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Navigating Changes in Small Pelagic Fish and Forage Communities: Climate, Ecosystems, and Sustainable Fisheries
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PICES ICES CIEM Food and Agriculture Organization of the United Nations
Endorsed by 2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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Dissipation of Energy in Ocean Models and Connectivity

IBM models for simulating the Early Life Stages of small pelagic: a generic code approach

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CSIC Consejo Superior de Investigaciones Científicas

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A biophysical model for the Early Life Stages of fish species

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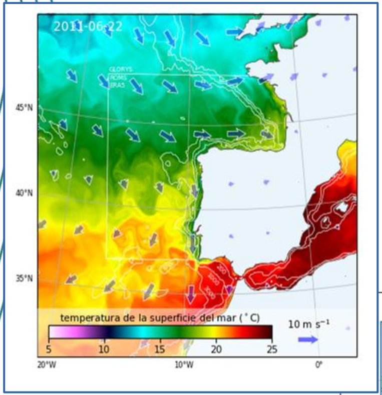
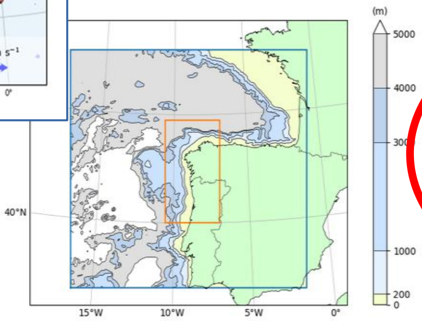
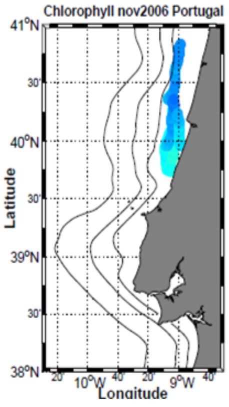
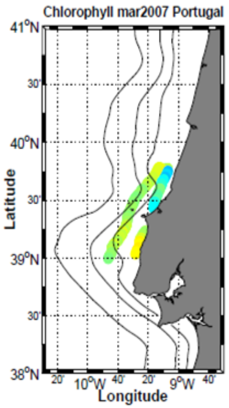
Hydrodynamic model (3D)
- ROMS Rutgers
- 30 vertical levels
- 3.5 km horizontal resolution
- Meteorological forcing
- Tides
- Rivers





Velocities
Turbulence
Temperature
Salinity
Density





Biogeochemical model
N2PZD2 (nutrient sources)
- Fennel et al, 2006

Phyto
Zoo

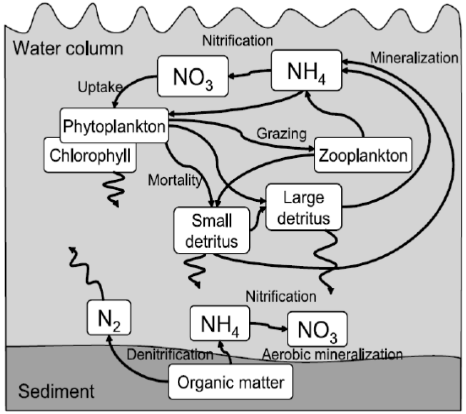


Figure 1. Biological model schematic.

Lagrangian IBM model
- Offline, Ichthyop or OpenDrift
- Physical processes (advection and dispersion)
- Biological behaviour of Early Life Stages (growth, buoyancy, vertical migration, etc.)

Transport
Survival
Connectivity

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A Lagrangian IBM for Early Life Stages

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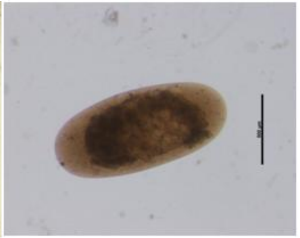
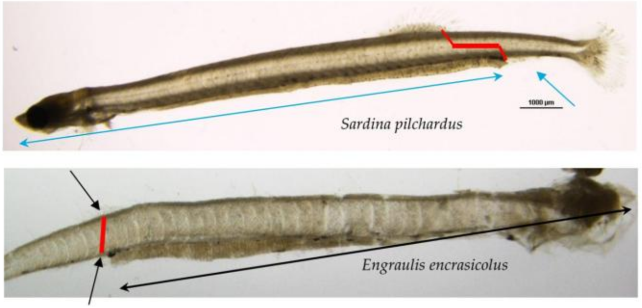
OpenDrift	Lagrangian model (offline)	Egg (<2.8 mm)	Yolk-sac larva (2.8–4.5 mm)	Feeding larva (>4.5 mm)
Physical processes	Horizontal advection	×	×	×
	Vertical advection	×	×	×
	Horizontal dispersion	×	×	×
	Vertical dispersion	×	×	×
Biological processes	Temperature dependent development/growth	×	×	
	Food limitation (LTL model)			×
	Development dependent buoyancy	×		
	Vertical migration			×

