http://www.nmfs.noaa.gov/habitat/habitatprotection/profile/pacificcouncil.htm

Modeling dispersal kernals with limited information

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CA Marine Life Protection Act

- Law mandates establishment of a network of marine protected areas along the coast of CA
- One goal is recovery of depleted fisheries
- Proceeding in phases
  - Central Coast enacted early '07
    - Roughly Santa Cruz - Pt. Conception ⟶
  - North Central coast in process
    - Roughly Pt. Arena - Santa Cruz

http://www.nmfs.noaa.gov/habitat/habitatprotection/profile/pacificcouncil.htm

http://www.riptide.net/

California Rockfish

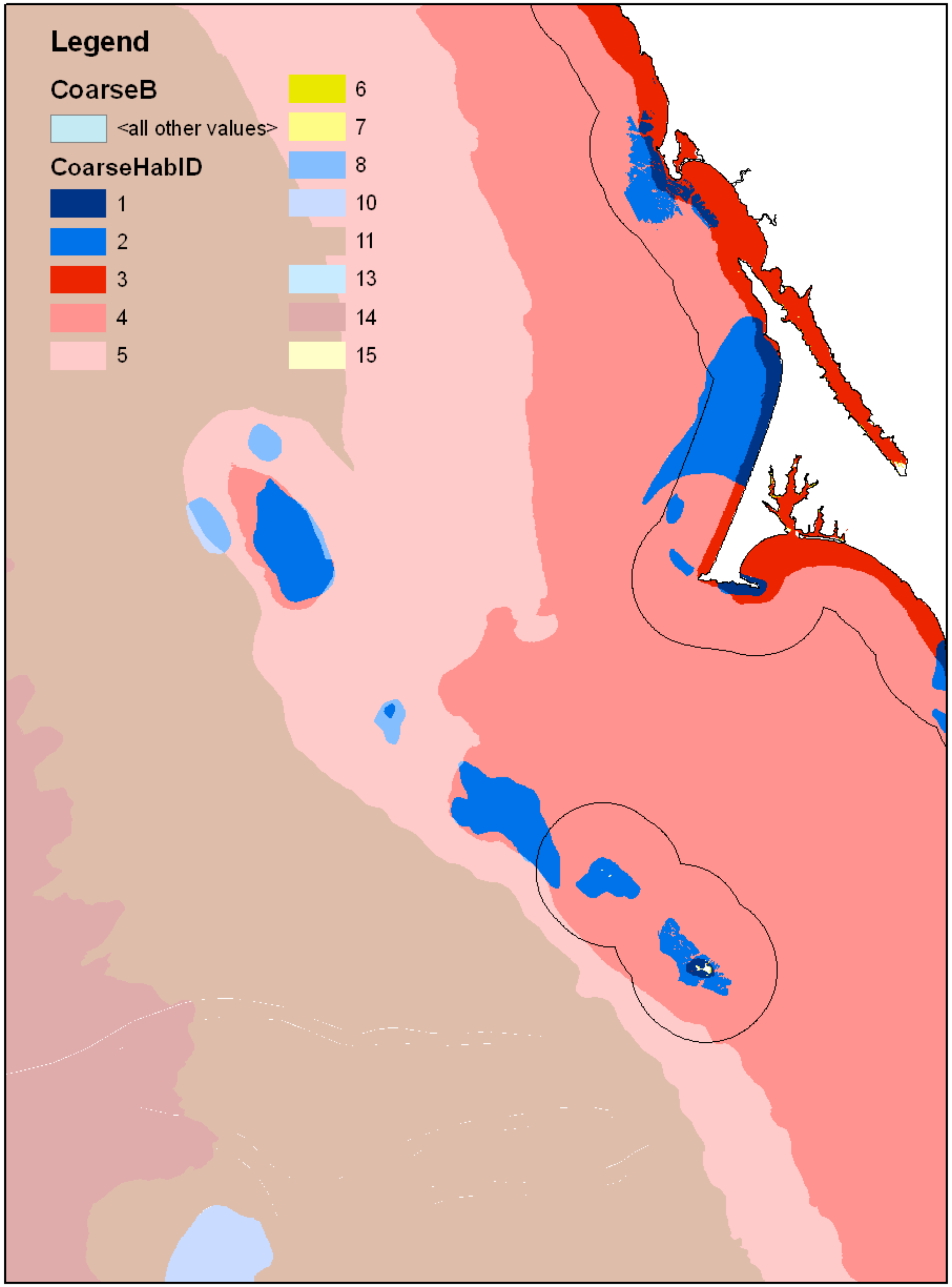
- Cryptic complex of scores of related reef fish
- Adults live on hard-bottom habitat only
- Important sport fishery
- Current exploitation levels may lead to collapse

Where to protect?

- State waters - 3 nautical miles
- Alternatives generated by
  - expert opinion, science advisory team
  - stakeholders
  - recently, some population modeling
- Priority for hard habitat

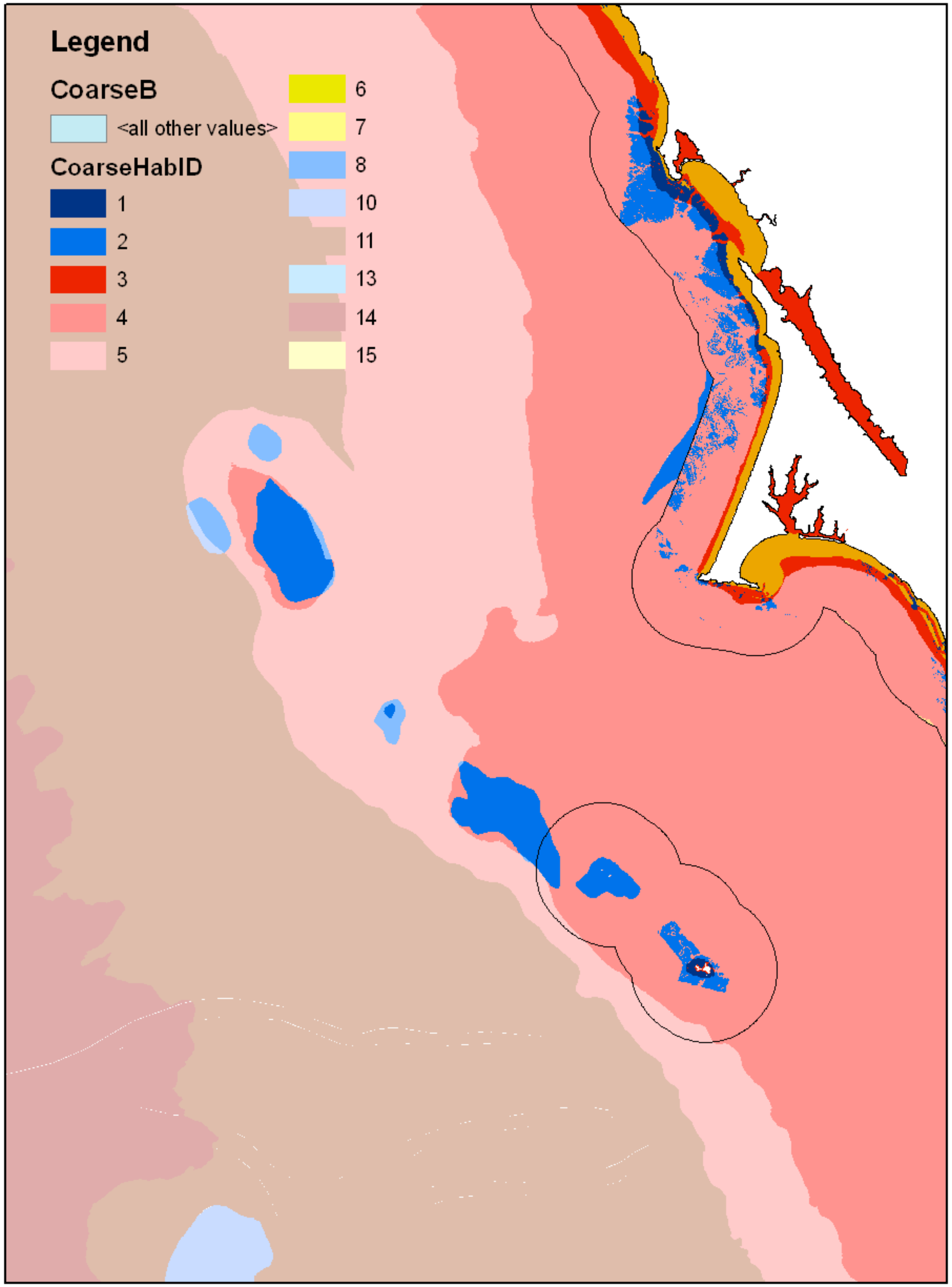
For effective marine conservation, we need to know:

1. where habitat patches exists,
2. how habitat patches are connected by larval dispersal,
3. what spatial patterns of habitat protection can improve population persistence.



