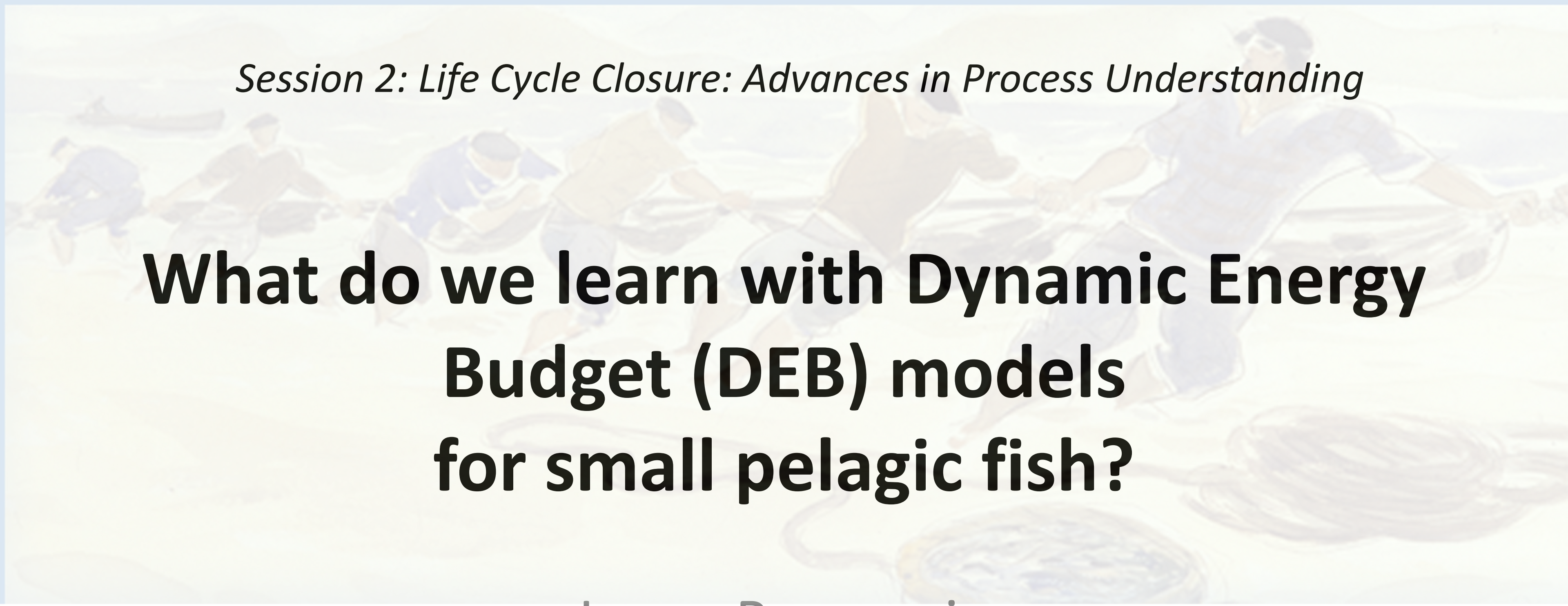


Session 2: Life Cycle Closure: Advances in Process Understanding

What do we learn with Dynamic Energy Budget (DEB) models for small pelagic fish?

Laure Pecquerie
IRD/LEMAR, IUEM, Brest, France

Many thanks to: C. Bacher, T. Brochier, L. de Cubber, J. Flores, P. Gatti, G. Groenewald, M. Huret, B. Kooijman, E. Le Moan, G. Marques, C. Menu, O. Maury, C. Nunes, H. Pethybridge, P. Petitgas, L. Thellier, T. Sousa

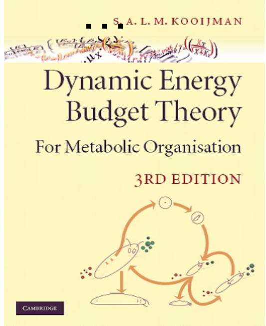
French National Research Institute for Sustainable Development
IRD
Institut de Recherche pour le Développement
FRANCE

LEMAR
laboratoire des sciences de l'environnement marin
UBO | CNRS | IRD | Ifremer

SPF – Nov. 7th 2022, Lisbon, Portugal

A bit of context

- B. Kooijman started developing Dynamic Energy Budget (DEB) theory in 1979 in an **ecotoxicological context**:
  - Effect of a toxicant on metabolic processes such as development, growth and reproduction?
  - Will a small reduction on the reproduction rate of Daphnia have an impact at the population level
- Which led him to develop a **theory for metabolic organization**, based on first principles, that applies to **all living organisms**
- **Large domain** of **disciplines** and **applications**
  → +1000 publications on the Zotero DEB Library



https://www.zotero.org/groups/500643/deb_library

A bit of context

- **OECD revision guidelines (2016)**: Use of mechanistic modelling to **extrapolate** to
  - different **scenarios** (exposure concentrations, pulses, env. conditions)
  - different **species**
  - **higher levels of organization** (population, communities, ecosystems)

- **EFSA Scientific opinion (2018)** recognized the “ great potential [of the DEB modelling approach] for future use in prospective Environmental Risk Assessment (ERA) for pesticides”

A bit of context

Objectives of my talk

- ~~**OECD revision guidelines (2016)**~~: Use of mechanistic modelling to **extrapolate** to
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Some participants of SPF 2022 Session 2 might recognize

- ~~**EFSA Scientific opinion (2018)** recognized~~ the " great potential [of the DEB modelling approach] for future use in prospective ~~Environmental Risk Assessment (ERA) for pesticides~~"

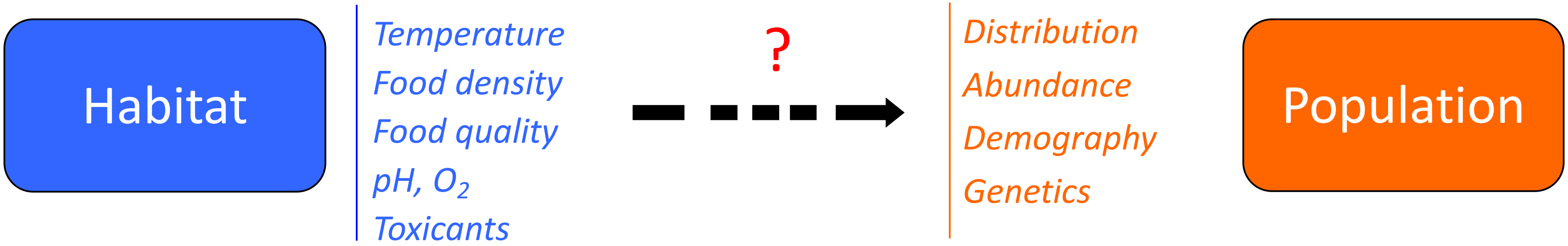
Climate change Risk Assessment on SPF populations

Outline

- Why DEB models for small pelagic fish?
- What is a DEB model? (and why do we have several?)
- (non-SPF and SPF) Applications examples
- Challenges for future applications of DEB theory to small pelagic fish

Spatial variability
Temporal variability

Density-dependence
Individual variability



Habitat

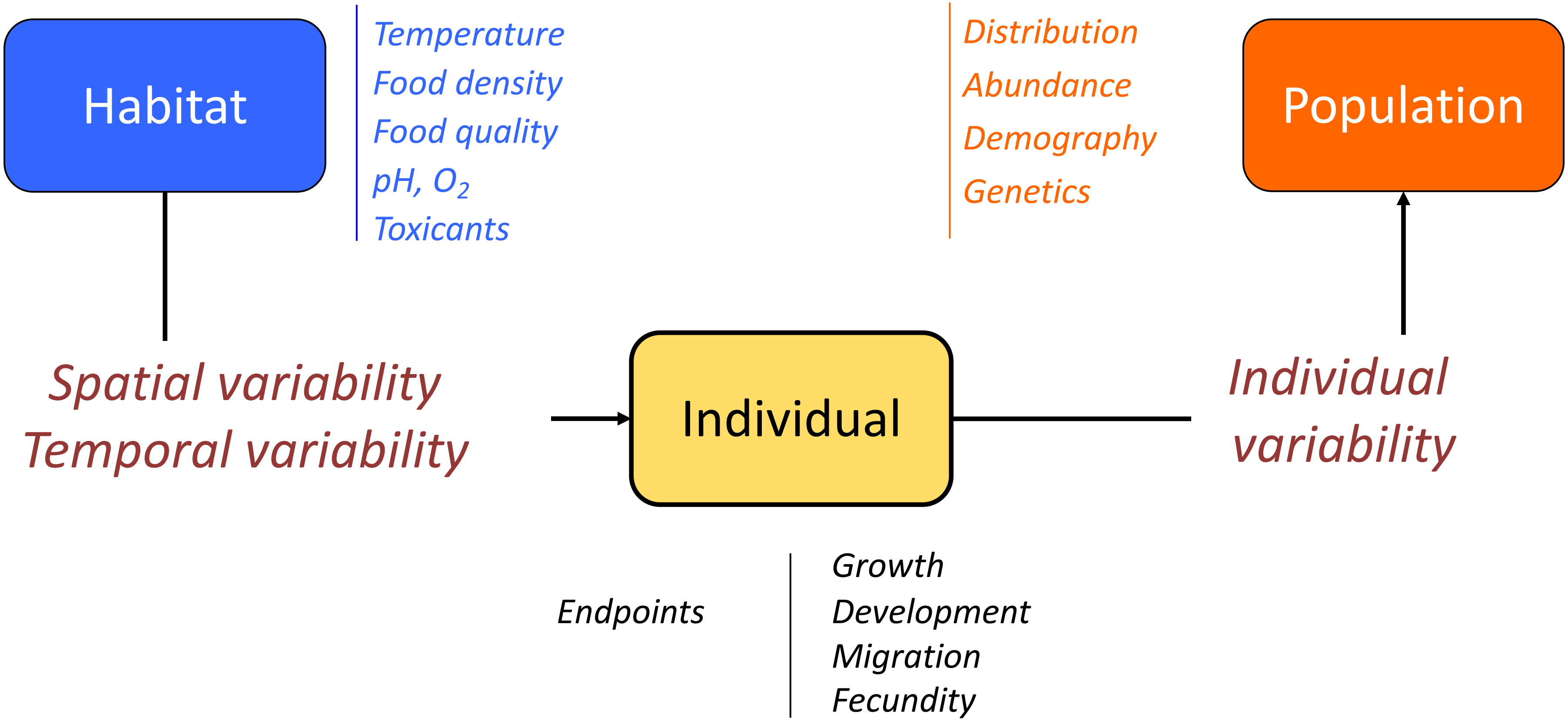
Temperature
Food density
Food quality
pH, O_2
Toxicants

?

Distribution
Abundance
Demography
Genetics

Population

Density-dependence



Habitat

Temperature
Food density
Food quality
pH, O_2
Toxicants

Spatial variability
Temporal variability

Individual

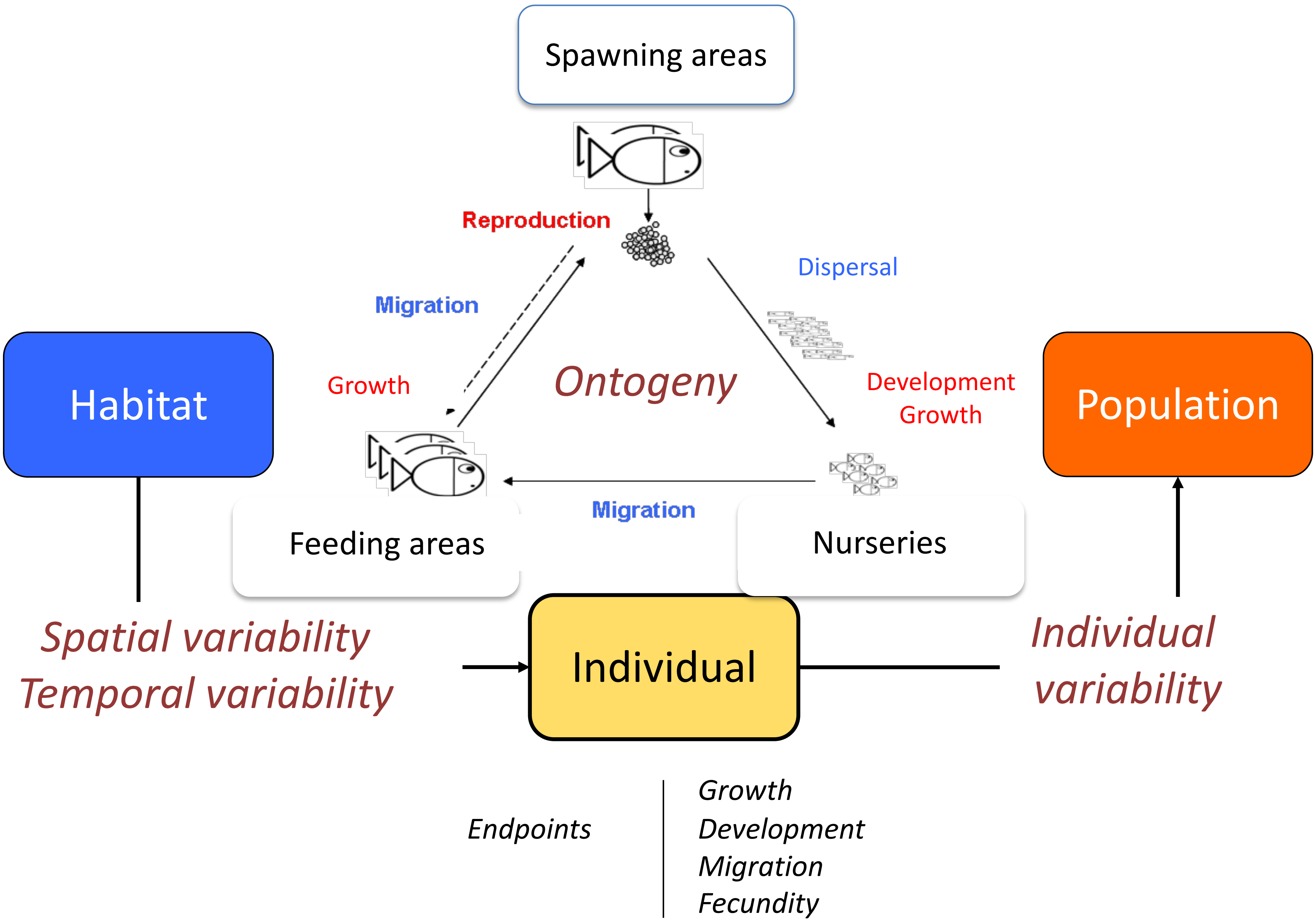
Endpoints

Growth
Development
Migration
Fecundity

Individual variability

Distribution
Abundance
Demography
Genetics

Population



Spawning areas

Reproduction

Migration

Dispersal

Ontogeny

Growth

Development
Growth

Habitat

Population

Feeding areas

Migration

Nurseries

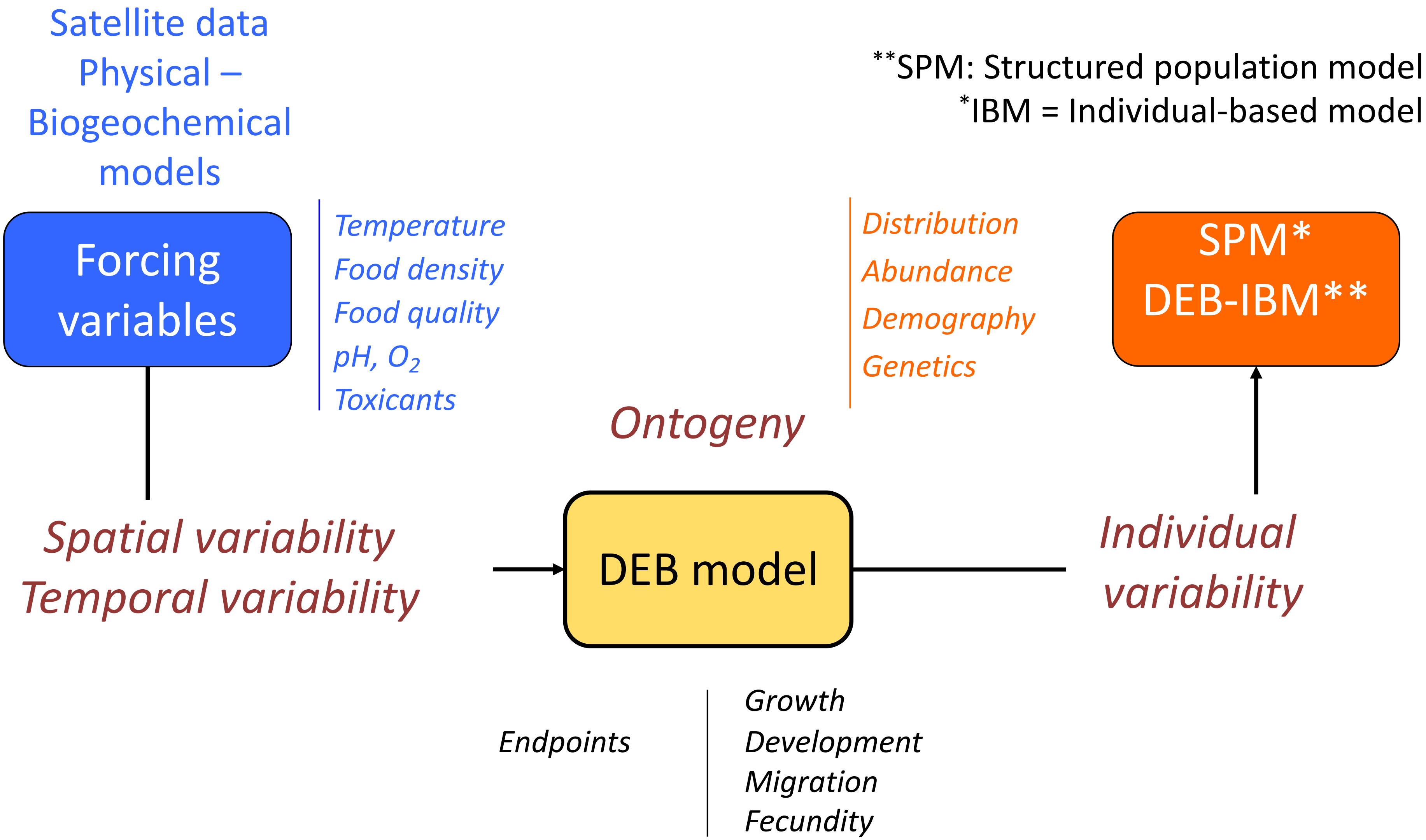
Individual

Spatial variability
Temporal variability

Individual variability

Endpoints

Growth
Development
Migration
Fecundity



Satellite data
Physical –
Biogeochemical
models

**SPM: Structured population model
*IBM = Individual-based model

Forcing variables

Temperature
Food density
Food quality
pH, O_2
Toxicants

Ontogeny

Distribution
Abundance
Demography
Genetics

SPM*
DEB-IBM**

Spatial variability
Temporal variability

DEB model

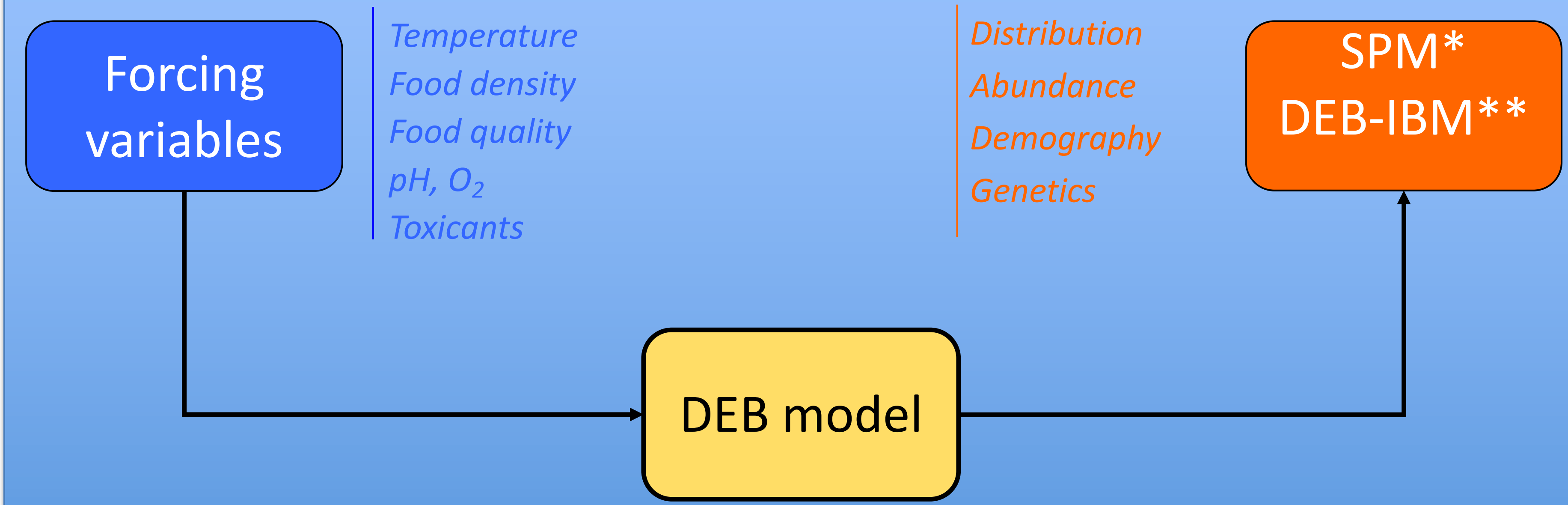
Individual variability

Endpoints

Growth
Development
Migration
Fecundity

End-to-end models: e.g. APECOSM

**SPM: Structured population model
*IBM = Individual-based model



Forcing variables

Temperature
Food density
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Distribution
Abundance
Demography
Genetics

SPM*
DEB-IBM**

DEB model

Endpoints

Growth
Development
Migration
Fecundity

But there is more!

