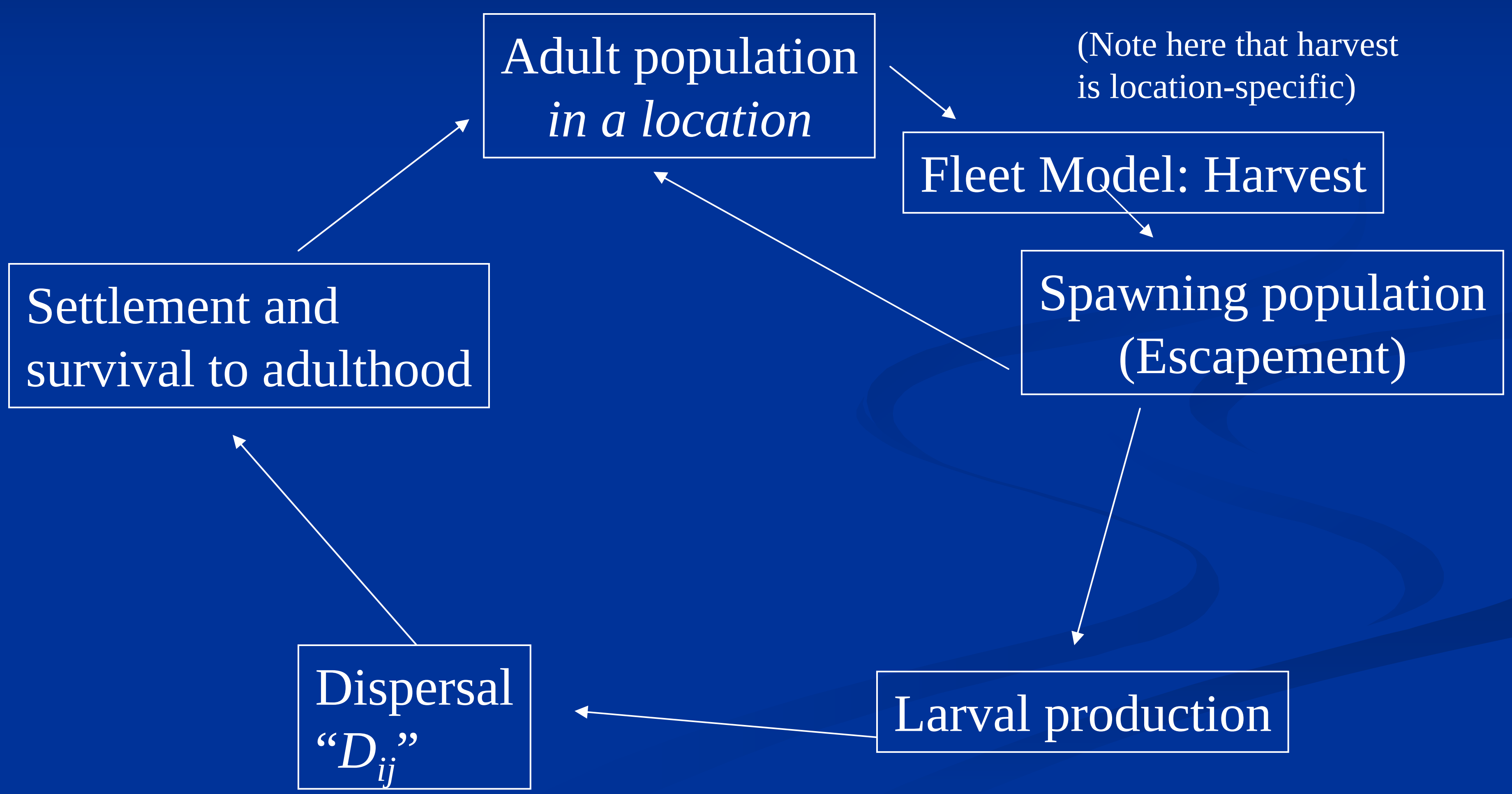
- Outputs: Spatial larval supply, biomass, fishing effort, harvest, profit…all for 6 or 7 "model" species

Southern CA parameterization

- Currently parameterizing: urchin, abalone, kelp bass, lingcod, cabezon, blue rockfish
  - Will likely add 3-4 to this list