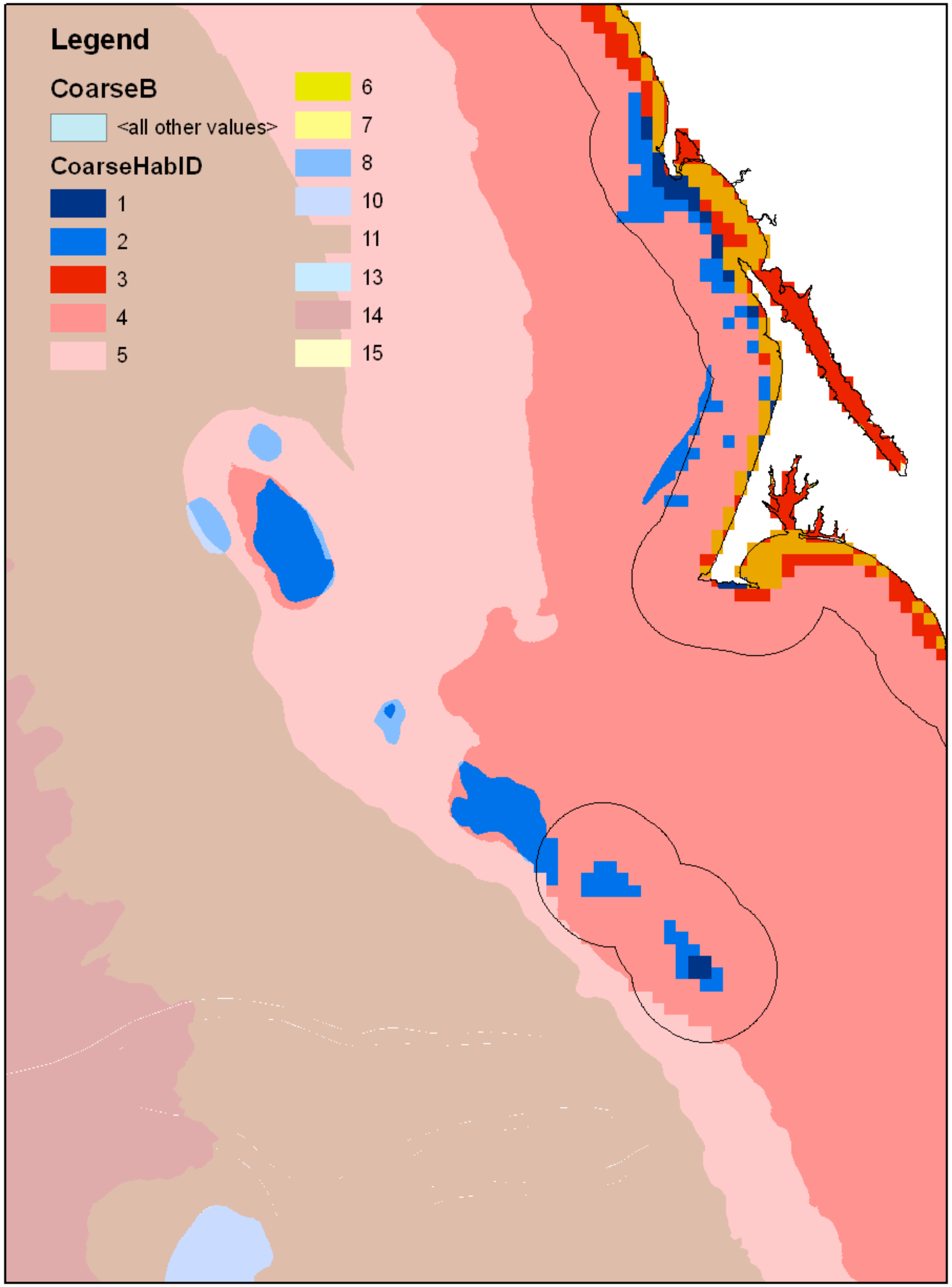
Where is hard habitat?

- Coarse scale data available statewide
- Hard habitat is blue – paler with depth
- Soft habitat is red
- Unknown is yellow
- Depth bins are 0-30m, 30-100m, 100-200m, 200-3000m, 3000m+
- State waters mostly 0-100m



Where is hard habitat?

- Fine-scale data from State waters disagree with coarse data
- Much less hard habitat than previously reported



Where is hard habitat?

- coarse-scale data overlaid with raster

Where is <u>ecologically meaningful</u> hard habitat?

- How big do patches have to be before they're useful?
- How densely packed do small patches have to be to be useful?

- Without sufficient information, we have to make our best guesses... then code a 1km grid

2. How are habitat patches connected by dispersal?

- Rockfish adults generally sessile
- Dispersal just by planktonic larvae
- Mean dispersal distance for black rockfish, based on a genetic study ~45km

- What is the spatial pattern of connectivity?

Estimating larval dispersal kernals

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Estimating larval dispersal kernals

- Tag and track every larva released over several years of variable climate

Estimating larval dispersal kernals

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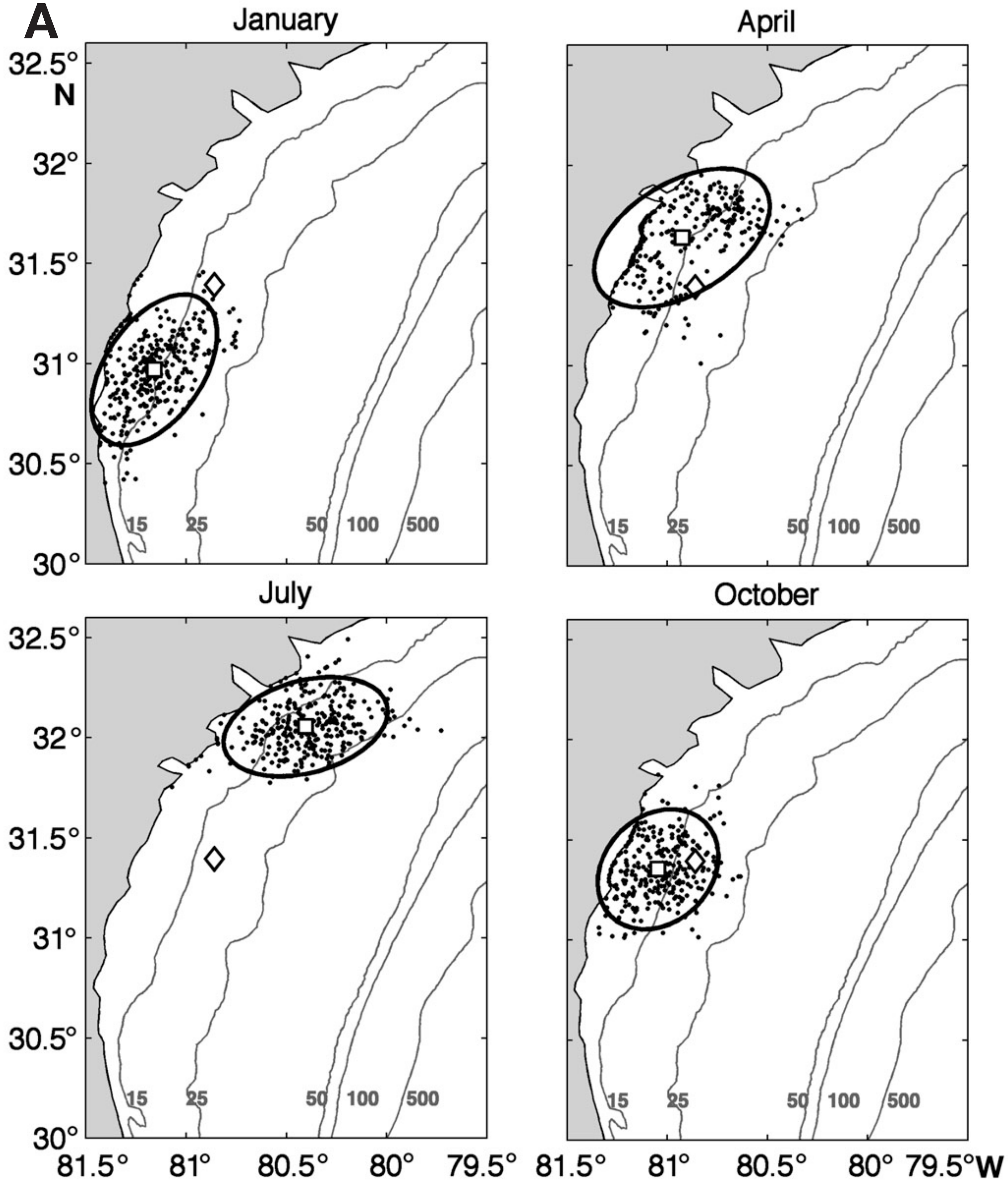
  - –right......

Estimating larval dispersal kernals

- Tag and track every larva released over several years of variable climate
  - right......
- Setup and run a circulation model for the region, calibrated with years of current data



