To Where the Currents Flow – Larval Dispersal and Connectivity along the U.S. West Coast

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Objective: Use regional **ocean circulation models** to study the **dispersal patterns** of marine organisms (fish, invertebrates) and the **connectivity** between adult populations along the **U.S. West Coast**

Why? **-- marine ecosystem dynamics**
-- marine spatial planning

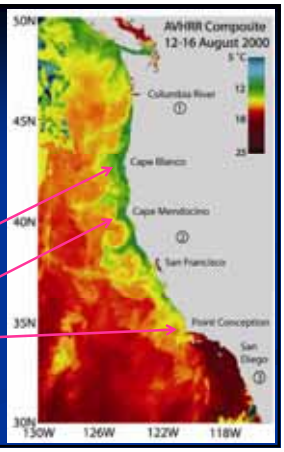
PISCO

California Current System

Influence of:

(1)major topographic features:

- Cape Blanco
- Cape Mendocino
- Point Conception



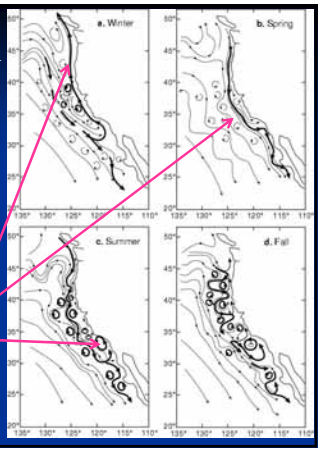
Checkley and Barth (2009)

California Current System

Influence of:

(2) Time-dependent currents:

- Davidson Current
- California Current
- Counter currents



Strub and James (2000)

Marine Reserve Networks

Selection criteria:
- Biogeographic regions
- Size
- Spacing
- Dispersal patterns
- Connectivity

Oregon pilot & proposed marine reserves

Some techniques and definitions

•Model planktonic larva as passive particles advected with 3-dimensional currents (u,v,w); easy to add behavior
•May include random vertical walk for mixing
•Pelagic Larval Duration (PLD): time spent by larvae drifting at sea; differs between species (30-180 d)
•Competency time window: time period during PLD when larvae are ready to settle (join adult population)
•Larvae settled at the shallowest place along the coast during the competency time window
•Examine statistics:
- Probability (Settlers from released Latitude / Total Settlers)
- Probability (Settlers at settled Latitude / Total Settlers)
- Probability (Self-seeding settlers / Total Settlers)

Regional Ocean Modeling System (ROMS)

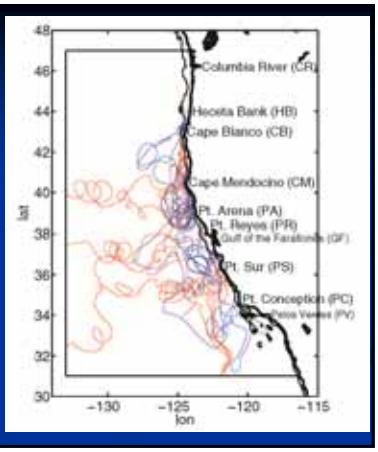
•terrain-following s-coordinates in vertical (~40 levels)
•Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS) winds and surface fluxes
•no tides or freshwater input

	California Current	**Oregon**
Domain	30.0-48.0 N	40.6-47.5 N
Horizontal resolution	2.5-3.7 km	3.1 km
Nesting	WOA monthly	Navy model
Vertical mixing	Generic Length Scale	MY 2.5
# particles	> 6 million	325,000
Competency Time Window	30-60d, 120-180d	15-35d

