Potential larval connectivity among nearshore marine reserves in Oregon: the importance of ~~temperature dependent pelagic durations and~~ vertical distribution

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Presentation Outline

- Oregon coastal and marine spatial planning (CMSP)
- Connectivity results from 1 km resolution model for 2002
- Real critter distributions (evidence from NoCal and OR)
- How shifts in vertical location impact transport & retention—2011 simulations using fields from a 3 km data assimilative RT model
- Conclusions and Future Work

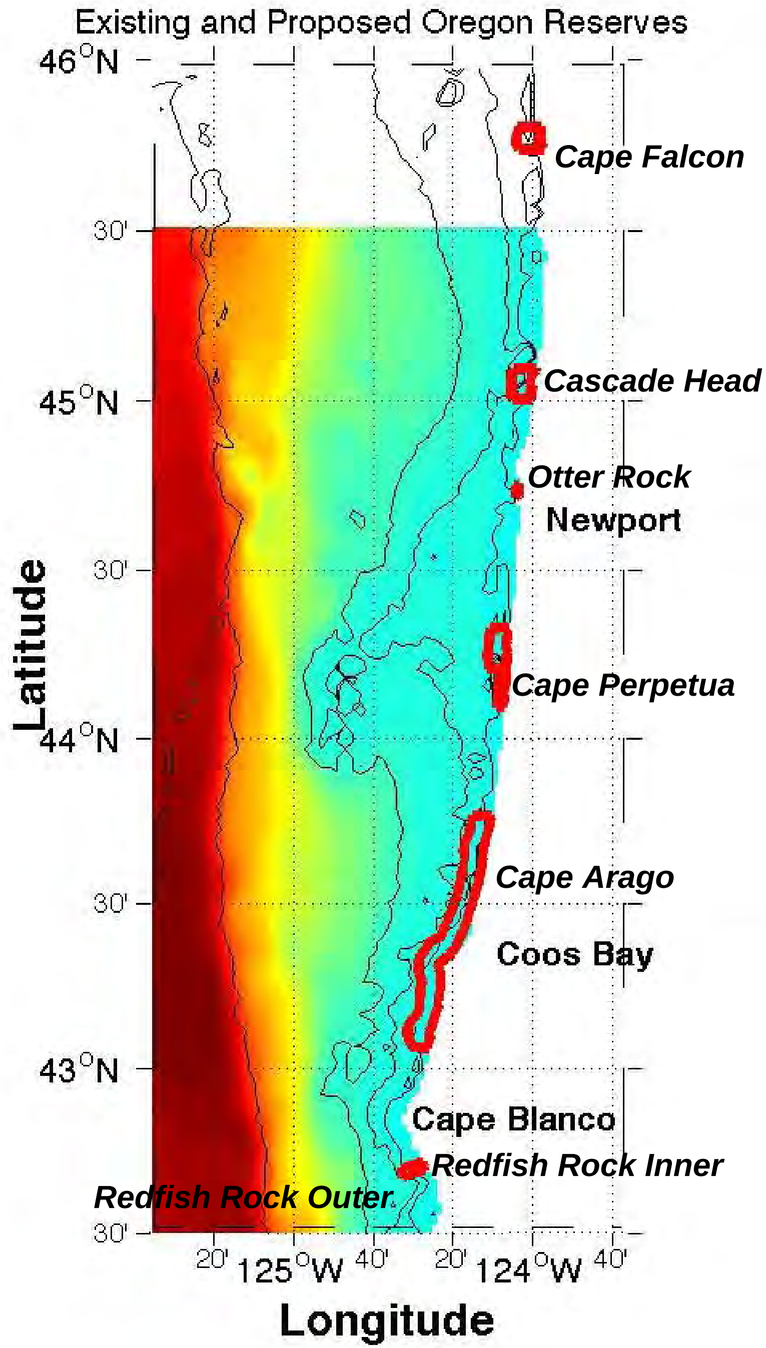
CMSP = Coastal and Marine Spatial Planning

1) A priority for NOAA Fisheries
2) A tool for implementing Ecosystem Based Management
3) Multi-sectorial: considers both marine resource harvest and other sectors such as energy siting issues (wind energy, wave energy, etc.)

CMSP in Oregon

Examine connectivity, self-seeding & residence time among specific targeted regions

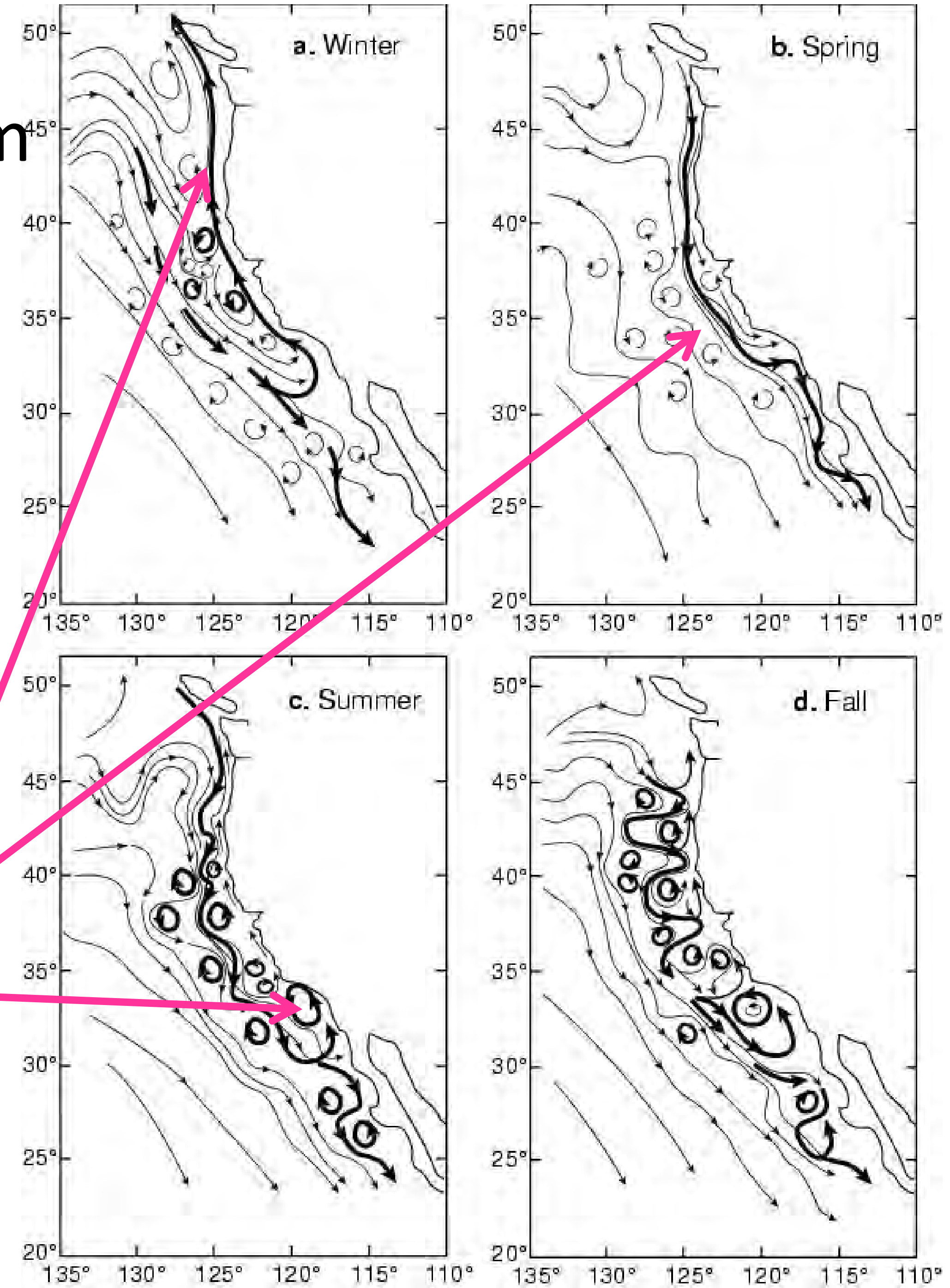
Caveat: at Territorial Sea scale (3 nm [5 km]), finer model resolution than 1 km is warranted