Coupling Experiments and DEB models

- Better interpretation of the results
- Calibration of proxies

Coupling Field observations and DEB models

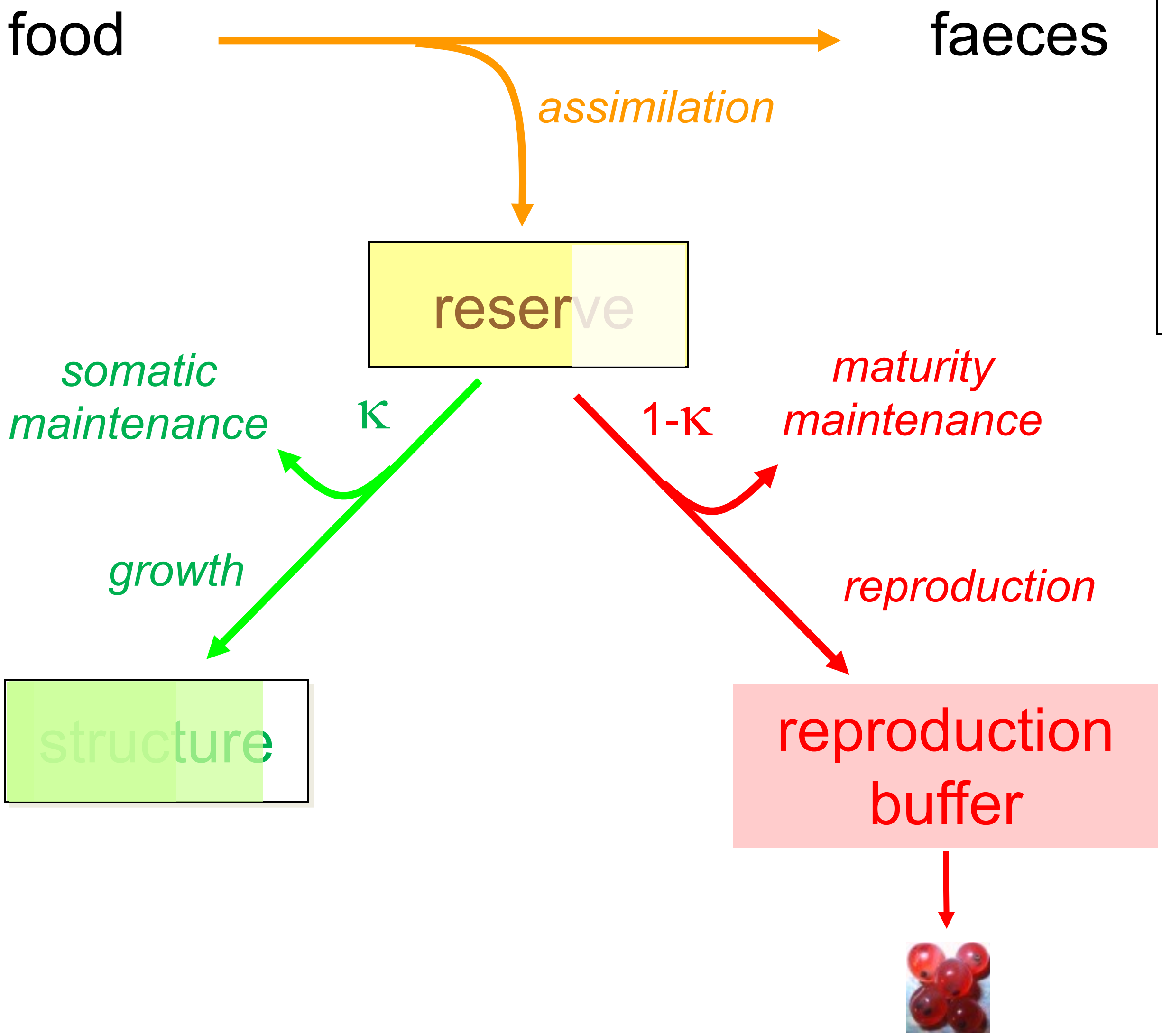
- Reconstruction of life histories

Coupling Statistical approaches and DEB models

- Scenario analyses
- Projections
- Uncertainty estimation

Comparing species to gain better insights and robustness
→ in order to then extrapolate to poor-data species

Standard DEB model



food

faeces

assimilation

reserve

somatic maintenance

κ

growth

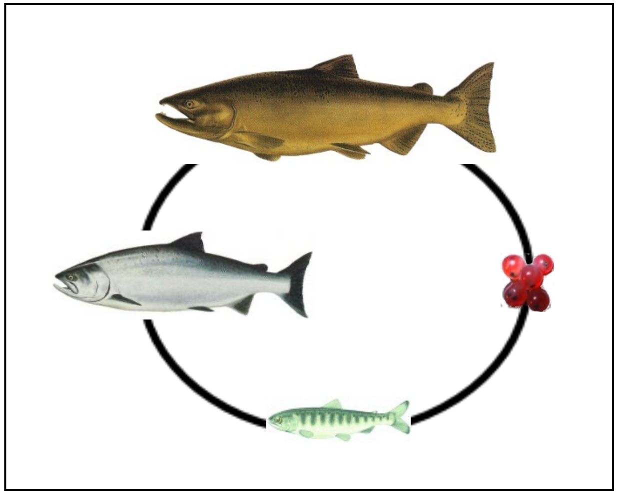
structure

1-κ

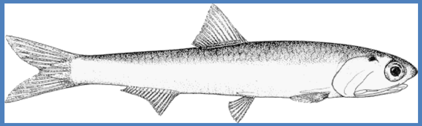
maturity maintenance

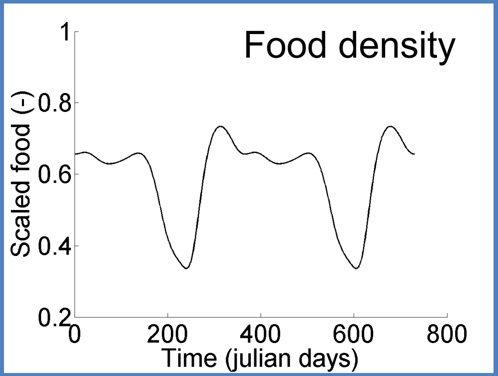
reproduction

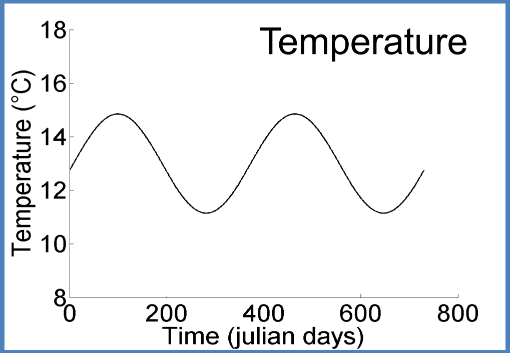
reproduction buffer

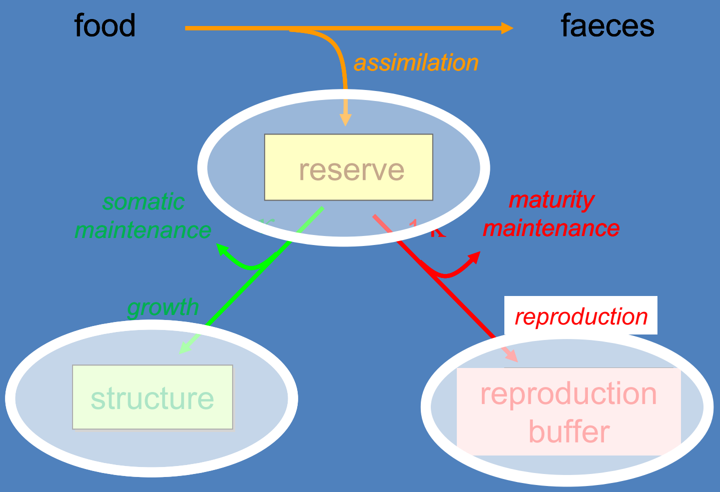


Example of a numerical simulation









food

faeces

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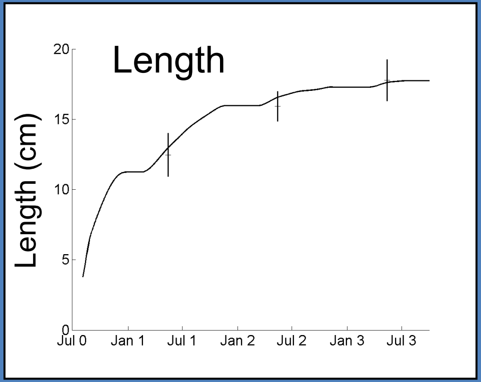
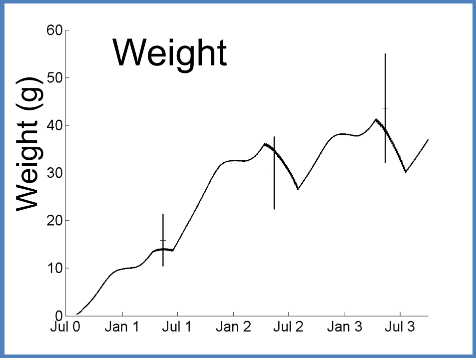
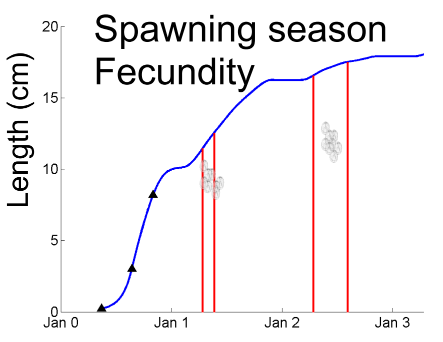
structure

reproduction buffer







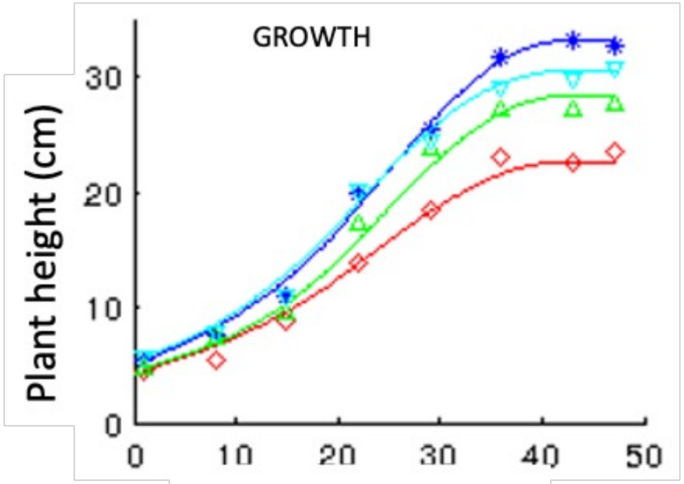
(Pecquerie et al. 2009)

INPUTS

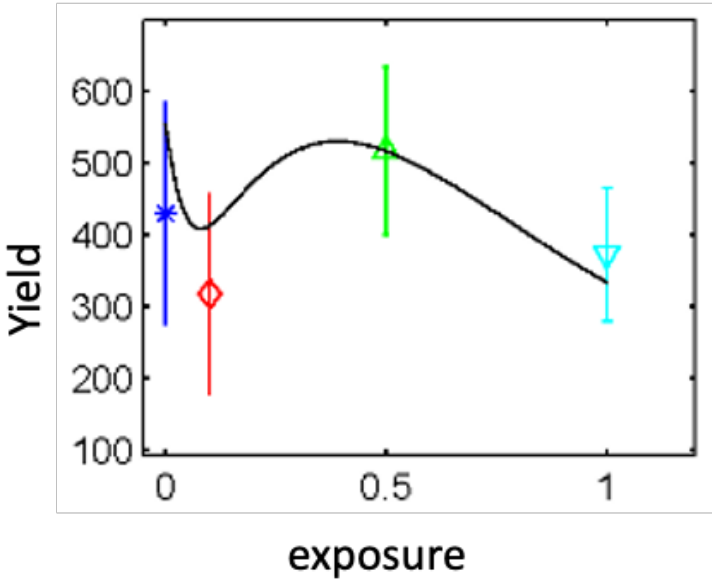
DEB MODEL

OUTPUTS

Non-monotonic response of Soybean plants exposed to Cerium Oxide Nanoparticules



REPRODUCTION

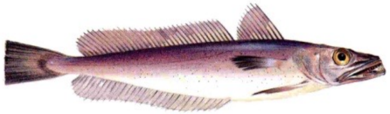


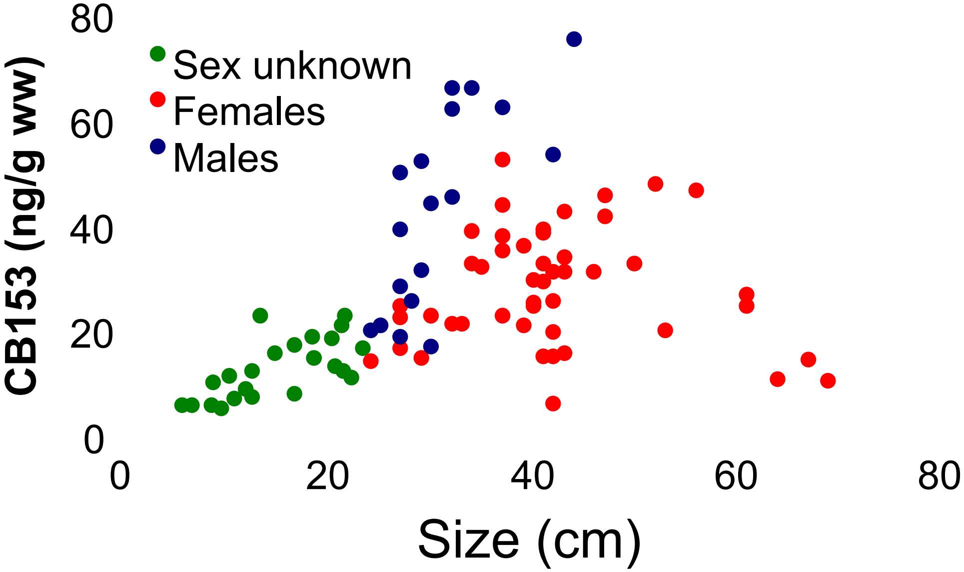
EXPOSURE	COSTS REDUCING PRODUCTION
NONE	Rhizobia
LOW	Rhizobia + systemic toxicity
MID	Low systemic toxicity
HIGH	High systemic toxicity

Reduction in rhizobia demands

Klanjscek, T.,et al 2017. Environmental Science and Technology 51(9):4944-4950.

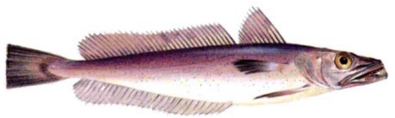
PCB bioaccumulation in hake in the Gulf of Lion

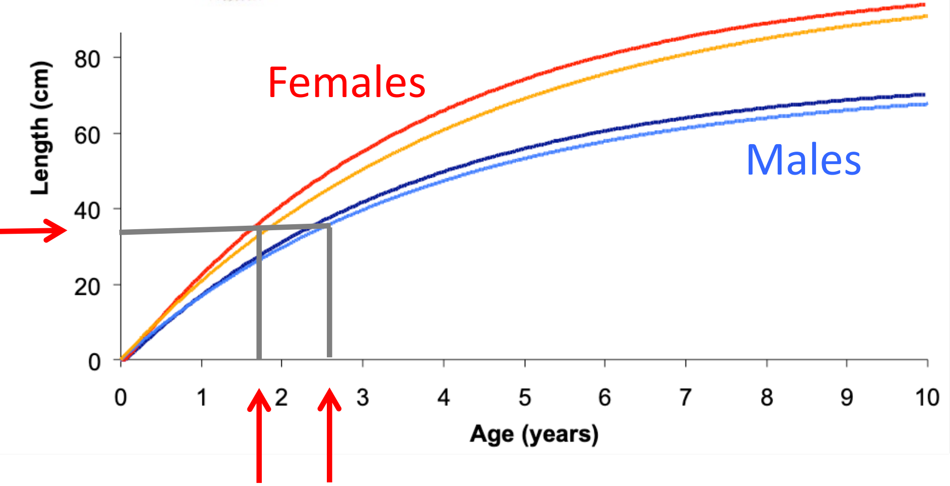


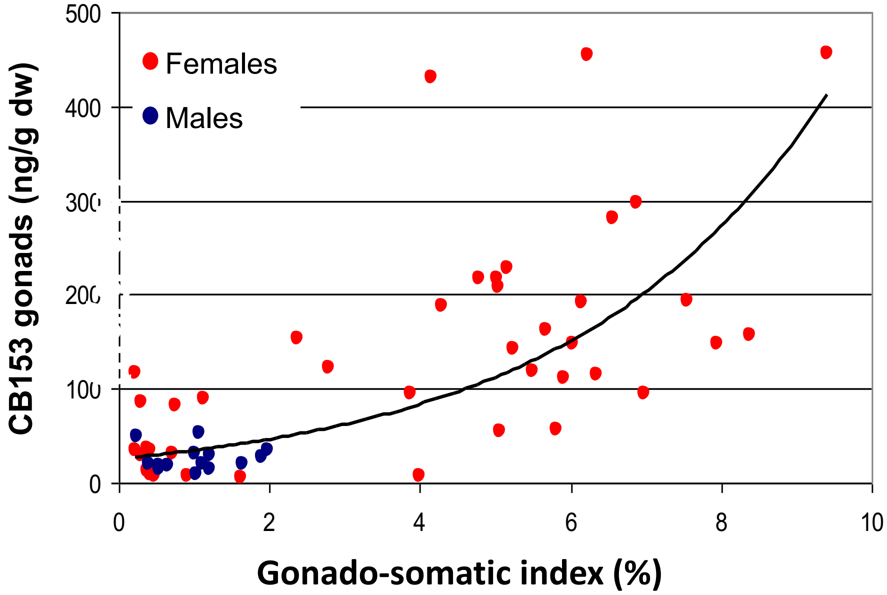


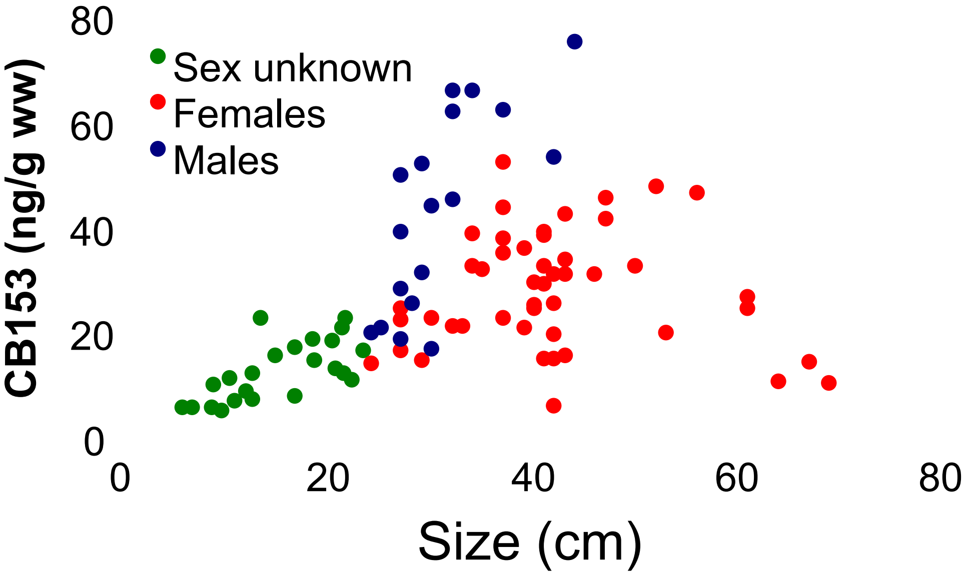
Bodiguel, X. et al. 2009.. Journal of Sea Research **62**:124-134.

