# Modelled Growth and Development of *Euphausia* pacifica in the Northern California Current

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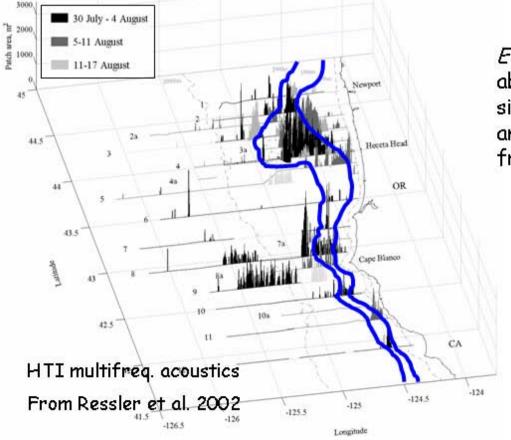


# Approach

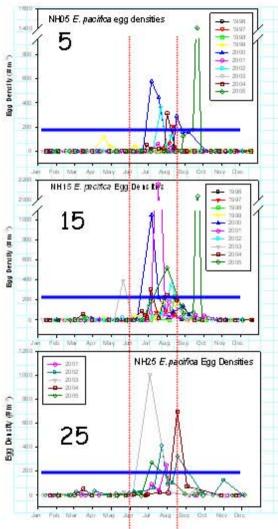
Demonstrative Modeling: Modeling to explore whether a hypothesized mechanism might explain an observation. Mathematical articulation of an

hypothesis.

Adult *E. pacifica* rarely observed nearshore in net or acoustic sampling in the Oregon upwelling system.



E. pacifica egg abundances similar at 5, 15 and 25 miles from shore.



Feinberg and Peterson, unpubl.

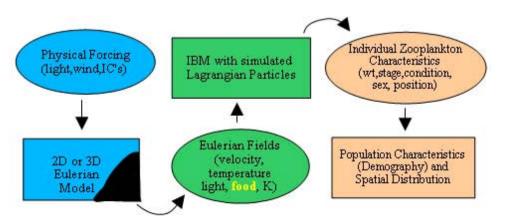
#### The modeling approach

Develop an individual-based bioenergetics model

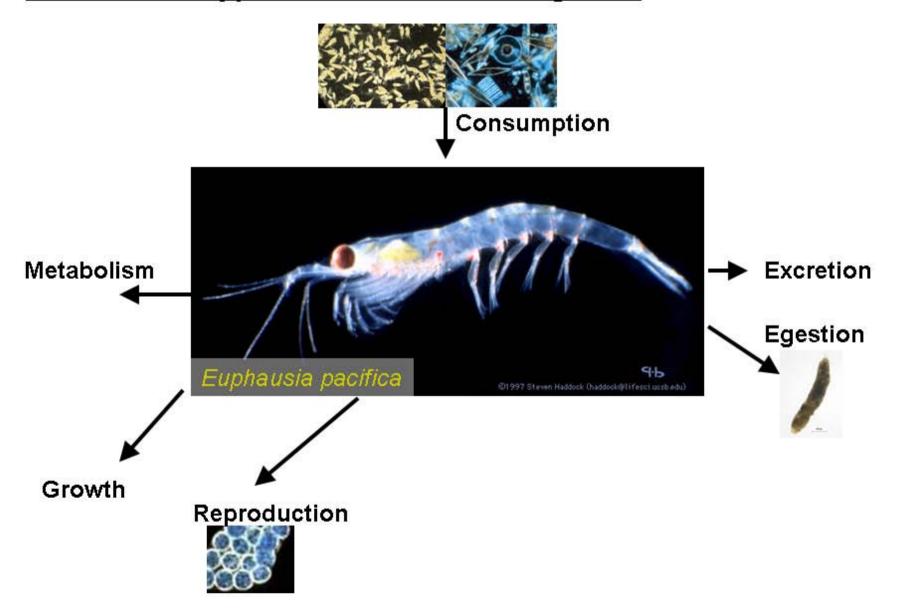
Use particle tracking to couple the IBM with ROMS physical fields (temperature; u-, v-, and w-velocities) and food fields from observations by GLOBEC in 2000 and 2002

Explore the influence of different euphausiid behaviors on retention, growth, and development:

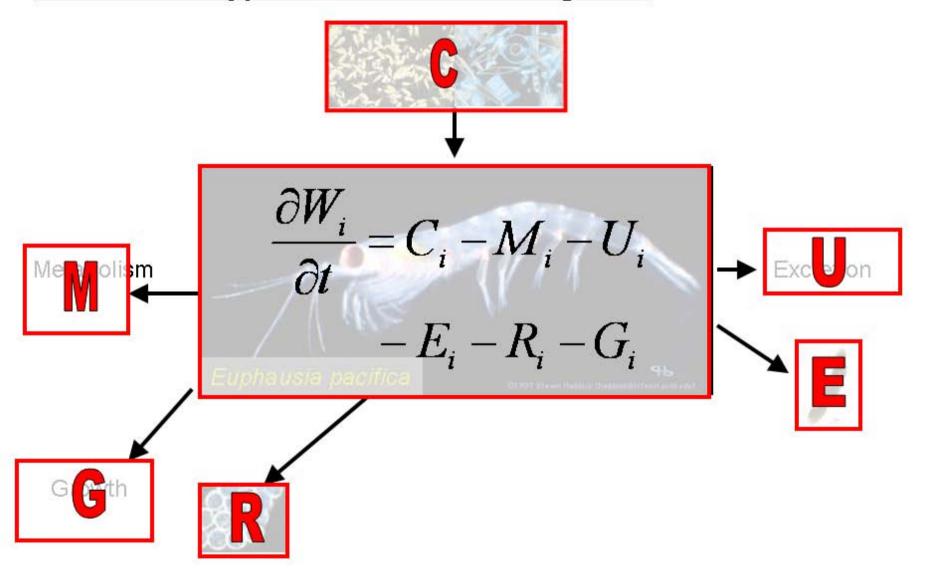
- fixed-depth transport
- passive transport
- ontogenetically-based diel-vertical migration

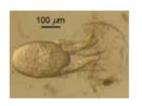


## A Different Type of Model: Bioenergetics



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Nauplius (1 - 2) – oval unsegmented body, no compound eyes, 3 pairs of appendages (which ultimately become the 2 pairs of antennae and 1 pair of mouthparts)



**Metanauplius** – body divided into two parts

Calyptopus (1 – 3) – body clearly divided into cephalothorax and abdomen, which begins to segment; compound eyes begin to form; antennae and mouthpart appendages present; first feeding stage in *E. pacifica* 



Furcilia (1 – 7) – compound eyes developed, antennae still used for swimming, thoracic legs and abdominal pleopods begin to develop



Juvenile – all limbs developed, but not yet full sized or sexually mature; strong swimmers



Adult - reproductively mature

#### **Developing the Bioenergetics Model**

There are some aspects of population dynamics that are poorly constrained. Behavior and mortality rates are examples.

#### We have to rely on:

Parameters found in the literature

Our own lab work (Thank you, Peterson group!)

Field observations

Inferences, educated guesses, and assumptions

#### **Developing the Bioenergetics Model**

#### Stage-specific relationships

- Respiration allometric relationship based on Robin Ross' $R=lpha W^b$ 
  - Includes a basal (fixed) cost component and a variable component related to consumption/activity
- Growth allometric, based on Ross (1982)
  - Depends primarily on <u>food</u>
- Development Stage-based, Belehradek curve
  - Depends primarily on <u>temperature</u>

Start with C1 (first feeding) stage of 3 µg C.

#### **Developing the Bioenergetics Model**

E. pacifica Belehradek function for time to stage as function of temperature

Basic Form is:

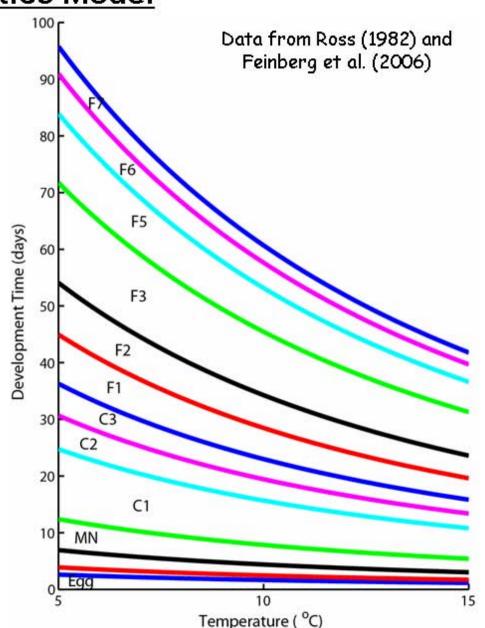
$$D_i = a_i (T + b)^c$$

**D**<sub>i</sub> is the time (days) from egg to stage i

a; is a stage specific constant

**b** is a stage-independent shift in temperature

c is assumed to be -2.05 (commonly observed from experiments; determines the curvature)