- Patches roughly 1km x 1km in size

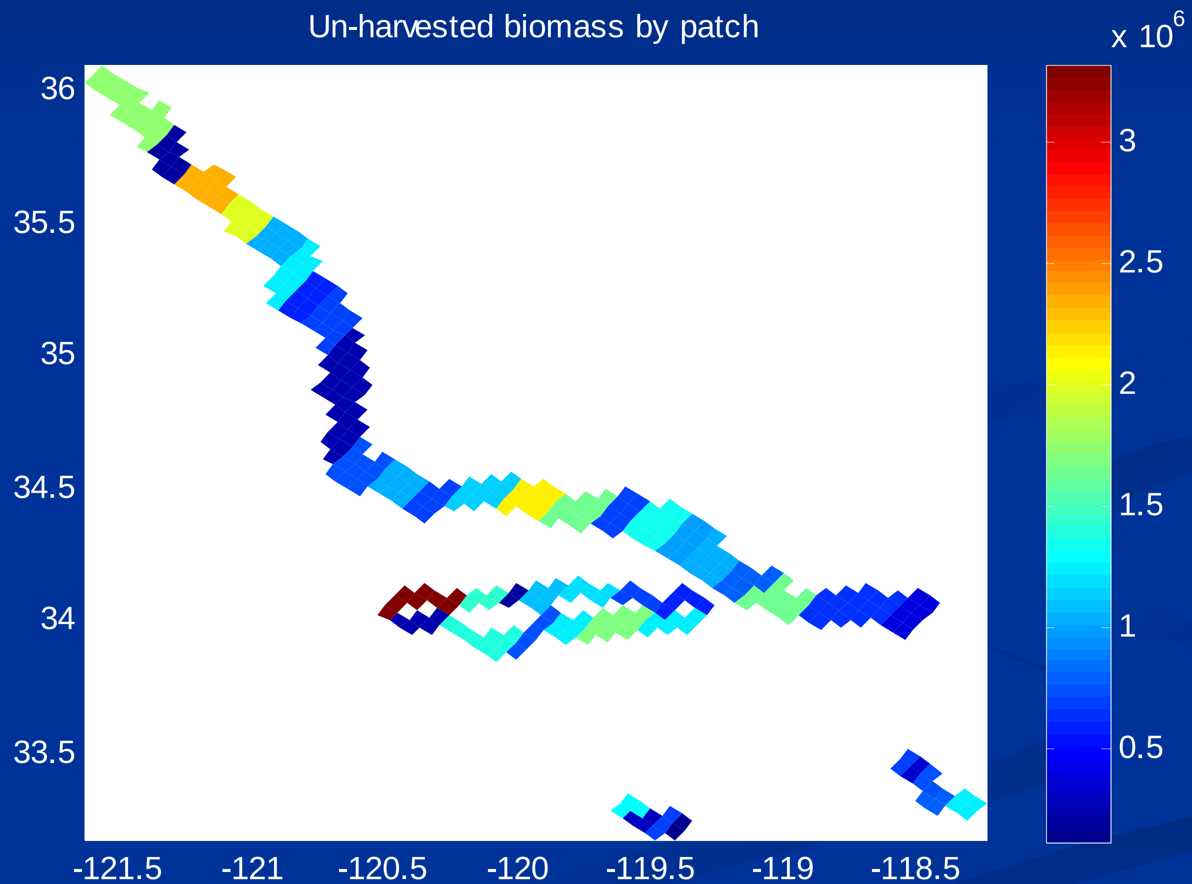
Timing


Adult population
in a location
(Note here that harvest
is location-specific)
Fleet Model: Harvest
Spawning population
(Escapement)
Settlement and
survival to adulthood
Larval production
Dispersal
"D_{ij}"

An application to California's South-Central Coast

- Initial test species: kelp bass
- Adults relatively sedentary
- Larval dispersal via ocean currents
  - PLD=26-36 days
  - Oceanographic model of currents
- Settlement success and recruitment
  - Beverton Holt, associated with kelp abundance in patch
- Constant price per unit harvest, stock-effect on harvest cost function

Heterogeneous Productivity & Larval Survival



Problem setup

- Maximize E{NPV} of profits from harvest. Find optimal patch-specific harvest strategy:
- Equation of motion:

$$X_{i,t+1} = z_{it}^{\mu}\mu_i(e_{it}) + z_{it}^{S}\sigma_i(\sum_{j=1}^{I} z_{jt}^{f} f_j(e_{jt})D_{ji})$$