PCB bioaccumulation in hake in the Gulf of Lion









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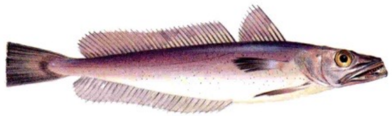
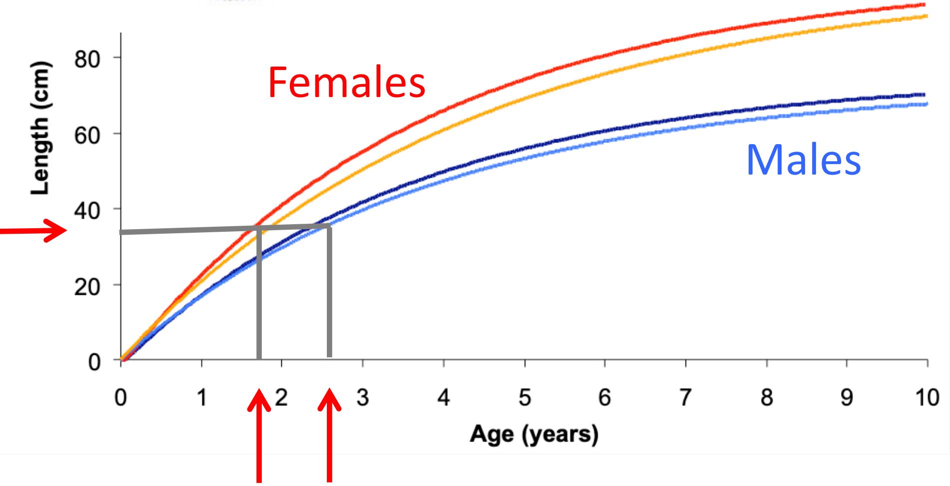
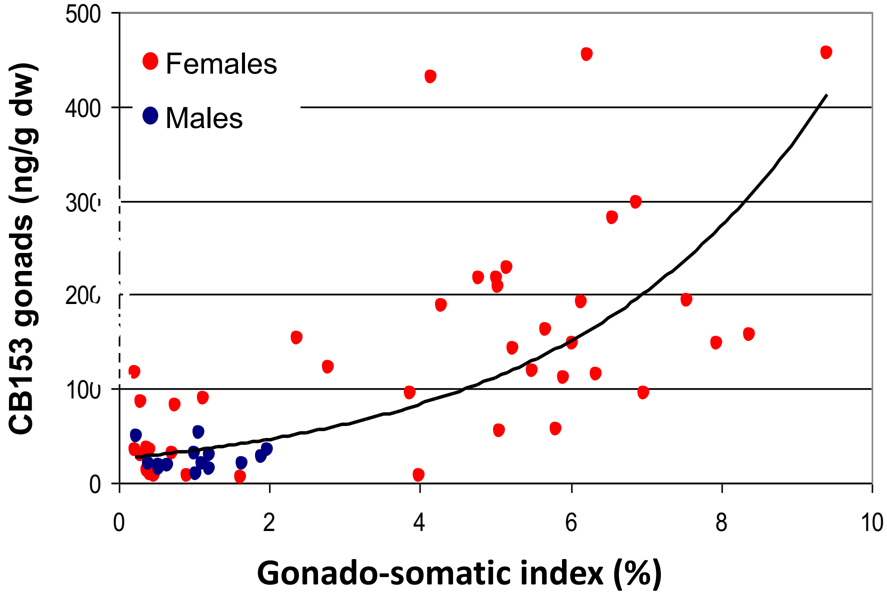
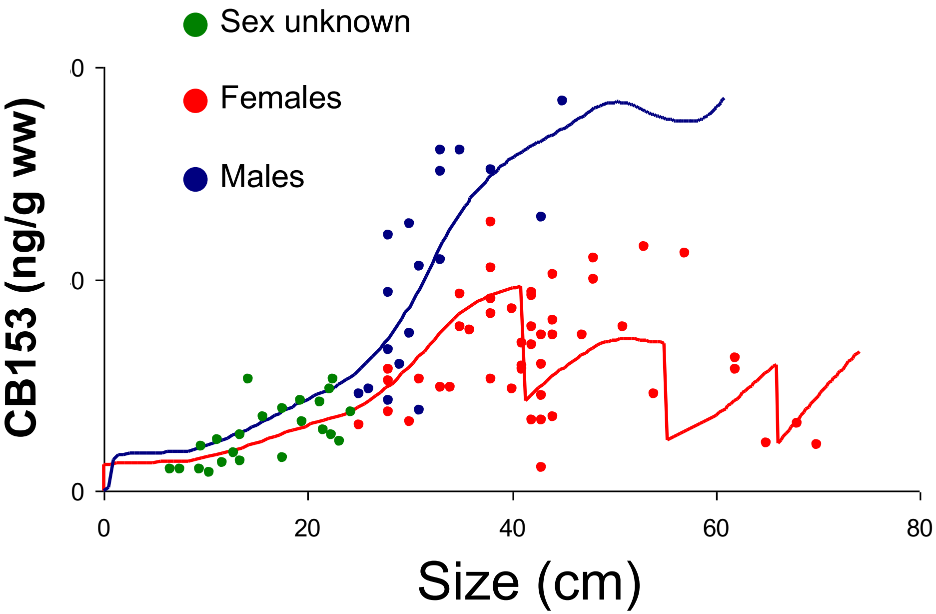
PCB bioaccumulation in hake in the Gulf of Lion



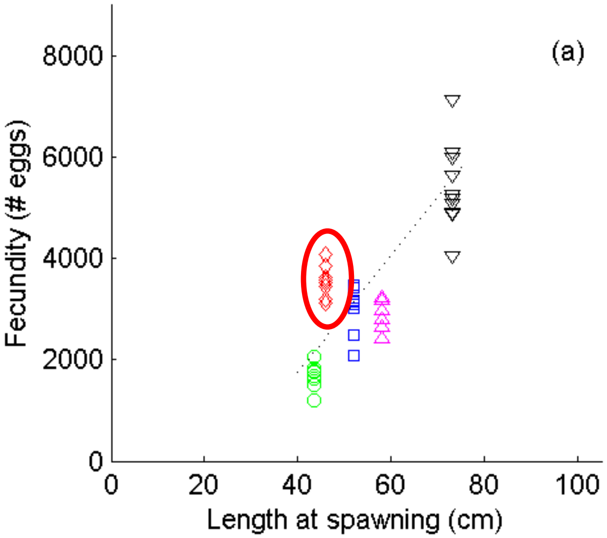


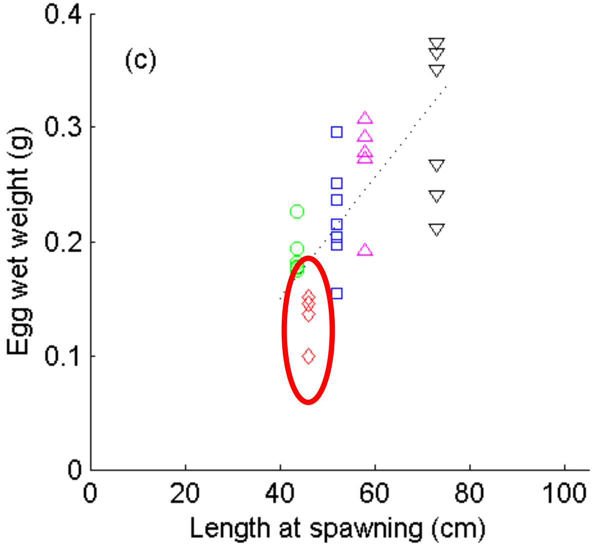


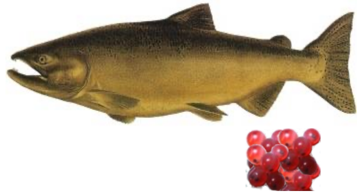


Bodiguel, X. et al. 2009.. Journal of Sea Research **62**:124-134.

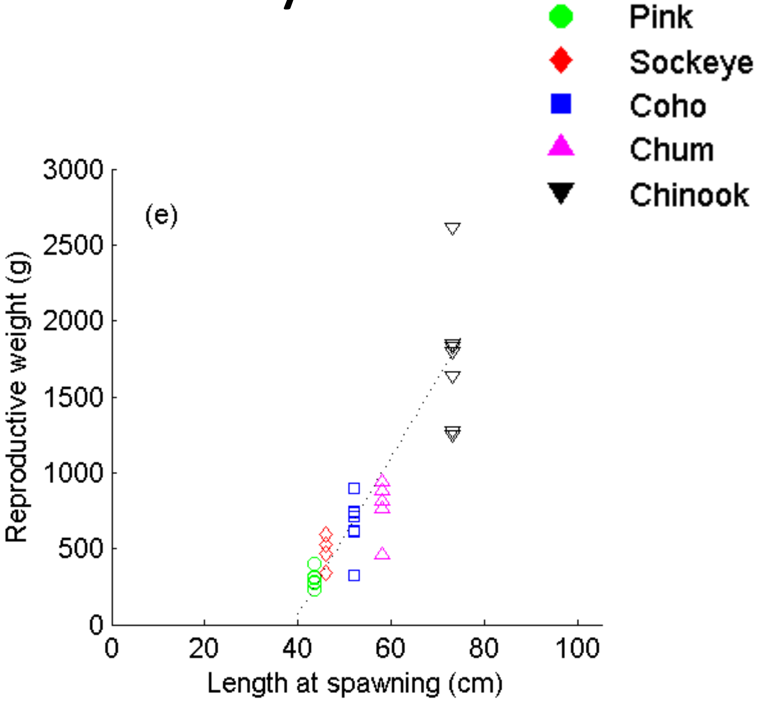
Related species share similar energetics and life traits







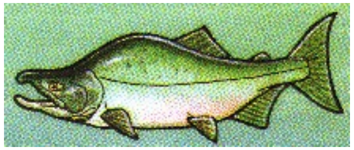
Data Analysis



(From Beacham and Murray, 1993)

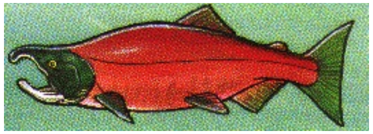
Related species share similar energetics and life traits

Pink
($L_{sp} = 53$ cm)



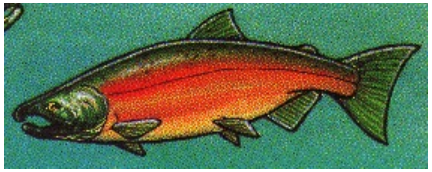
$z = 53/87$
$= 0.6$

Sockeye
($L_{sp} = 55$ cm)



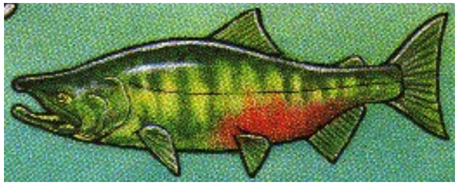
$z = 55/87$
$= 0.63$

Coho
($L_{sp} = 64$ cm)



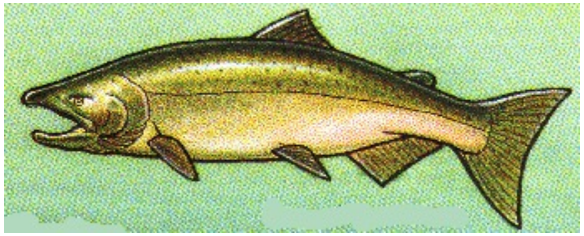
$z = 64/87$
$= 0.74$

Chum
($L_{sp} = 68$ cm)



$z = 68/87$
$= 0.78$

Chinook
($L_{sp} = 87$ cm)



$z = 1$

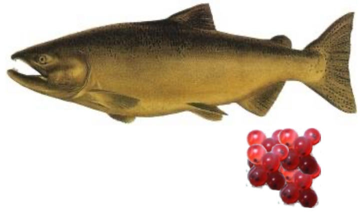
Some parameters vary:

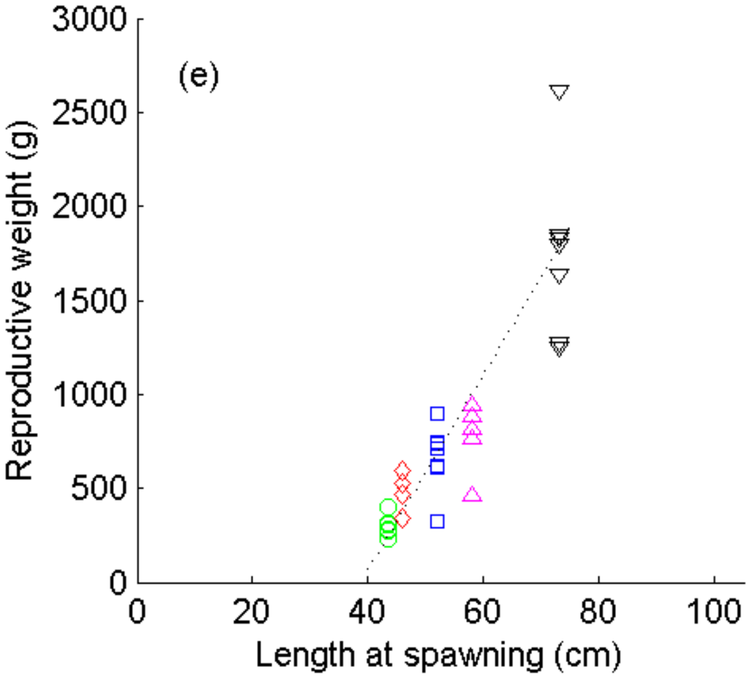
- Assimilation
- Development thresholds

Other parameters stay constant

(Pecquerie et al. 2011)

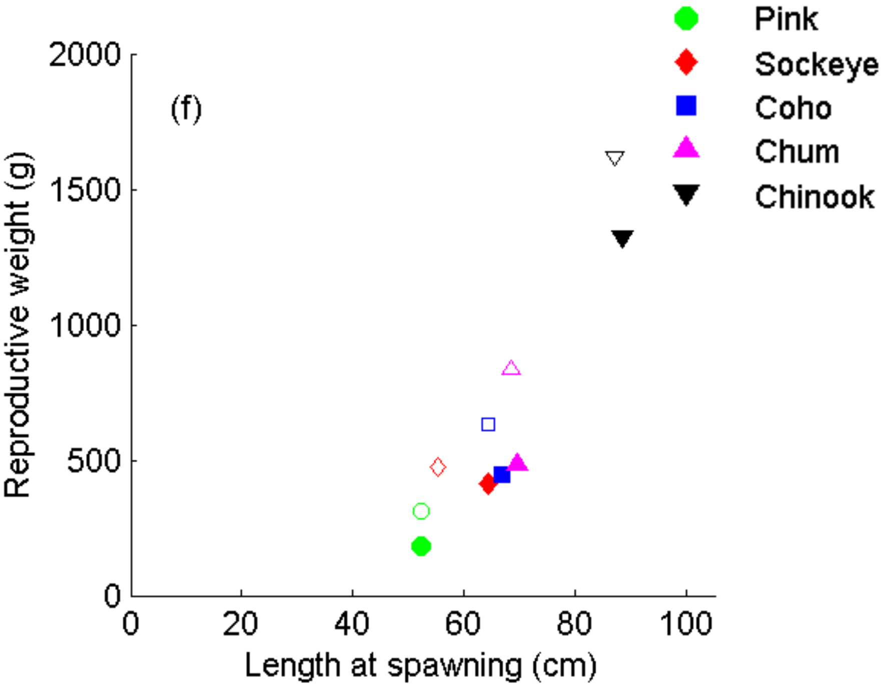
Related species share similar energetics and life traits





Data

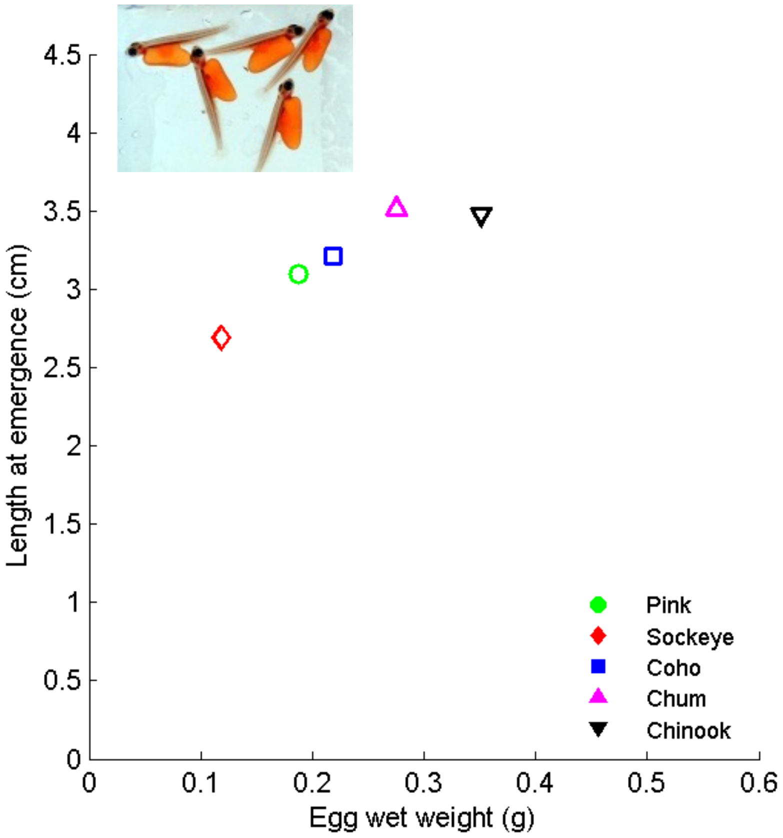
(From Beacham and Murray, 1993)



Simulations

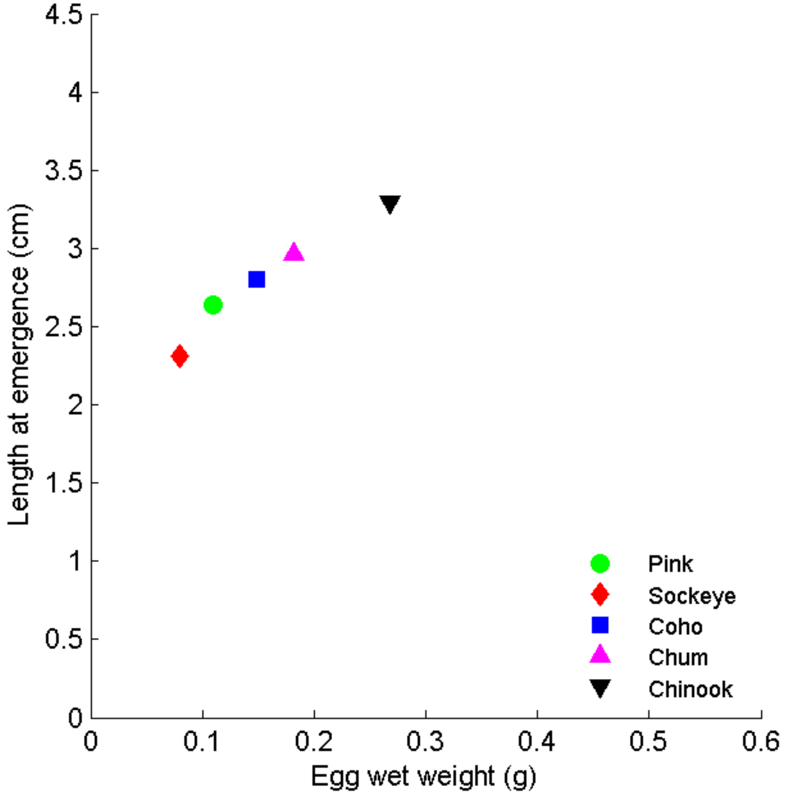
(Pecquerie et al. 2011)