	Yolk-sac	Autonomous
Anchovy	3.5 mm	4.5 mm
Sardine	4.0 mm	5. 5mm

Egg



Larvae



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Egg stage

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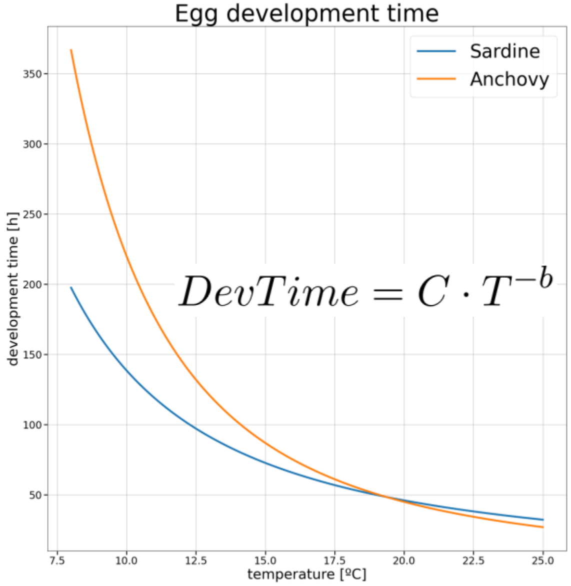
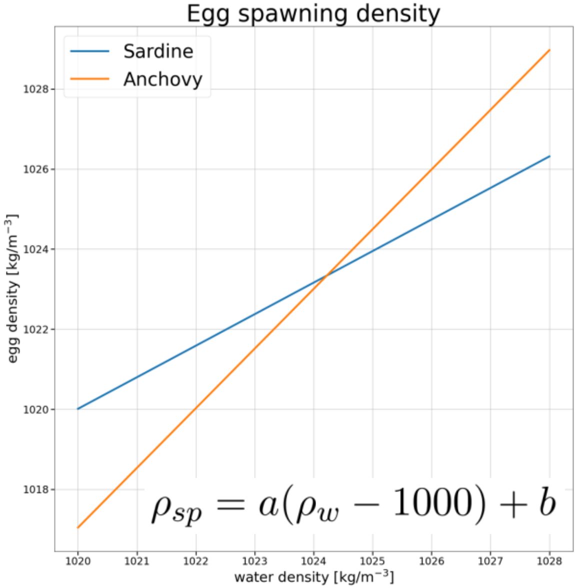
Atlantic Iberian Sardine (*Sardina pilchardus*)

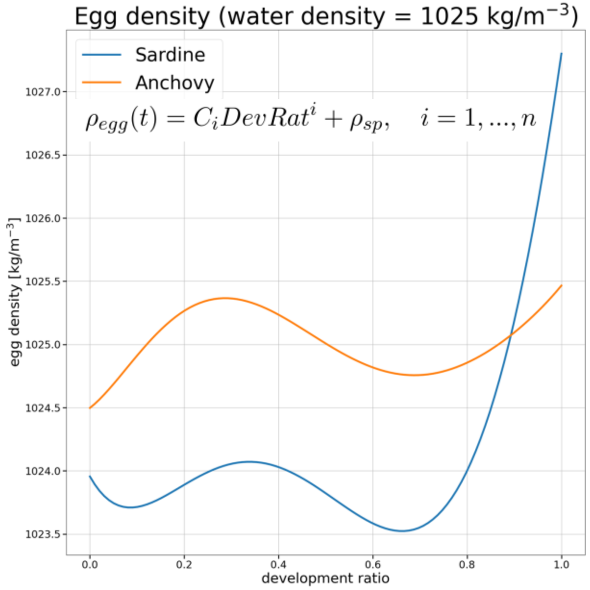
$d = 1.63$ mm

European Anchovy (*Engraulis encrasicolus*)