# NEP ROMS Implementation

Domain: 20 - 73N, 115 - 210E

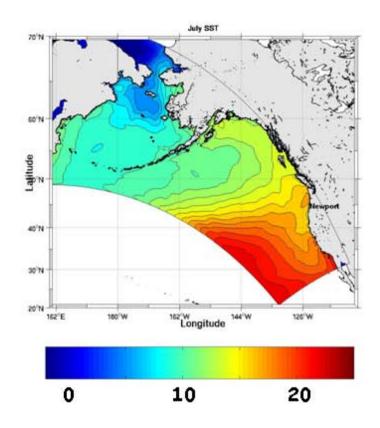
ROMS: 226 × 642 × 42 gridpoints on curvilinear grid (10 km horiz. res.)

Subdaily (6 hr) T42 (2.8°) CORE wind and fluxes (Large and Yeager)

Initial/boundary conditions provided by CCSM-POP hindcast model

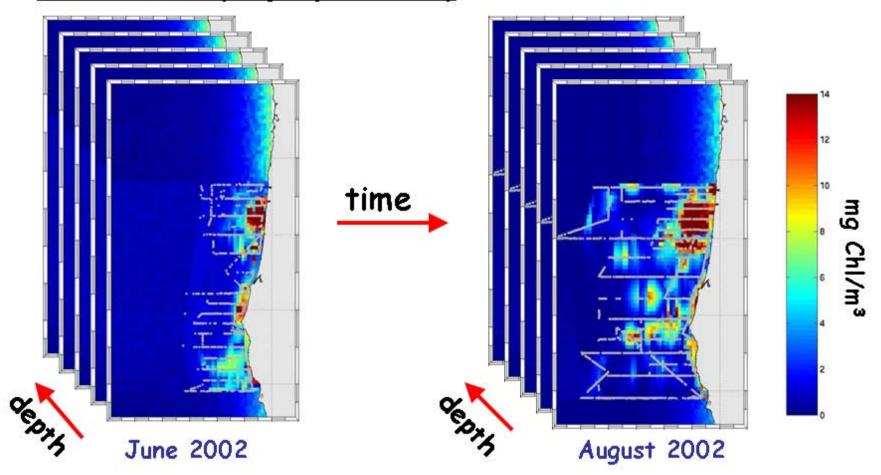
Forward run for 1958-2004—includes multiple El Nino's, Regime Shifts, and 2002 cold intrusion

Product: Daily averaged physical snapshots of velocity, temperature, etc.



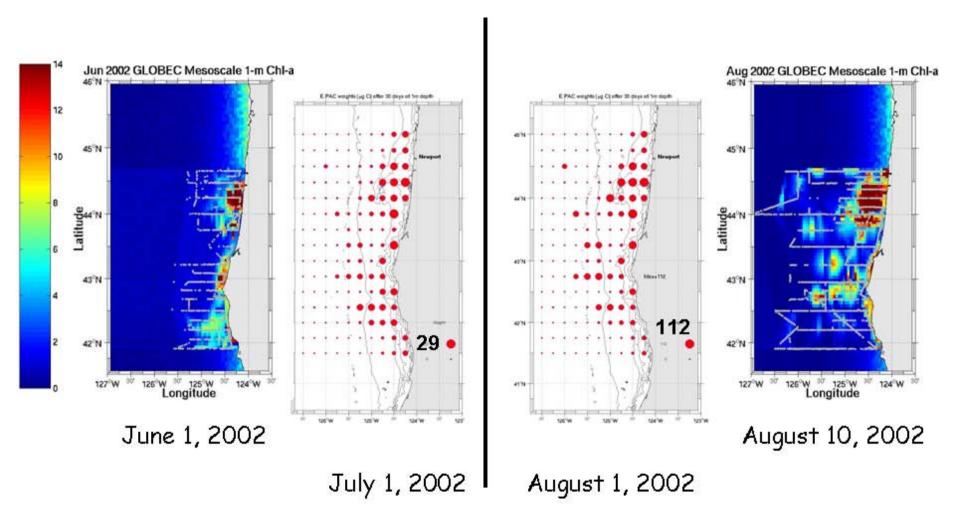
Authors thank Kate Hedstrom (UAF) for providing these model fields.

