

Copepod modeling for fun & profit



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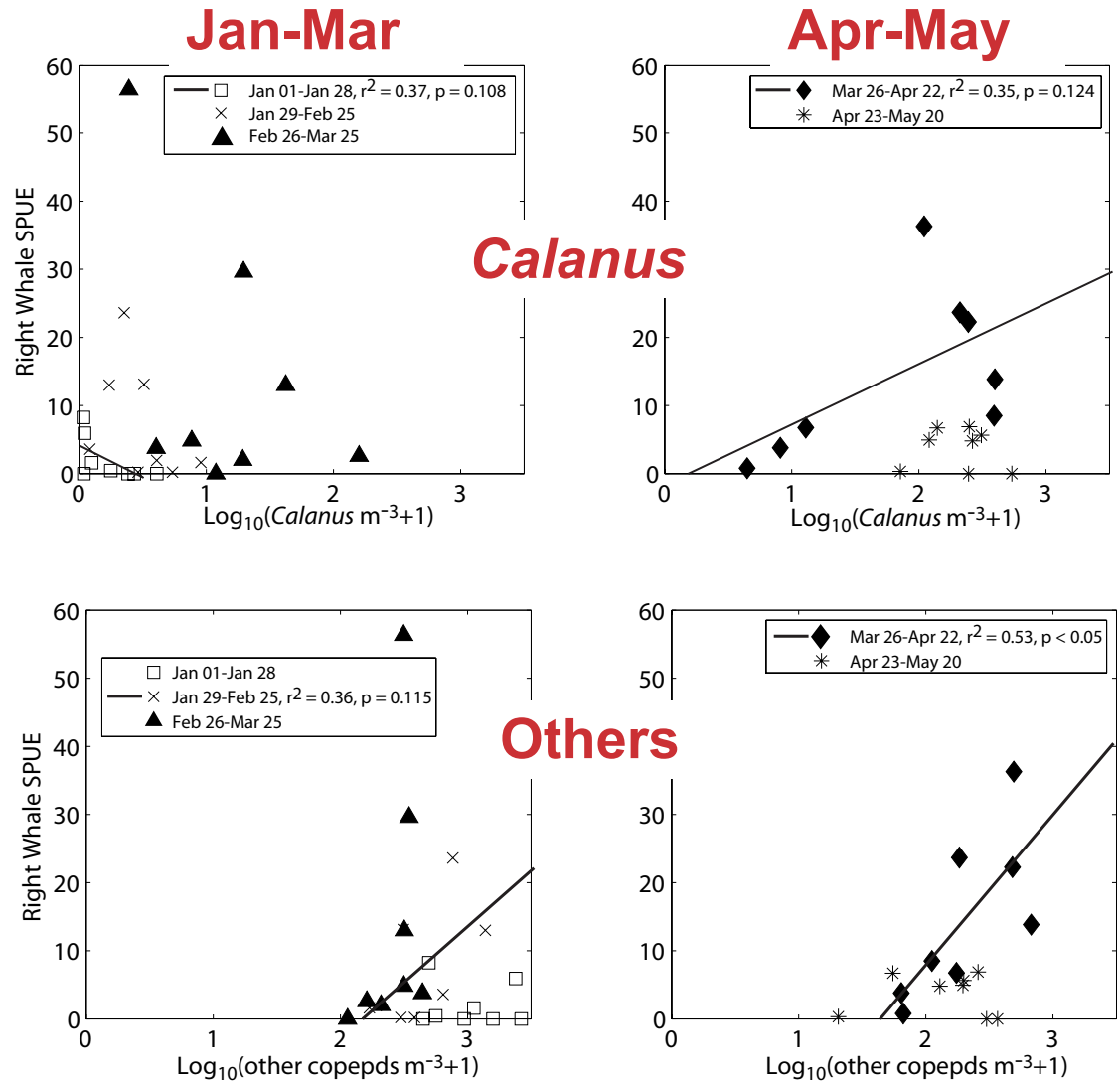
Right whale, wrong time?

- Threats to population
 - Ship strikes
 - Fishing gear
- All management options depend on knowing where whales are