Length at emergence as a function of egg weight is also well reproduced



Data

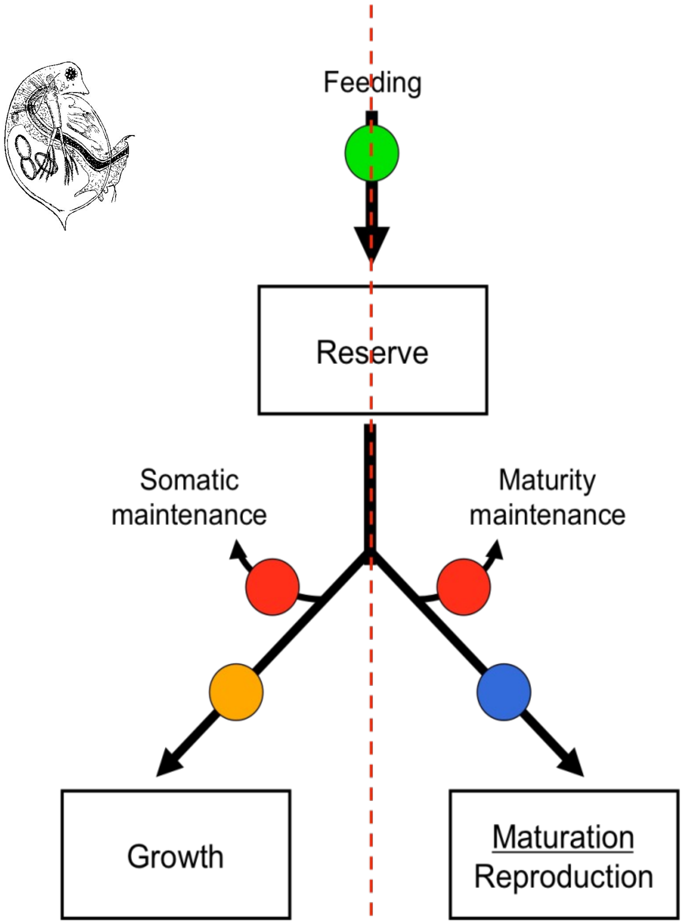
(From Beacham and Murray, 1990)



Simulations

(Pecquerie et al. 2011)

From individuals to population



Feeding

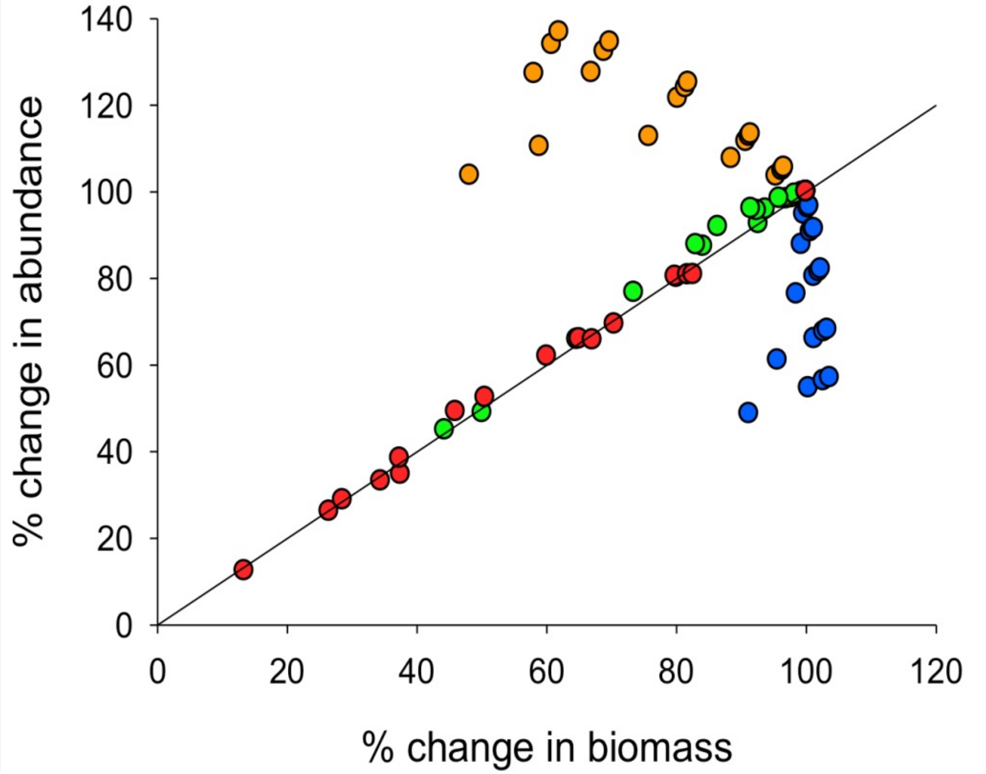
Reserve

Somatic maintenance

Maturity maintenance

Growth

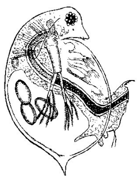
Maturation Reproduction

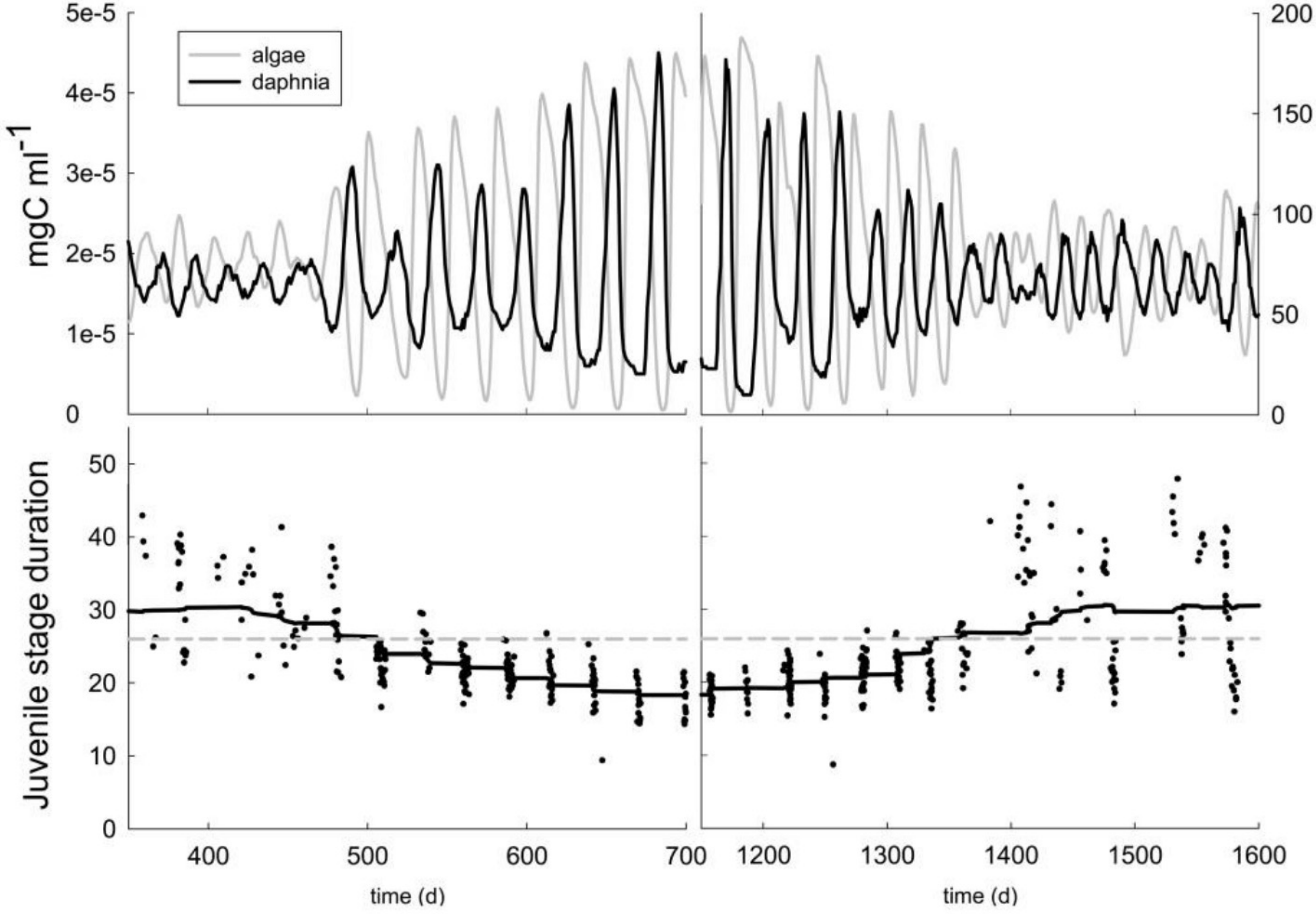


relating physiological mode of action of toxicants to demography of populations near equilibrium

Martin, Jager,, Nisbet, Preuss, and Grimm, V, *Ecological Applications,* 2014.

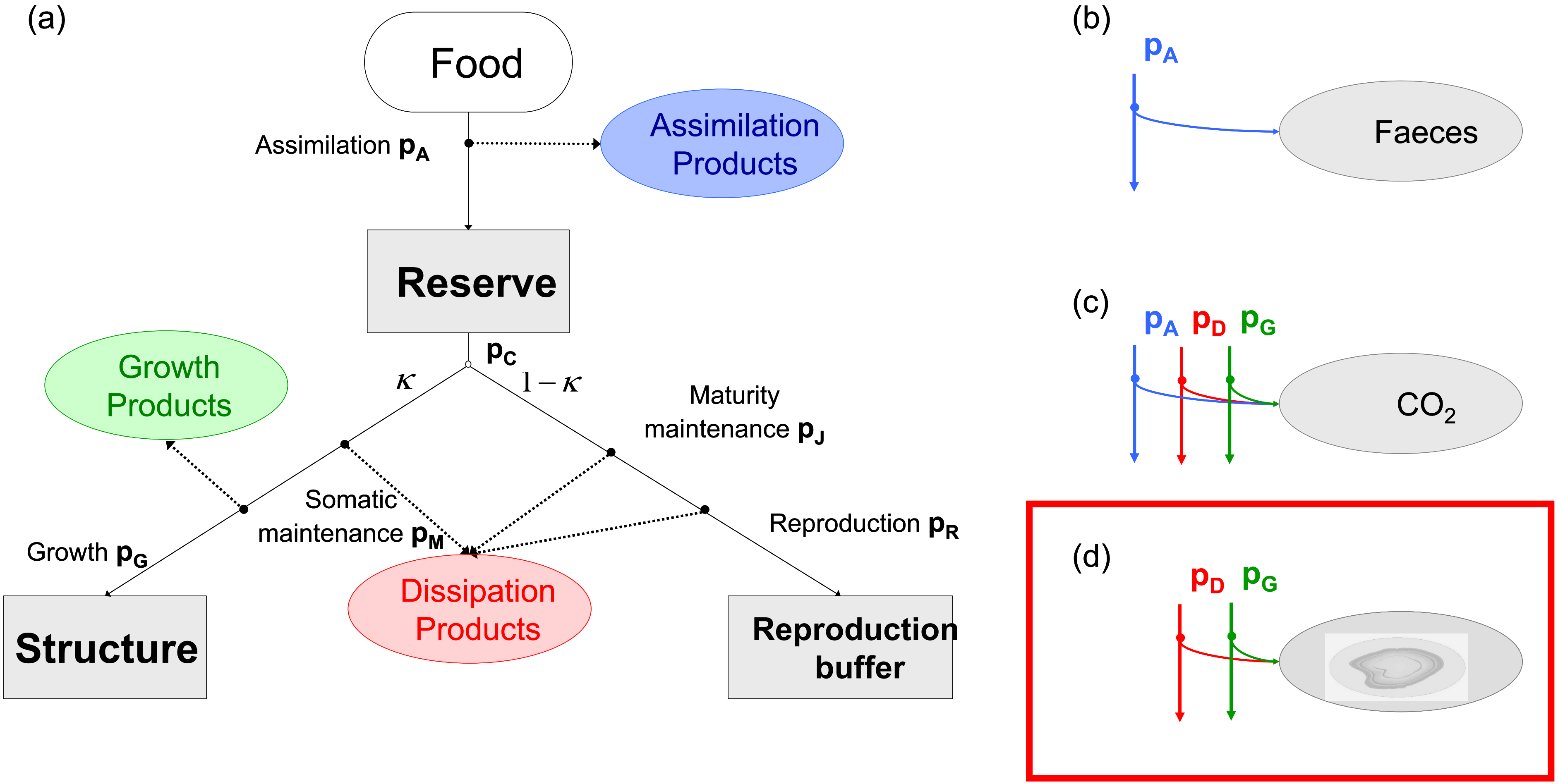
From individuals to population





Martin et al. American Naturalist, 2013.

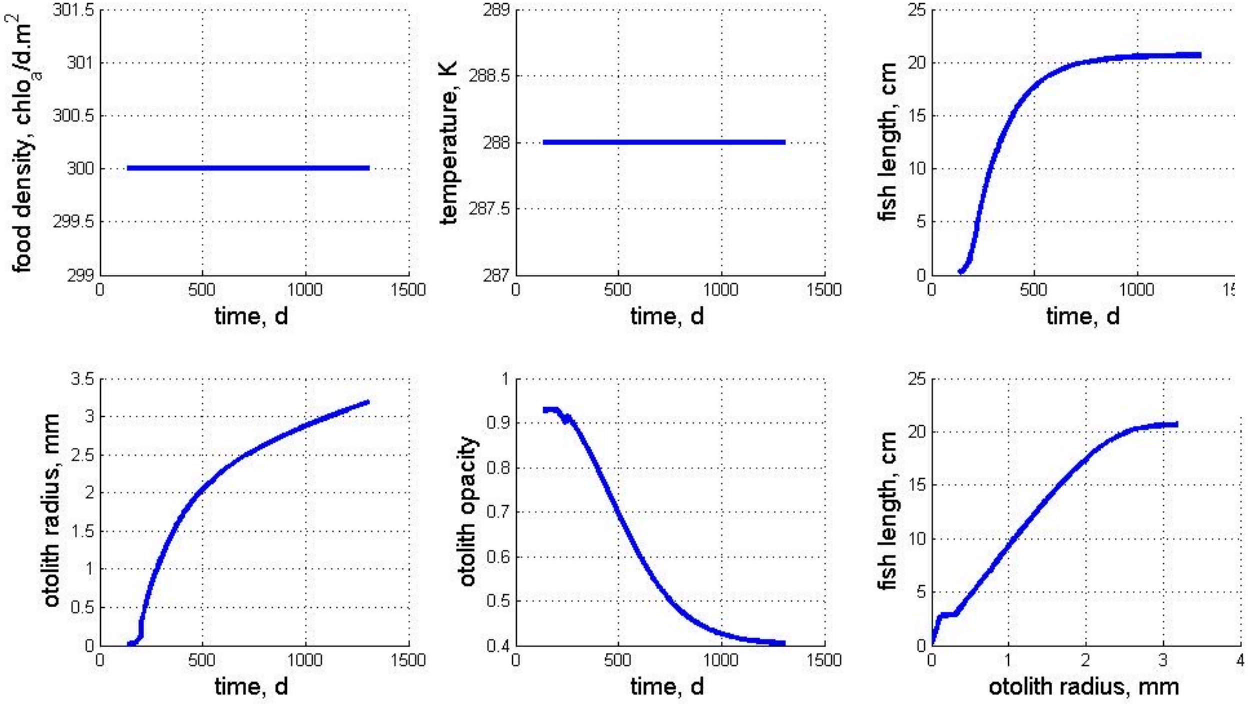
Biocarbonate = metabolic product



Assumption: biocarbonate formation coupled to growth + maintenance fluxes

Biocarbonate = metabolic product

Simulation for a constant environment

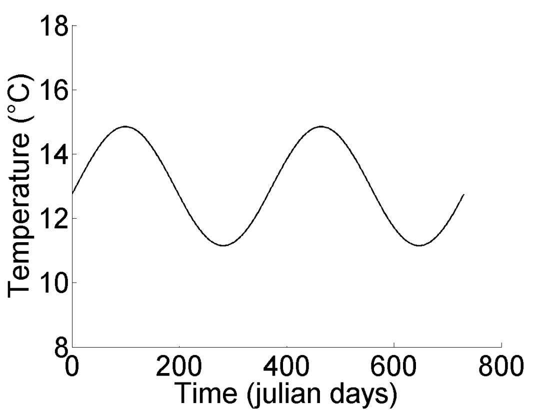


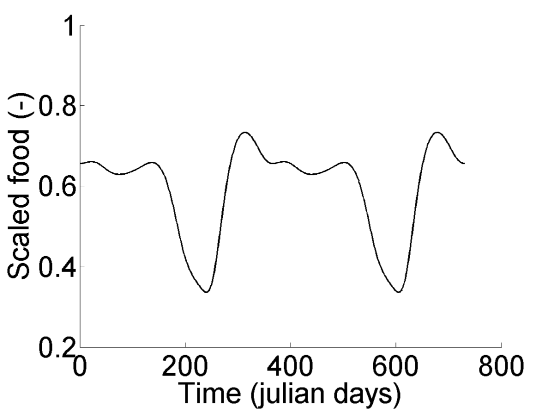
$$\frac{dV_O}{dt} = \alpha \dot{p}_G + \beta \dot{p}_D$$

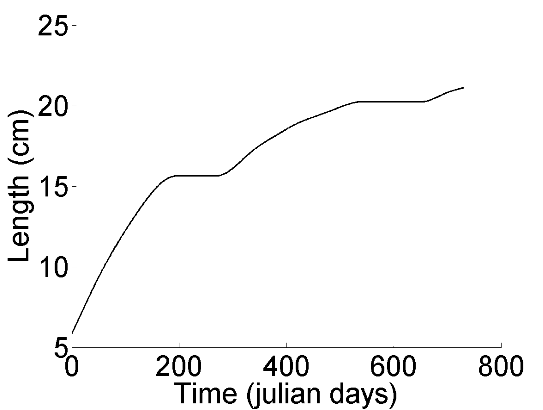
$$O = \frac{\alpha \dot{p}_G}{\alpha \dot{p}_G + \beta \dot{p}_D}$$