### Food fields (Phytoplankton)



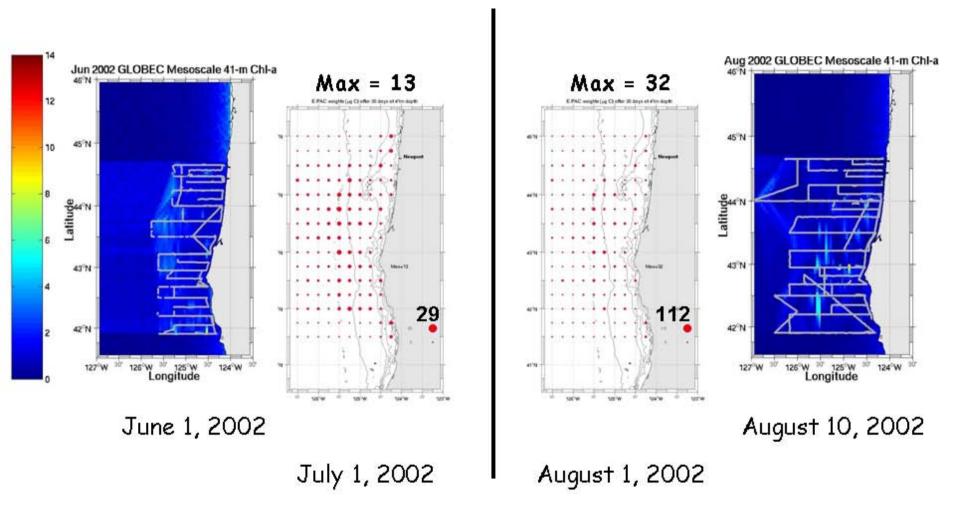
SEASOAR (chlorophyll) observations from US GLOBEC Cruises

## Fixed Location - Growth (No Advection)



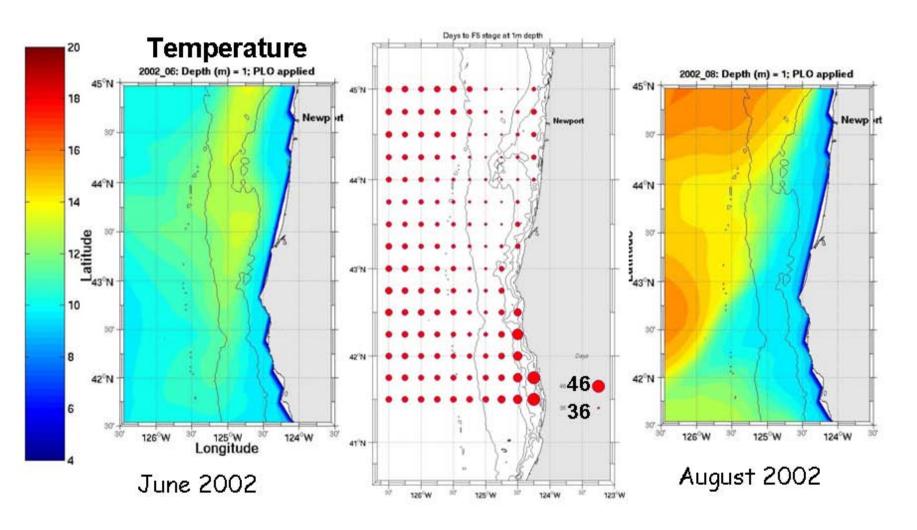
1-m Depth - Individual weight (µg C)

## Fixed Location - Growth (No Advection)



41-m Depth - Individual weight (µg C)