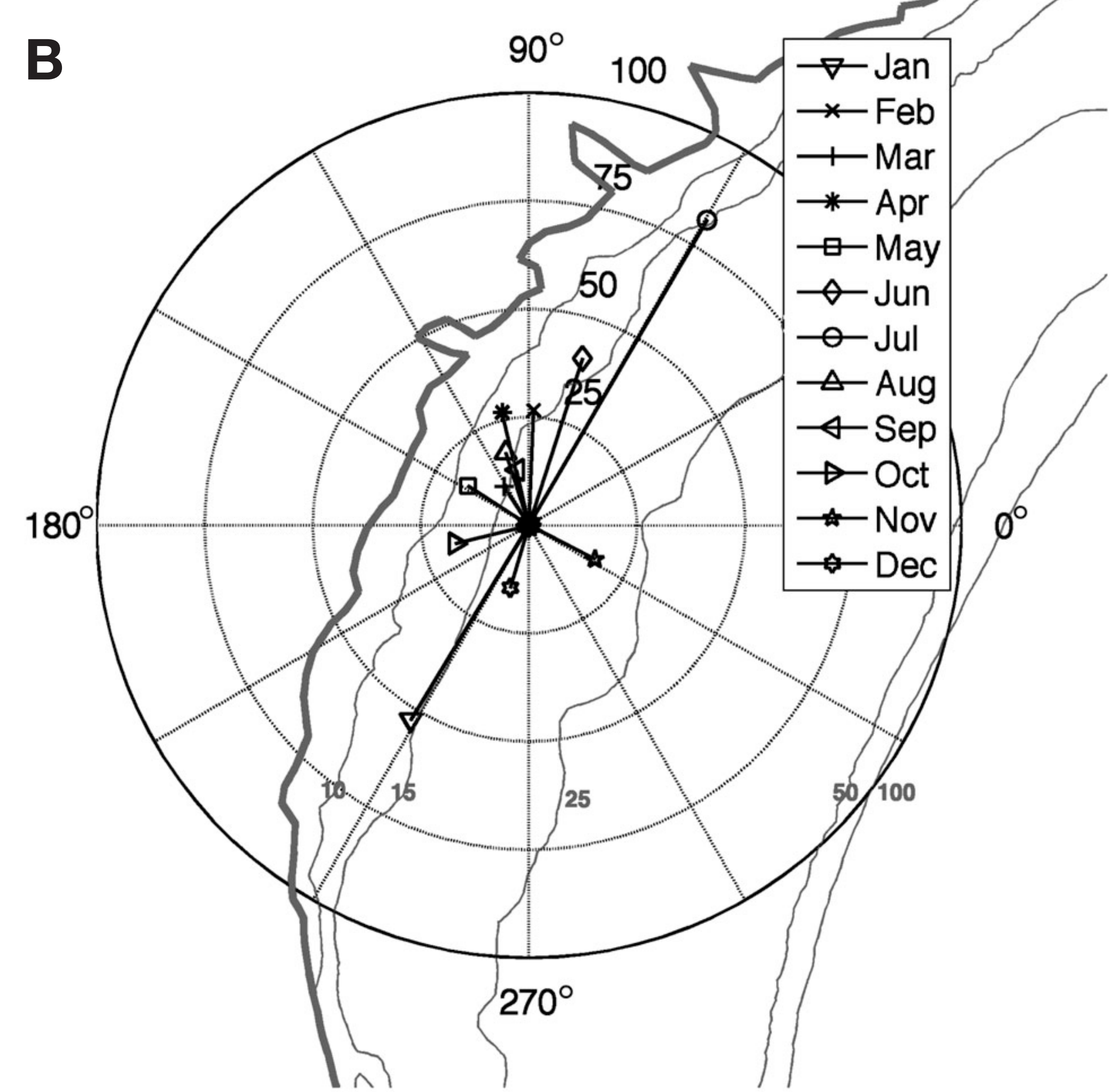


Fig. 2. (A) Ending position of passive particles released in Gray's Reef National Marine Sanctuary (GRNMS) in representative months (January, April, July and October) for each season. Also included are: mean starting location (◇), mean ending location (□) and variance ellipse (2σ) from PCA (black ellipse). Isobaths (m) shown in gray. (B) Monthly mean dispersal distance and direction of particles released in GRNMS with dispersion coefficient (K) = 10 m^2 s^{-1}, duration = 30 d, and passive particles released at mid-depth. Model coastline and isobaths (m) shown in gray

Circulation model results from Edwards et al. 2007. *MEPS*

Dispersal calculated based on:
mean monthly flow (1975-99)
+ hourly tidal currents
+ small Gaussian random walks

Circulation model results

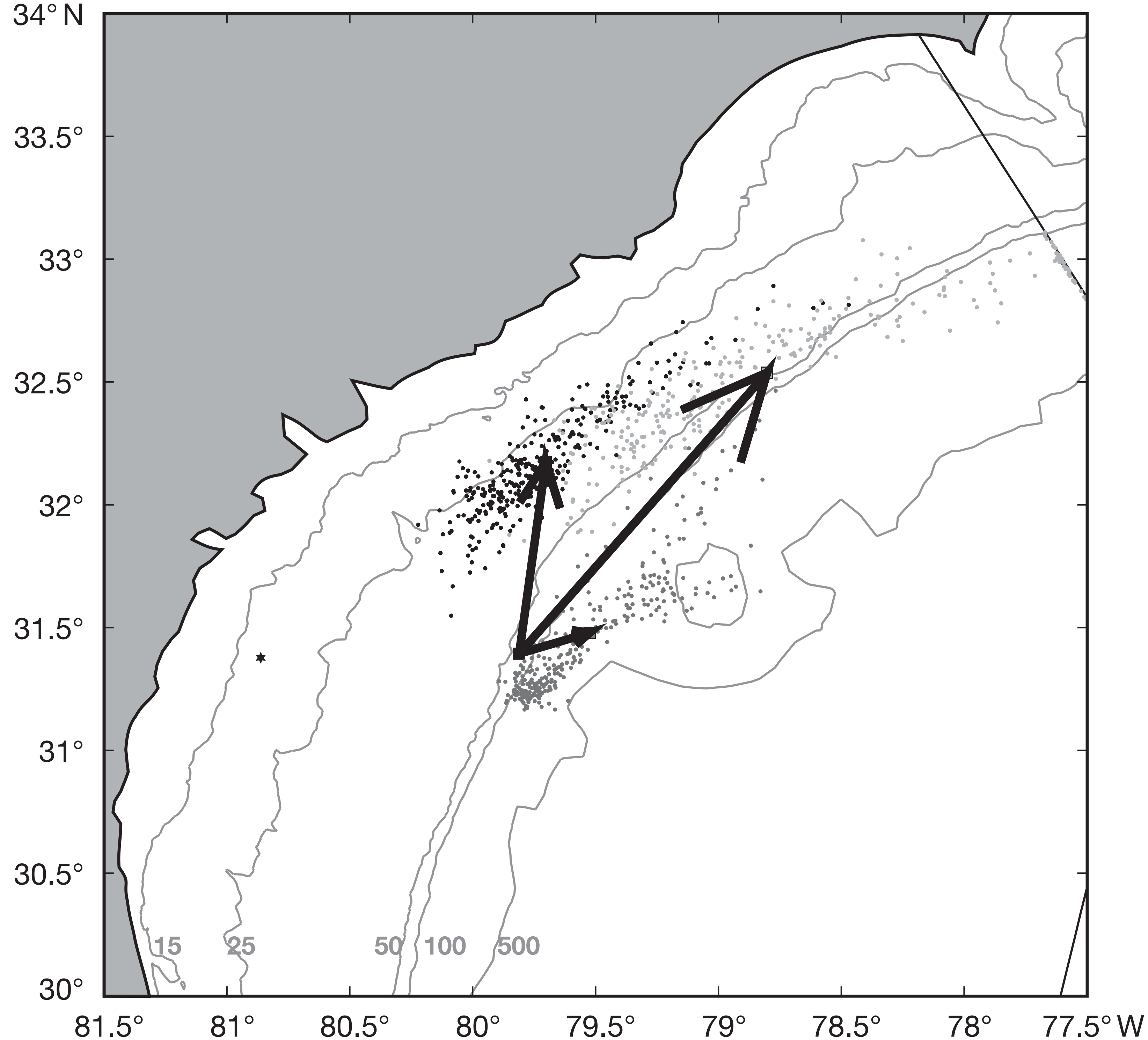


Fig. 7. Ending position of particles released at a location directly offshore of Gray's Reef National Marine Sanctuary (GRNMS,*) at the 60 m isobath for each of the 3 larval behaviors. Black squares: surface-fixed particles; medium gray squares: mid-depth passive particles; light gray squares: deep particles at a fixed depth above the bottom. Arrows point from the starting location of all particles to the center of the ending position of each behavior. Diagonal line in upper and lower right-hand corners mark end of model domain

- Highly complex models
- Labor and data intensive
- Ignorant of planktonic behavior