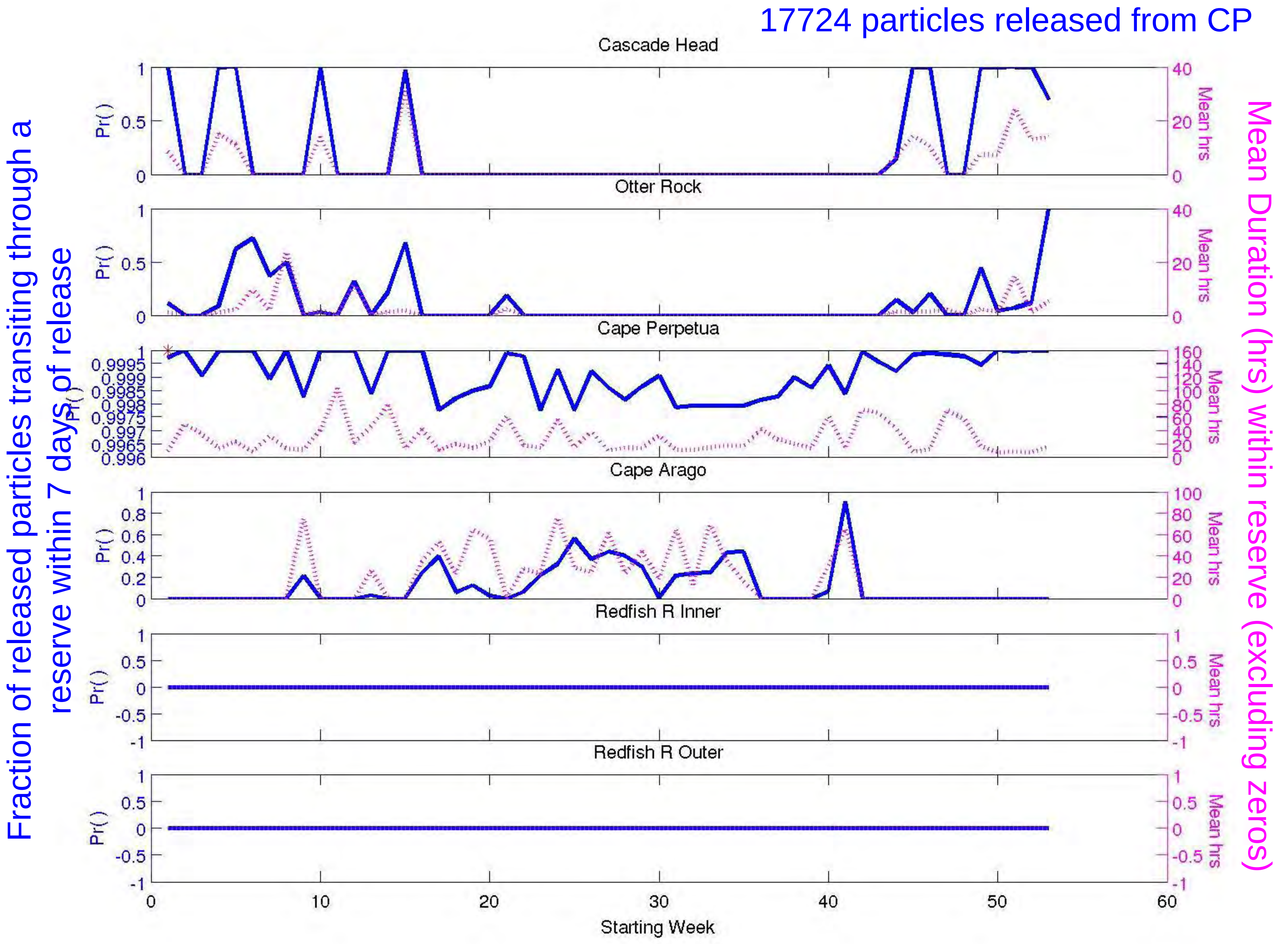
California Current System

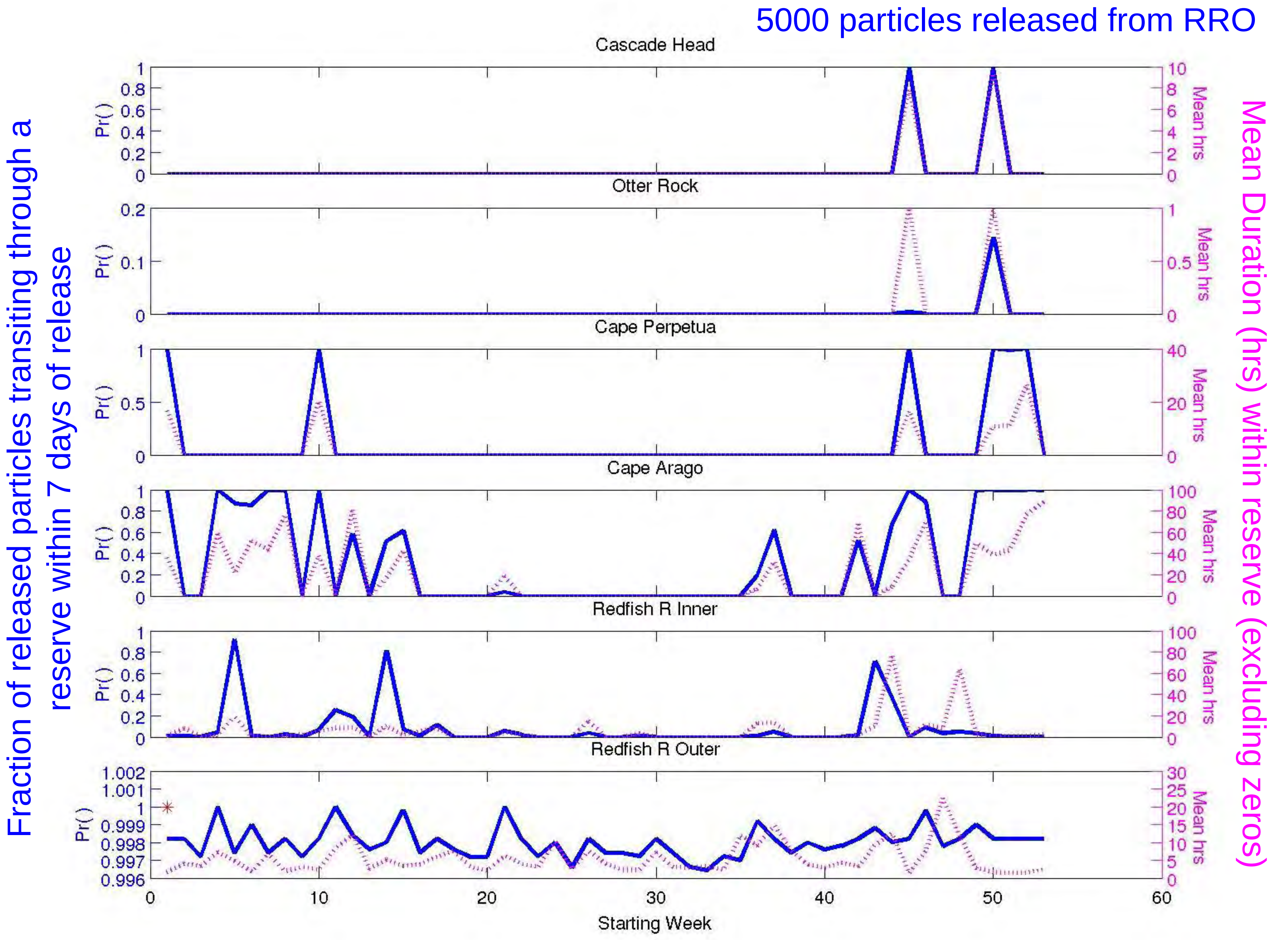
Seasonally-dependent currents:

- Davidson Current
- California Current
- Counter currents



Strub and James (2000)


17724 particles released from CP
Cascade Head
Otter Rock
Cape Perpetua
Cape Arago
Redfish R Inner
Redfish R Outer
Pr( )
Mean hrs
Starting Week
Fraction of released particles transiting through a reserve within 7 days of release
Mean Duration (hrs) within reserve (excluding zeros)


5000 particles released from RRO
Cascade Head
Otter Rock
Cape Perpetua
Cape Arago
Redfish R Inner
Redfish R Outer
Pr( )
Mean hrs
Starting Week
Fraction of released particles transiting through a reserve within 7 days of release
Mean Duration (hrs) within reserve (excluding zeros)

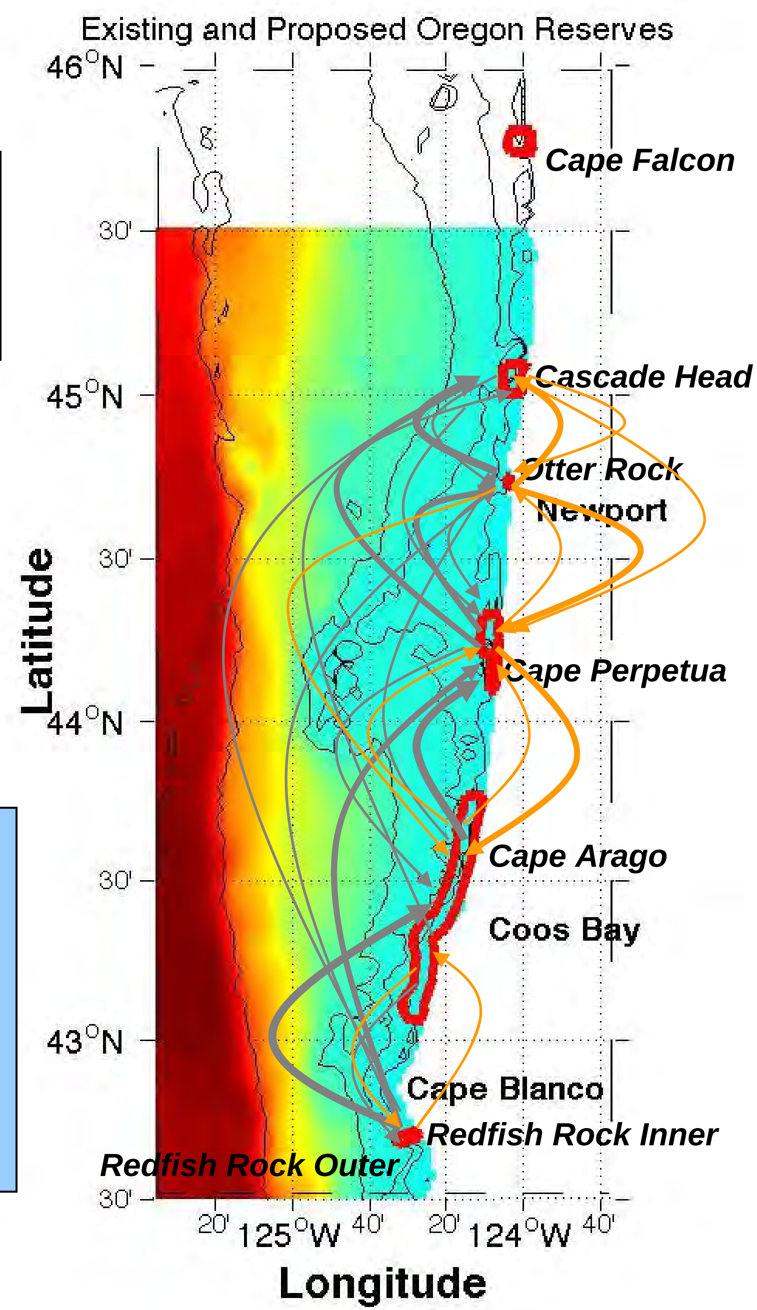
Oregon Shelf Marine Connectivity

Particle tracking using ROMS circulation (1 km resolution) of 2002 reveal seasonal and spatial patterns of connectivity among proposed Oregon territorial sea marine reserves.

Shown: Connectivity (% of released particles) reaching another reserve.