#### <u>Fixed Location – Development (No Advection)</u>

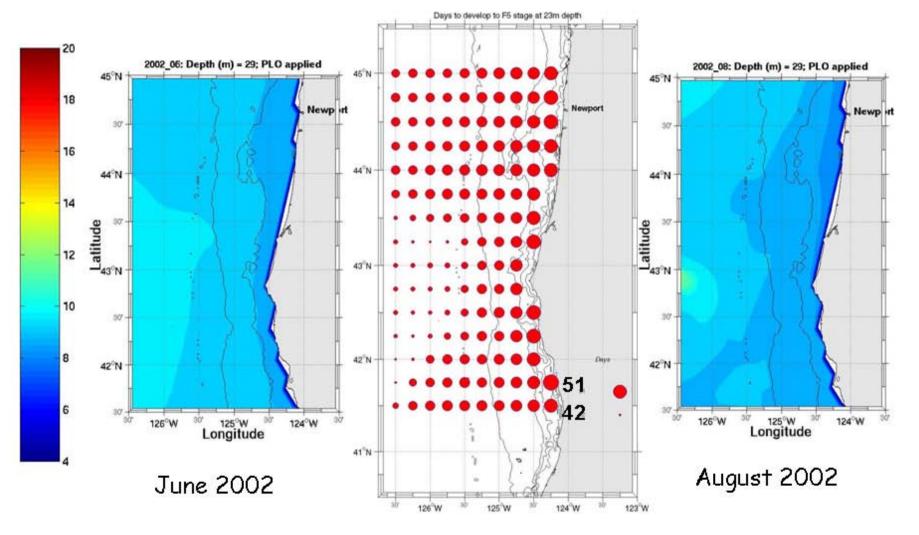


1-m Depth

Mid-July 2002

Days required to develop:  $C1 \rightarrow C2 \rightarrow C3 \rightarrow F1 \rightarrow ... \rightarrow F5$ 

#### <u>Fixed Location – Development (No Advection)</u>

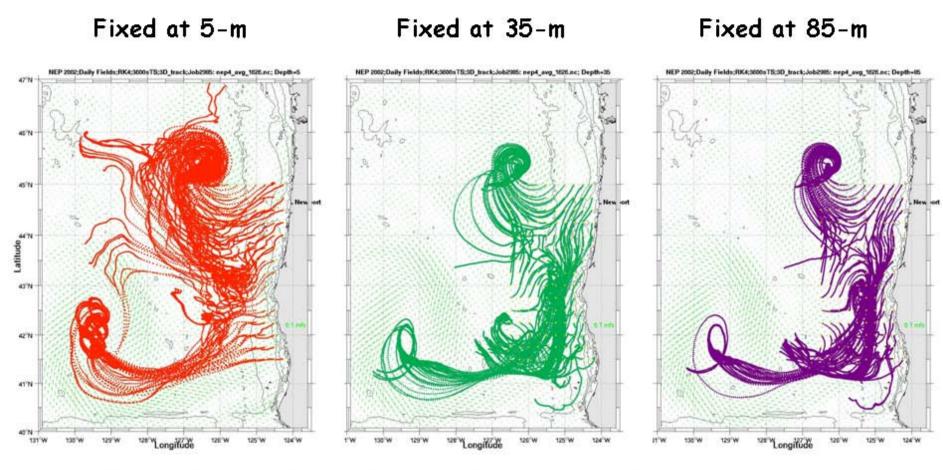


23-m Depth

Mid-July 2002

Days required to develop:  $C1 \rightarrow C2 \rightarrow C3 \rightarrow F1 \rightarrow ... \rightarrow F5$ 

#### Fixed Depth - Horizontal Advection

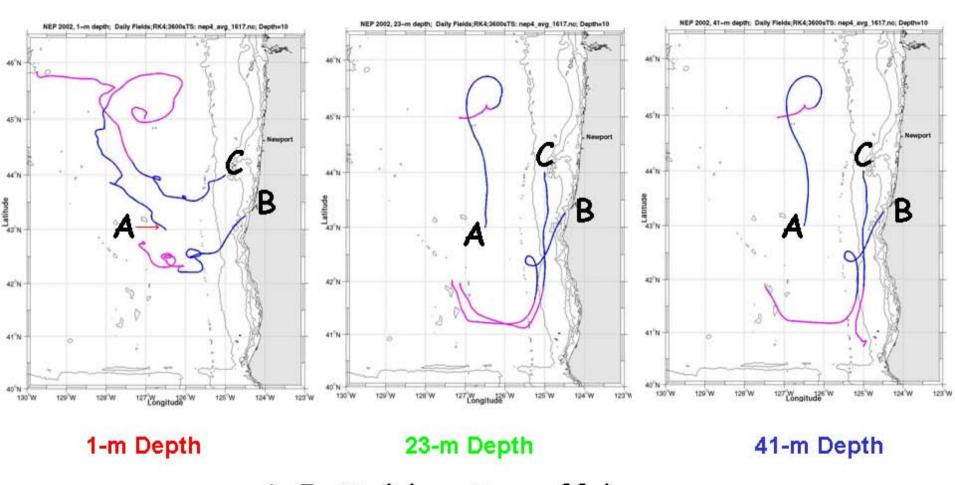


5-m: all particles moved offshore rapidly

35-m and 85-m: less offshore movement; some recirculation; more southward transport;