California Current Model

Example model trajectories

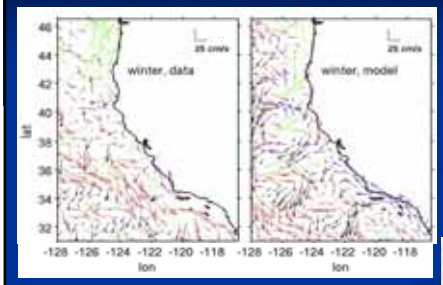
Blue = settled
Red = lost



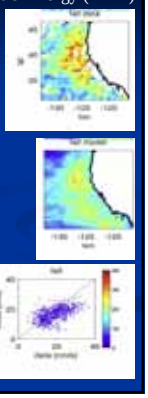
Drake et al. (2011)

How well does the model do?

surface drifter observations



eddy speed from Eddy Kinetic Energy (EKE)



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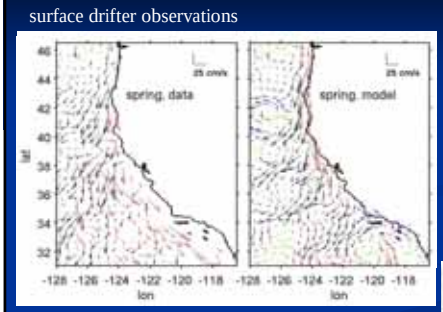
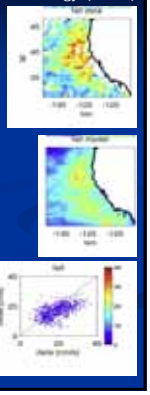




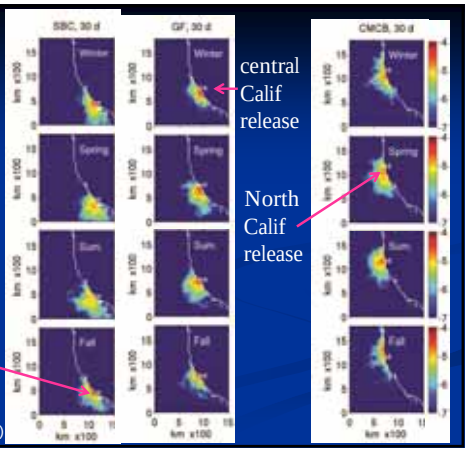
Drake et al. (2011)

Particle density (km^{-2}) (log scale) 30-d after release (0-20 m)

central Calif release

North Calif release

south Calif release

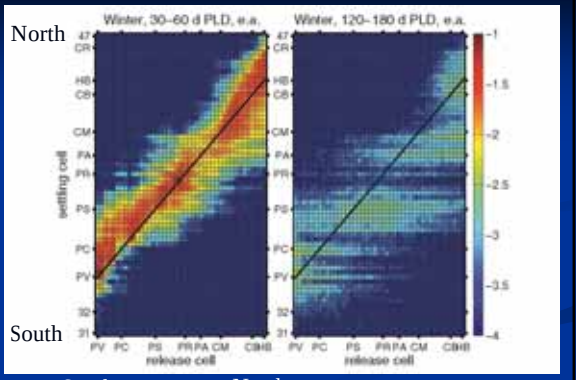


Drake et al. (2011)

Connectivity matrices (settling < 10 km from coast)

North

South



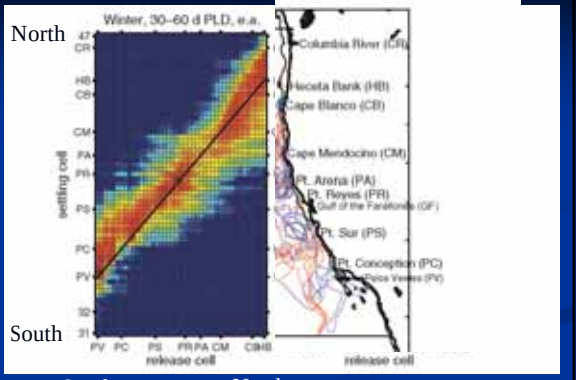
South North

Drake et al. (2011)

Connectivity matrices (settling < 10 km from coast)