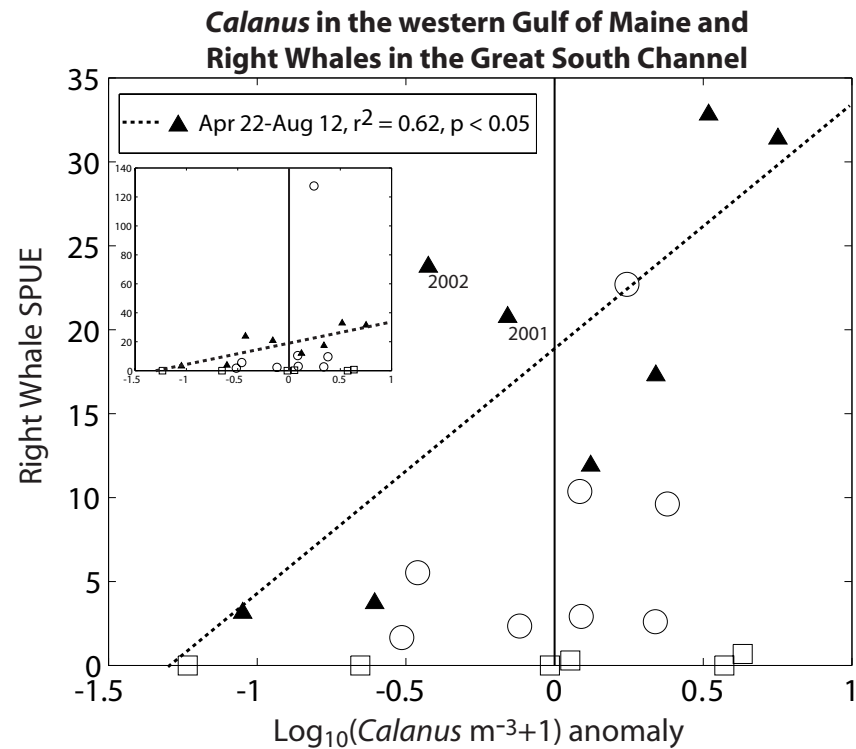
Story II: Whales follow food

- On the habitat scale, whales follow food
 - CCB:
 - Othe copepods early
 - *Calanus* briefly
 - Costa et al. (2006)
 - Pendleton et al. (2009)



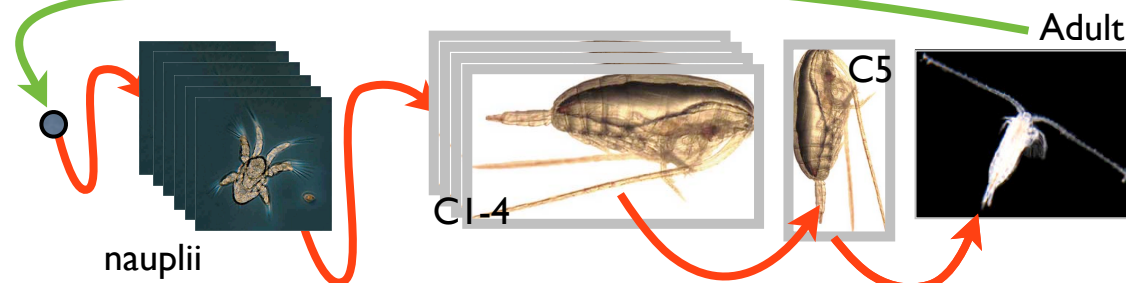
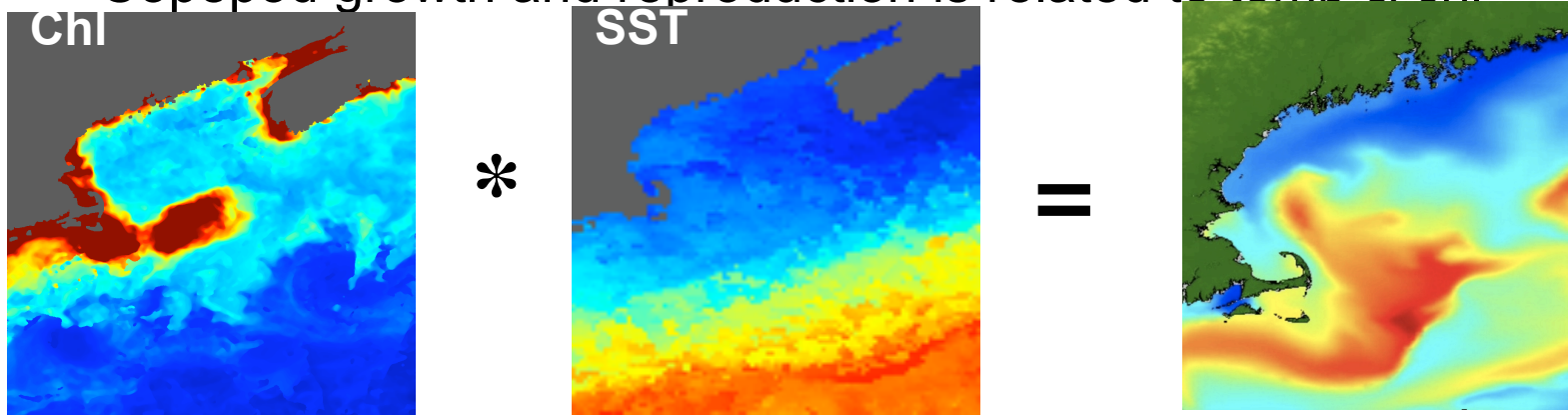
Story II: Whales follow food

- On the habitat scale, whales follow food
 - GSC:
 - Spring *Calanus*
 - Pendleton et al. (2009)