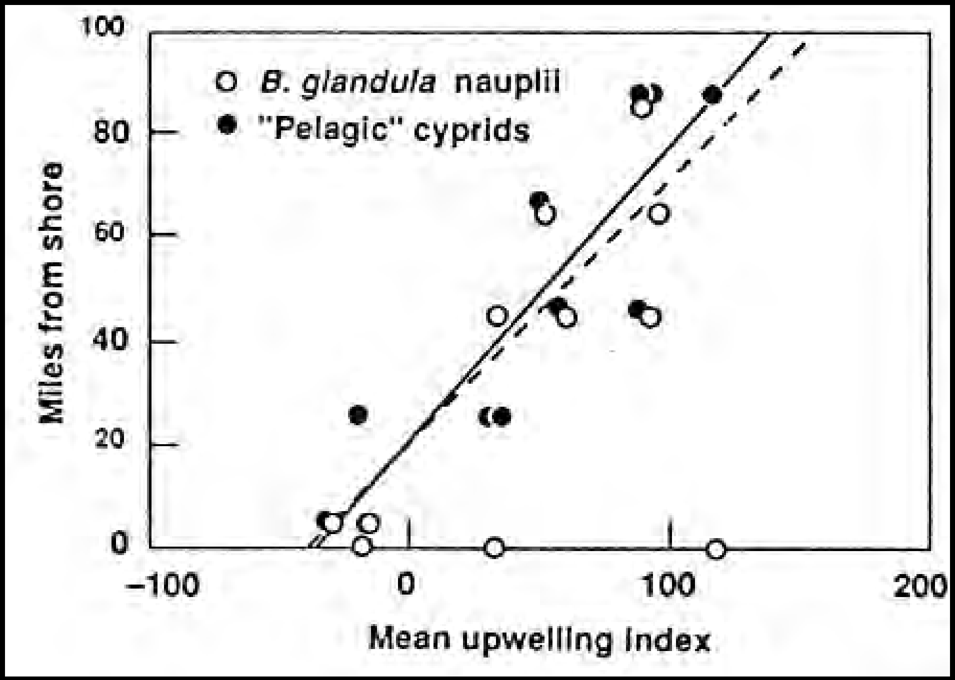
Period	*1-10%*	*10-40%*	*>40%*
Downwelling	←	←	←
Upwelling	←	←	←

Alongshore connectivity is highly seasonal; upwelling periods have high N→S connectivity; downwelling periods have high S→N connectivity. Alongshore connectivity is greater in winter downwelling. Cape Blanco is a barrier to connectivity, esp. in summer. Larger reserves are more connected than small reserves.



Are larvae swept offshore?

11 year record of cross-shelf distributions of *Balanus glandula* larvae



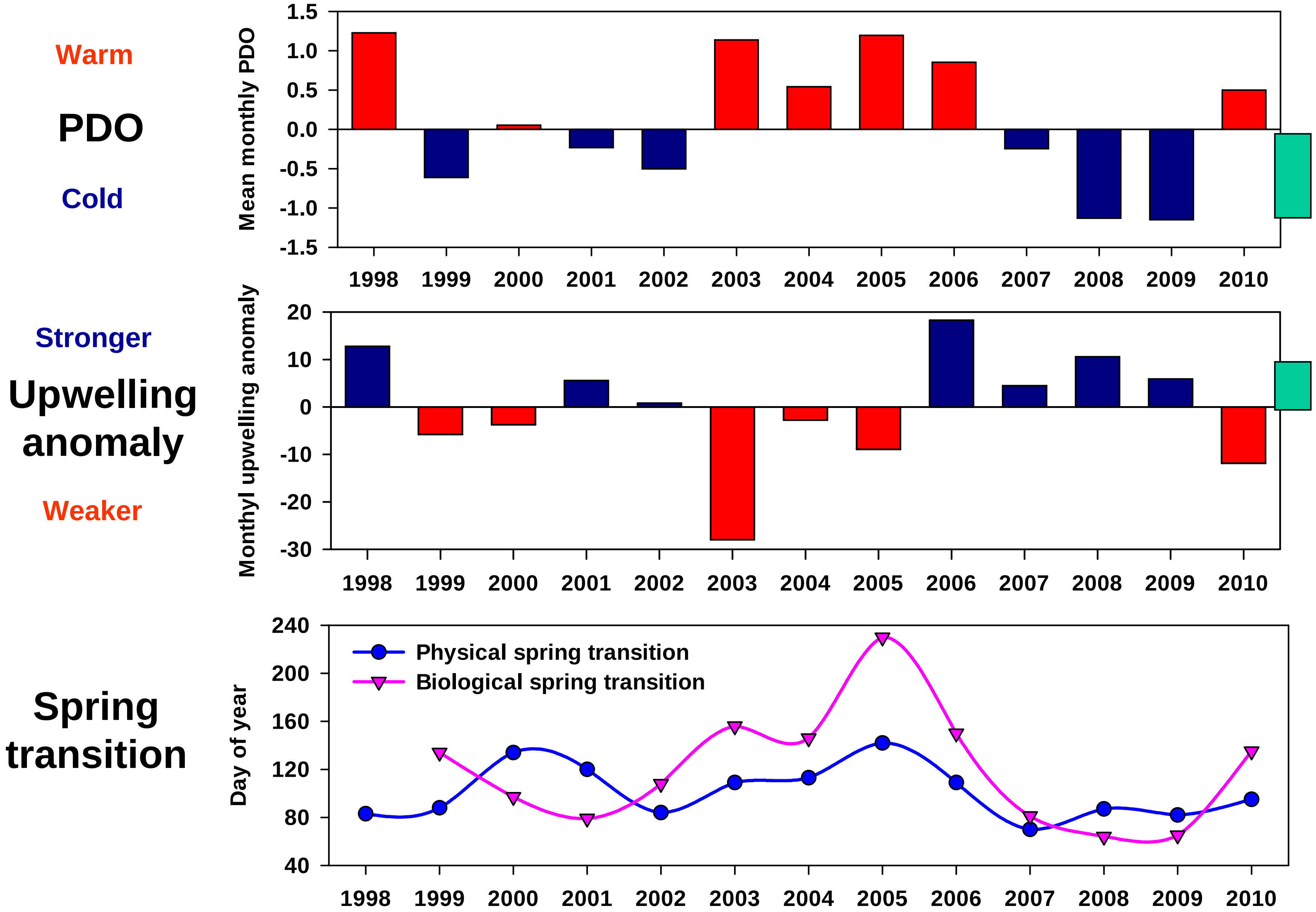
Strong upwelling in central California increases offshore transport

Roughgarden et al. 1988 Science

Images by: Wim van Egmond

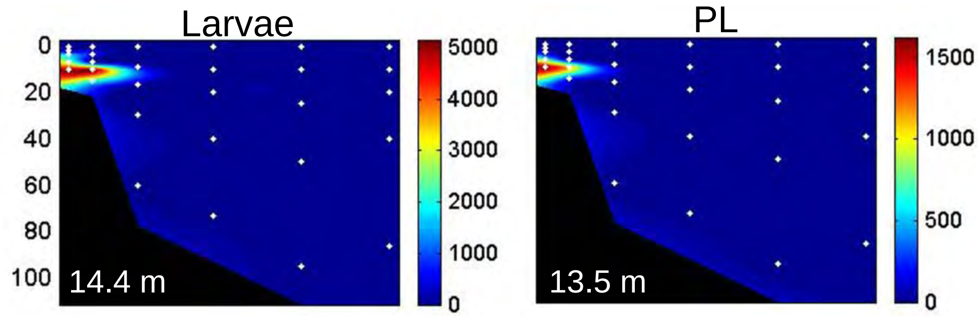
Variable physical forcing during the study period