North

South



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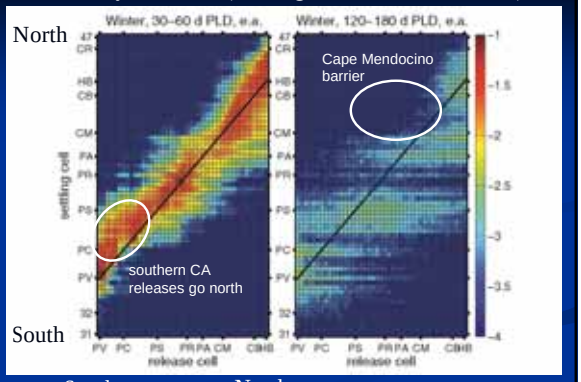

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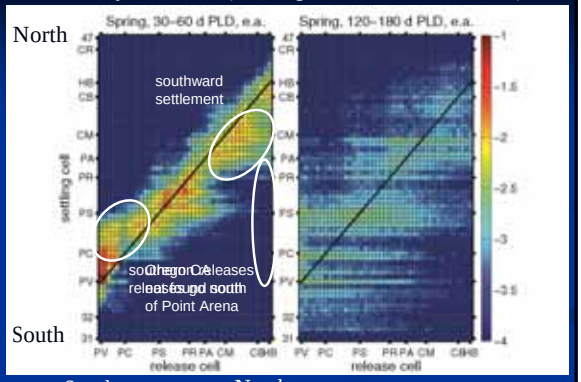
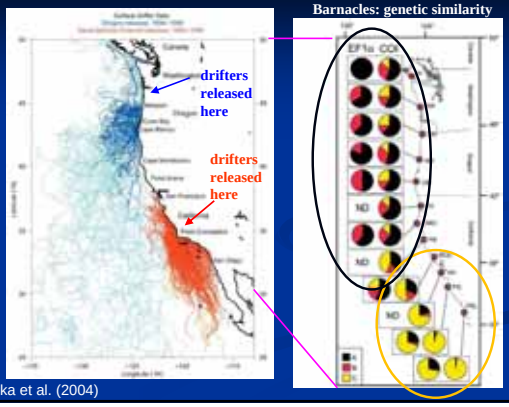


South North

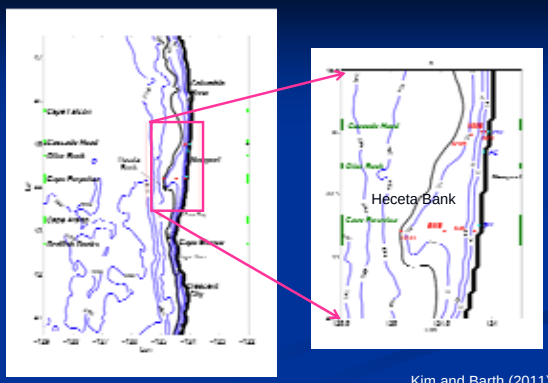
Drake et al. (2011)

Ocean drifters and barnacle genetic cline



Sotka et al. (2004)

Oregon Model

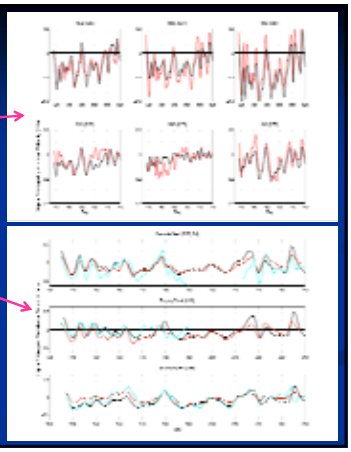


Kim and Barth (2011)

Oregon Model-Data Comparison

Shelf moorings
(50, 80, 130 m)
RMSE < 0.09 m/s
Correlation > 0.7
(99% significance)

Inner-shelf moorings
(15 m)
RMSE ~ 0.12-0.21 m/s
Correlation > 0.6
(95% significance)