RWPS 1.0

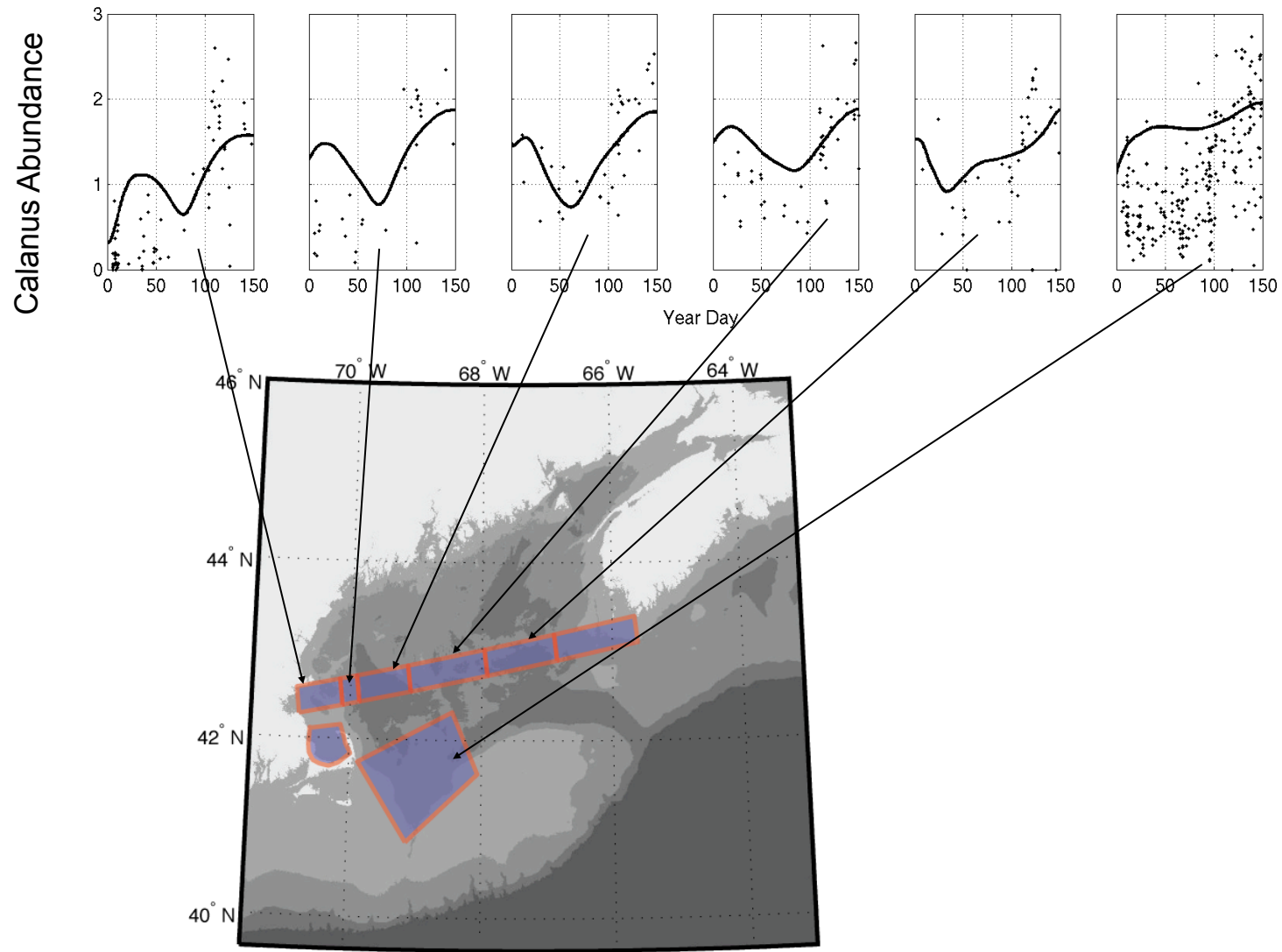
- **SEASCAPE**=**S**atellite-based **E**stimates and **A**nalysis of **S**tage-resolved **C**opepod **A**bundance in **P**elagic **E**cosystems
 - Satellites can measure temperature and chlorophyll from space
 - Copepod growth and reproduction is related to temp & chl