March - June



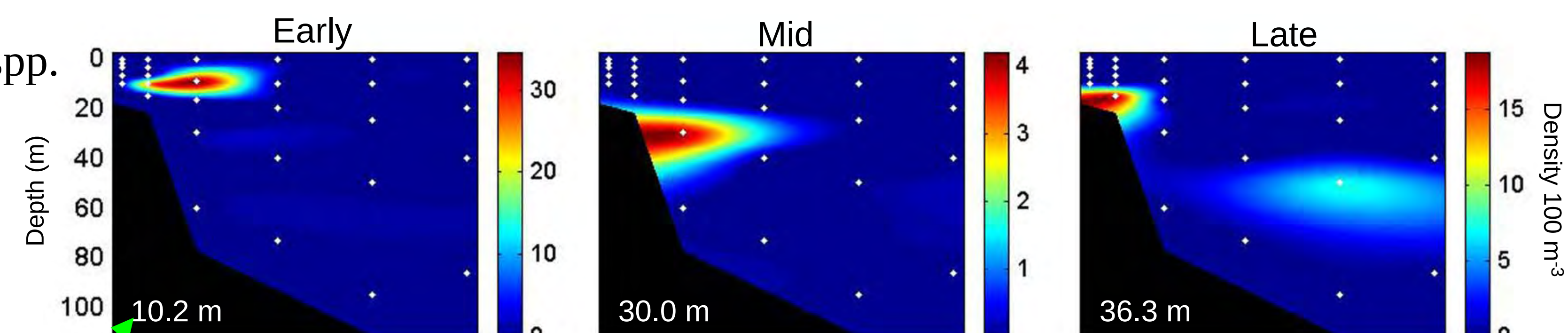
Cross-shelf distributions regulated by ontogenetic depth preferences
Northern California, 2005 - 2006

Nearshore
Barnacles
(3 spp.)



PLD at ca. 10°C = 14 days 4 days Nearshore Source

Mid-shelf
Pagurus spp.
(3 spp.)



Depth Center of Mass

2 stages~20 days 2 stages~20 days 1 stage~10 days

Nearshore to Mid-shelf Source

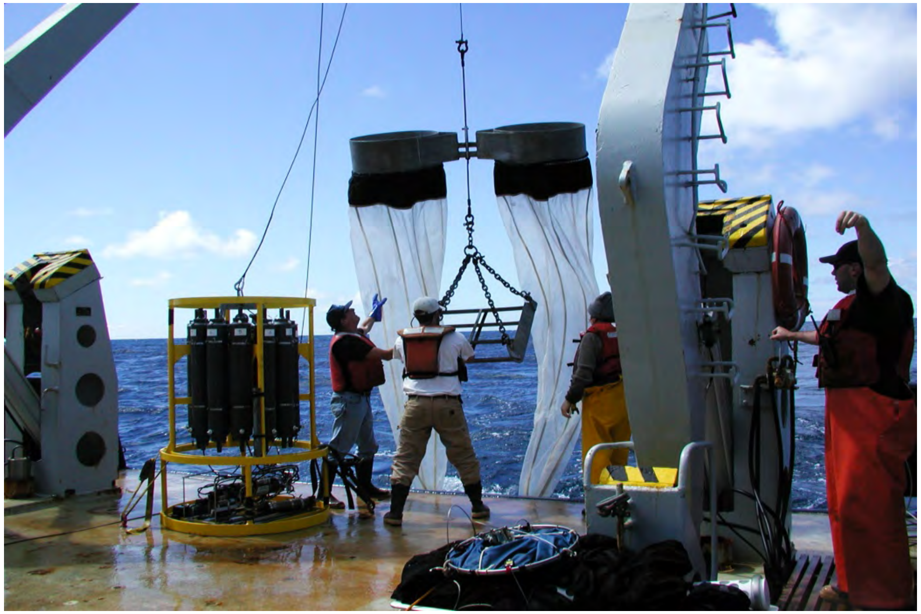
Morgan, Fisher et al. 2009 Ecology

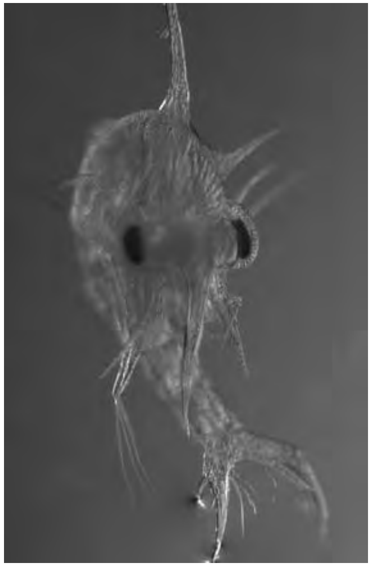
Life history characteristics of the focal study species

Taxa	No. larval stages	PLD (days)	Primary release site	Cross-shelf distribution	DVM
Barnacles	6	11 - 21	Sheltered/ exposed	Nearshore	No
Paguridae	5	49 – 90	Exposed	Near – mid-shelf	Yes

Sampling methods Oregon

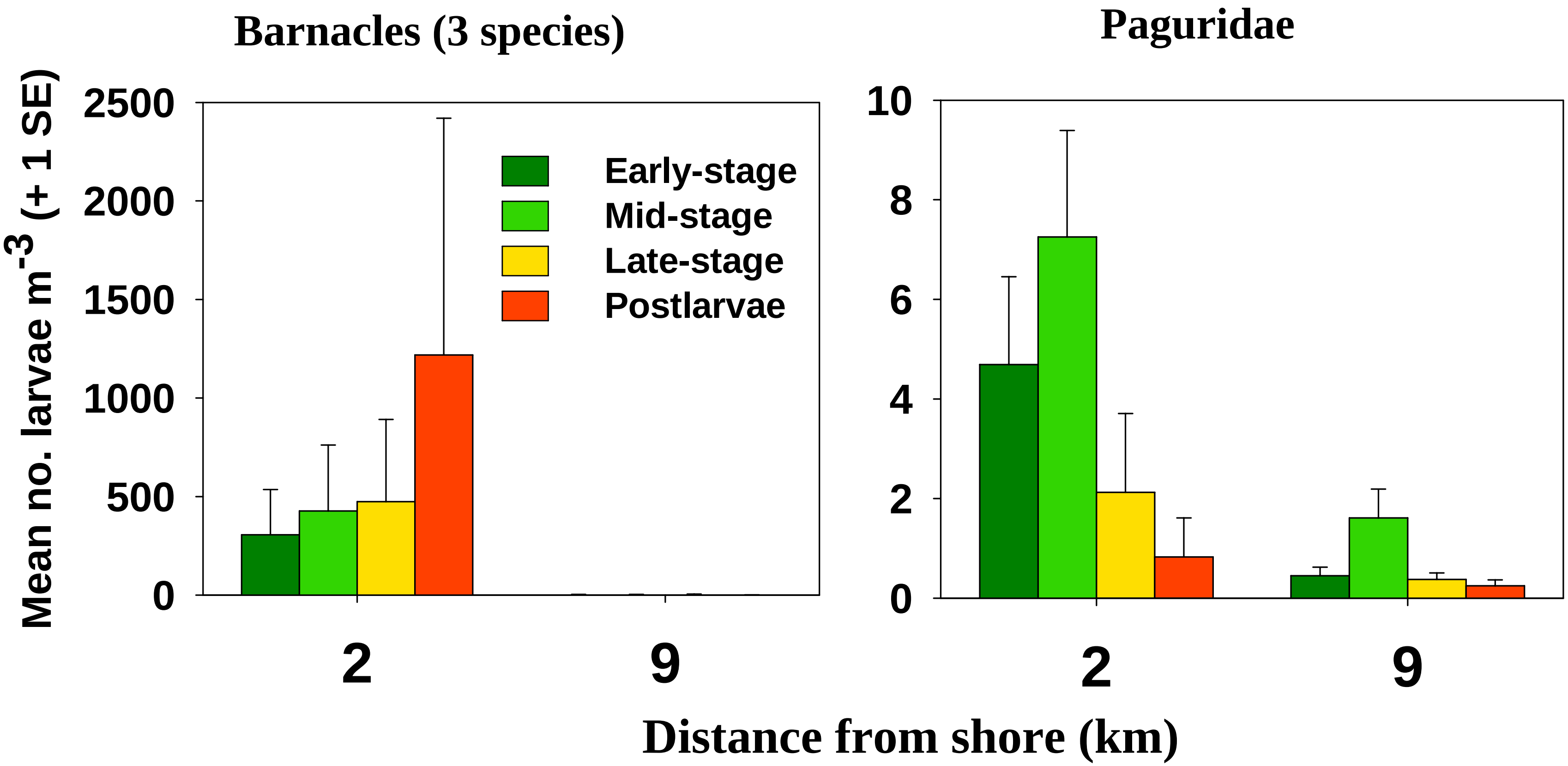
- Collection methods
  - ~Bi-weekly sampling
  - 1 m net 1996 - 2000
  - 60 cm bongo 2001- present
  - Upper 20 m
- Distance offshore (8 yrs)
  - 2 and 9 km stations
  - 7 years 1998 – 2002 & 2009 – 2011
- Time-series
  - 9 km station (NH05)
  - 13 years (1998 – 2011)
- Crustacean (crab & barnacle) larvae
  - March – June samples
  - Grouped species for presentation