$a = 0.5$ mm, $b = 1.4$ mm, $d = 0.7047$ mm

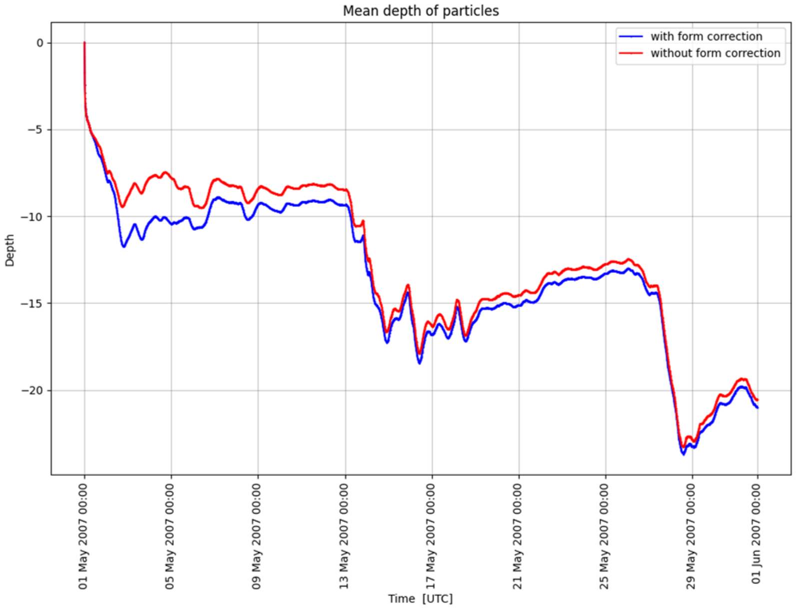


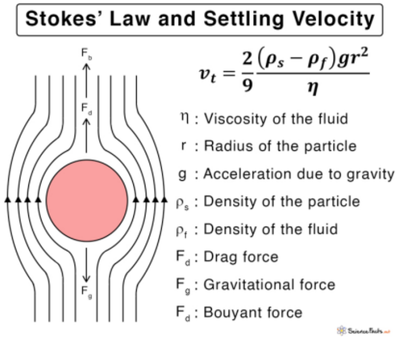




Egg stage

Elliptical vs Spherical eggs

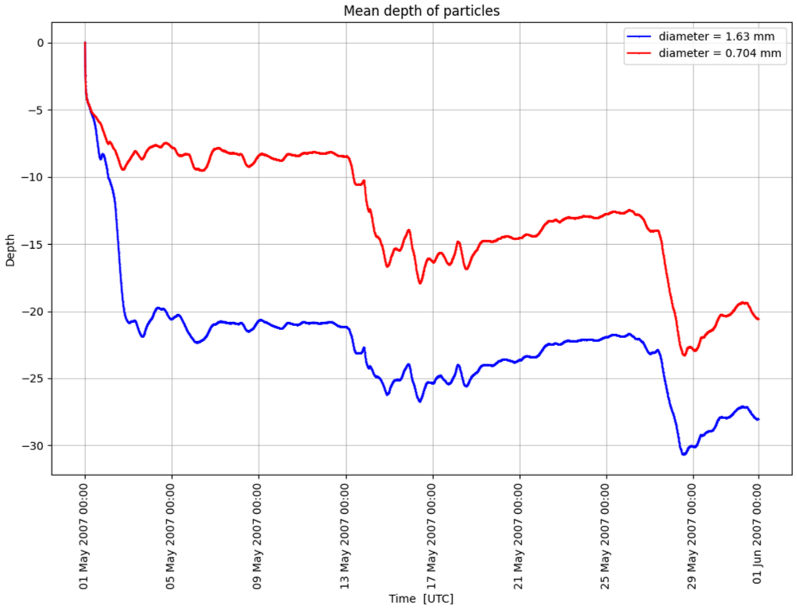




Shape correction for ellipsoid

$$W = \frac{1}{18} g d^2 \Delta\rho\mu^{-1}, \; W_{ellip} = \frac{A_{sphere}}{A_{ellip}} W [\mathrm{m/s}]$$