SEASCAPE

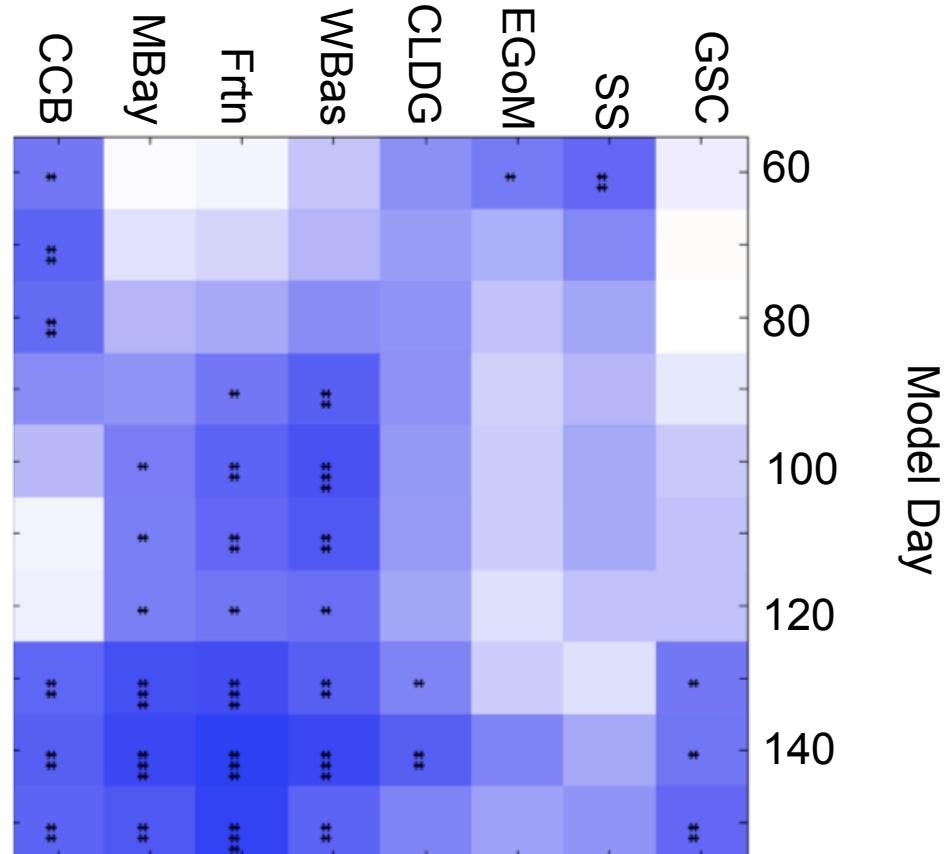
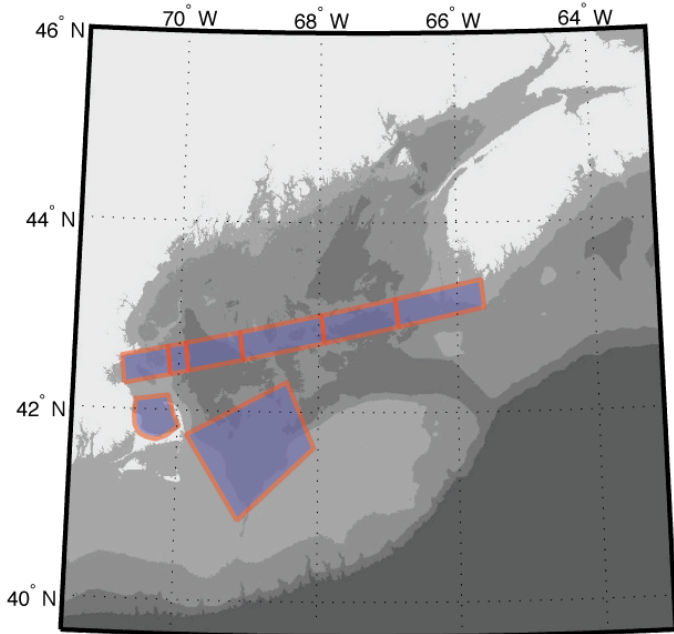
- Designed for operations, parameter estimation, assimilation
- Dynamics
 - Campbell development--f(SST)
 - Runge, Durbin EPR--f(Chl)
 - Speirs mortality--f(SST, Chl, Calanus)
- Key simplifications
 - 2D vertically integrated
 - top 20m
 - spring only
 - no DVM
 - no diapause