***Cancer magister* Zoeae stage I**

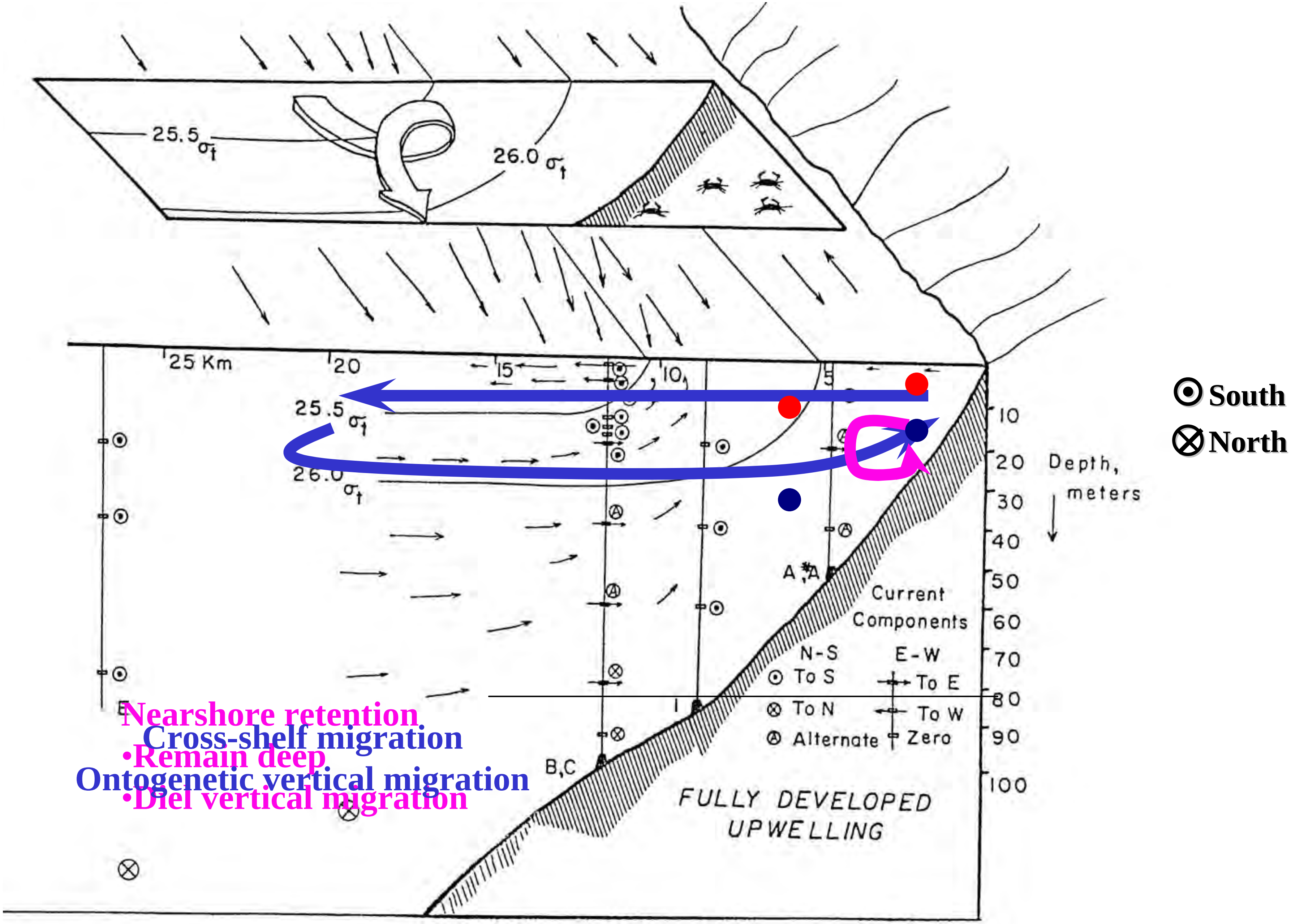
Cross-shelf distributions similar off Oregon



All larval stages occur nearshore

All larval stages occur at both stations

How is differential transport accomplished?



Nearshore retention
•Remain deep
•Diel vertical migration

Cross-shelf migration
Ontogenetic vertical migration

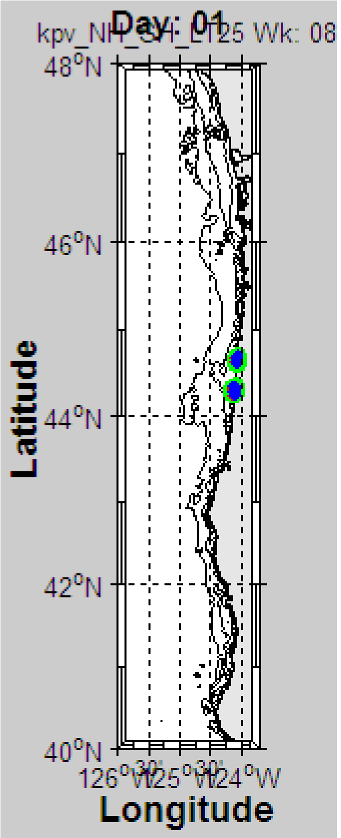
Peterson et al. 1979 Deep-Sea Research

Note: these are animations…

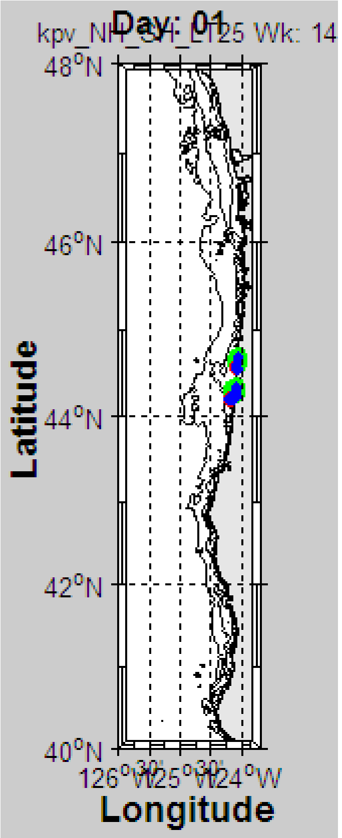
Inner-shelf releases (bottom depths LT 25m) (==barnacles)