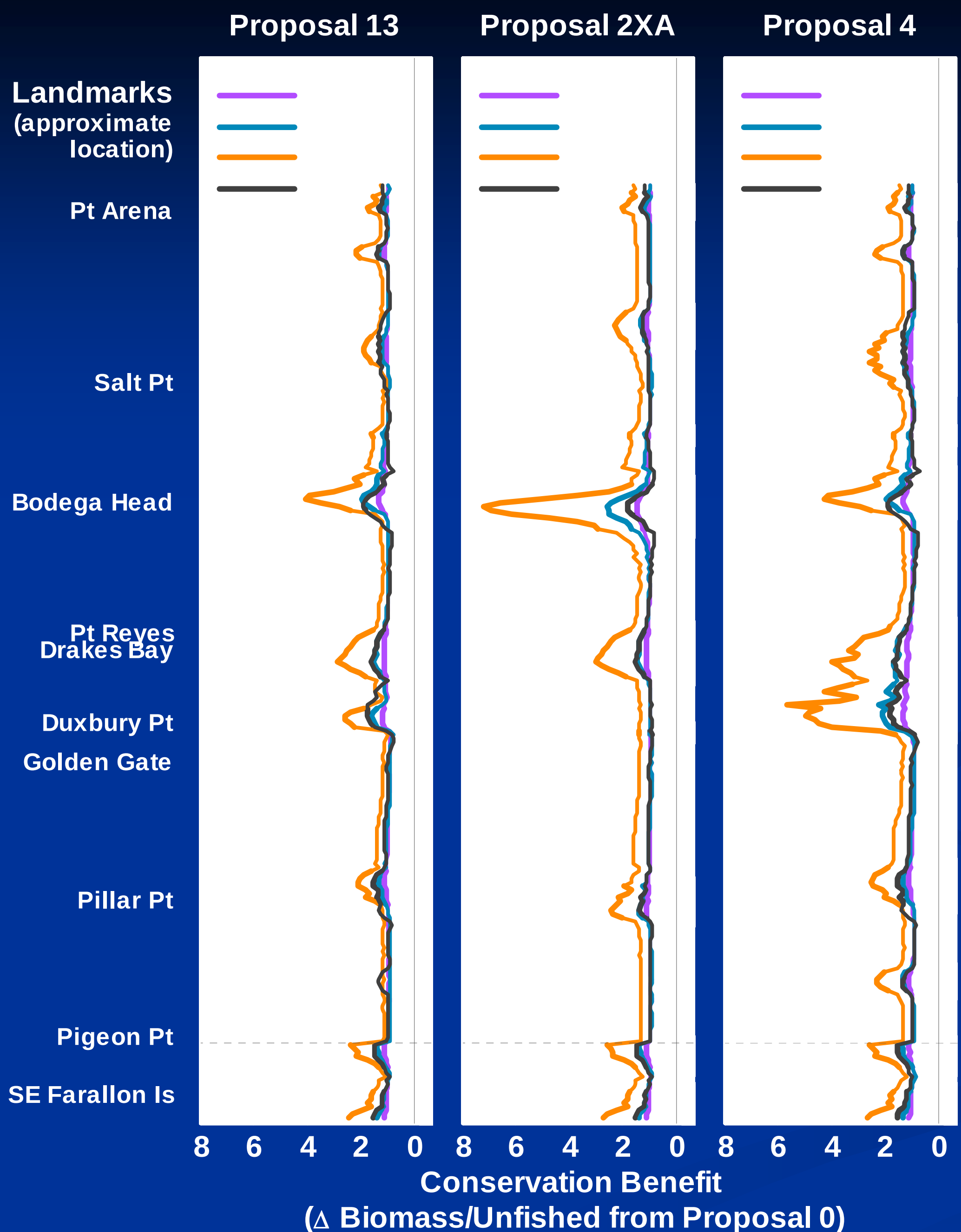
- Dynamic Programming Equation (vector notation):

$$V_t(x_t) = \max_{e_t} \sum_{i=1}^{I} \pi_i(x_{it}, e_{it}) + \delta E V_{t+1}(X_{t+1})$$

Spatial implications for conservation

- Complex interactions:
  - MPA size and placement interacts with habitat, dispersal, home ranges, fisheries behavior to create complex spatial consequences.