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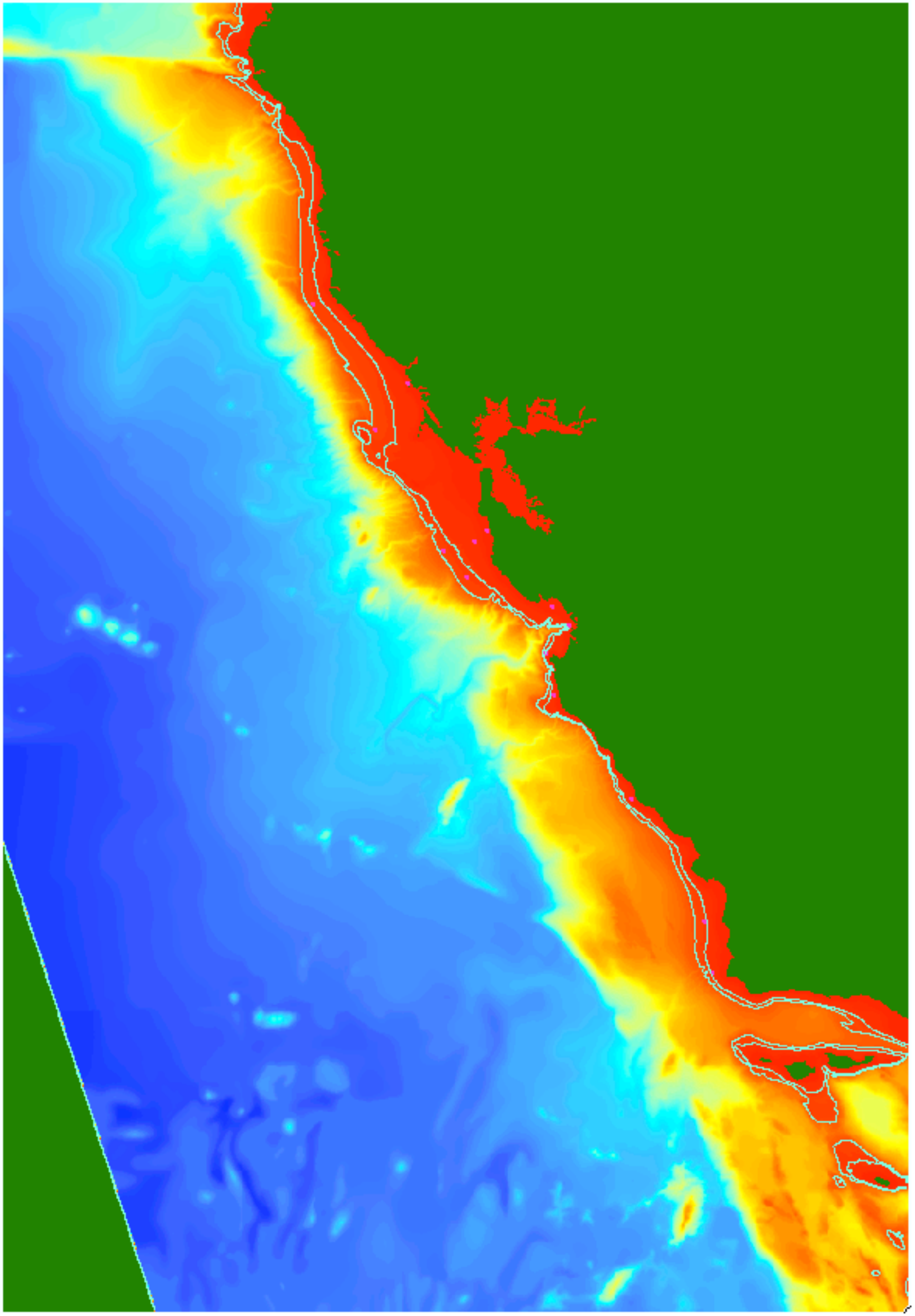
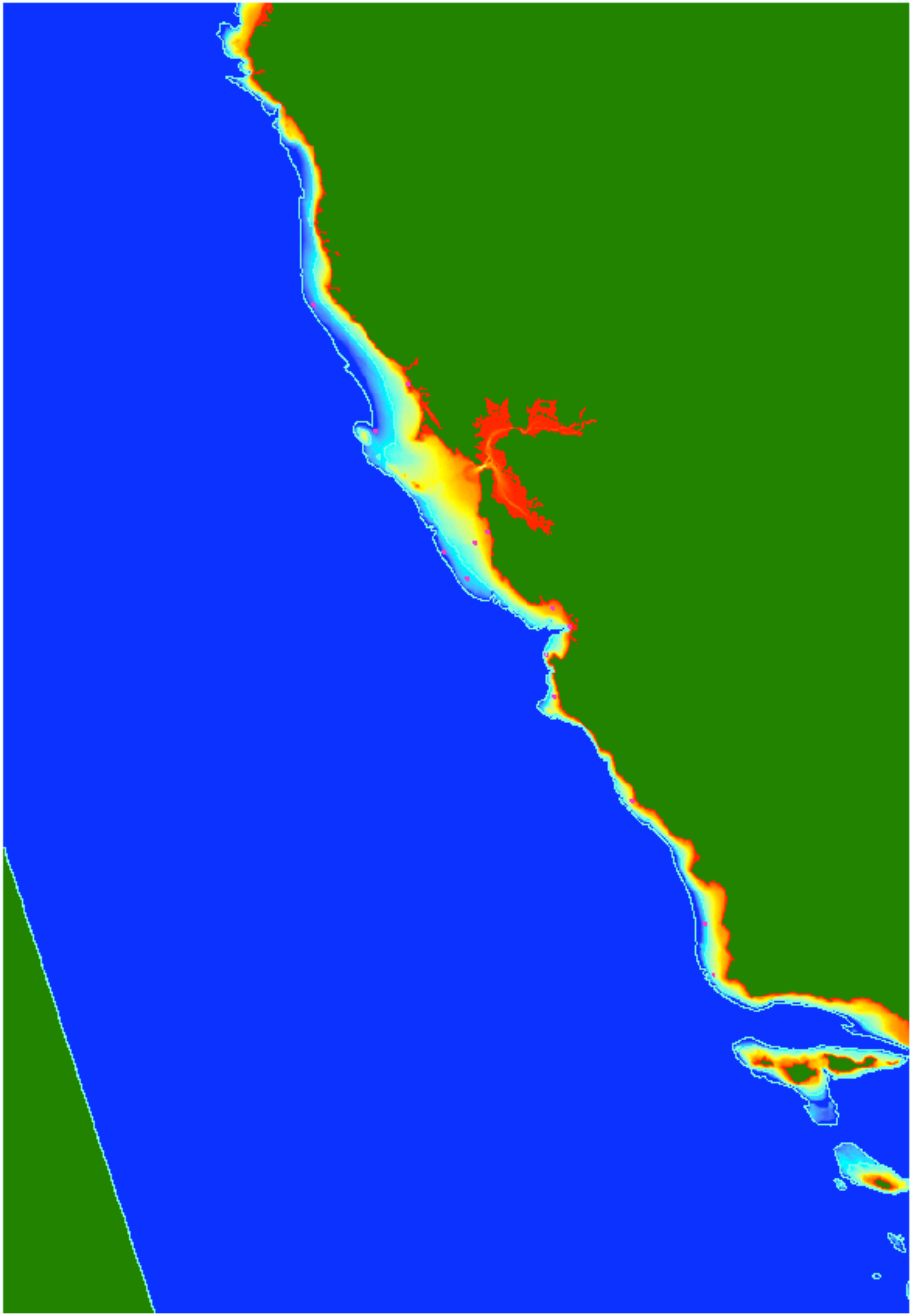
Dispersal estimates are needed now to inform conservation decisions

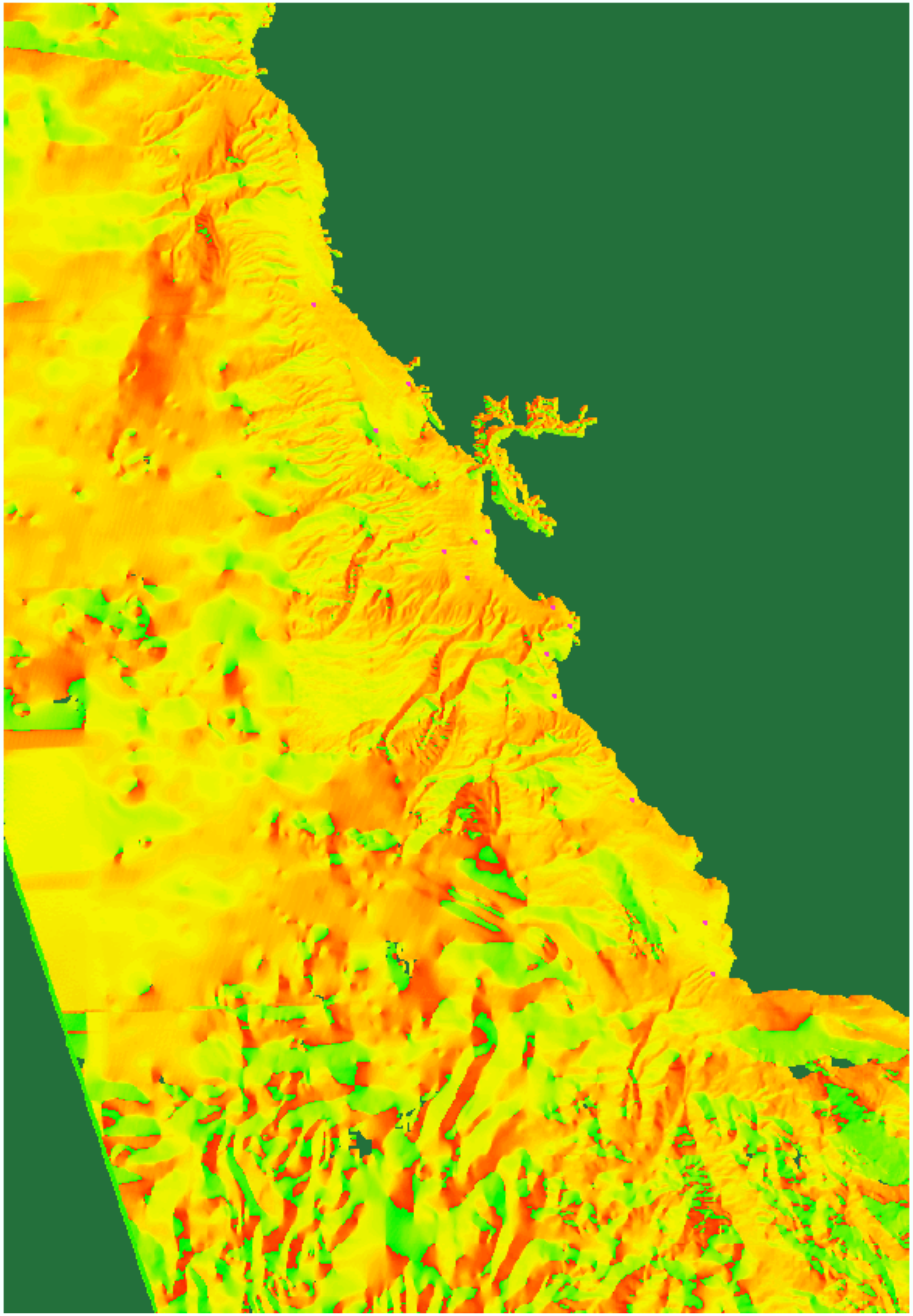
- Simple approach building on general knowledge
- Plankton both diffuse and advect from their source
- Transport is slower across-shore than along-shore
- Transport is slower in shallow water than deep water



- Bathymetry for Central Coast
- Resampled to 1km
- Light contours are 100 and 200m depth
- Green = No Data