Assumption: biocarbonate formation coupled to growth + maintenance fluxes

Otolith modeling : individual history

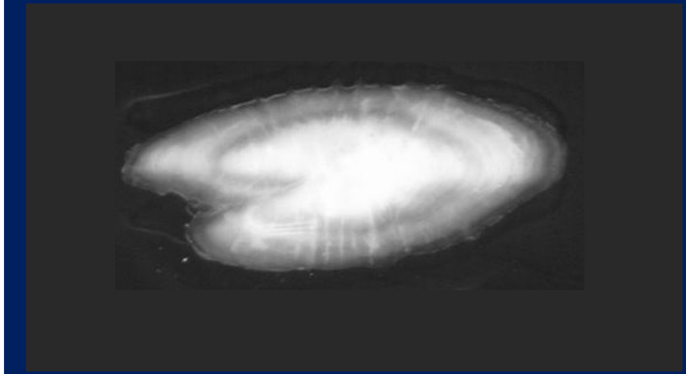






Otolith growth
and opacity

Data



Simulation

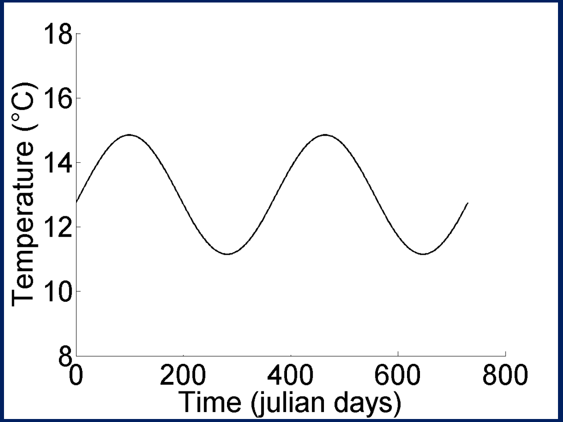
Environment → Length

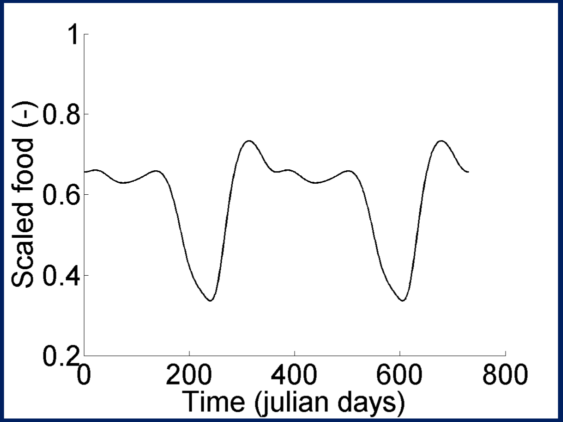
↑

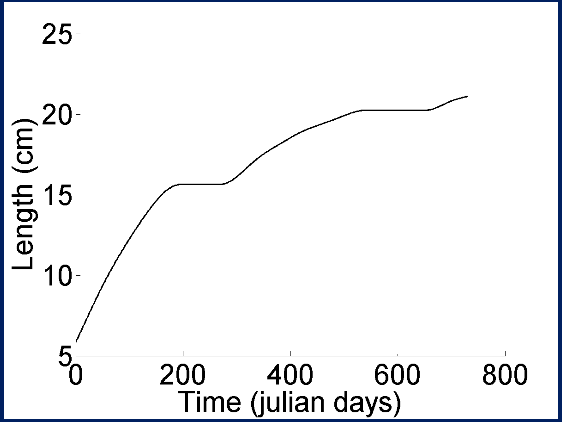
DEB model

(Pecquerie et al. 2012)

Otolith modeling : individual history





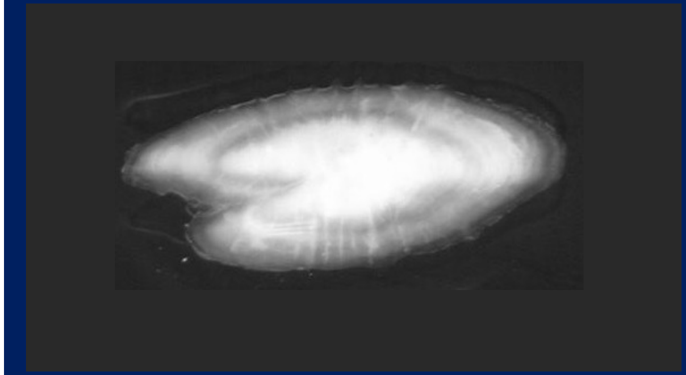


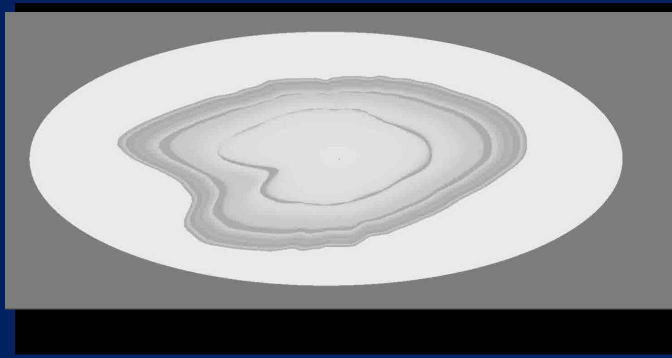
Environment → Length

DEB model

Otolith growth and opacity

Data



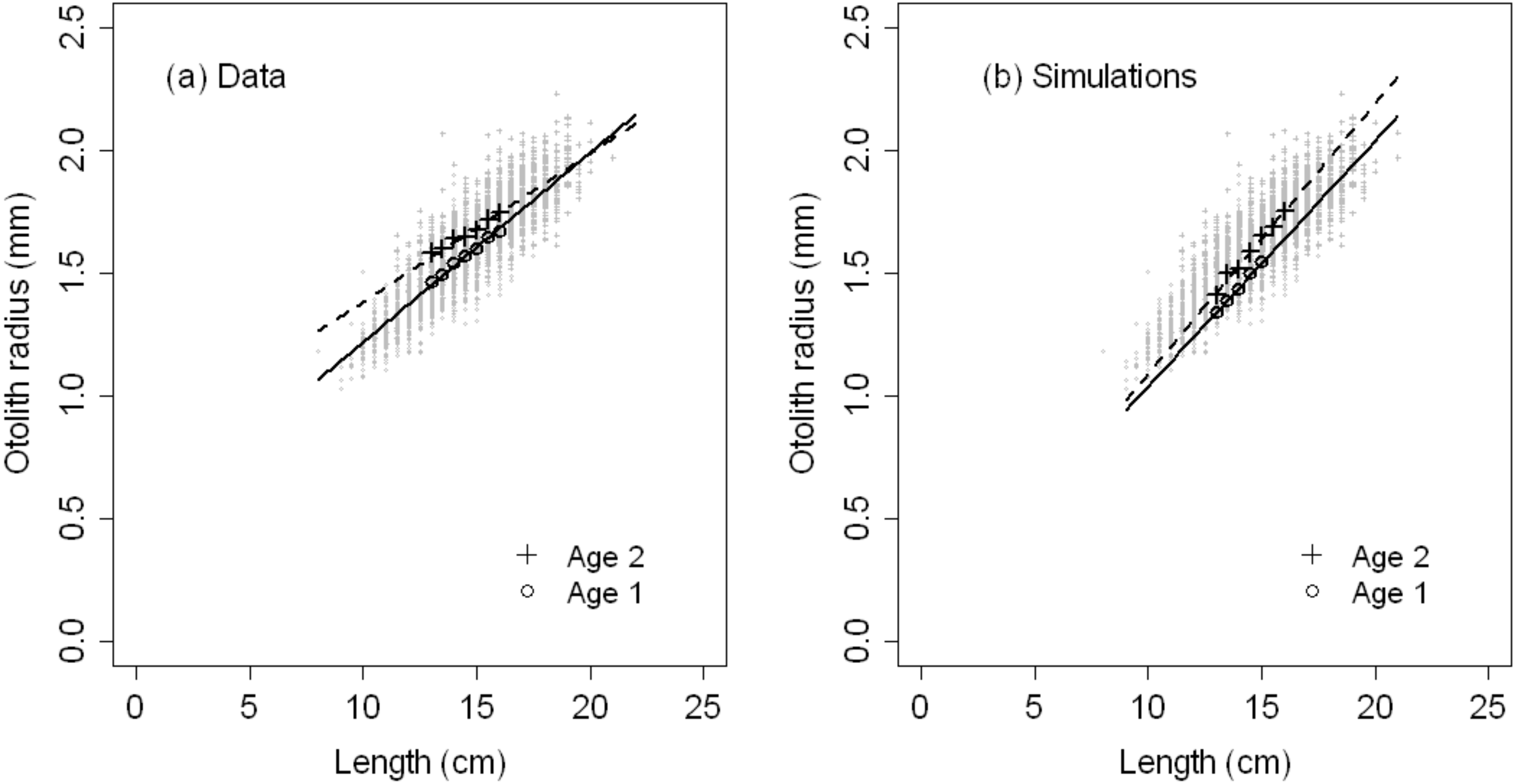


Simulation

(Pecquerie et al. 2012)

Otolith modeling : individual history

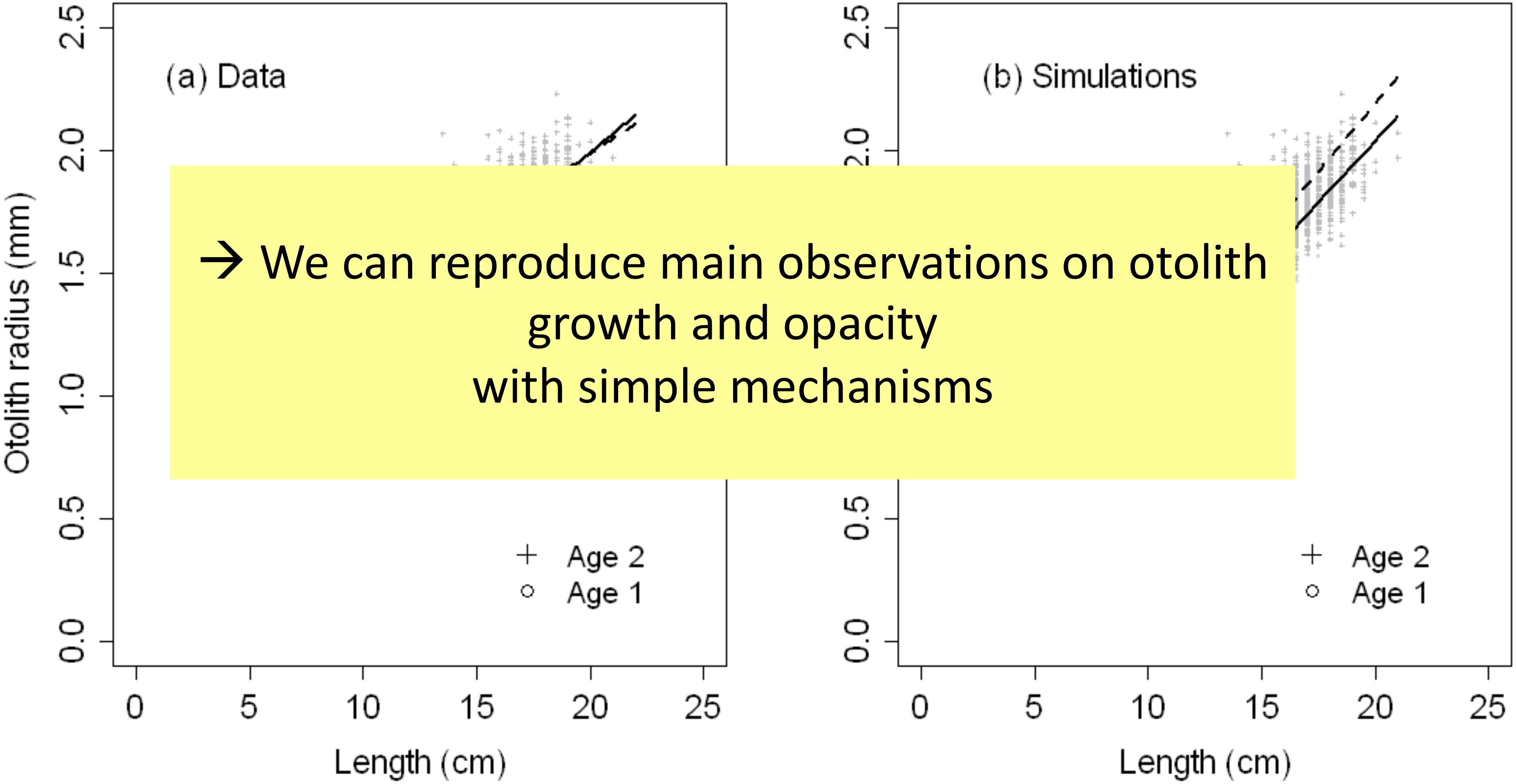
Slow growing fish have larger otoliths



(Pecquerie et al. 2012)

Otolith modeling : individual history

Slow growing fish have larger otoliths

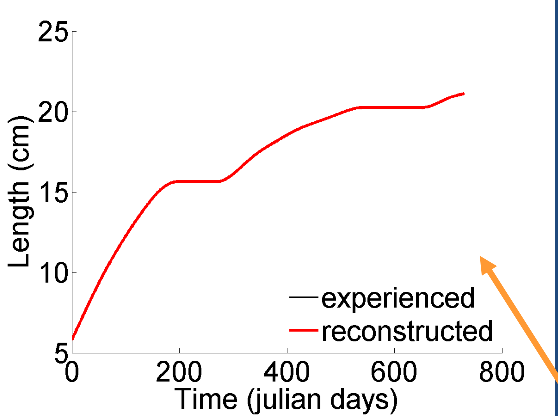


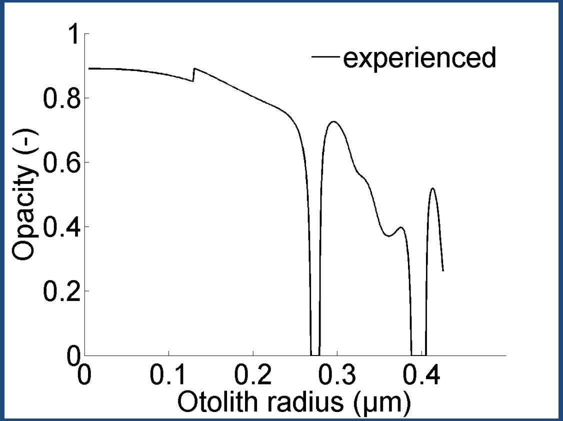
→ We can reproduce main observations on otolith growth and opacity
with simple mechanisms

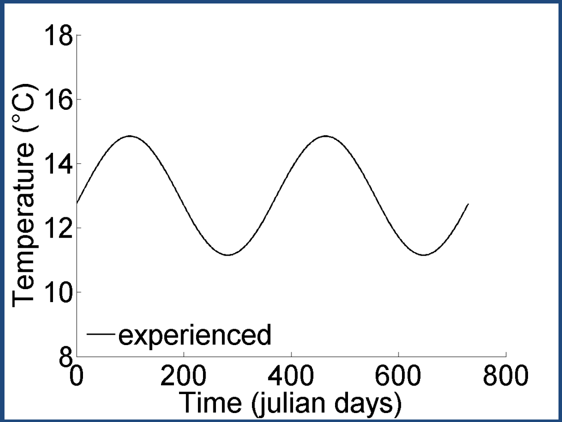
(Pecquerie et al. 2012)

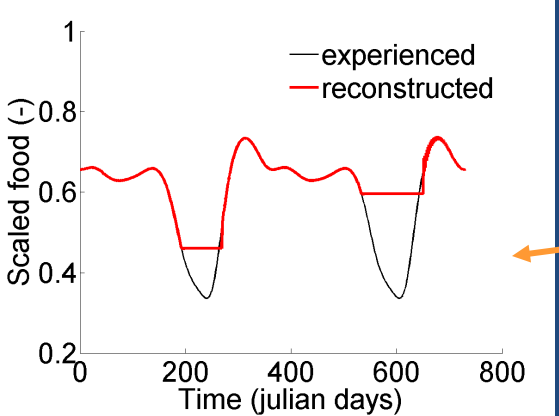
Food history reconstruction from otolith

DEB model









Assimilated food + Reconstruction of length

(Pecquerie et al. 2012)

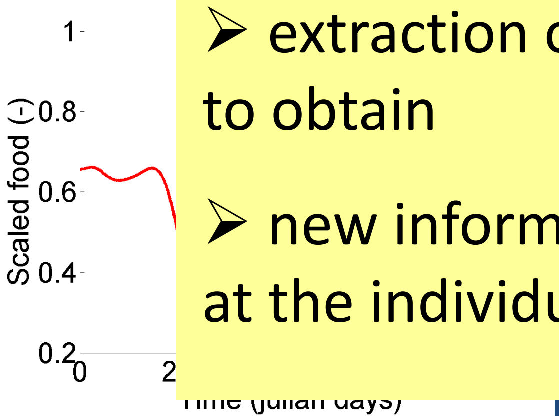
DEBtool routine: animal/o2f.m

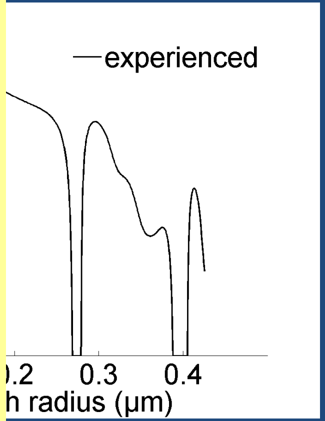
Food history reconstruction from otolith

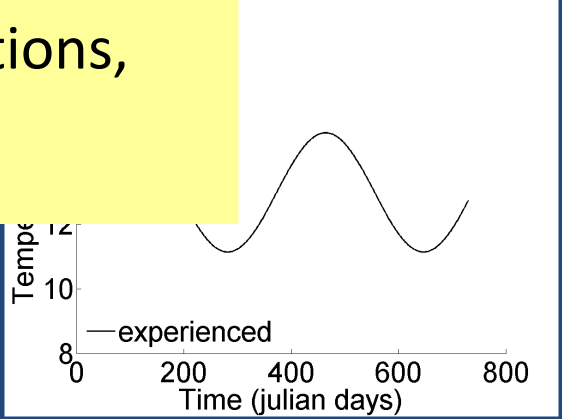
DEB model

We can theoretically reconstruct both growth and assimilated food
from temperature and otolith data

- ➢ extraction of new information from data difficult to obtain
- ➢ new information = food in natural conditions, at the individual scale





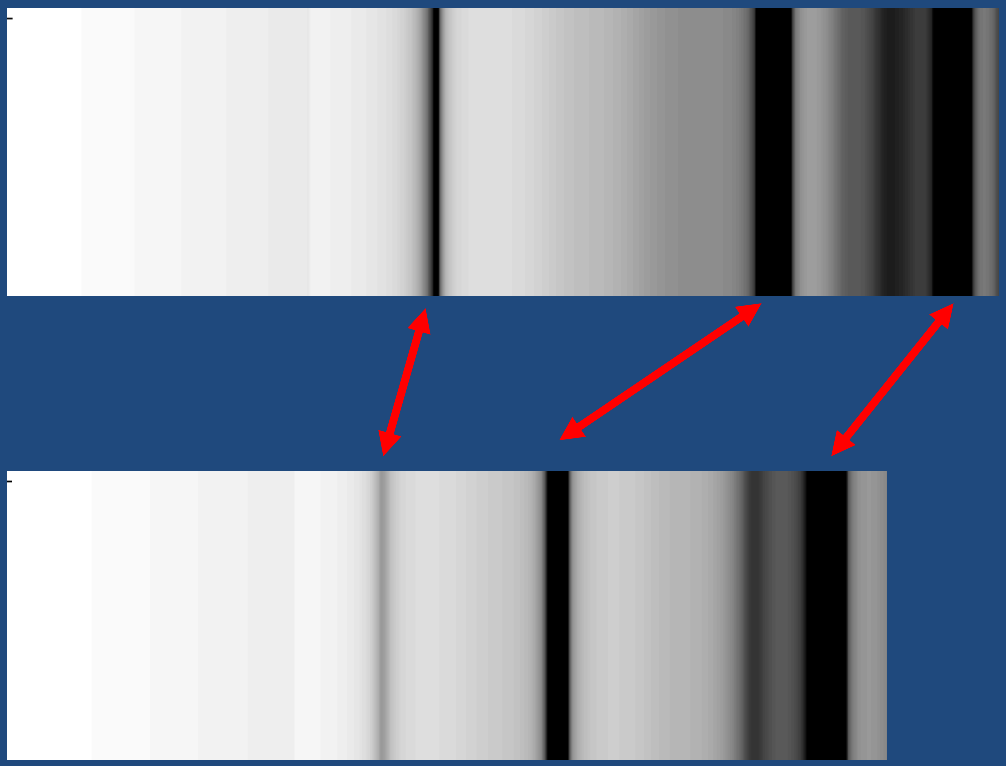


Assimilated food + Reconstruction of length

(Pecquerie et al. 2012)