Developing the Model



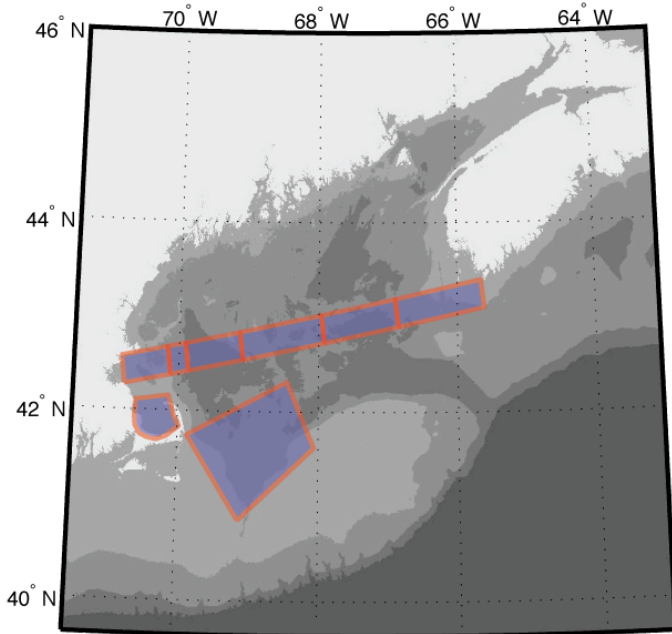
Predicting Whales from *Calanus*

Whale Arrival Date

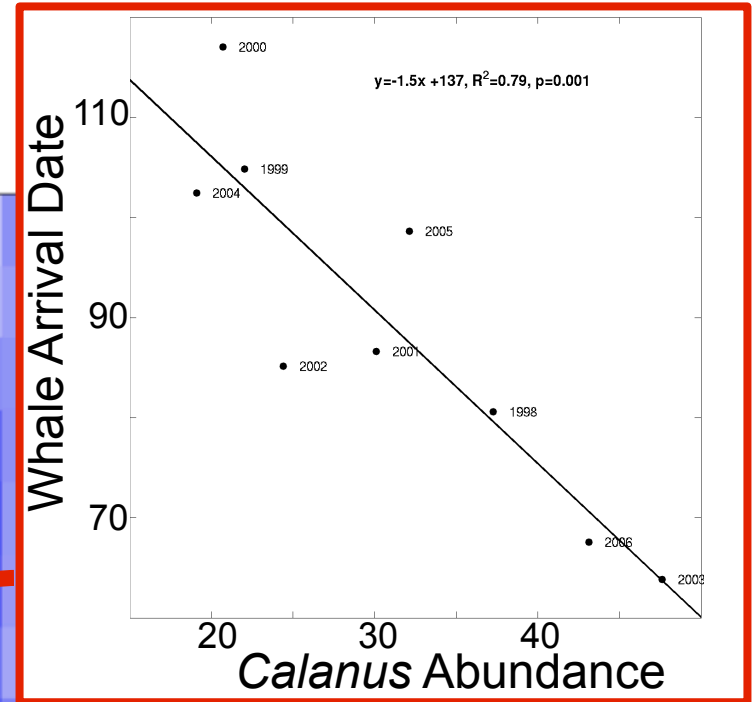
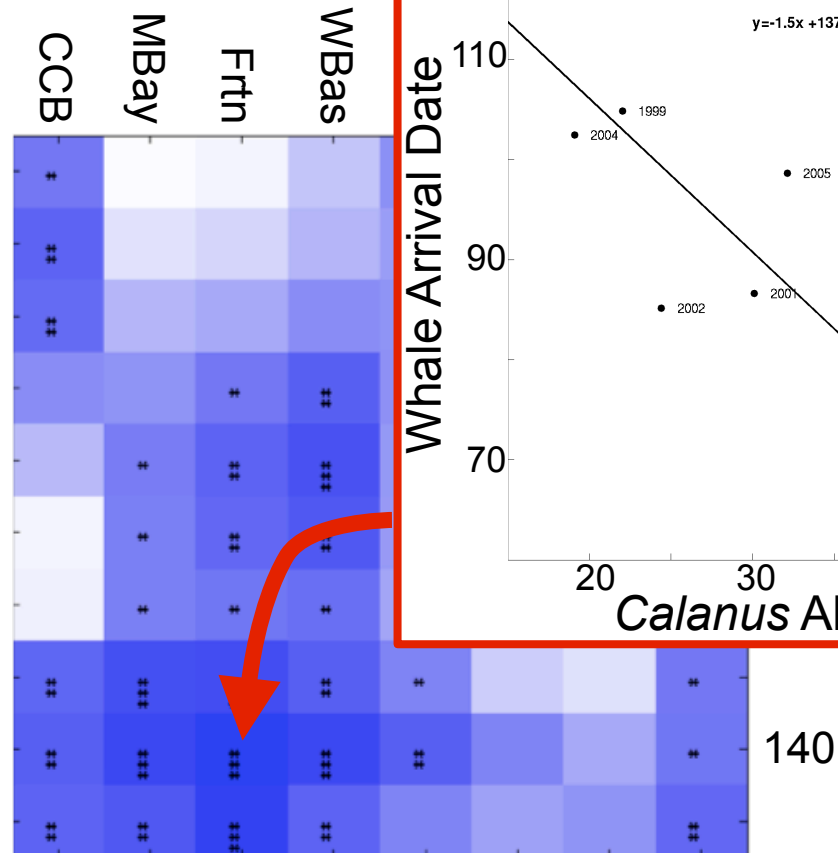


Predicting Whales from *Calanus*

Whale Arrival Date



Whales arrive early when food is abundant



RWPS 2.0

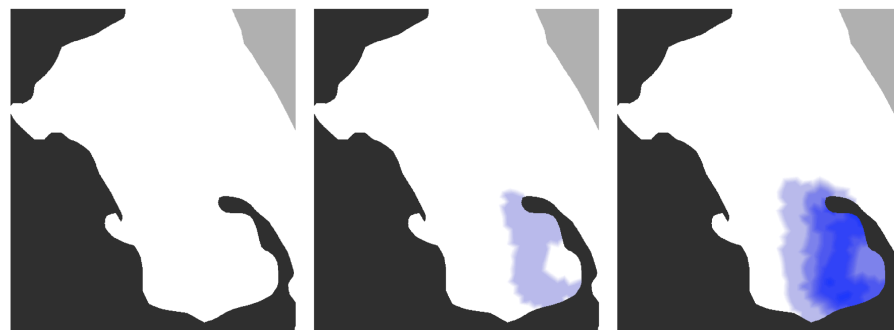
- 2009 focus on Mass Bay
 - *Pseudocalanus*, *Centropages*, *Calanus*
 - assimilating PCCS surveys using ensemble Kalman filter
 - available at seascapemodeling.org



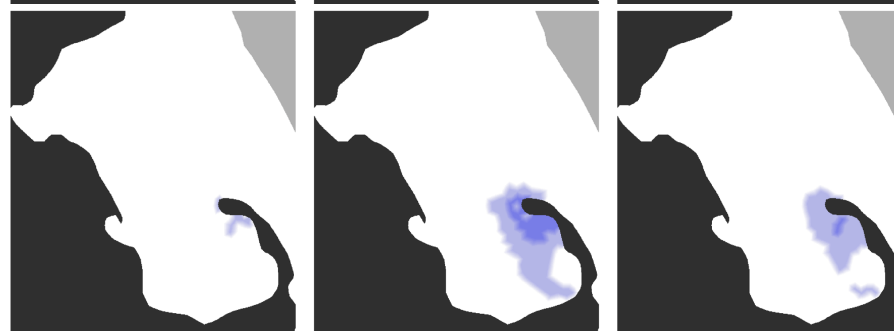
Pseudocalanus

No assimilation January cruises Jan-Feb cruises

2/25/09



3/6/09



>> %%%%%%%%%%% Parameterizing models %%%%%%%%%%%
>>
>> Some parameters are well studied and/or static
>>
>> . temperature/stage-dependent development rates
>> . stage-based weights
>> . number of stages
>> . maximum egg production rate
>> . critical temperature for mortality
>>
>>
>> Others are not well known or dynamic
>>
>> . temperature-dependent mortality
>> . exponent for temperature-dependent mortality
>> . density dependent mortality
>> . starvation threshold
>> . maximum food-dependent mortality
>> . maximum egg production rate
>> . egg baseline mortality
>> . naupliar baseline mortality
>> . copepodid baseline mortality
>> . adult baseline mortality
>> . sex ratio
>> . cannibalism rate
>>
>>

>> %%%%%%%%%%% Parameterizing models %%%%%%%%%%%

>>

>>

>>

>> what does a good fit to data mean?