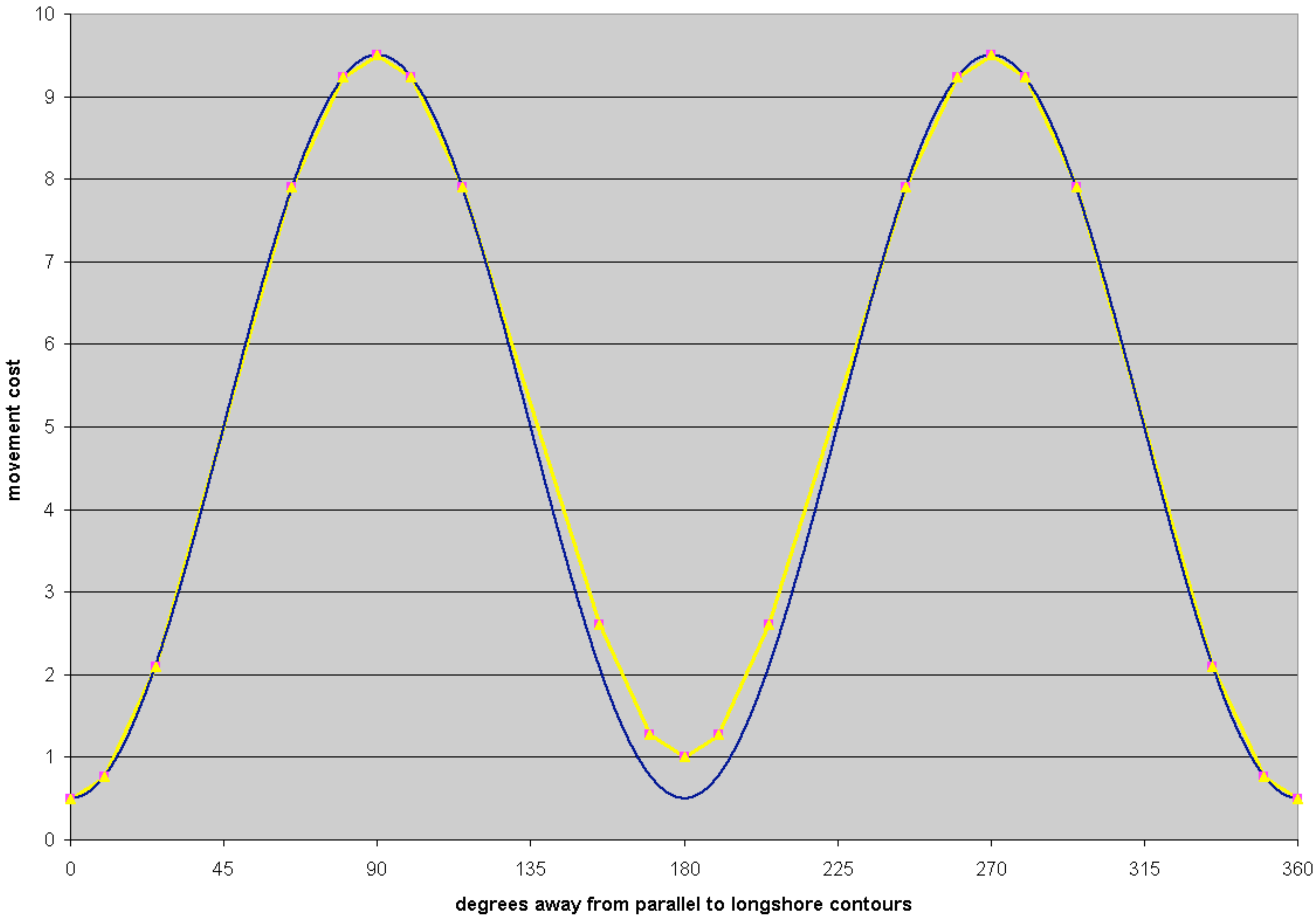


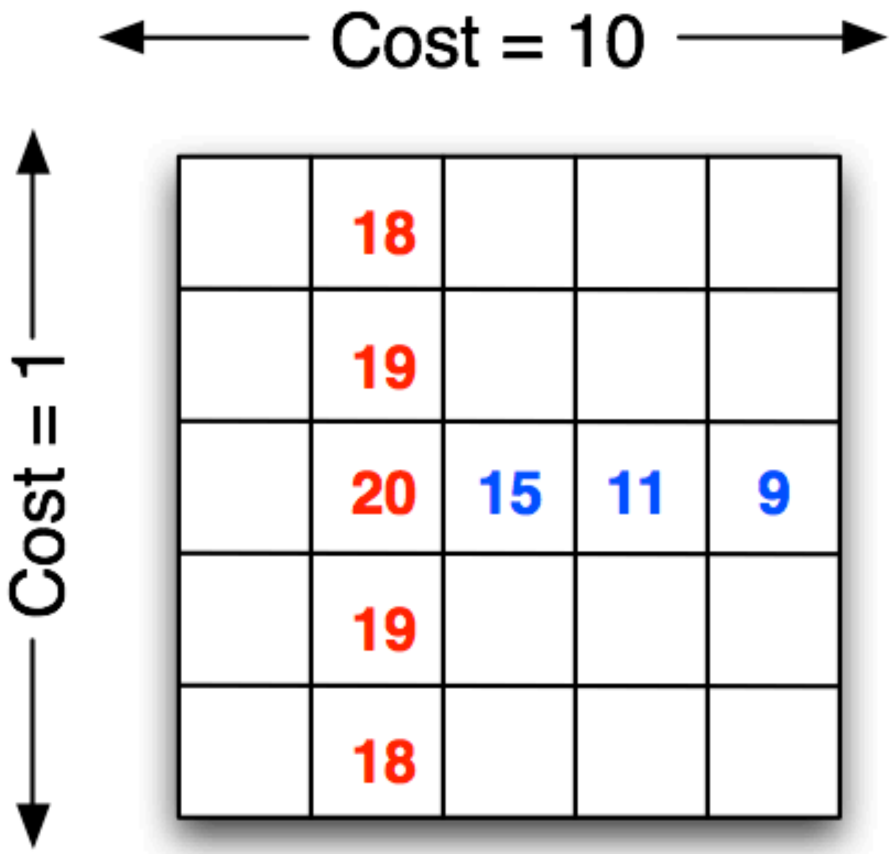
- Cost surface based on bathymetry
- Blue background is 0.5 for water >=150m
- Movement cost increases linearly with shoaling to beach where cost = 1

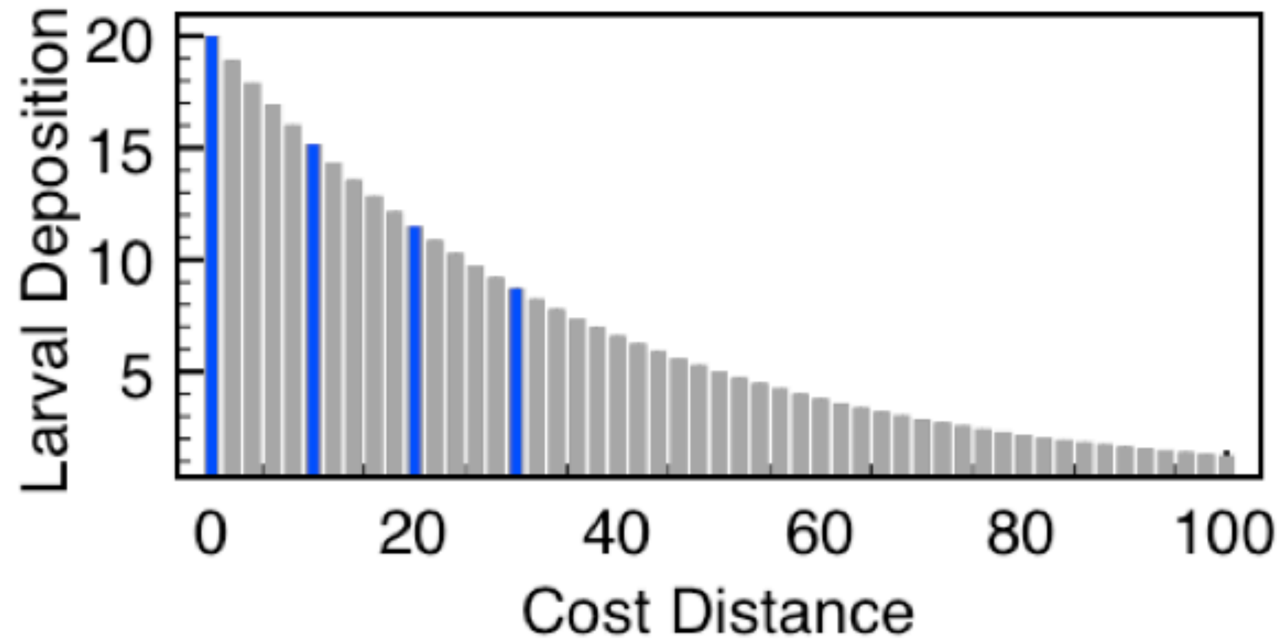


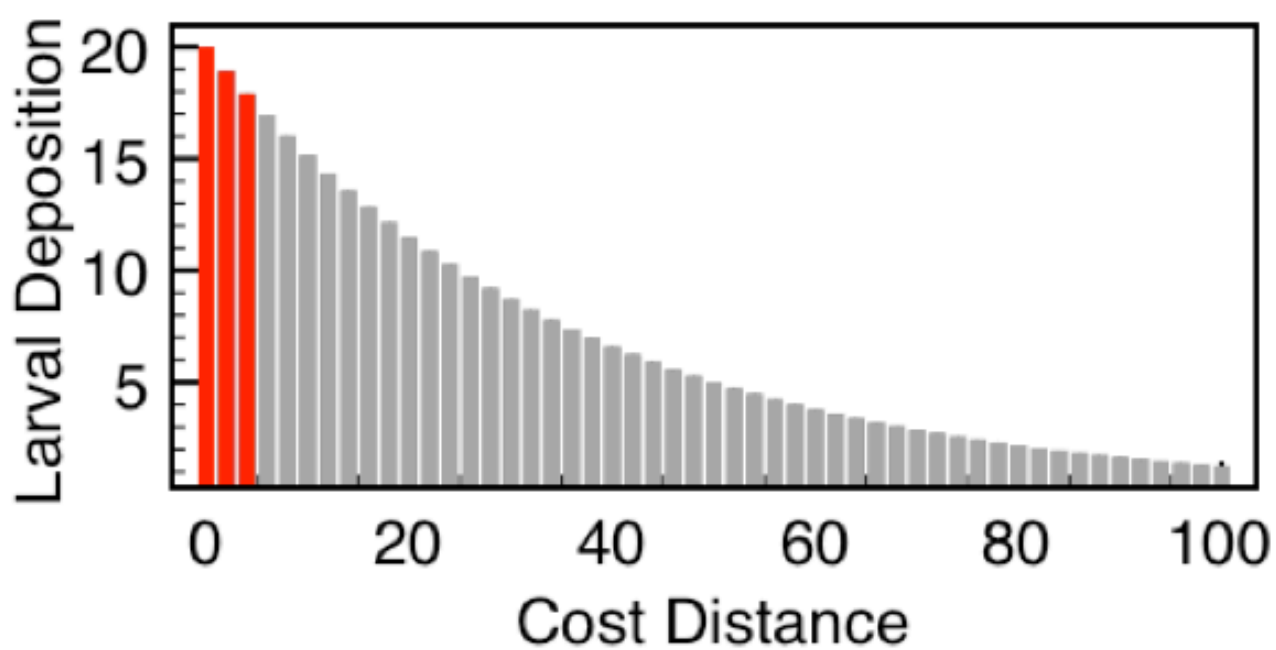
- Aspect calculated from 1km bathymetry
- Red faces NNE, fading clockwise to yellow at S, fading to lime green at NNW
- Magenta dots are sampling points discussed later