- Use spatially-explicit models to predict:
  - Biomass of different species across space
  - Yield, Effort and Profit across space
  - Change from status quo

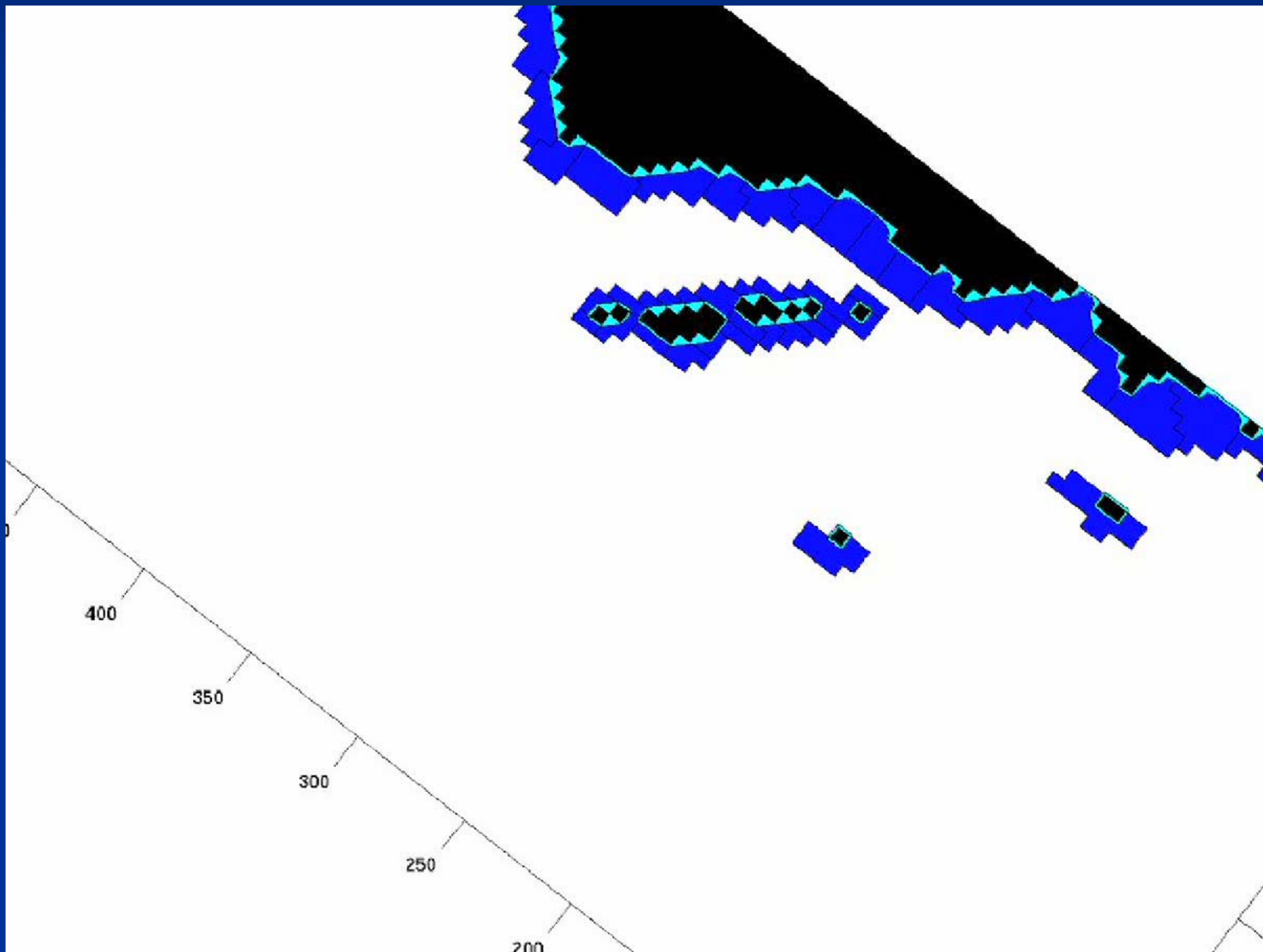


- Used EDOM model to predict biomass across space
- Notice large biomass increases inside MPAs
- Generates predictions for monitoring