>>

>> Does a good fit to data mean that the parameter values
>> represent something in reality? ...or are in some way
>> correct?

>>

>>

>>

>> also...

>>

>> How do we achieve a good fit to data?

>>

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>> %%%%%%%%%%% Genetic Algorithm %%%%%%%%%%%

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>>

>> A directed random search technique
>> used in computing and inspired by
>> processes in evolutionary biology.

>>

>> Formalized/popularized by John Holland -->

>>

>>

>>

>> 1) A tool for parameterizing (“tuning”) a model
>> lots of parameters.

>>

>> 2) A tool for evaluating the truthiness of a model that
>> fits data well.

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>> %%%%%%%%%% Genetic Algorithm %%%%%%%%%%

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>> STEP 1: Start with a population of "chromosomes"

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>>

>> [001101101...]

>> [100101010...]

>> [010010101...]

>> [100010111...]

>>

>> ...

>>

>> [111010101...]

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>> (each one is a different parameterization)

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>> %%%%%%%%%%% Genetic Algorithm %%%%%%%%%%%

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>> STEP 2: Evaluate each one by fitting to data

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>>

>> [001101101...]

>> [100101010...]

>> [010010101...]

>> [100010111...]

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>> ...

>> [111010101...]

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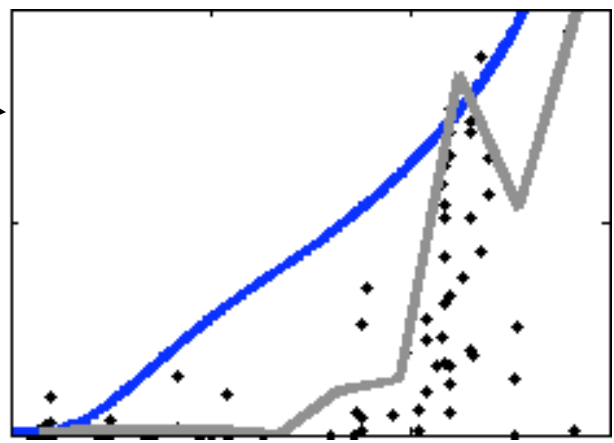
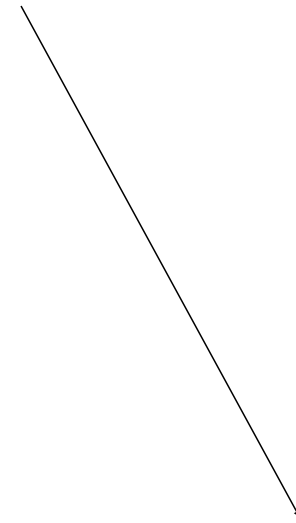
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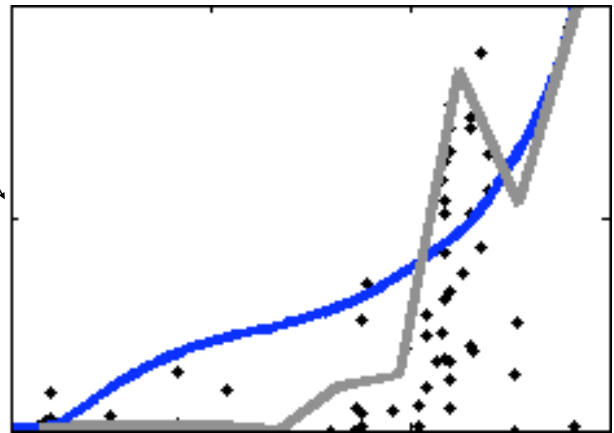
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Not very good



Somewhat good

>> %%%%%%%%%%% Genetic Algorithm %%%%%%%%%%%

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>> STEP 3: Resort the population, ranking by fitness

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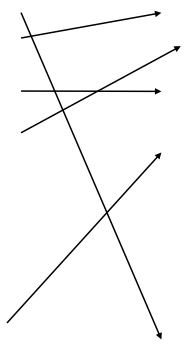
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[001101101...]
[100101010...]
[010010101...]
[100010111...]
...
[111010101...]



[100101010...]
[100010111...]
[010010101...]
[111010101...]
[001101101...]

>> %%%%%%%%%%% Genetic Algorithm %%%%%%%%%%%

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>> STEP 4: Make a new generation, using the best chromosomes

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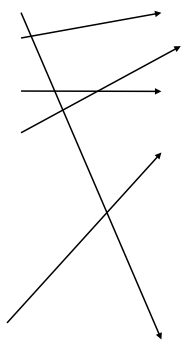
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>>

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>>

[001101101...]
[100101010...]
[010010101...]
[100010111...]
...
[111010101...]



[100101010...]
[100010111...]
[010010101...]
[111010101...]
...
[001101101...]

combination & mutation

New generation

[001001101...]
[001001001...]
[011001101...]
[100001010...]
[100001011...]
[101001010...]
[010010111...]
[010000111...]
[110010111...]
...