Fixed depth trajectories: Red=5m; Blue=15m; Green=Starts

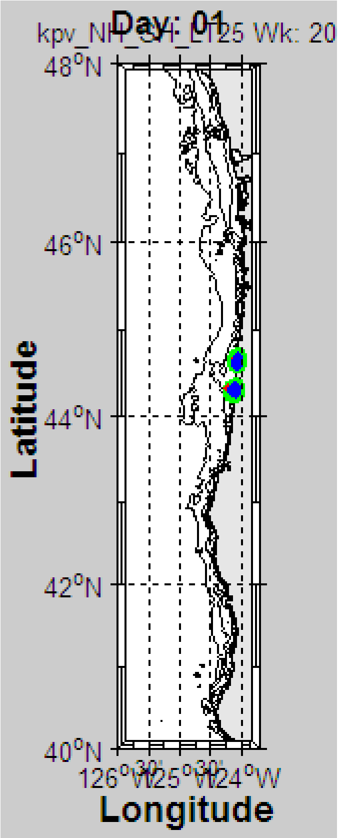
Downwelling (winter) period: Weeks 1-11 (Jan-Mar 2011 starts)

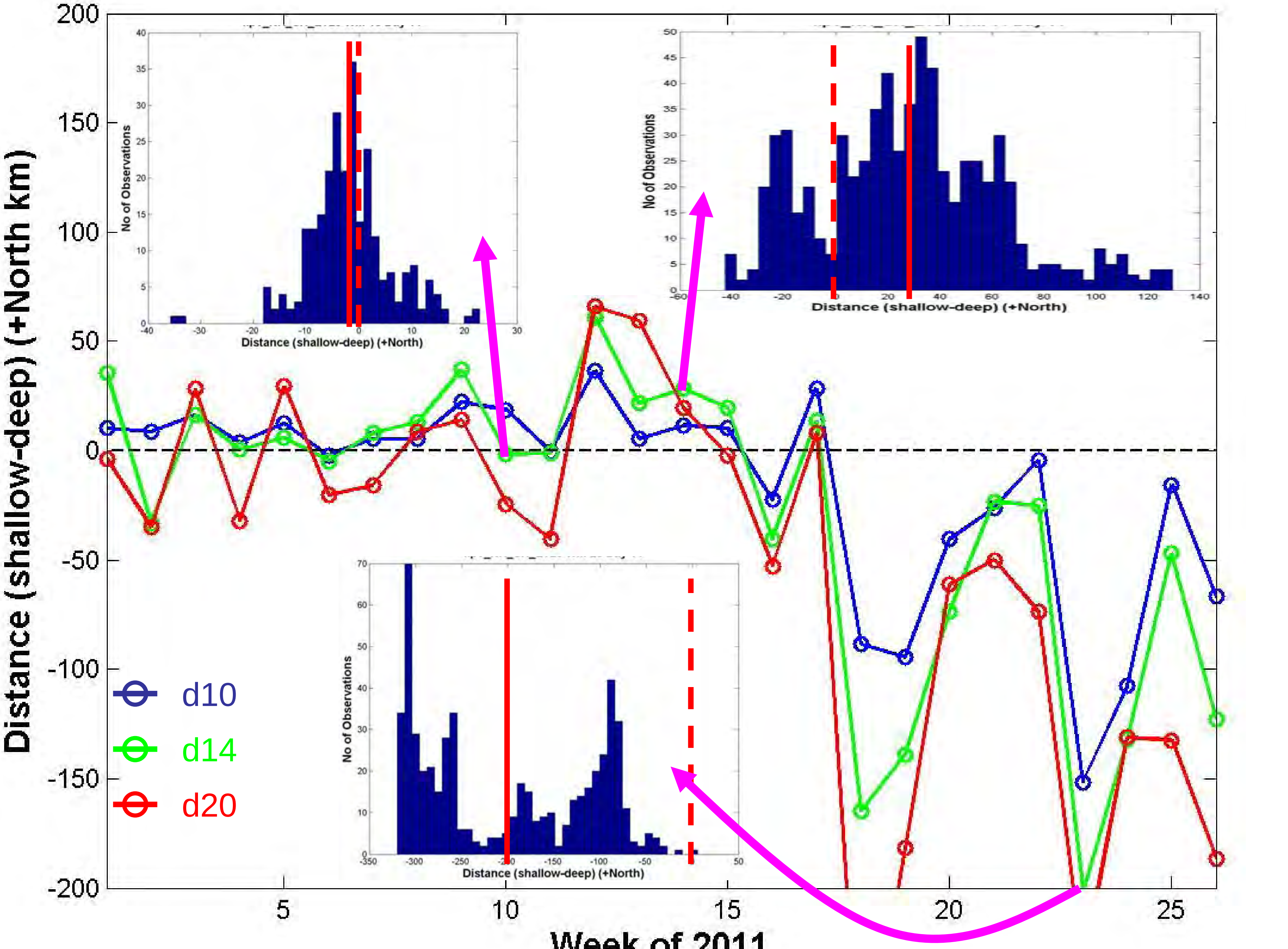


Transition period: Weeks 12-15 (April 2011 starts)



Upwelling period: Weeks 16-26 (May-Jun 2011 starts)





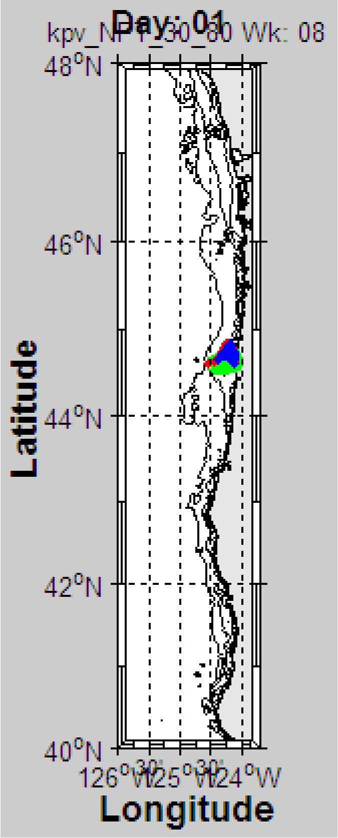
Kpv_NH_SH_LT25 **5m vs. 15m**

Note: these are animations…

Midshelf releases (bottom depths of 30-80m) (==Pagurid crabs)