Bigger vs Smaller eggs

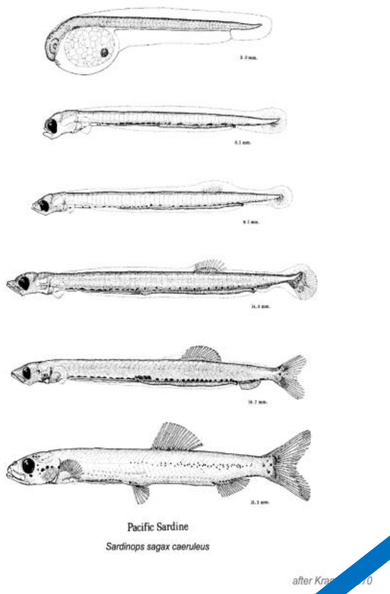


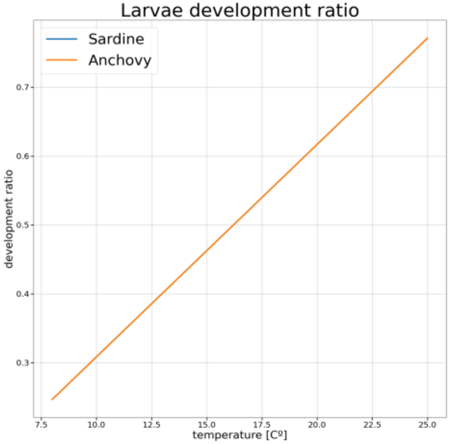
The trajectory model is not highly sensitive to shape correction but it is to egg size

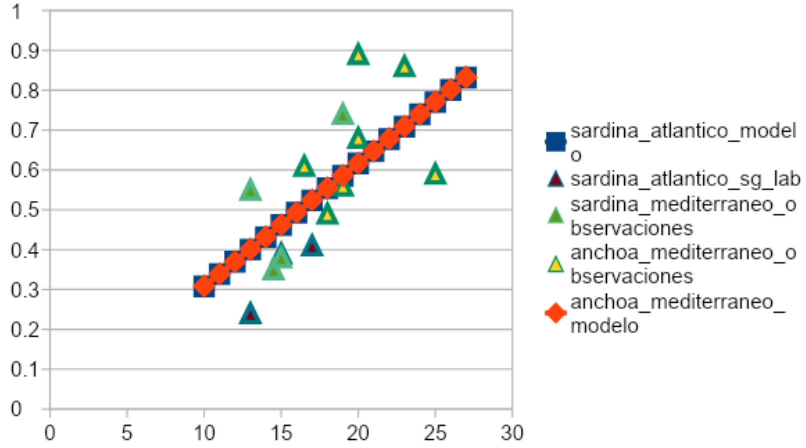
Larval stage

Yolk-sac larvae → **Linear growth dependent on temperature**

$$\theta(T) = a \cdot T + b$$





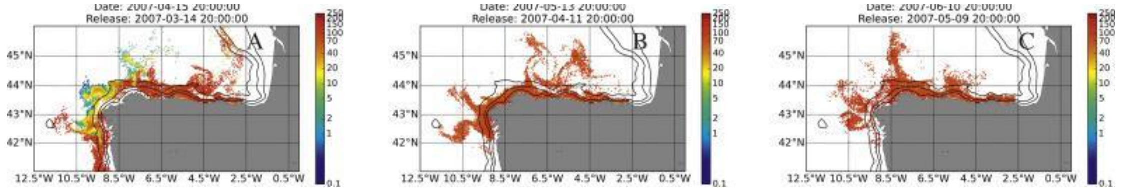


Food Limitation Factor (FLF)

$$\theta(T) = (a \cdot T + b) \cdot FLF$$

$$\text{FLF} = \frac{a + \lambda Z_{max} + (1-\lambda)F_{max}}{\lambda Z_{max} + (1-\lambda)F_{max}} \cdot \frac{\lambda Z(t) + (1-\lambda)F(t)}{a + \lambda Z(t) + (1-\lambda)F(t)}, \ \lambda \in [0,1]$$

Self-feeding autonomous larvae → **Vertical migration**



What is the impact of vertical migration on larval dispersion?