>> %%%%%%%%%% Genetic Algorithm %%%%%%%%%%

>>

>>

>> The genetic algorithm gives us “solutions” to the
>> problem of fitting a model to data.

>>

>> Questions:

>>

>> 1) what information is important for finding a solution?

>>

>> -> 2) How unique is a solution?

>>

>> -> 3) what are the consequences of multiple solutions?

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>> 4) How effective is this tuning method for our goal
>> of an operational, ecosystem-forecasting model?

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>> %%%%%%%%%%% Twin Experiments %%%%%%%%%%%

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>> Results

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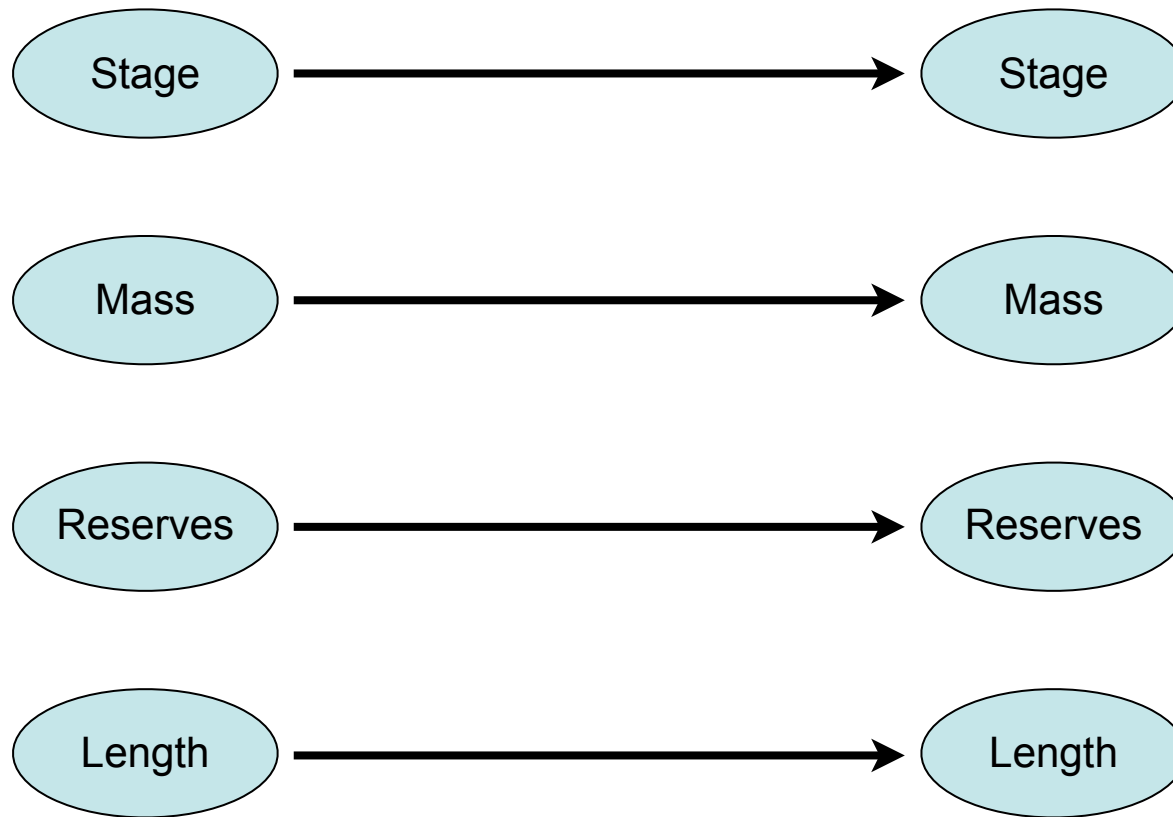
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- 1) Some parameters are inflexible
 - probably have some basis in reality
 - => fitting to data can inform us about these
- 2) Some parameters are highly flexible
 - tuning of these is fairly subjective
 - there are tuning trade-offs
- 3) A false parameterization can be useful
 - forecasting over limited durations