Fixed depth trajectories: Red=10m; Blue=30m; Green=Starts

Downwelling (winter) period: Weeks 1-11 (Jan-Mar 2011 starts)



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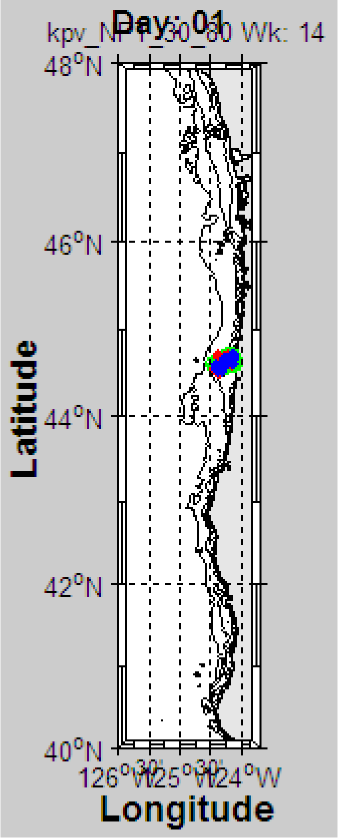

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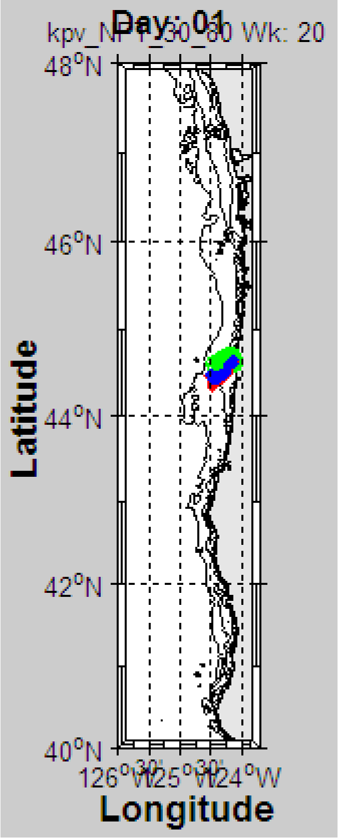

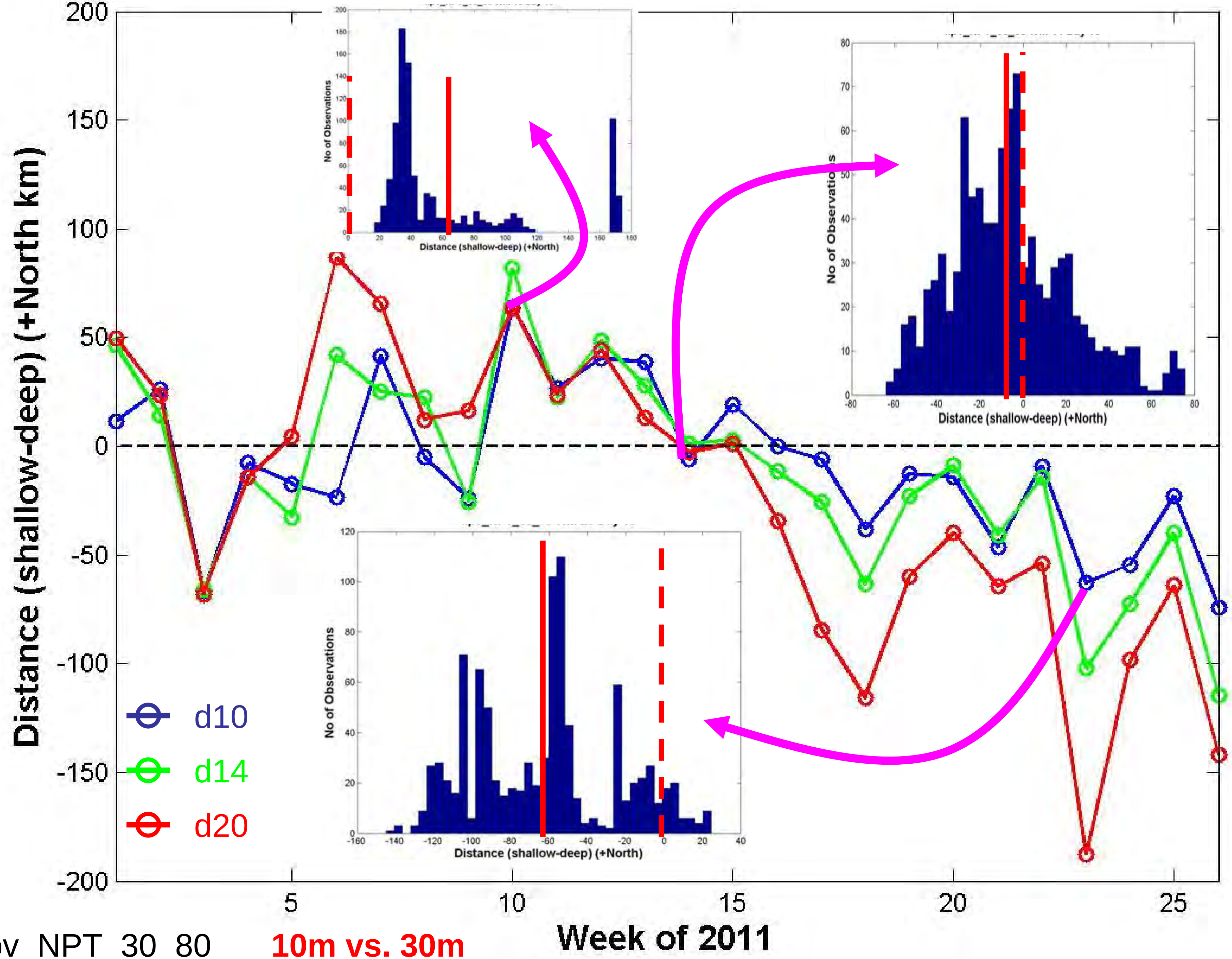

Kpv_NPT_30_80 **10m vs. 30m**

Conclusions (1)

- Connectivity very dependent on season
  - higher in winter downwelling—less offshore loss
- Connectivity among adjacent reserves higher than among distant reserves
- Larger reserves have higher connectivity, and higher potential for self-seeding
- Cape Blanco is a barrier to MR connectivity during upwelling; some MR connectivity exists during winter

Conclusions (2)

- Dispersal distances of nearshore (inshore of 25m isobath):
  - similar for 5m and 15m during downwelling
  - shallower particles advected much further during upwelling (and high loss offshore)
- Dispersal distances of midshelf “species” (between 30 and 80m isobath):
  - transport at 10m much greater than 30m depth during both winter downwelling (to North) and summer upwelling (to South)
  - greater loss offshore (not to nearshore MR) in summer

Directions for Future Work

- full analysis of 2011 results
- attempt to simulate entire pelagic life cycle—difficult for longer PLDs with small model domain
- determine PLDs using temperature dependent functions
- examine other ontogenetic migrations
- examine effect of diel vertical migrations