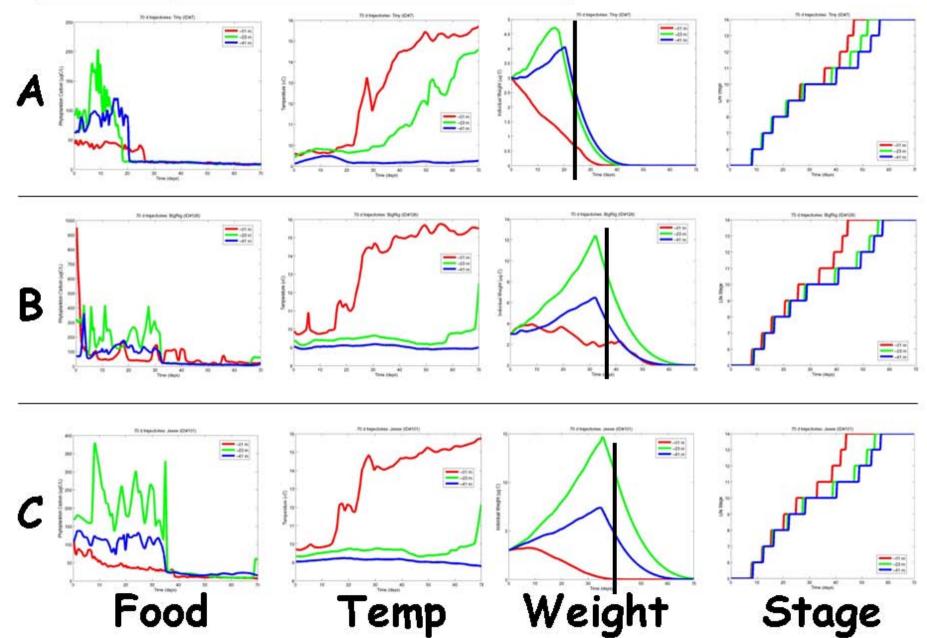
ALL: two off-shelf eddies draw particles off shelf; once entrained in eddy, retained there.