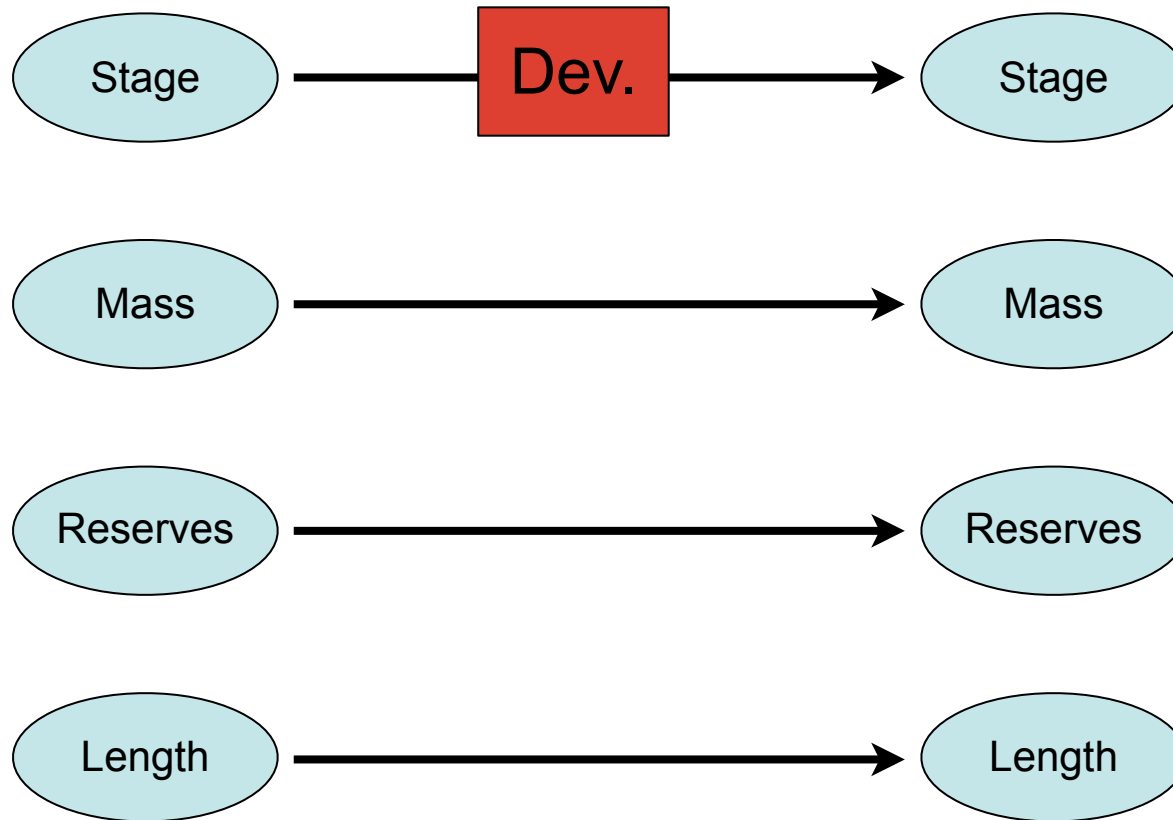
Generic Copepod Model

- Is there a simple model (= few parameters) that can simulate a wide range of copepod species?
- Focus on relationships between size, temperature, growth

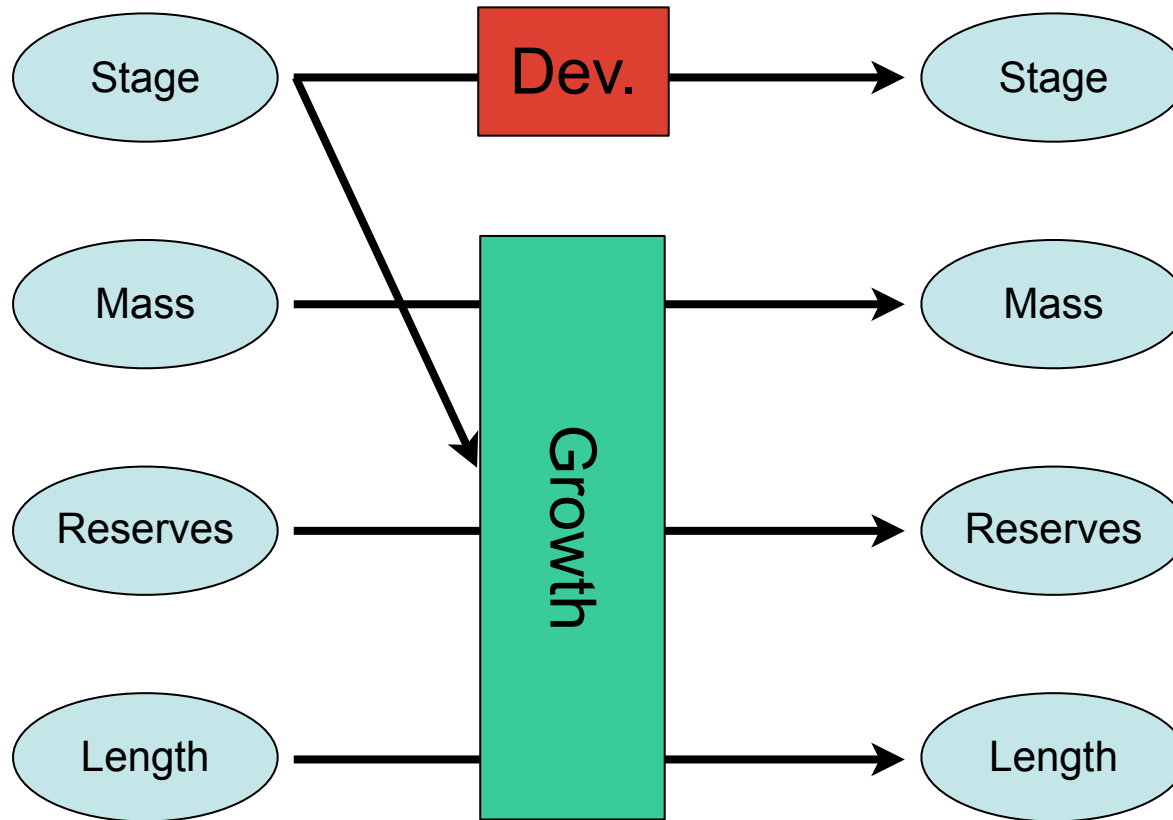
Generic copepod



Generic copepod



Generic copepod



Generic copepod