DEBtool routine: animal/o2f.m

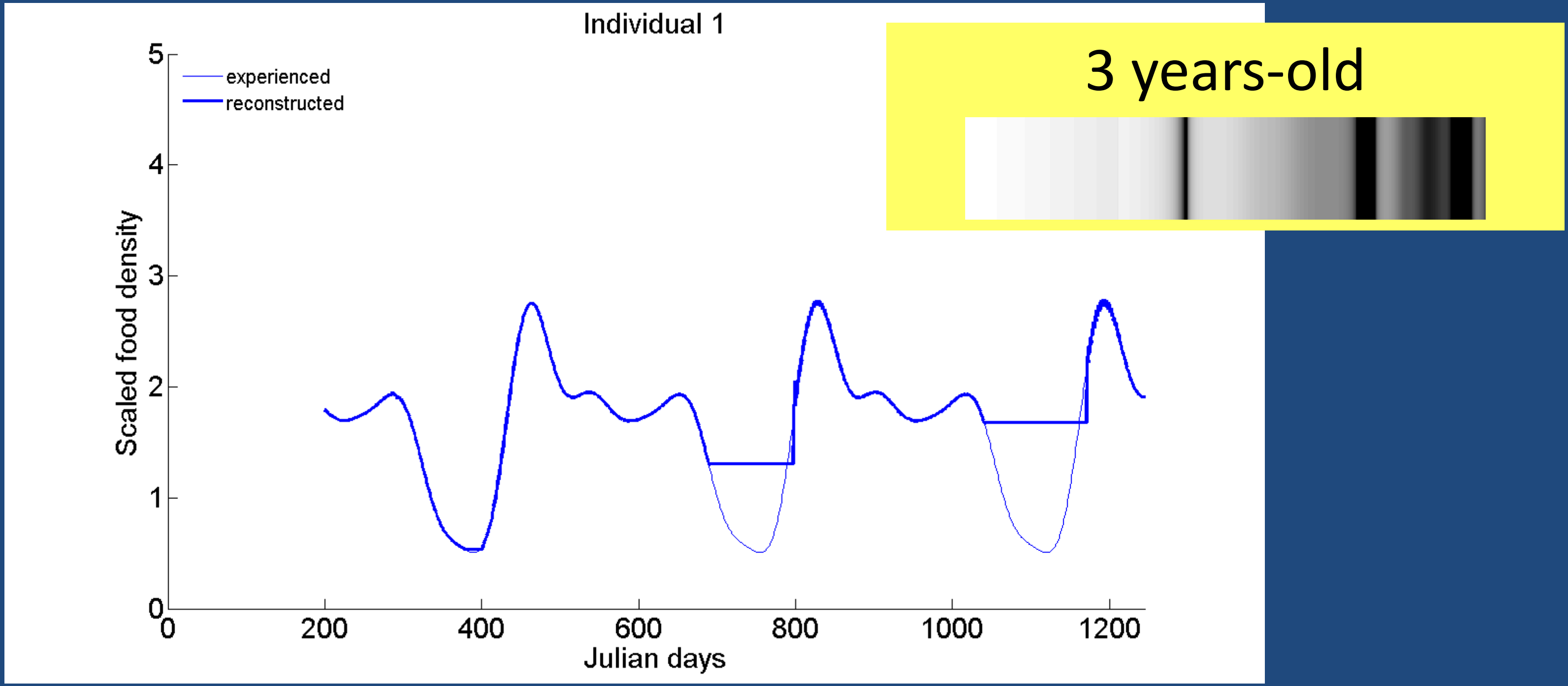
Two age-3 individuals ?



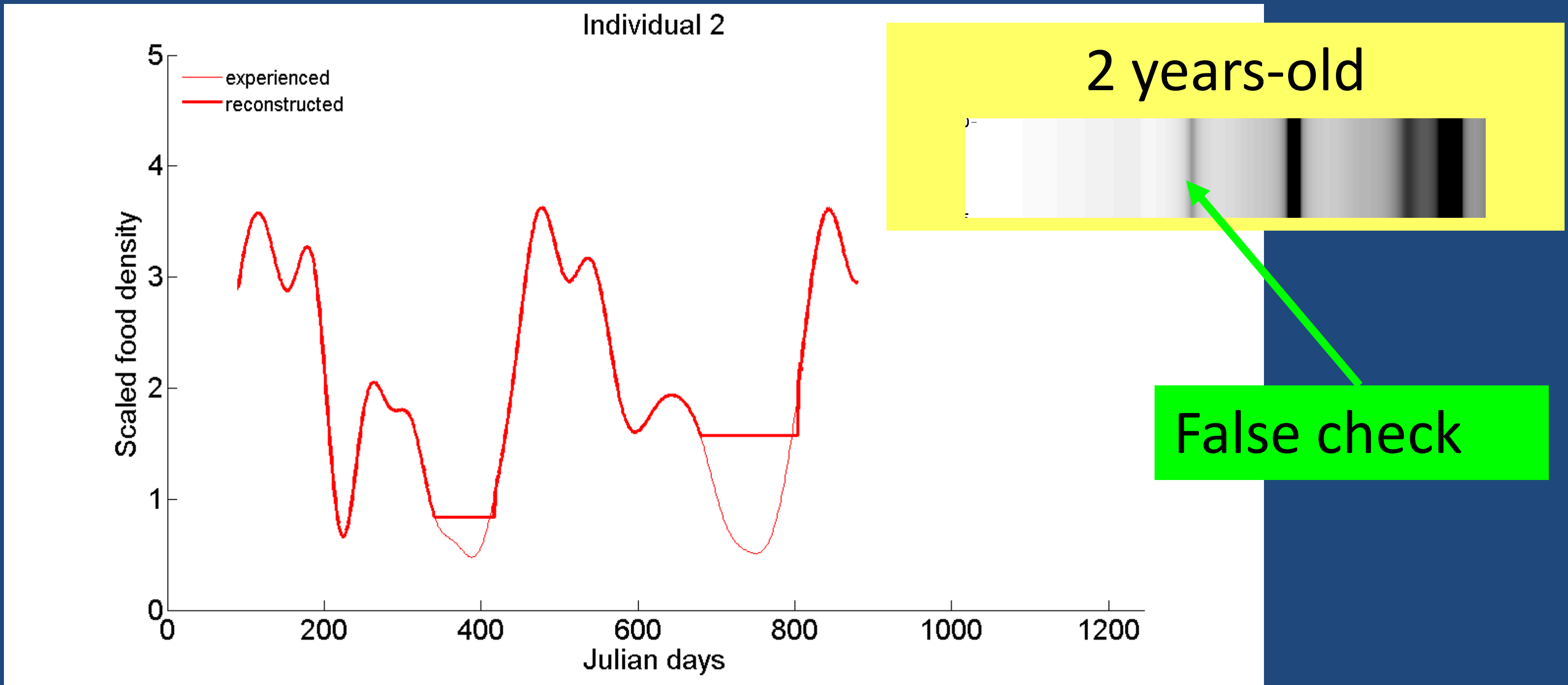
Individual 1

Individual 2

(Pecquerie et al. 2012)



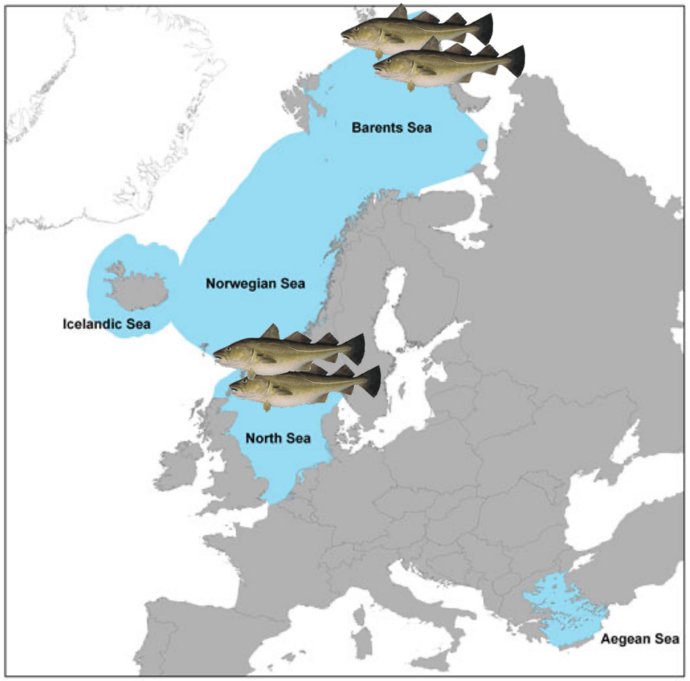
3 years-old



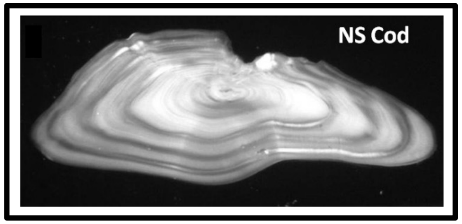
2 years-old

False check

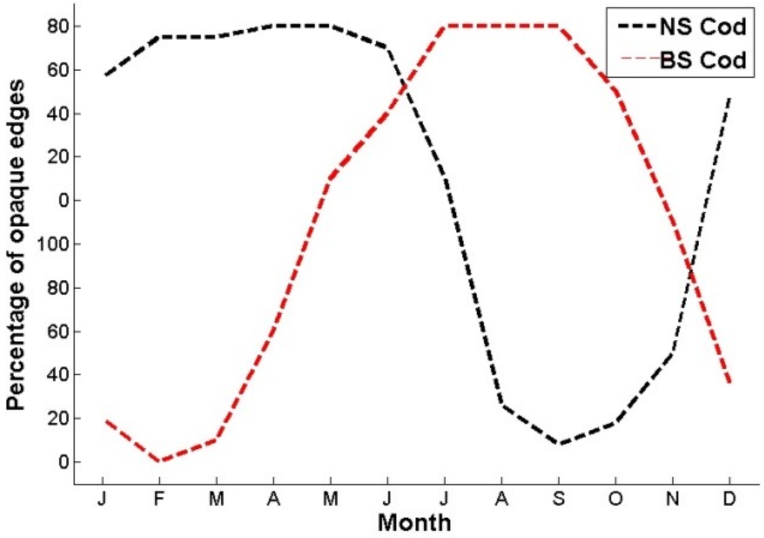
Application: North Sea (NS) cod otoliths at odds with Barents sea (BS) cod otoliths



Classic pattern:
translucent edge in winter
→ Slow growth in winter

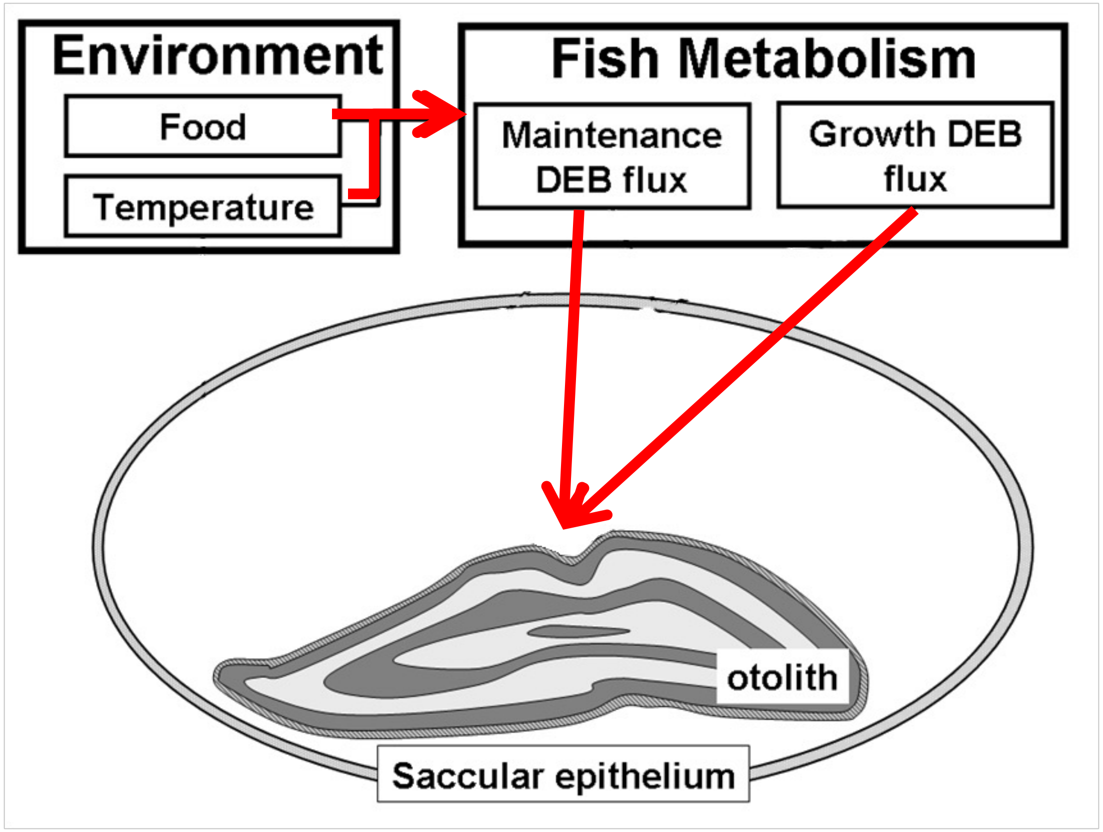


Opposite pattern:
translucent edge in summer
→ Slow growth in summer ?



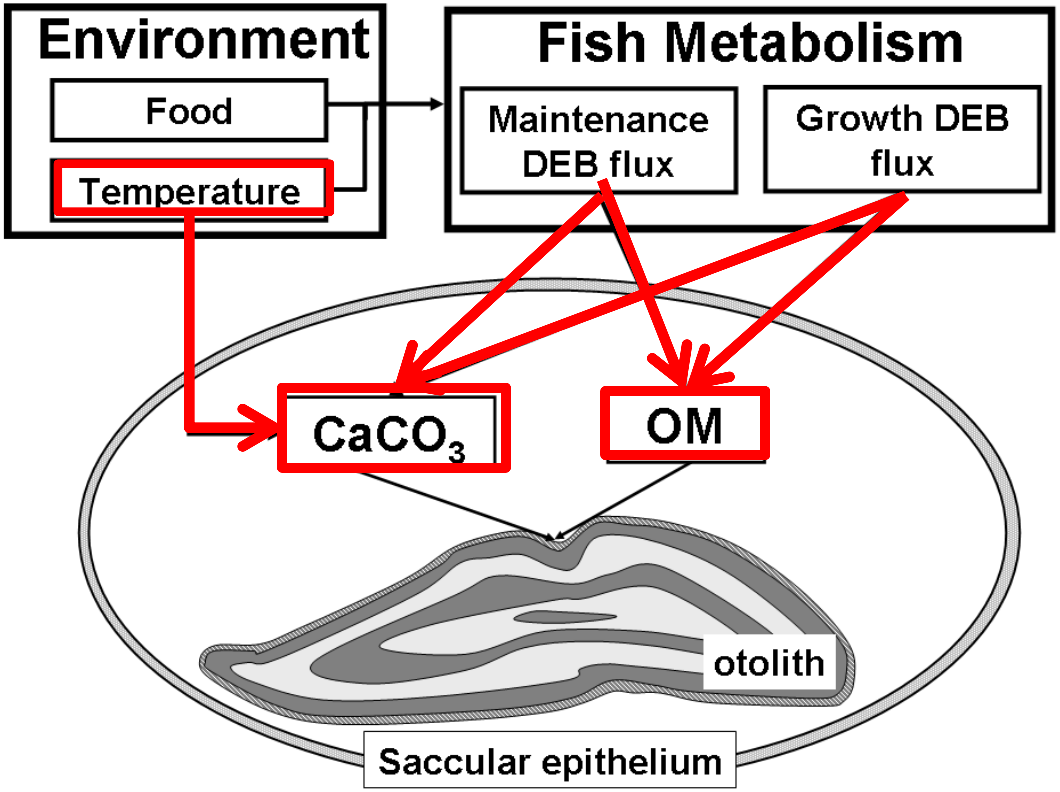
(Beckman *et al.* 1996, Hoie et al. 2009)

Model extension to take into account temperature effect on $CaCO_3$ precipitation



Fablet et al. 2011, PLoS ONE

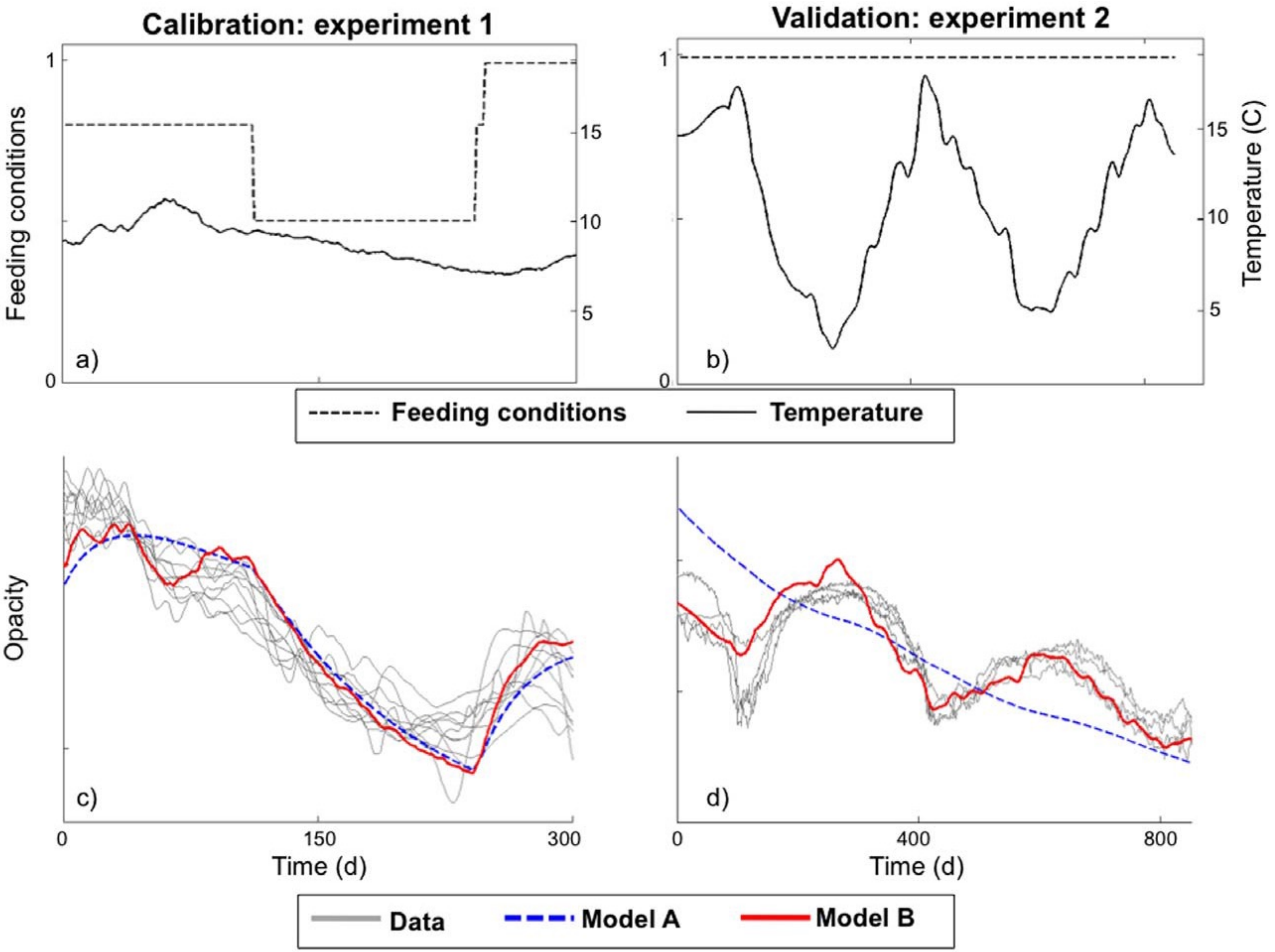
Model extension to take into account temperature effect on $CaCO_3$ precipitation