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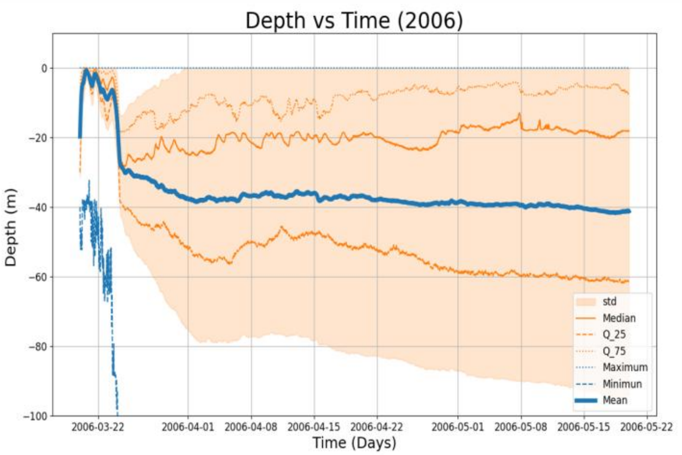
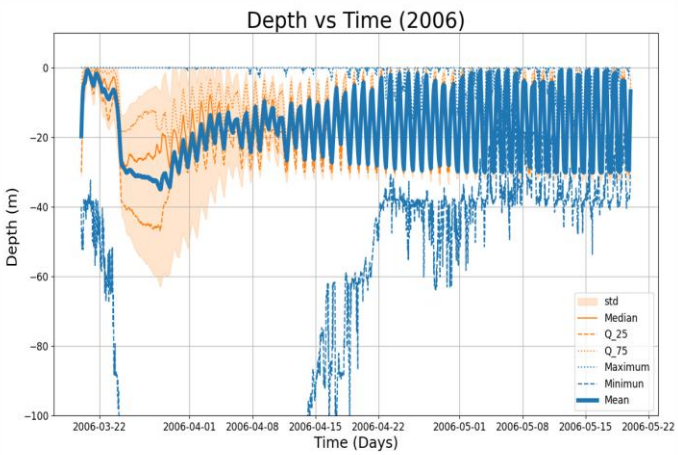
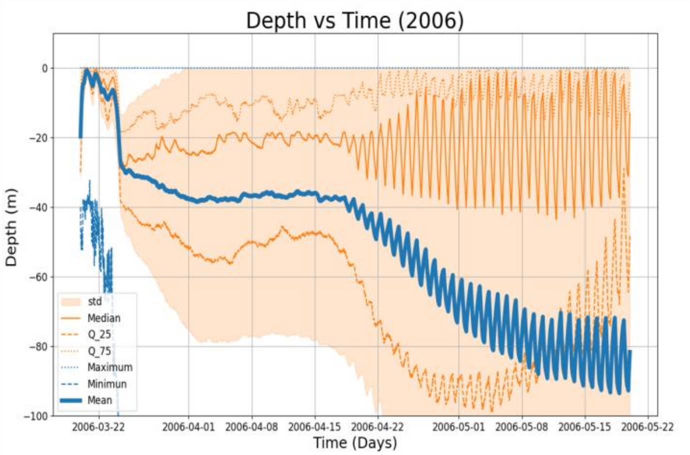
No vertical migration



Vertical migration



Vertical migration at 10 mm



Vertical positions of particles: depth limit and checked different sizes at which vertical migration starts

Spawning areas and periods

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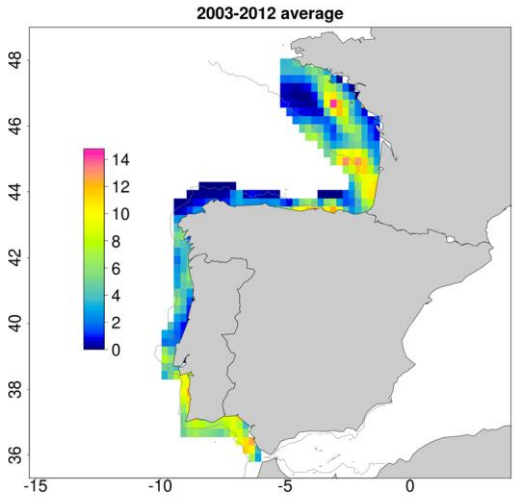
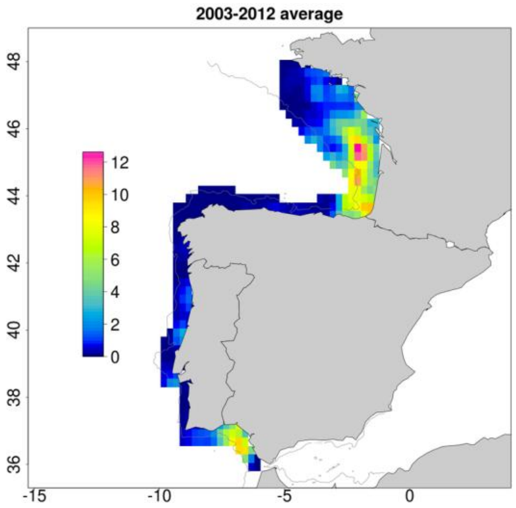
Positions for spawning of eggs