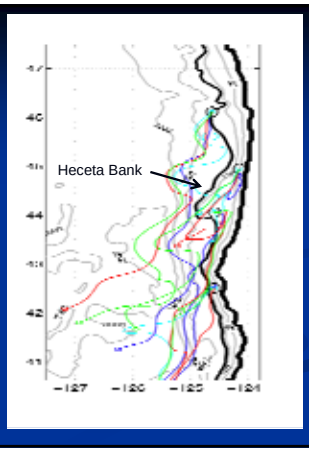


Kim and Barth (2011)

Oregon model

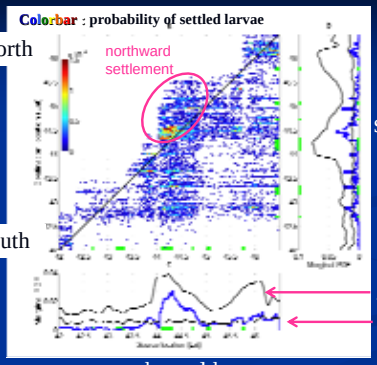
Example Trajectories

Releasing days of
- 144 (blue)
- 168 (red)
- 192 (green)
- 216 (cyan)



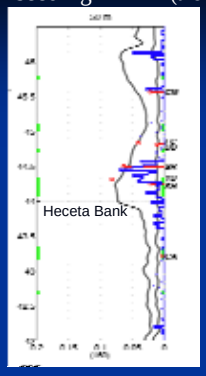
Kim and Barth (2011)

Connectivity Matrix – 50 m larval release & settlement



Kim and Barth (2011)

Self-seeding PDF (along diagonal of connectivity matrix)



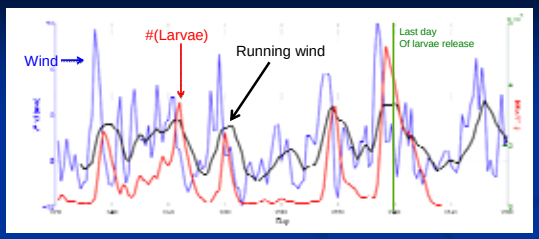
Marginal PDF; # recruits/day

In Red
Mussel recruits per day (2000-2006) (Menge et al., 2009)

Cape Meares (CM), Fogarty Creek (FC), Boiler Bay (BB), Seal Rock (SR), Yachats Beach (YB), Strawberry Hill (SH), and Cape Arago (CA)

Kim and Barth (2011)

Correlation between settled larvae and meridional wind

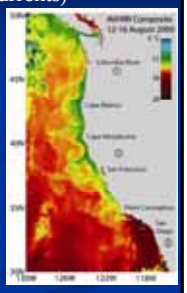


- Near-shore (≤ 30-m isobath) larval settlement is greatest when the integrated wind is downwelling favorable (> 0)
- Strong relation between the number of larvae ≤ 30 m and past 8-day running wind mean
- Best timing for larvae release can be predicted by 8-day running mean wind

Kim and Barth (2011)

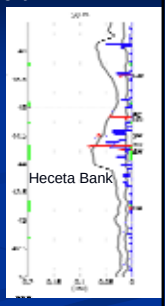
Summary (1/2)

- Regional coastal circulation models compare well with data (seasonal currents, EKE, low-frequency currents)
- Larval dispersal varies with release region, release season and time-since-release
- Releases from southern California dispersed north regardless of season (!)
- Major geographic features influence connectivity:
  - Cape Mendocino limits northward settlement
  - Point Conception is not a barrier for dispersal from south
- Oregon releases not found south of Pt Arena
- Qualitative agreement with barnacle genetic clines



Summary (2/2)

- Larvae from Heceta Bank can settle to the north
- Heceta Bank is a good source and destination for settled larvae
- Alongshore difference in settlement agree qualitatively with barnacle recruitment data
- Larvae settle when winds, averaged over the previous 6-8 days, are relaxed or downwelling favorable



Next Steps

- Year-round dispersal and connectivity off Oregon
- Include rivers and tides
- Include larval behavior