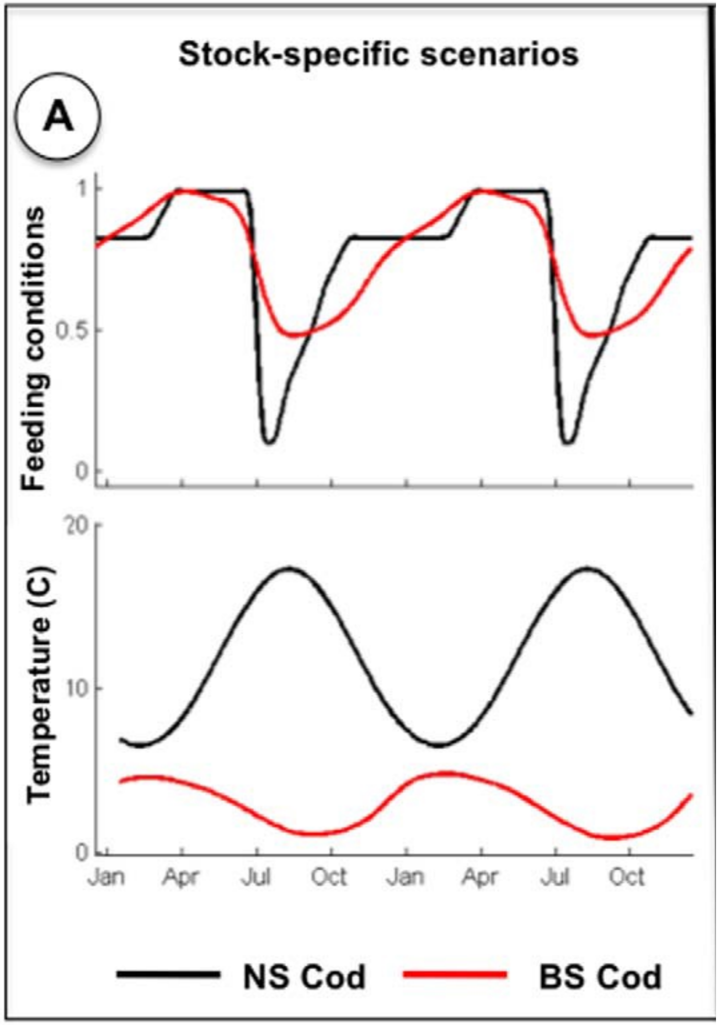


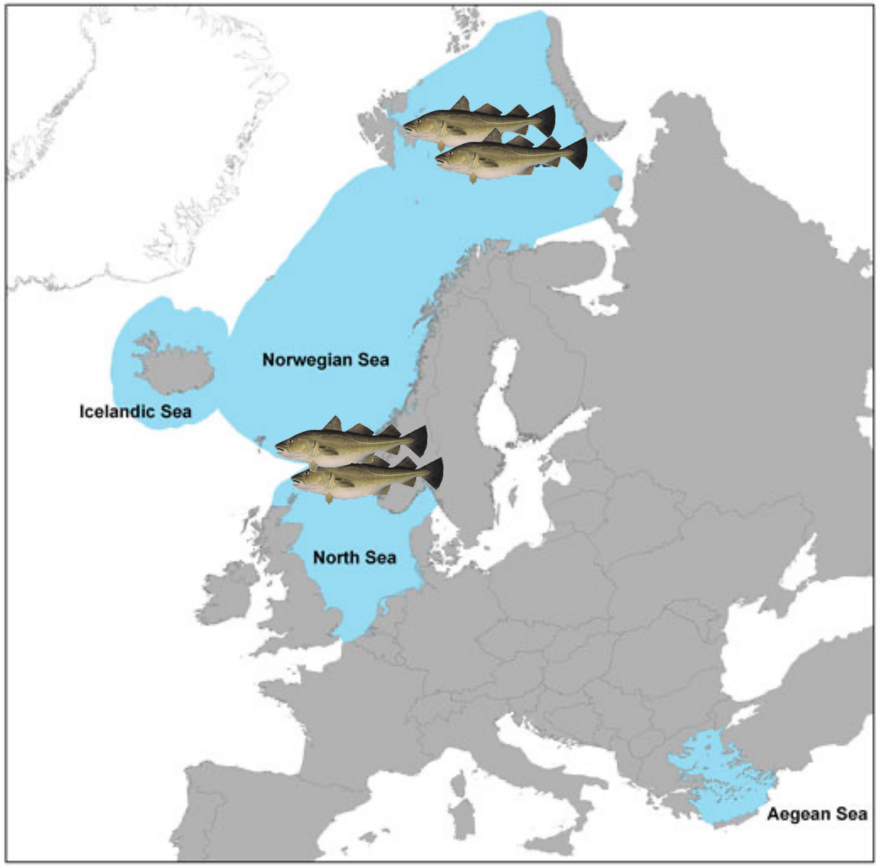
OM:
Organic Matrix

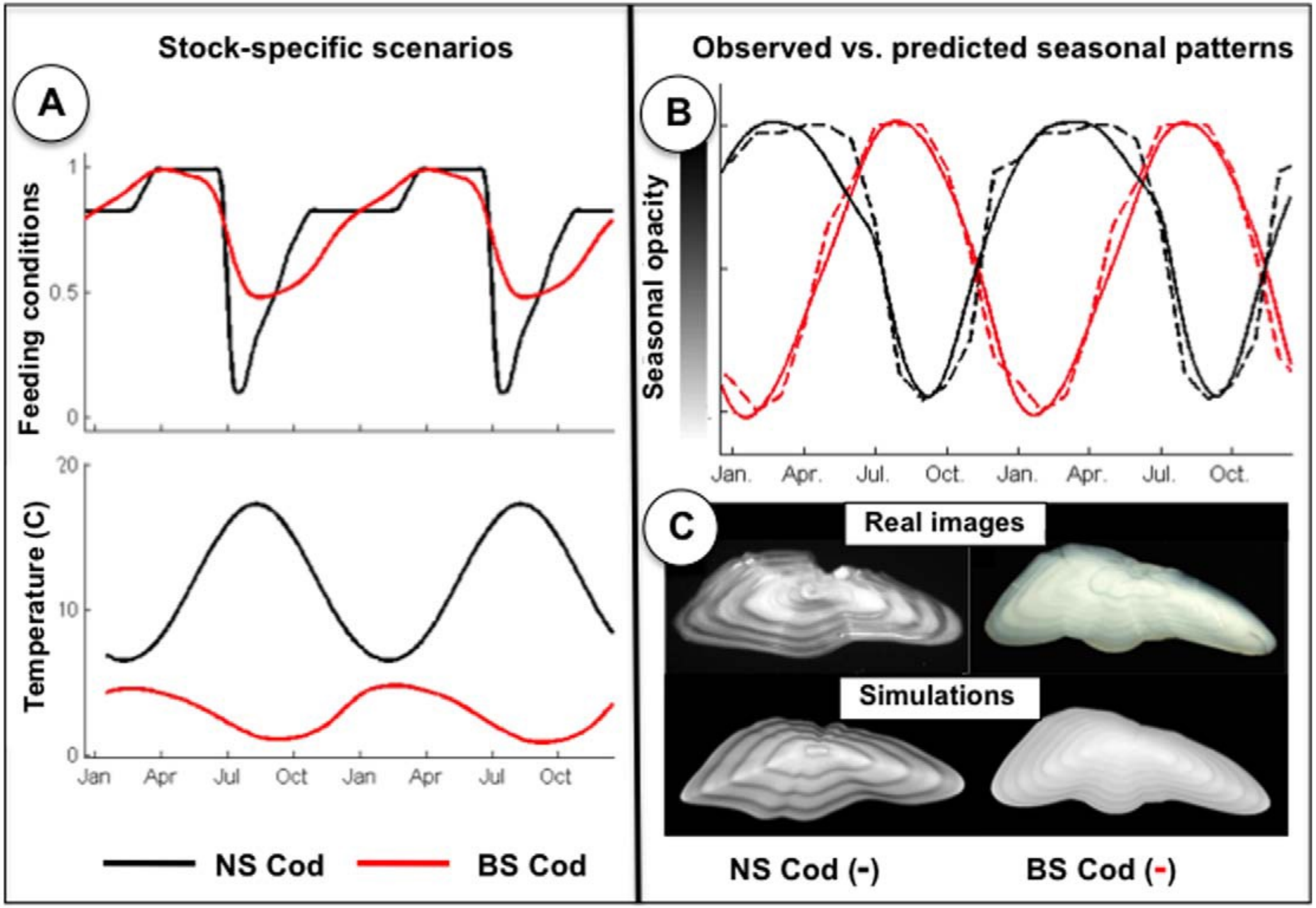
Fablet et al. 2011, PLoS ONE

Model calibration and validation with long-term experimental data




Stock-specific scenarios
A
Feeding conditions
1
0.5
0
Temperature (C)
20
10
0
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
NS Cod
BS Cod

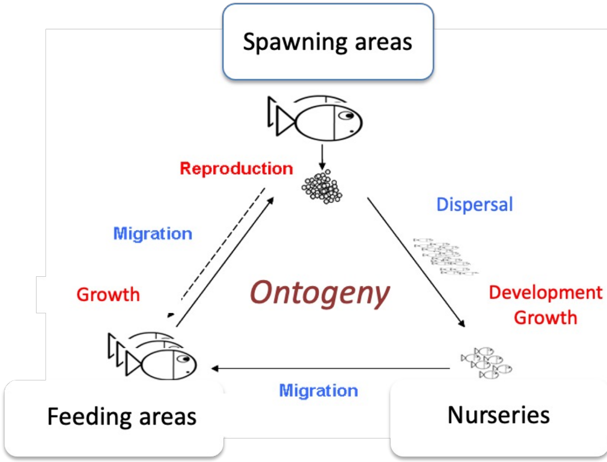

Norwegian Sea
Icelandic Sea
North Sea
Aegean Sea



Stock-specific scenarios

Observed vs. predicted seasonal patterns

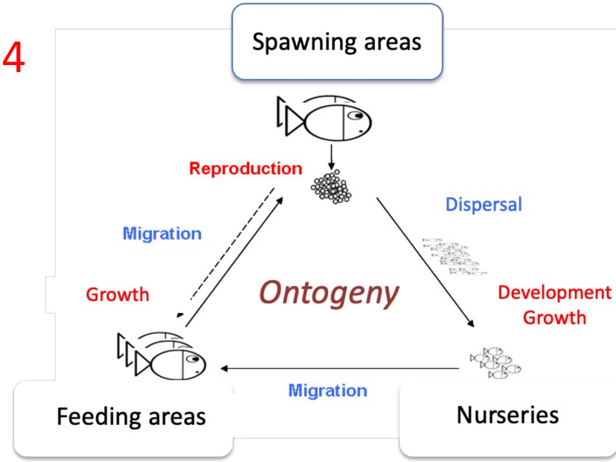
Processes under study in SPF DEB applications



Processes under study in SPF DEB applications

L. de Cubber S2

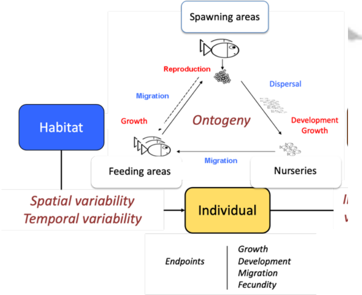
- Larval growth, dispersal and survival according to spawning dates/locations/depths
- Winter starvation/survival <-> Seasonal energy storage <-> Total egg production / number of batches (ie. Spawning dates next generation)
- Migration of juveniles and adults T. Brochier S4
- Food quality C. Menu S2
- …



SPF applications including a DEB module

Pecquerie PhD (2007),
Pecquerie et al. (2009)
Politikos et al. (2015)

Nunes, Garrido, et al. on going work



One species / One ecosystem

Engraulis encrasicolus, Sardina pilchardus

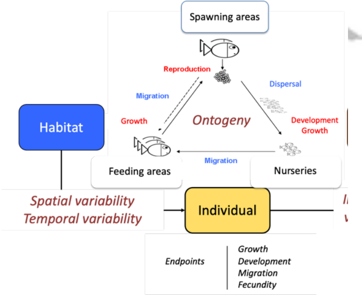
SPF applications including a DEB module

Gatti PhD (2017),
Gatti et al (2017)
Pecquerie PhD (2007),
Pecquerie et al. (2009)
Politikos et al. (2015)

Nunes, Garrido, et al. on going work

Le Thellier Master thesis (2021)
SOLAB Project (on-going)

Groenewald PhD (2021)
De Cubber Post-doc (on-going, Triatlas Project)

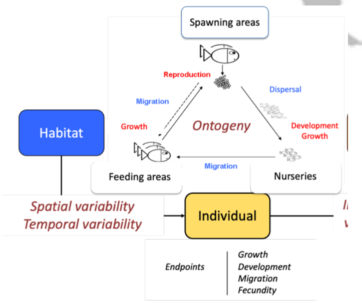


Several species / One ecosystem

Engraulis encrasicolus, Sardina pilchardus, Etrumeus whiteheadi, Sardinella aurita, Sardinella maderensis

SPF applications including a DEB module

Huret et al. (2019)

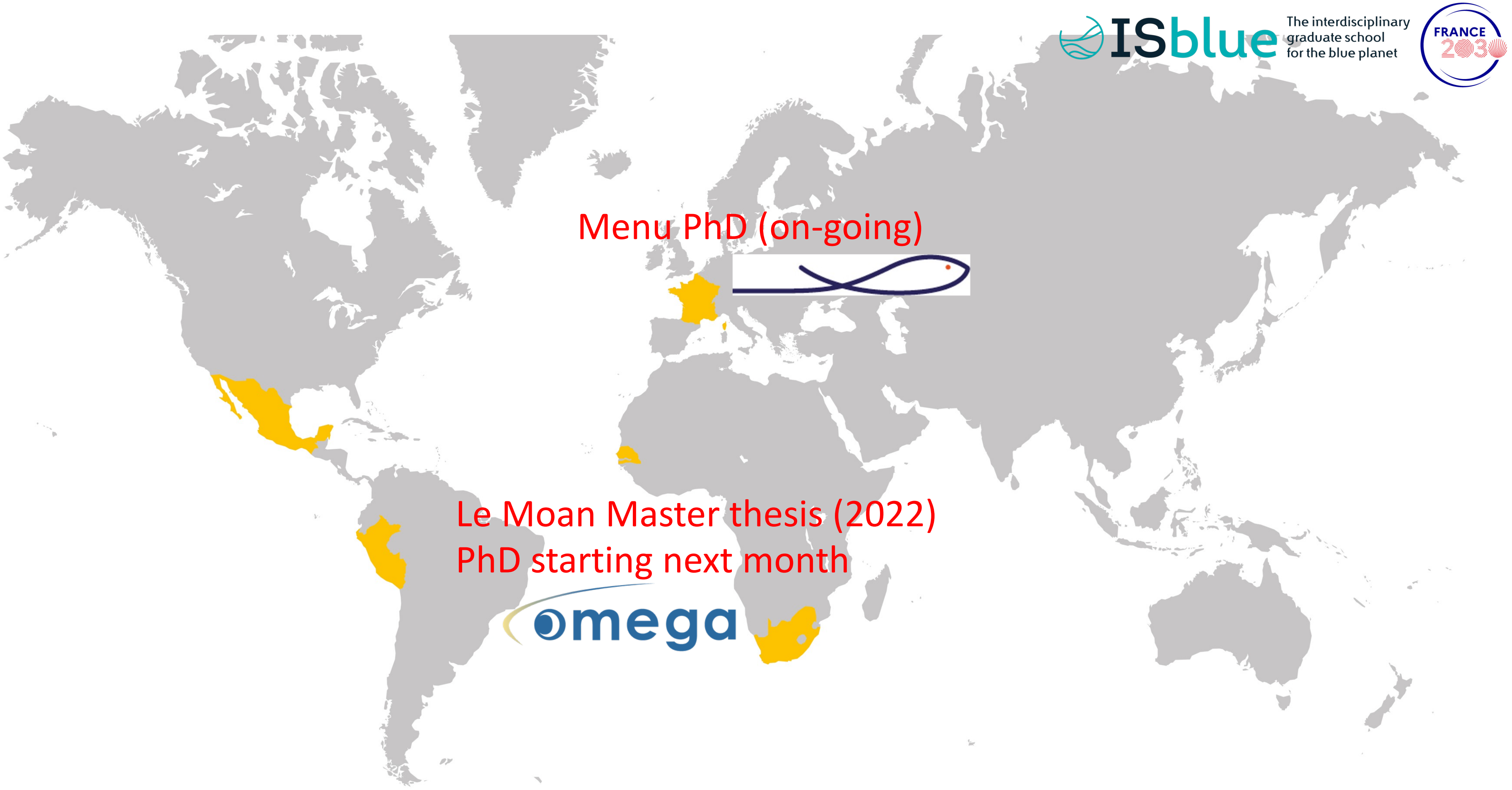


One species / Several ecosystems

E. Encrasicolus Bay of Biscay, North Sea, North Aegean Sea

SPF applications including a DEB module

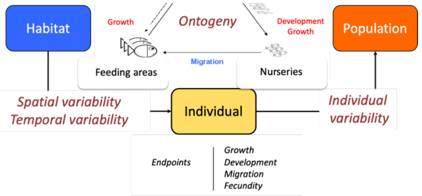
The interdisciplinary graduate school for the blue planet



Menu PhD (on-going)

Le Moan Master thesis (2022)

PhD starting next month

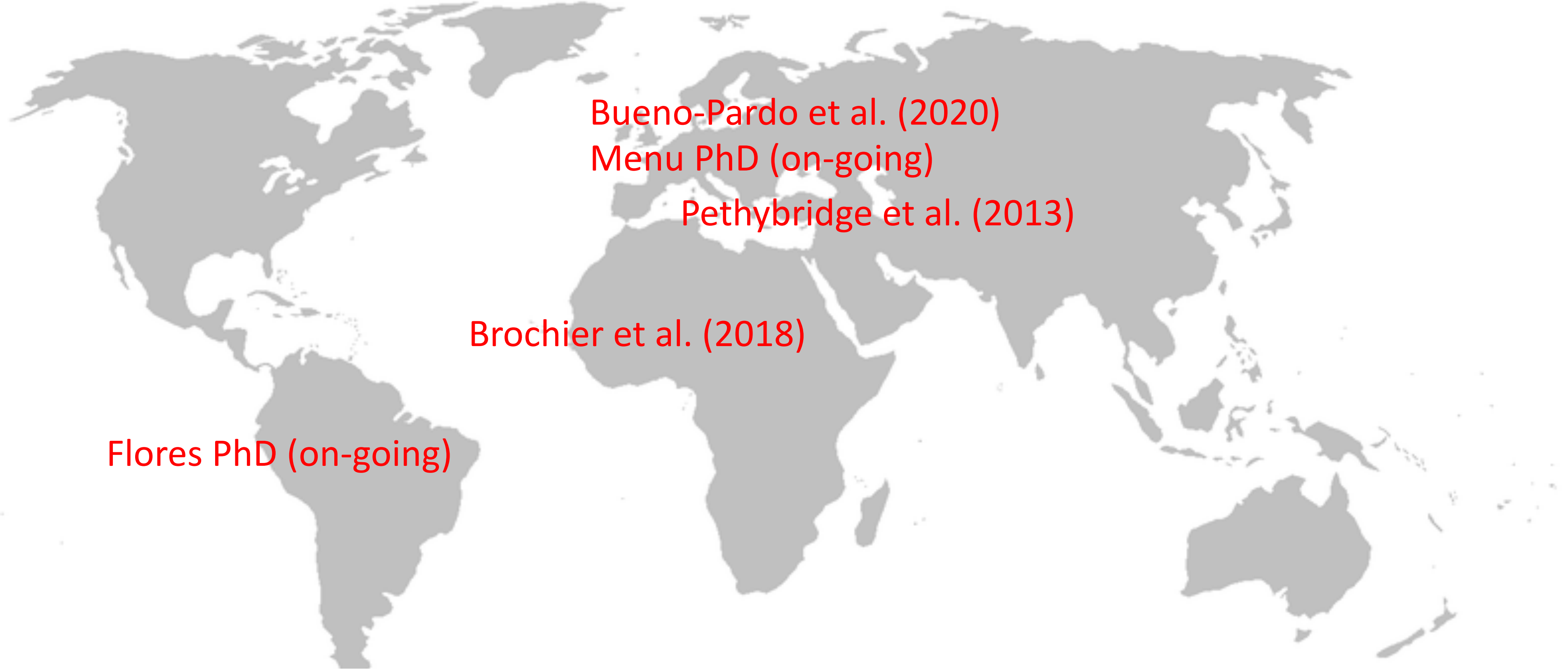


Several species / Several ecosystems

Engraulis encrasicolus., S. pilchardus,

Engraulis spp. , S. pilchardus, S. sagax, Etrumeus spp., Sardinella spp.