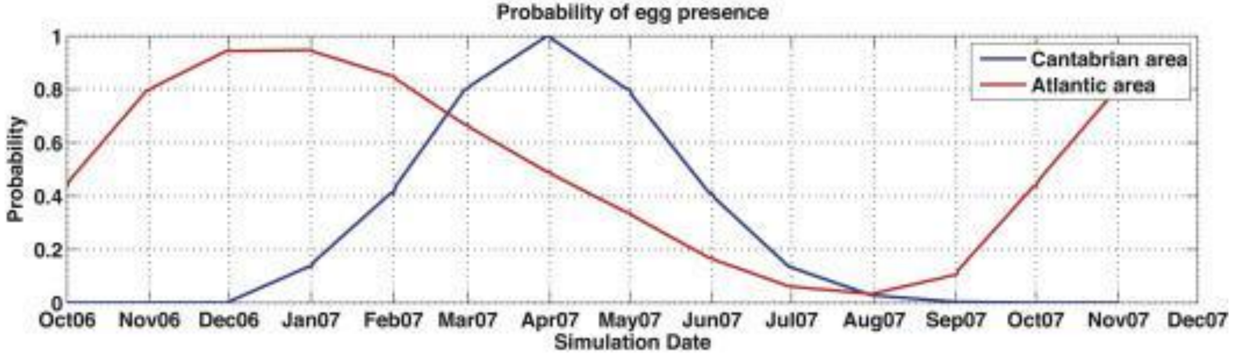
Sardine



Anchovy

Egg density from CUFES surveys (average 2003-2012). ICES WGAEGG

Time for spawning of eggs



Sardine

Stratoudakis et al., 2007

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Target species of commercial interest

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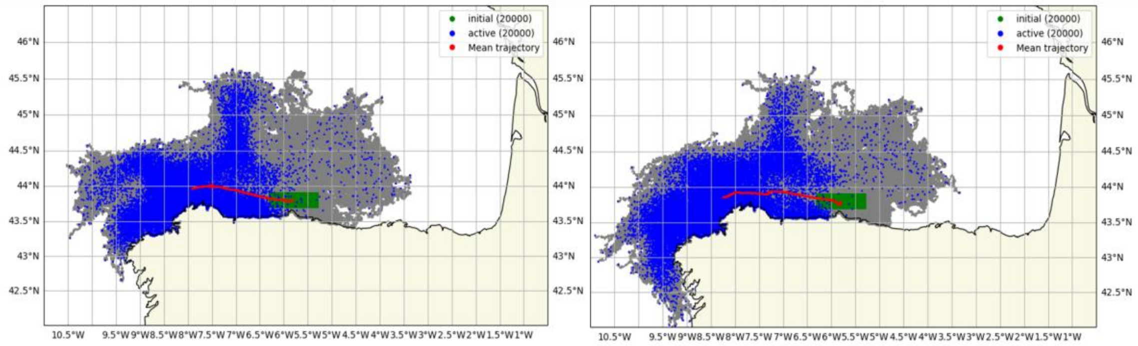
Sardine

Anchovy

Hake

Octopus



Can we simulate species that are not SPF using our IBM generic code approach?