#### Fixed Depth - Horizontal Advection

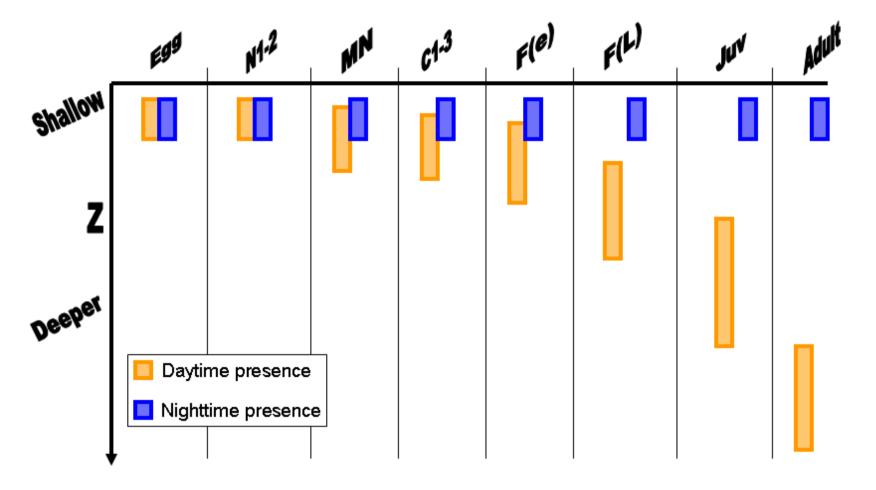


A-Initial location offshore B-Very Nearshore C-Just offshore of Heceta Bank

## Fixed Depth - Horizontal Advection



#### Euphausia pacifica off the Oregon Coast

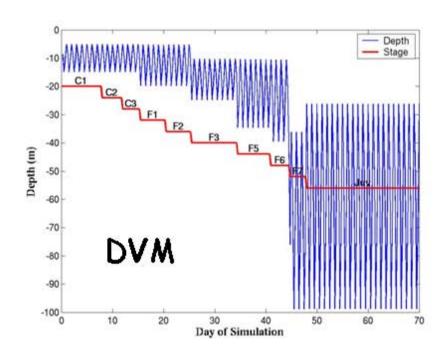


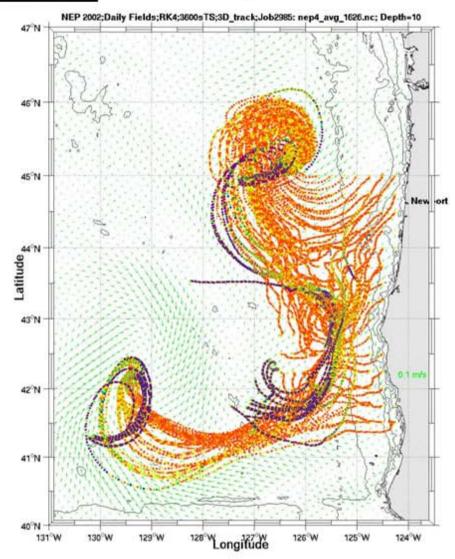
Stage-based differences in vertical migration extent (schematic based on Vance et al, 2002)

## Advection + Stage Dependent DVM

#### 70-d trajectories

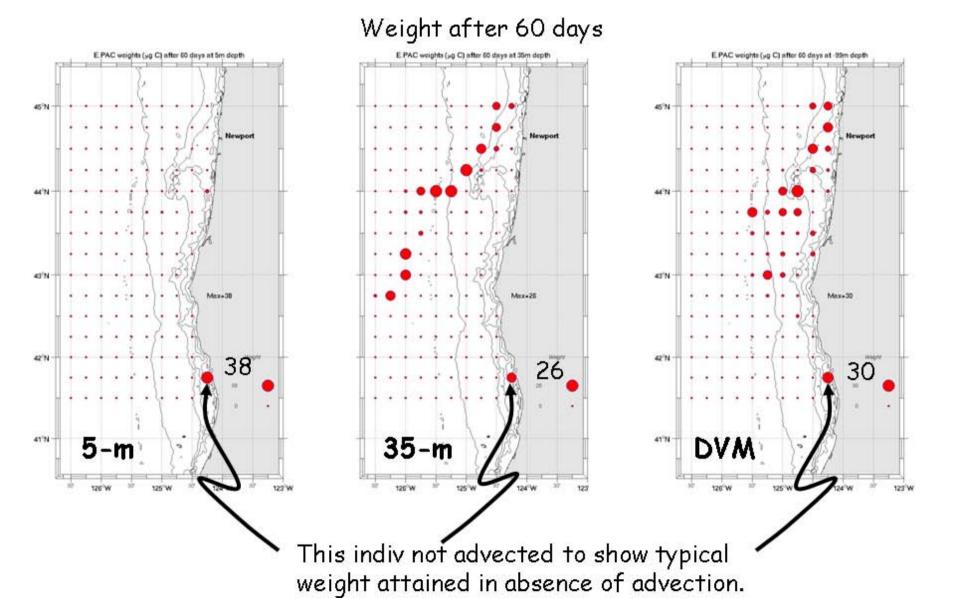
Trajectories not that different from trajectories obtained with fixed 35-m depth.





Orange-yellow near surface; blues/purples near 100 m.

#### Horiz. Advect only or Advection + Stage Dependent DVM



#### Our results so far...

- It is hard to get eggs onto the shelf without also having the females on the shelf. Egg development times are ca. 3 days at temperatures common to Oregon shelf. Possible explanations or contributing factors are:
- The NEP model is not high enough resolution to adequately represent upwelling, the upwelling jet, and the opposed onshore-offshore flows.
- 2. The eggs are deeper than we think. Eggs in the surface layer are difficult to transport toward shore, except during brief wind relaxations. Eggs layed at depths of 100-150m near the shelf break could be moved onshore during upwelling periods. - Not likely!
- We have ignored diffusive transports. Diffusion is important to retention of nearshore meroplankton (Batchelder, 2006).

The very <u>weak coupling of growth and development</u>, without considering mortality, leads to <u>rapid development even when growth is poor</u> (or negative). We have not yet considered the plasticity of larval development in euphausiids (Feinberg et al. 2006; others). Nor have we included data on non-chl prey. Future modeling will include OPC observations, diffusion, and higher (3 km) resolution model products. We will also use BITT modeling to examine sources, rather than destinations of individuals.

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K. Hedstrom for model products.

The many authors of published *E. pacifica* papers.



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