Models for real-time design

- Use as interactive "design tool"
  - Delineate MPA network on a map
  - Run model (takes < 1 minute)
  - Assess conservation and economic impacts (cumulative or spatial, dynamic or equilibrium)
- Value of individual MPAs
  - Ecological and Economic performance measures
  - Depends on whole network
  - System-wide performance with/without an MPA
- Generates predictions to guide monitoring
- Comparison across MPA network proposals

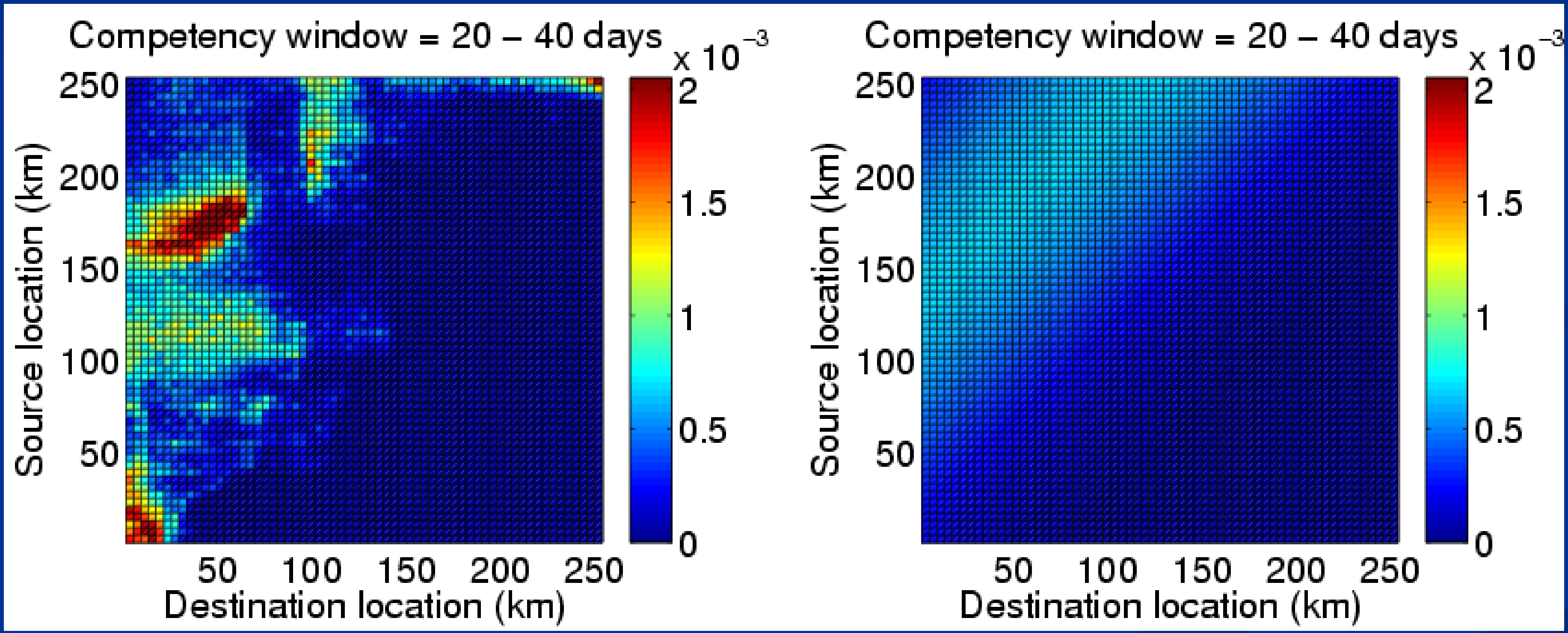
2-D dispersal from oceanographic model



"Patchy" dispersal vs. diffusion

Simulation Result

Diffusion Model



This relationship is highly variable – not a smooth dispersal kernel
Dispersal kernel is proportion of larvae that go from source to dest.

Temporal variability in dispersal

- Dispersal kernel is species-specific matrix of connections between source and destinations
- Estimated dispersal kernels are "mean"; what about temporal variability?
- Suppose dispersal kernel K_j has probability of occurrence p_j
- Can use to derive distribution over effects of an MPA network – which networks perform well under a *range* of conditions?
- Dynamic