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Some results for hake

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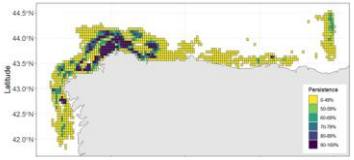
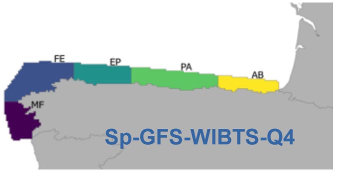
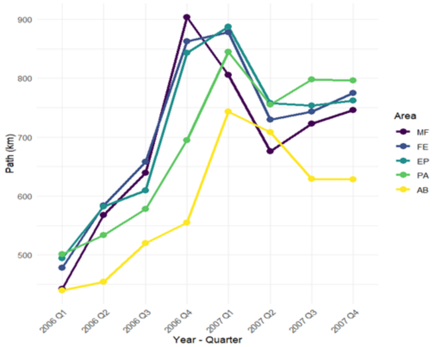
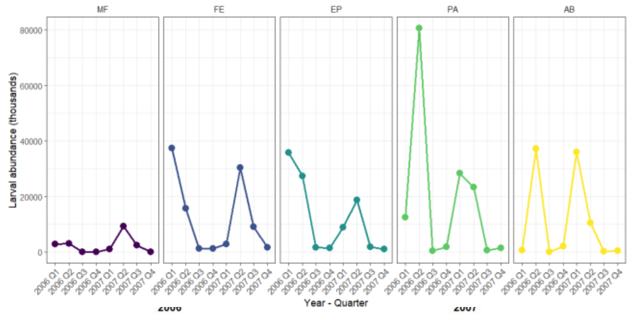
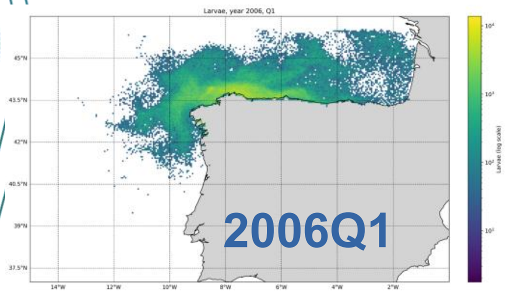
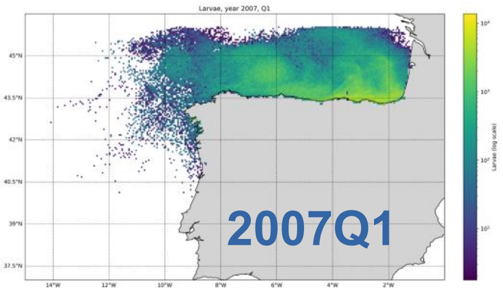


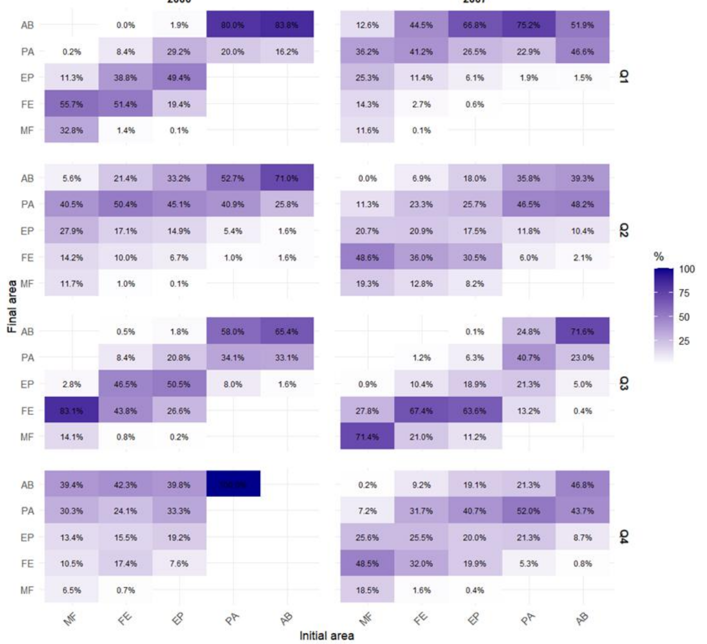








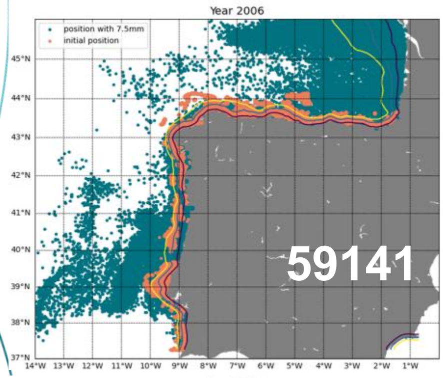


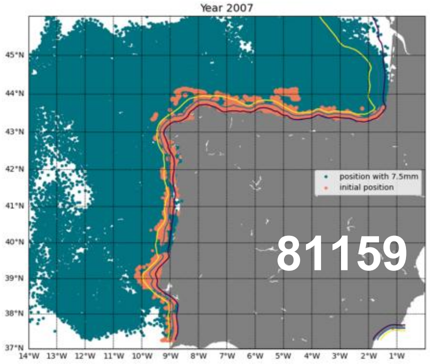


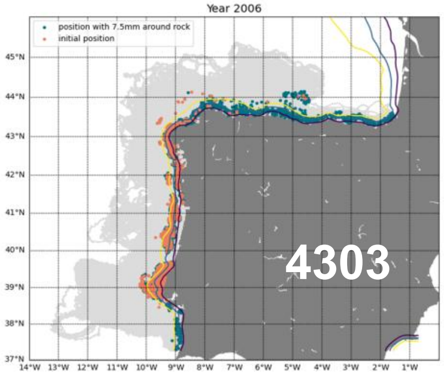
Success: reaching Sp-GFS-WIBTS-Q4 areas. Overcome mortality models (depth 330, surface dehydration, 22ºC). Influence of seasonality in spawning.