- Directional cost of movement
- Yellow is function used - blue is sine for reference









- Deposition is taken from an exponential distribution based on "cost distance" from the source
- Height of the distribution is adjusted so that the total # of larvae is the same for each source

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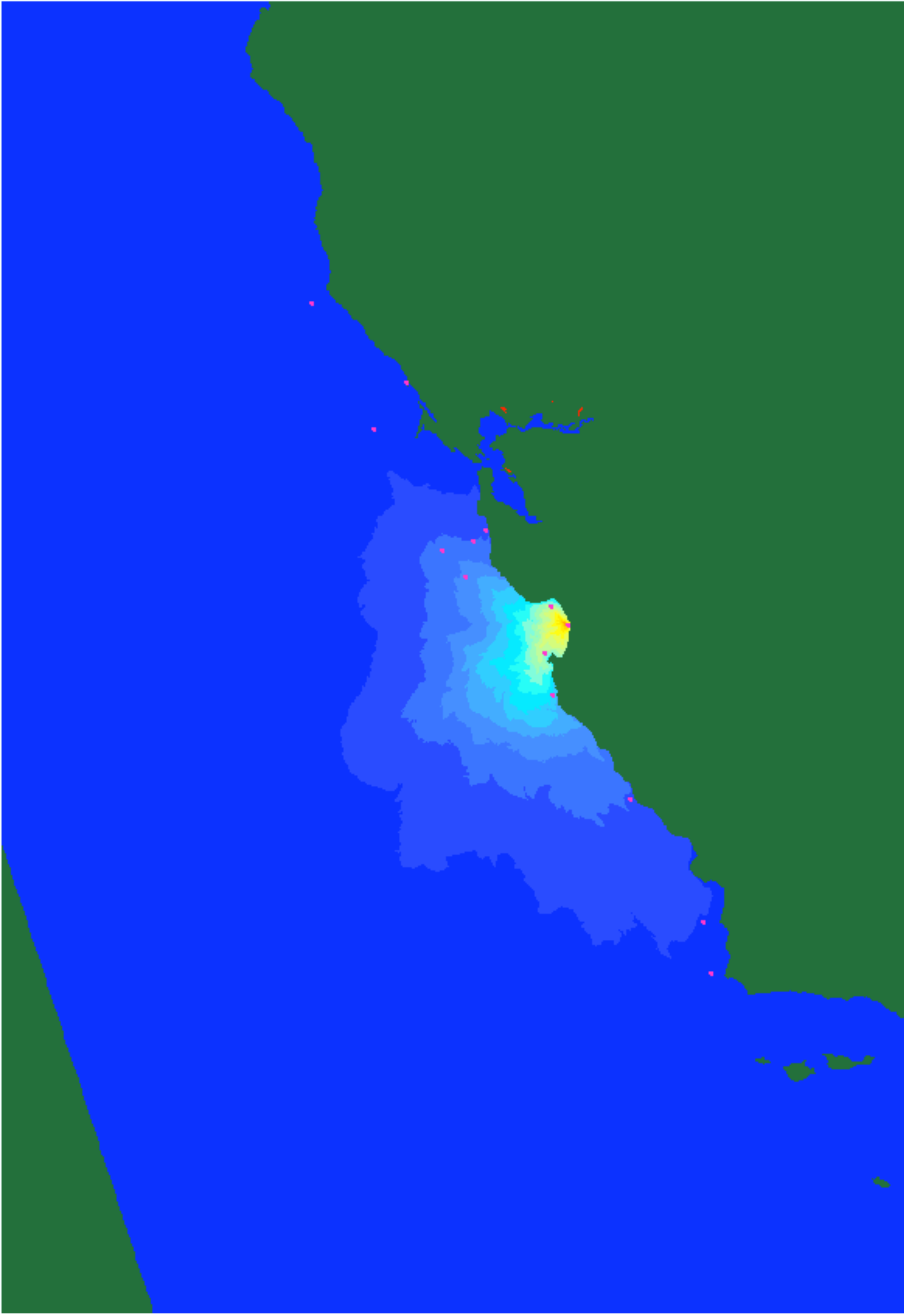
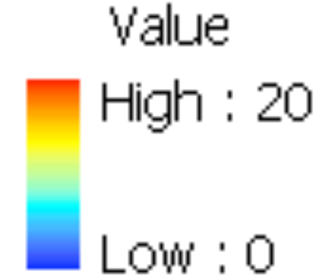
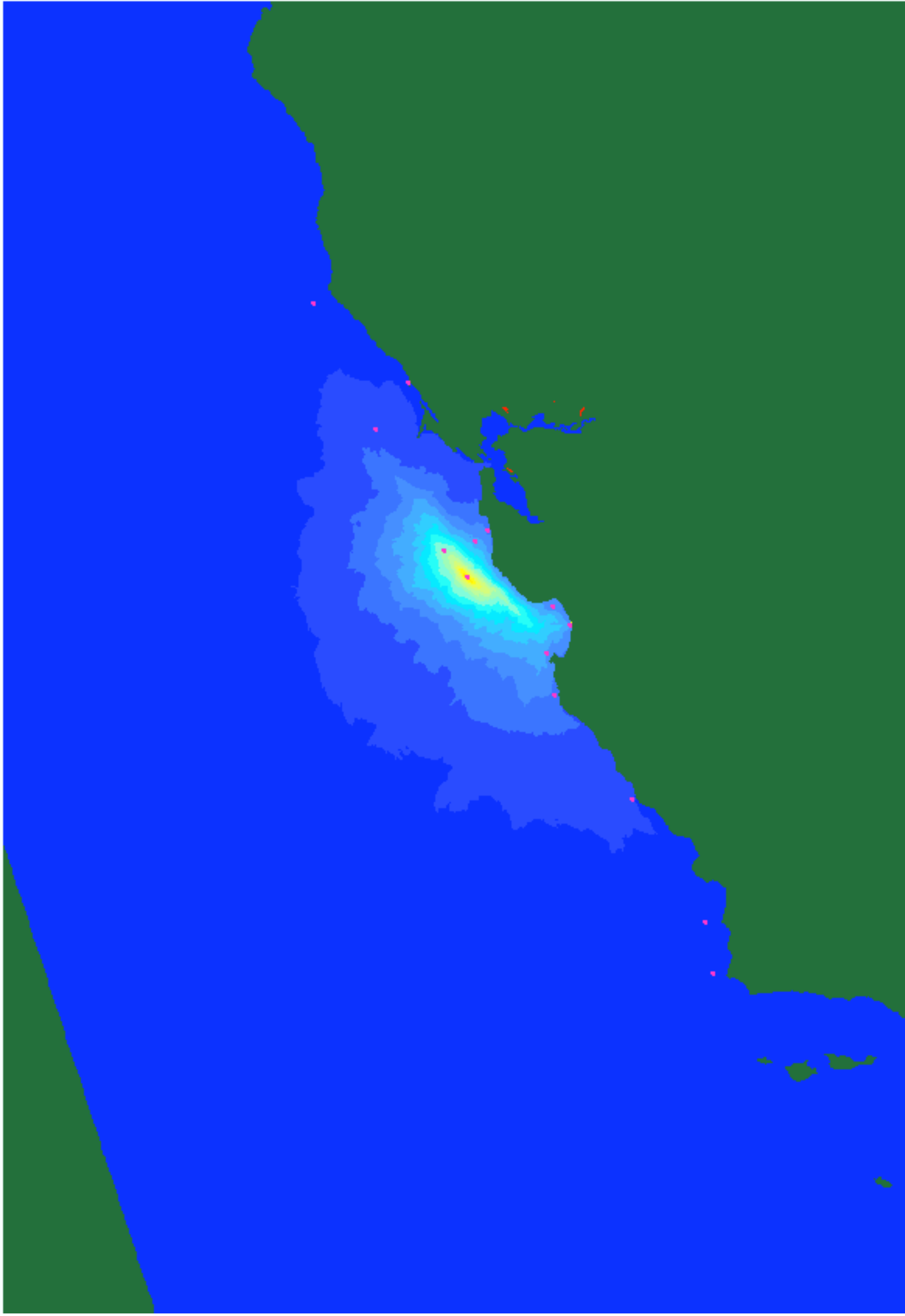
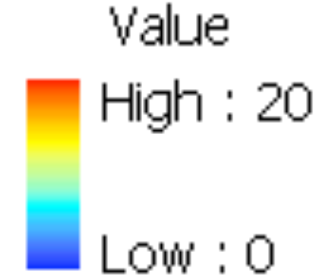