SPF applications including a DEB module

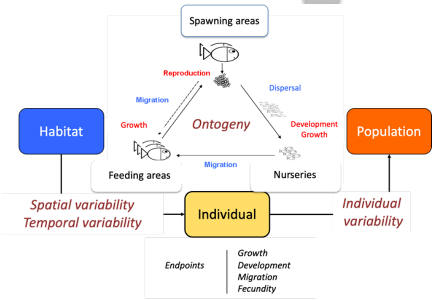


Bueno-Pardo et al. (2020)
Menu PhD (on-going)

Pethybridge et al. (2013)

Brochier et al. (2018)

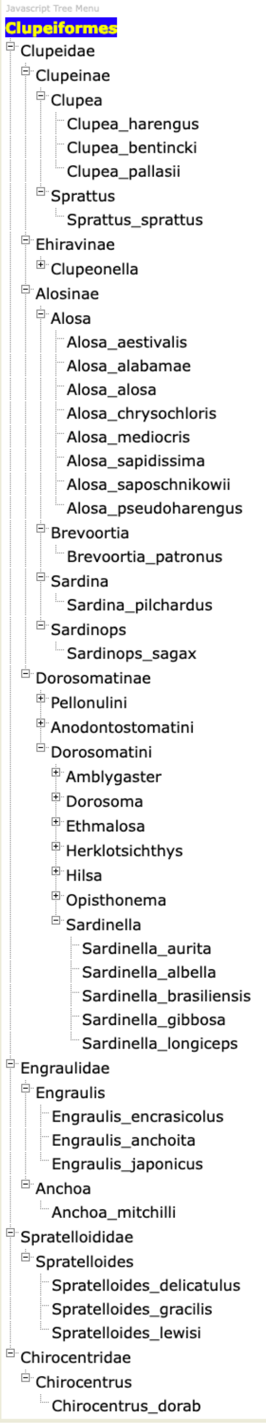
Flores PhD (on-going)



Individuals to population

Comparing species: AmP Library

- 3800 Species/populations
- From the Clupeiform order:
    - Temperate and tropical species
    - 32 clupeidae, 4 Engraulidae
    - 3 Spratelloididae, 1 Chirocentridae



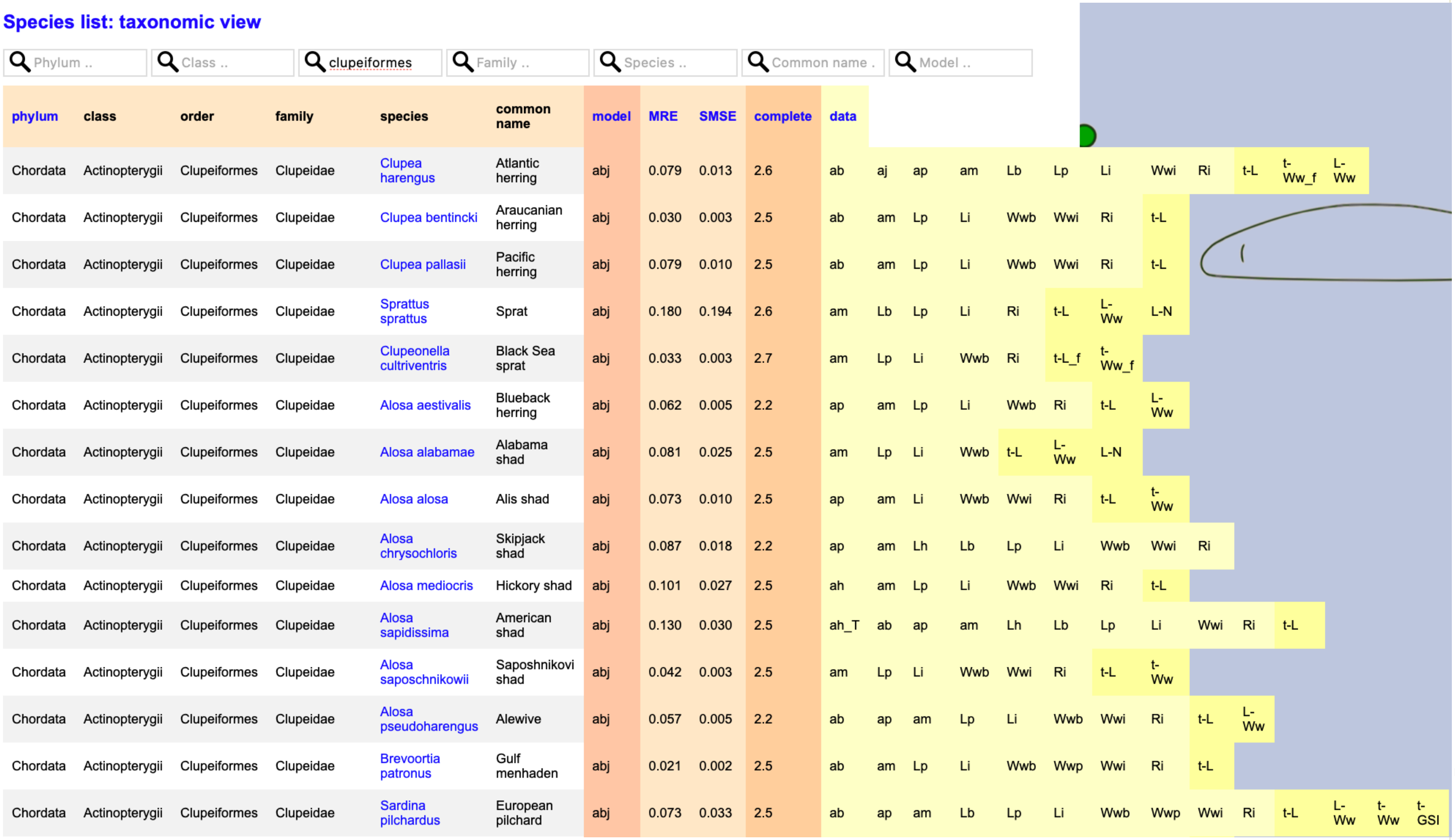
Javascript Tree Menu

Clupeiformes

- ⊟ Clupeidae
    - ⊟ Clupeinae
        - ⊟ Clupea
            - Clupea_harengus
            - Clupea_bentincki
            - Clupea_pallasii
        - ⊟ Sprattus
            - Sprattus_sprattus
    - ⊟ Ehiravinae
        - ⊞ Clupeonella
    - ⊟ Alosinae
        - ⊟ Alosa
            - Alosa_aestivalis
            - Alosa_alabamae
            - Alosa_alosa
            - Alosa_chrysochloris
            - Alosa_mediocris
            - Alosa_sapidissima
            - Alosa_saposchnikowii
            - Alosa_pseudoharengus
        - ⊟ Brevoortia
            - Brevoortia_patronus
        - ⊟ Sardina
            - Sardina_pilchardus
        - ⊟ Sardinops
            - Sardinops_sagax
    - ⊟ Dorosomatinae
        - ⊞ Pellonulini
        - ⊞ Anodontostomatini
        - ⊟ Dorosomatini
            - ⊞ Amblygaster
            - ⊞ Dorosoma
            - ⊞ Ethmalosa
            - ⊞ Herklotsichthys
            - ⊞ Hilsa
            - ⊞ Opisthonema
            - ⊟ Sardinella
                - Sardinella_aurita
                - Sardinella_albella
                - Sardinella_brasiliensis
                - Sardinella_gibbosa
                - Sardinella_longiceps
- ⊟ Engraulidae
    - ⊟ Engraulis
        - Engraulis_encrasicolus
        - Engraulis_anchoita
        - Engraulis_japonicus
    - ⊟ Anchoa
        - Anchoa_mitchilli
- ⊟ Spratelloididae
    - ⊟ Spratelloides
        - Spratelloides_delicatulus
        - Spratelloides_gracilis
        - Spratelloides_lewisi
- ⊟ Chirocentridae
    - ⊟ Chirocentrus
        - Chirocentrus_dorab

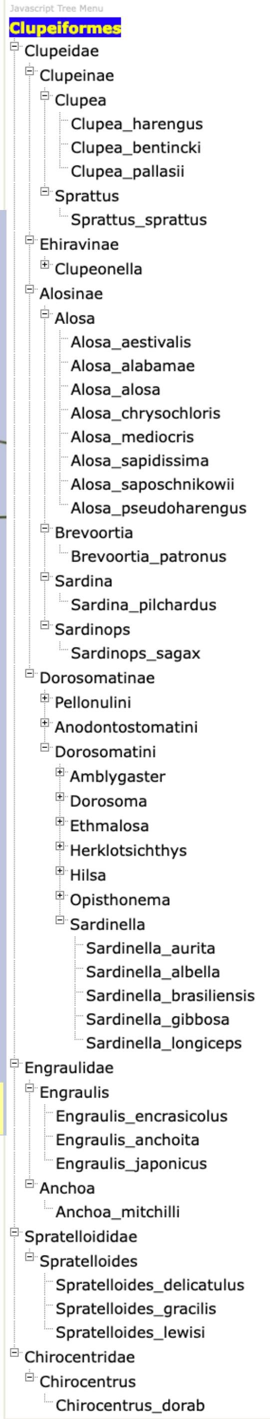
https://www.bio.vu.nl/thb/deb/deblab/add_my_pet/species_list.html

Comparing species: AmP Library



Species list: taxonomic view

phylum	class	order	family	species	common name	model	MRE	SMSE	complete	data													
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Clupea harengus	Atlantic herring	abj	0.079	0.013	2.6	ab	aj	ap	am	Lb	Lp	Li	Wwi	Ri	t-L	t-Ww_f	L-Ww		
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Clupea bentincki	Araucanian herring	abj	0.030	0.003	2.5	ab	am	Lp	Li	Wwb	Wwi	Ri	t-L						
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Clupea pallasii	Pacific herring	abj	0.079	0.010	2.5	ab	am	Lp	Li	Wwb	Wwi	Ri	t-L						
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Sprattus sprattus	Sprat	abj	0.180	0.194	2.6	am	Lb	Lp	Li	Ri	t-L	L-Ww	L-N						
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Clupeonella cultriventris	Black Sea sprat	abj	0.033	0.003	2.7	am	Lp	Li	Wwb	Ri	t-L_f	t-Ww_f							
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Alosa aestivalis	Blueback herring	abj	0.062	0.005	2.2	ap	am	Lp	Li	Wwb	Ri	t-L	L-Ww						
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Alosa alabamae	Alabama shad	abj	0.081	0.025	2.5	am	Lp	Li	Wwb	t-L	L-Ww	L-N							
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Alosa alosa	Alis shad	abj	0.073	0.010	2.5	ap	am	Li	Wwb	Wwi	Ri	t-L	t-Ww						
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Alosa chrysochloris	Skipjack shad	abj	0.087	0.018	2.2	ap	am	Lh	Lb	Lp	Li	Wwb	Wwi	Ri					
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Alosa mediocris	Hickory shad	abj	0.101	0.027	2.5	ah	am	Lp	Li	Wwb	Wwi	Ri	t-L						
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Alosa sapidissima	American shad	abj	0.130	0.030	2.5	ah_T	ab	ap	am	Lh	Lb	Lp	Li	Wwi	Ri	t-L			
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Alosa saposhnikowii	Saposhnikovi shad	abj	0.042	0.003	2.5	am	Lp	Li	Wwb	Wwi	Ri	t-L	t-Ww						
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Alosa pseudoharengus	Alewive	abj	0.057	0.005	2.2	ab	ap	am	Lp	Li	Wwb	Wwi	Ri	t-L	L-Ww				
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Brevoortia patronus	Gulf menhaden	abj	0.021	0.002	2.5	ab	am	Lp	Li	Wwb	Wwp	Wwi	Ri	t-L					
Chordata	Actinopterygii	Clupeiformes	Clupeidae	Sardina pilchardus	European pilchard	abj	0.073	0.033	2.5	ab	ap	am	Lb	Lp	Li	Wwb	Wwp	Wwi	Ri	t-L	L-Ww	t-Ww	t-GSI



Clupeiformes

- Clupeidae
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    - Clupea
      - Clupea_harengus
      - Clupea_bentincki
      - Clupea_pallasii
    - Sprattus
      - Sprattus_sprattus
  - Ehiravinae
    - Clupeonella
  - Alosinae
    - Alosa
      - Alosa_aestivalis
      - Alosa_alabamae
      - Alosa_alosa
      - Alosa_chrysochloris
      - Alosa_mediocris
      - Alosa_sapidissima
      - Alosa_saposchnikowii
      - Alosa_pseudoharengus
    - Brevoortia
      - Brevoortia_patronus
    - Sardina
      - Sardina_pilchardus
    - Sardinops
      - Sardinops_sagax
  - Dorosomatinae
    - Pellonulini
    - Anodontostomatini
    - Dorosomatini
      - Amblygaster
      - Dorosoma
      - Ethmalosa
      - Herklotsichthys
      - Hilsa
      - Opisthonema
      - Sardinella
        - Sardinella_aurita
        - Sardinella_albella
        - Sardinella_brasiliensis
        - Sardinella_gibbosa
        - Sardinella_longiceps
- Engraulidae
  - Engraulis
    - Engraulis_encrasicolus
    - Engraulis_anchoita
    - Engraulis_japonicus
  - Anchoa
    - Anchoa_mitchilli
- Spratelloididae
  - Spratelloides
    - Spratelloides_delicatulus
    - Spratelloides_gracilis
    - Spratelloides_lewisi
- Chirocentridae
  - Chirocentrus
    - Chirocentrus_dorab

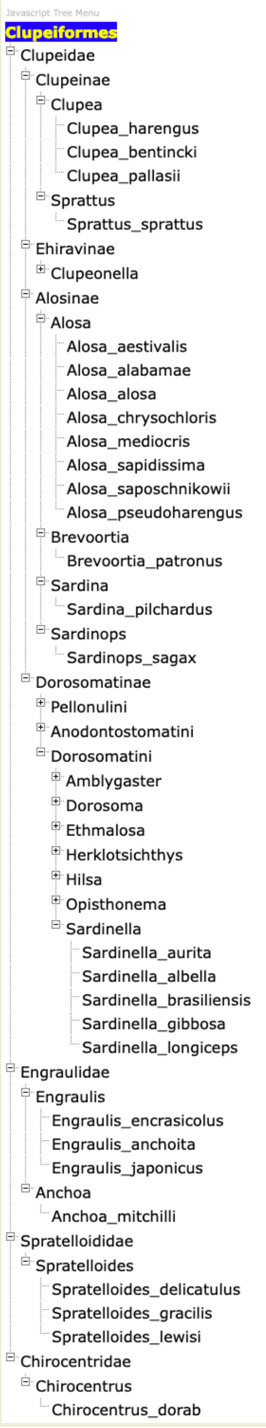
https://www.bio.vu.nl/thb/deb/deblab/add_my_pet/species_list.html

Comparing species: AmP Library

- 3800 Species/populations
- From the Clupeiform order:
  - Temperate and tropical species
  - 32 clupeidae, 4 Engraulidae
  - 3 Spratelloididae, 1 Chirocentridae
- Model used:
  - Standard DEB model with acceleration during the larval stage; no use of reproduction reserves to survive winter in temperate regions
- SPF growth and energy content are often lacking at a seasonal scale (but see e.g. Petitgas and Dubrueil, Gatti et al. 2018, Rosa et al. 2013 for European anchovy and sardine)

→ May explain some of the non-realistic parameter estimates : new round of parameter estimation is required

https://www.bio.vu.nl/thb/deb/deblab/add_my_pet/species_list.html



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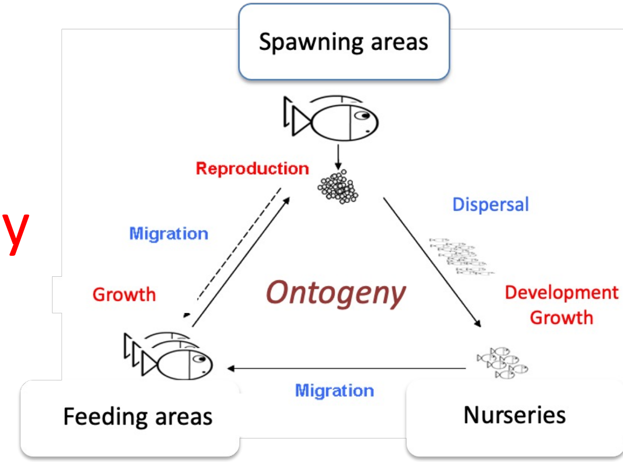
      - Sprattus_sprattus
  - ⊟ Ehiravinae
    - ⊞ Clupeonella
  - ⊟ Alosinae
    - ⊟ Alosa
      - Alosa_aestivalis
      - Alosa_alabamae
      - Alosa_alosa
      - Alosa_chrysochloris
      - Alosa_mediocris
      - Alosa_sapidissima
      - Alosa_saposchnikowii
      - Alosa_pseudoharengus
    - ⊟ Brevoortia
      - Brevoortia_patronus
    - ⊟ Sardina
      - Sardina_pilchardus
    - ⊟ Sardinops
      - Sardinops_sagax
  - ⊟ Dorosomatinae
    - ⊞ Pellonulini
    - ⊞ Anodontostomatini
    - ⊟ Dorosomatini
      - ⊞ Amblygaster
      - ⊞ Dorosoma
      - ⊞ Ethmalosa
      - ⊞ Herklotsichthys
      - ⊞ Hilsa
      - ⊞ Opisthonema
      - ⊟ Sardinella
        - Sardinella_aurita
        - Sardinella_albella
        - Sardinella_brasiliensis
        - Sardinella_gibbosa
        - Sardinella_longiceps
- ⊟ Engraulidae
  - ⊟ Engraulis
    - Engraulis_encrasicolus
    - Engraulis_anchoita
    - Engraulis_japonicus
  - ⊟ Anchoa
    - Anchoa_mitchilli
- ⊟ Spratelloididae
  - ⊟ Spratelloides
    - Spratelloides_delicatulus
    - Spratelloides_gracilis
    - Spratelloides_lewisi
- ⊟ Chirocentridae
  - ⊟ Chirocentrus
    - Chirocentrus_dorab

Processes under study and challenges

- Larval growth, dispersal and survival according to spawning dates/locations/depths
- Winter starvation/survival <-> Seasonal energy storage <-> Total egg production / number of batches (ie. Spawning dates next generation)
- Migration of juveniles and adults
- Food quality
- Seasonal data on growth and energy density is key (e.g. Gatti et al. 2017, 2018)
- Individual spawning scheme <-> Population spawning period and peak
- Experimental data on thermal tolerance range of the different life stages (fundamental/realized niches)



To take home

“Have no meaning unless they are united" (F. Bacon)

Three studies of Lucian Freud (Tryptic from Francis Bacon, 1969)

Scientific approach

- Experiments
- Observations
- Mechanistic Modelling

→ Three distorted representation of the same reality

To take home

- Coupling Observations/Experiments and DEB models to better interpret data and reconstruct individual life histories of small pelagic fish
- We need better confidence in DEB parameter estimates of life cycle models for small pelagic fish
- Comparing life-history traits of closely related SPF species using DEB models is a clearly difficult/time-consuming task…

  … worth undertaking as a community of SPF scientists

→ We could build on the approach developed by
Activity 5 of the joint PICES/ICES WGSPF
led by M. Huret, M. Lindegren and F. Berg

How to get involved / get started?

DEBSea

Deuxième partie

Chapitre 5 : Le modèle DEB standard, concepts et mise en équations

- Subscribe to the *deb mailing list* for the release of the online DEBSea course ('Introduction to DEB theory and applications in marine ecology, fisheries sciences and aquaculture')
- Funding options for research opportunities in Brest from ISblue
  - Invited Researchers and Professors (1 to 6 months)
  - International Post-docs Fellowships (2 years)
  - Incoming master mobility (up to 6 months)

Visit https://www.isblue.fr/en/funding-opportunities/ !
Send me an email: laure.pecquerie@ird.fr

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Thank you to the Session 2 convenors for their invitation and to the organizers of the SPF 2022 Symposium!