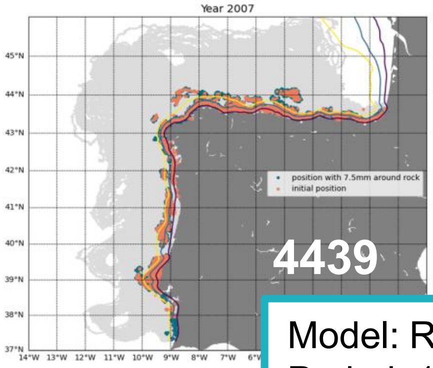
Model: ROMS + Opendrift
Period: 5Jan06 - 31Dec07
Particles: 24510
Run: Advection+Dispersion (H &V) + behaviour (growth depending on temperature) + mortality

Some results for octopus







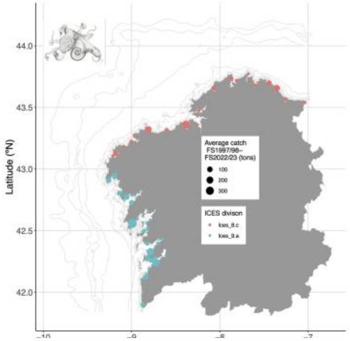


Success: reaching 7.5mm close to rocks.
Higher possibility of settling.
Metric for recruitment!?

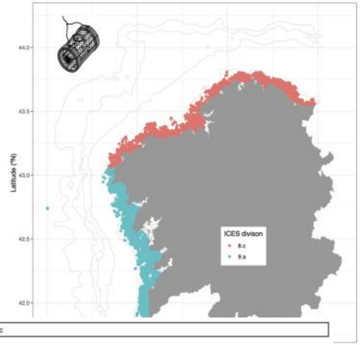
Model: ROMS + Opendrift
Period: 1Sept-31Dec
Particles: 100000
Run: Advection+Dispersion (H &V) + behaviour (growth depending on temperature)

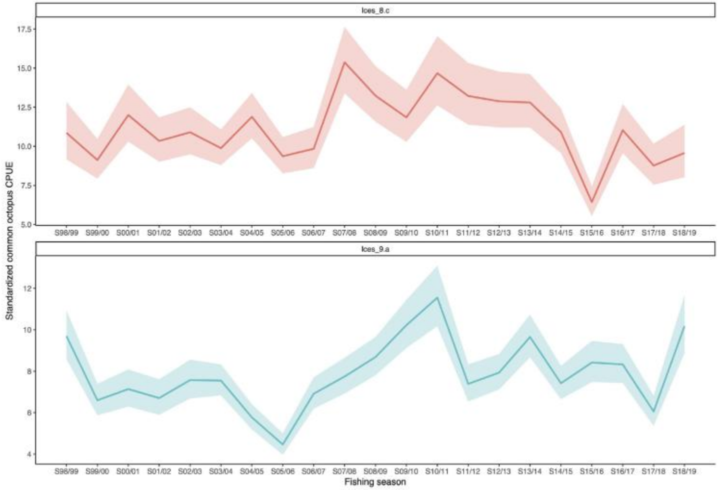
Data for model validation

Captures



Observers on artesanal fishing vessels





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A generic code for simulating the Early Life Stages of small pelagic

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A multi-species IBM has been developed.

- Anchovy IBM and sardine IBM have been merged attending their similarities
- Hake and octopus IBMs have been recently added
- Other similar species could be simulated (user defined parameters)
- Same physical and biological processes
- Different spawning periods and areas for seeding particles
- Different input data depending on the species:
    - initial larval length
    - length for larval stage change
    - vertical migration length
    - egg diameter
    - coefficients for the parametrizations
- Lagrangian models are data demanding and there is a lot of information lacking for certain species

GitHub

Coming soon

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Closing remarks

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- Biophysical models help disentangle how environmental variability shapes spatio-temporal distributions of SPF

- A flexible and user-friendly framework enables multi-species exploration and adaptation

- Integrating models and data is key to strengthen fisheries advice in a highly variable and changing ocean