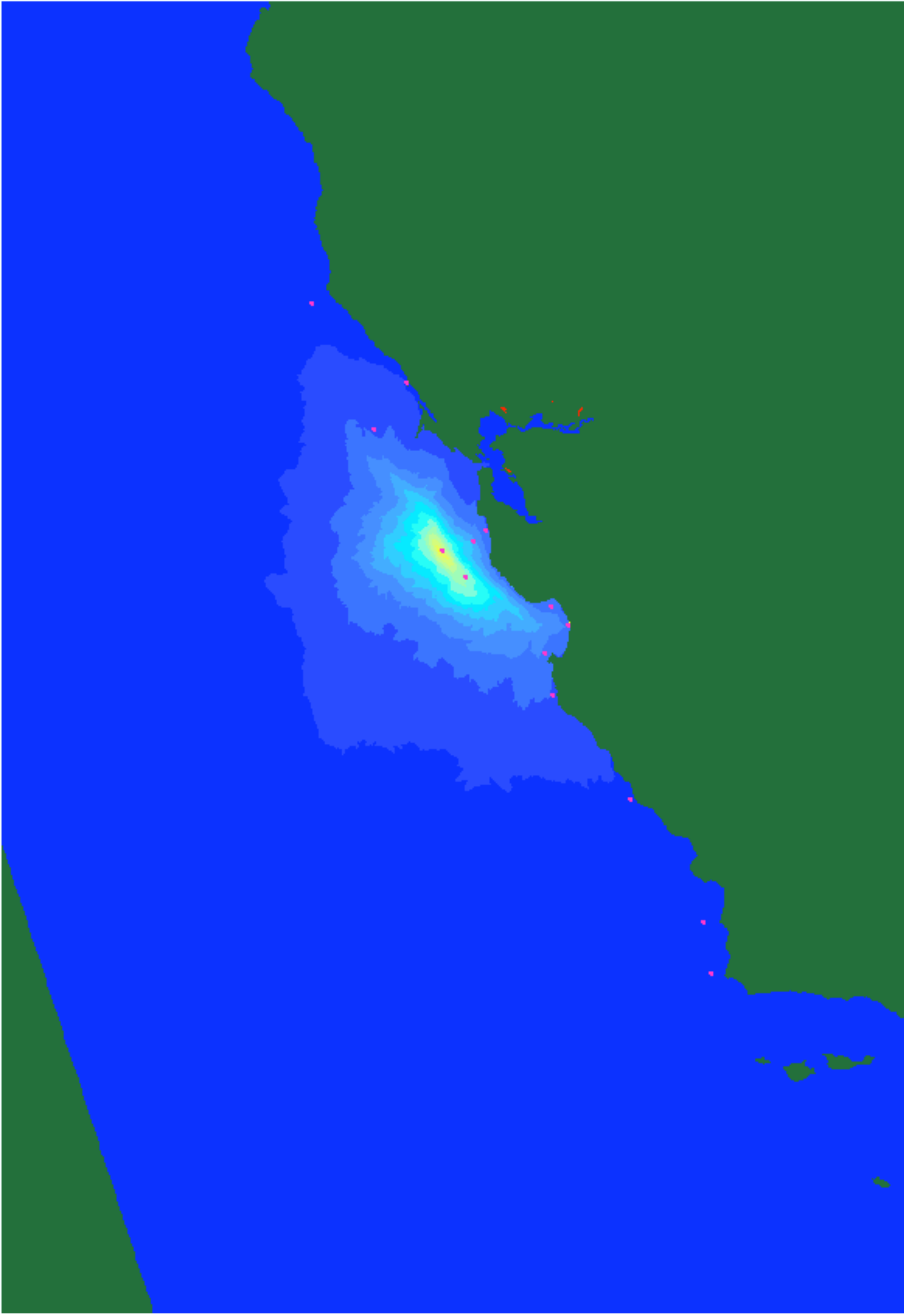
- In Monterey Bay

- Starting from very shallow water with a somewhat broader shelf



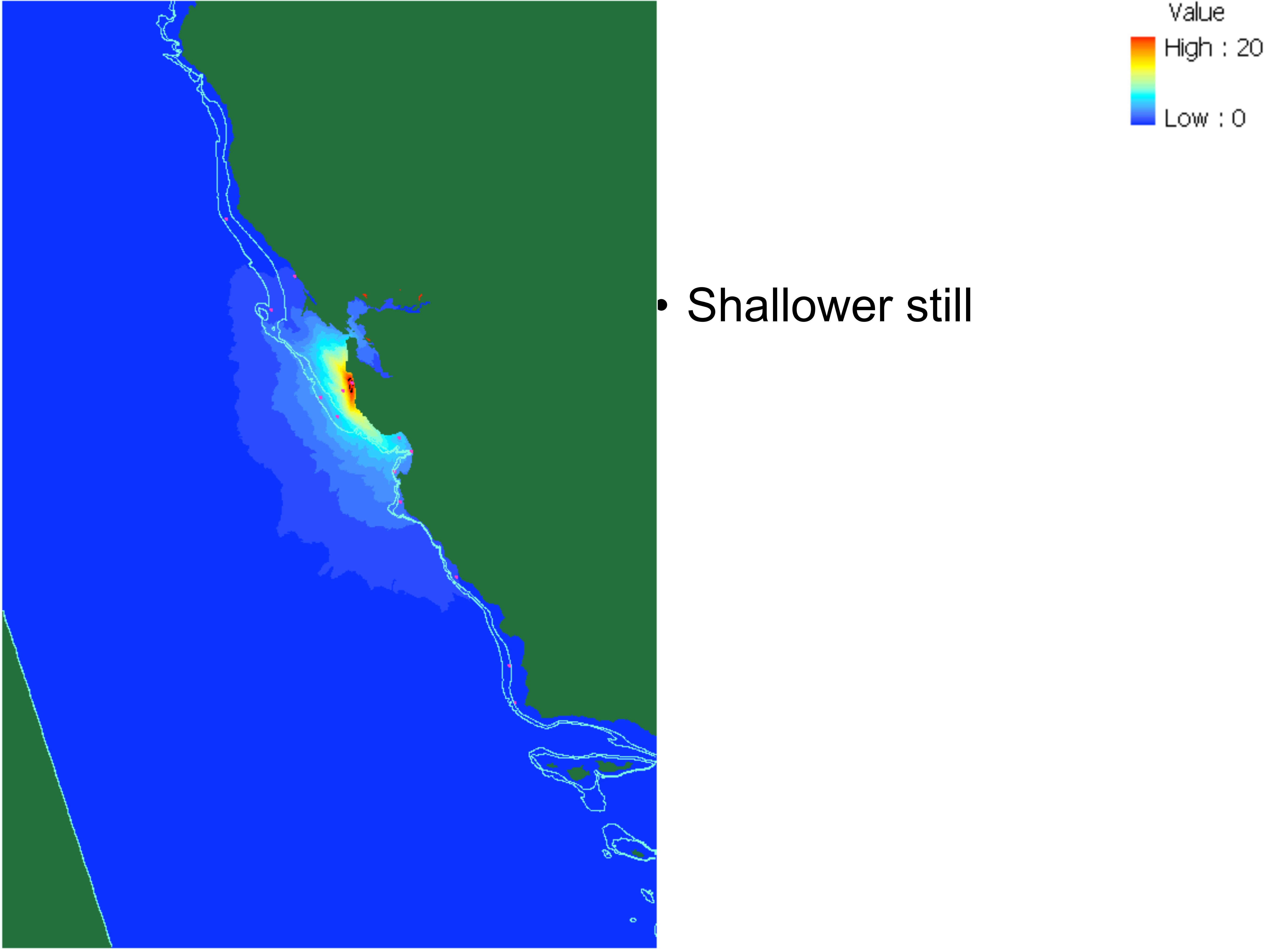


- Note the lack of dispersal onshore into the Gulf of the Farallones, but no such problem into the deeper water of Monterey Bay



- Offshore-most of a series of three sources

- Just onshore from the last one
- Again a smaller core kernal from shallower water
- Offshore tails (skirts?) of distribution less affected



- Shallower still

Dispersal model based on bathymetry

- Captures known general patterns of dispersal, including larval retention behind headlands, etc.
- It’s not correct - but it gives some insight nonetheless
- Allows a first pass at calculating population connectivity and persistence

3. What spatial patterns of protection can improve population persistence?

- We calculated dispersal from all grid cells of hard habitat
- Placed the results in a population model
- Calculated which areas may be contributing the most larvae to the metapopulation

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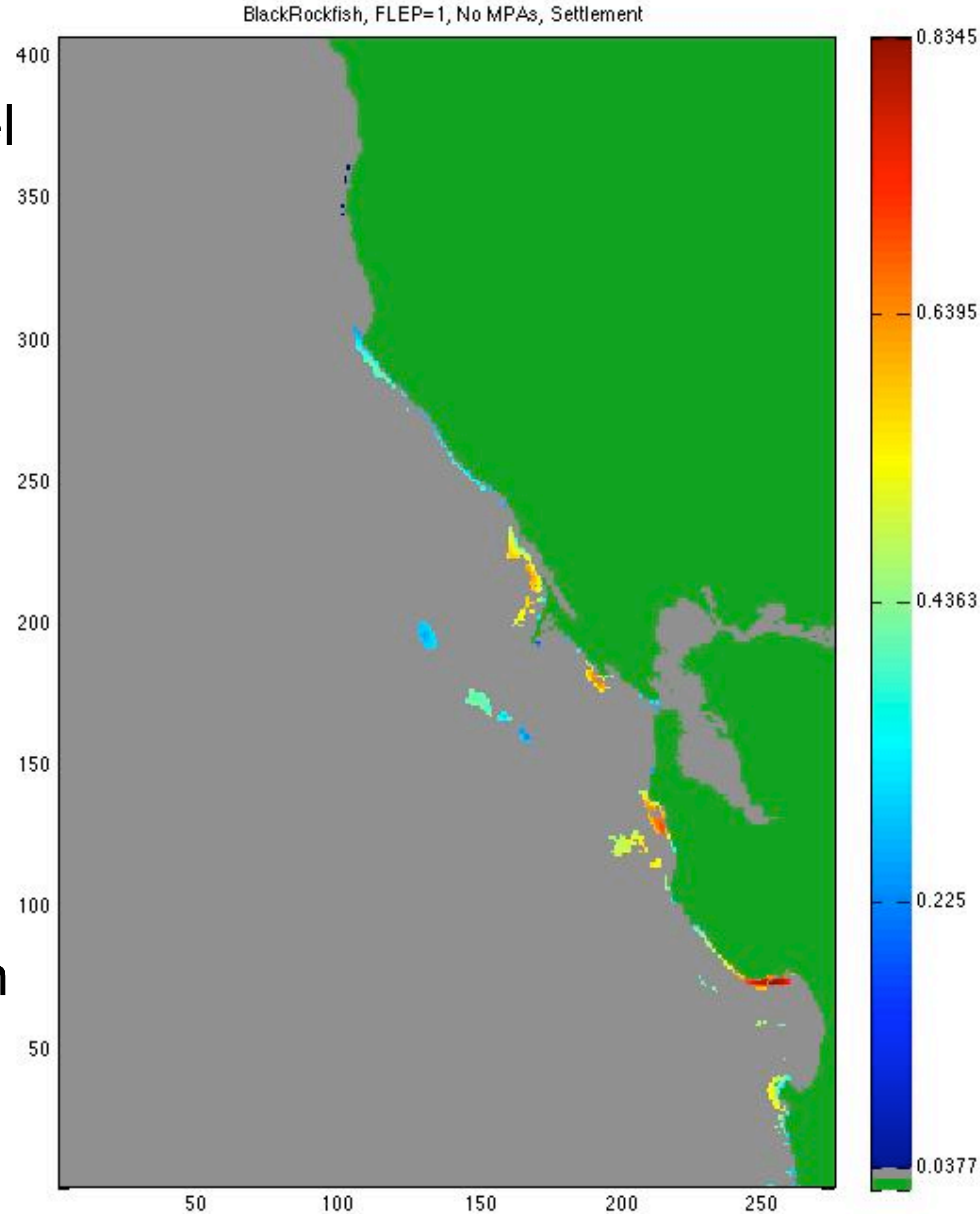
Results of population model using these dispersal kernals:

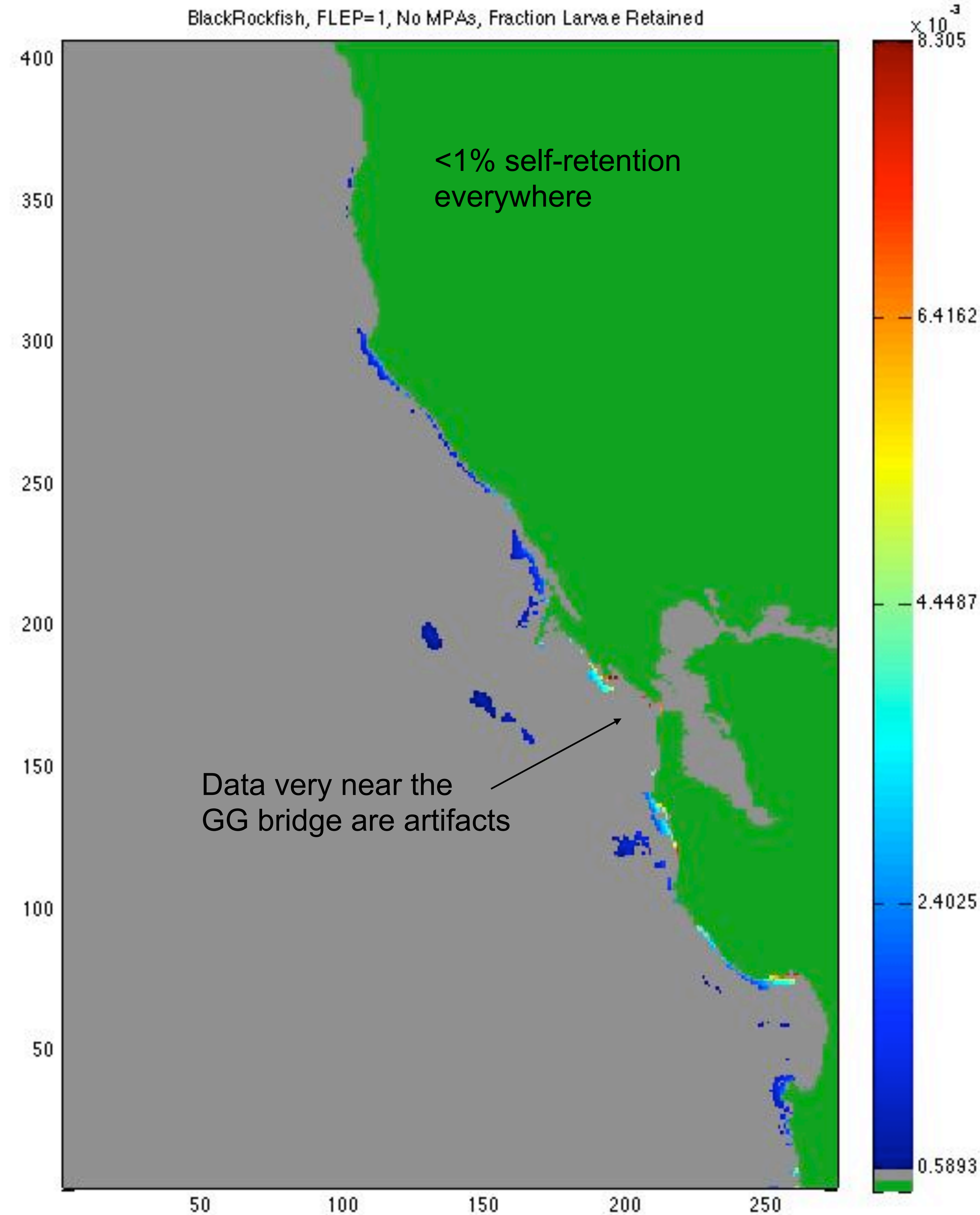
Settlement is higher in and near concentrations of habitat.

Larval dispersal = 45 km (nominal), no adult movement, no fishing. Fish use hard habitat, 0-100 m depth.



"Self retention":
the fraction of spawned larvae that settle locally

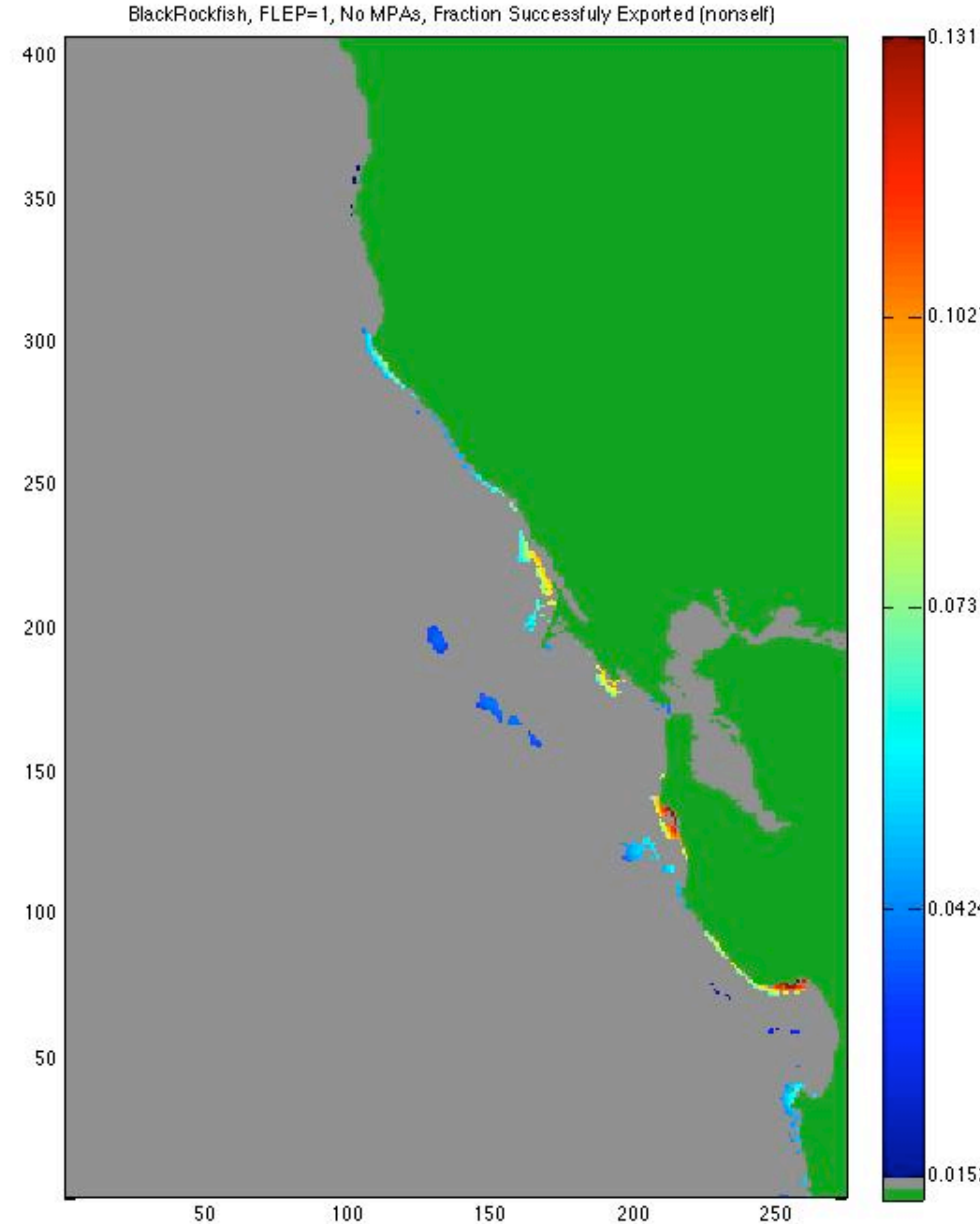
Highest in shallower water near the coast where long-shore currents are slower



"Larval export": fraction of spawned larvae that *successfully* settle elsewhere

Areas in or near concentrations of habitat.

Priorities for conservation due to larval contribution to metapopulation



Conservation priorities

- Areas of high successful export are on broad shelves near/within concentrations of habitat
  - This result is robust across a range of dispersal distances and dispersal kernal shapes
- Other important areas are stepping stones between concentrations of habitat
  - their importance from the model varies somewhat with dispersal kernal size and shape

Summary

- Conservation decisions are being made now, without information on connectivity of habitat
- Simple dispersal models can provide at least some insight into spatial patterns of connectivity
- Until better data and models are available, these insights should still improve the effectiveness of protected areas

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Future research

- Refining and validating dispersal models

- Improving population persistence models to include more population dynamics, increased fishing effort outside reserves, movement of adult fish, etc.

- Optimizing design of reserve networks to maximize population persistence

Acknowledgments

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  - CA Dept. of Fish and Game, Marine Life Protection Act Initiative
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  - CSU Northridge