Modelling fish larvae dynamics in the Canary Current Upwelling System

Modelação biofísica da dinâmica larvar no Sistema de Afloramento da Corrente das Canárias

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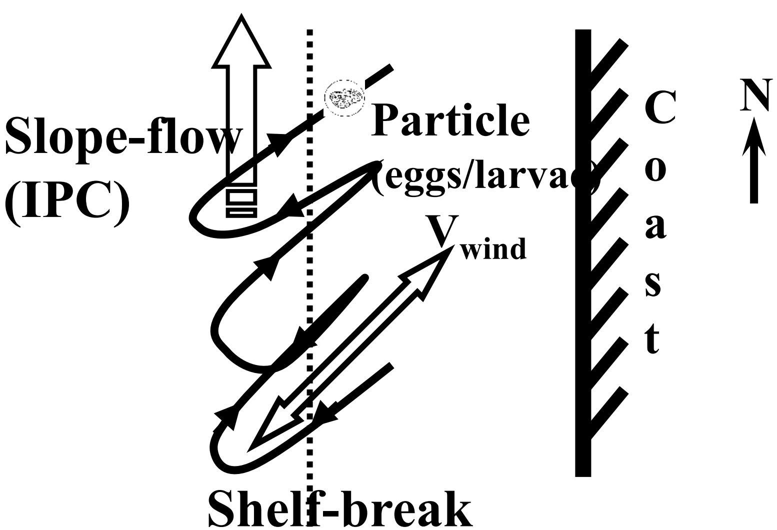
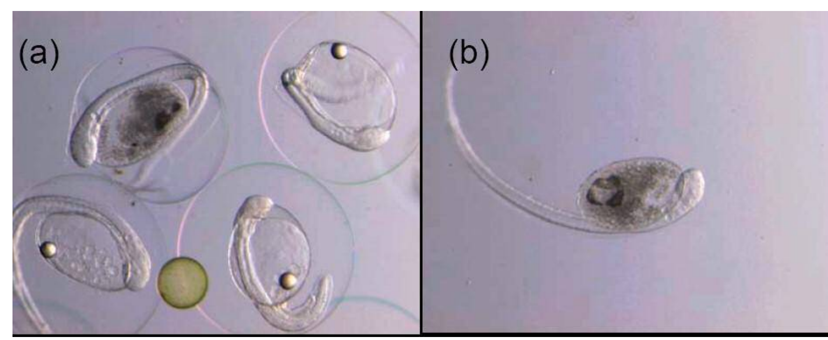
IPMA Instituto Português do Mar e da Atmosfera
CCMAR Centro de Ciências do Mar
IDL
IRD Institut de Recherche pour le Développement France
Ifremer
CAP RUN Centre Technique d'Appui à la Pêche Réunionnaise

OBJECTIVE

Understand the interaction between biology and (climatological) ocean conditions on larval sardine dispersion, retention, and recruitment in the northern Canary Current Upwelling System.



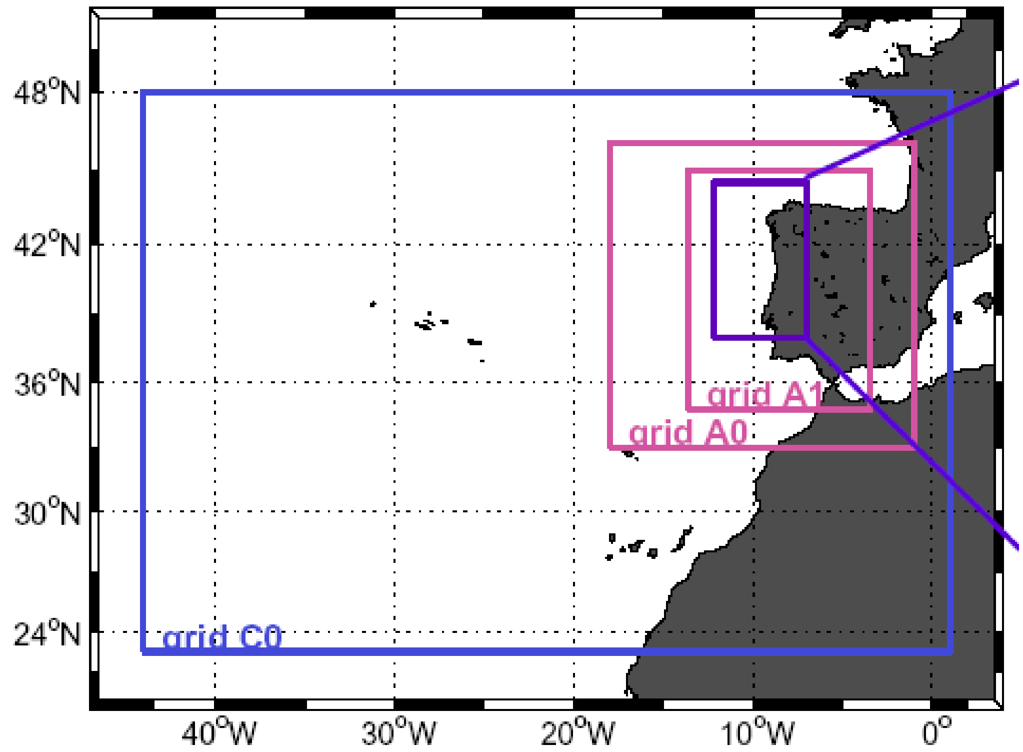
Santos et al. (2004). Cont. Shelf Res., **24**: 149-165



Meneses & Angélico (2006). GLOBEC Int. Newsl., 12(1): 14-16

MODEL

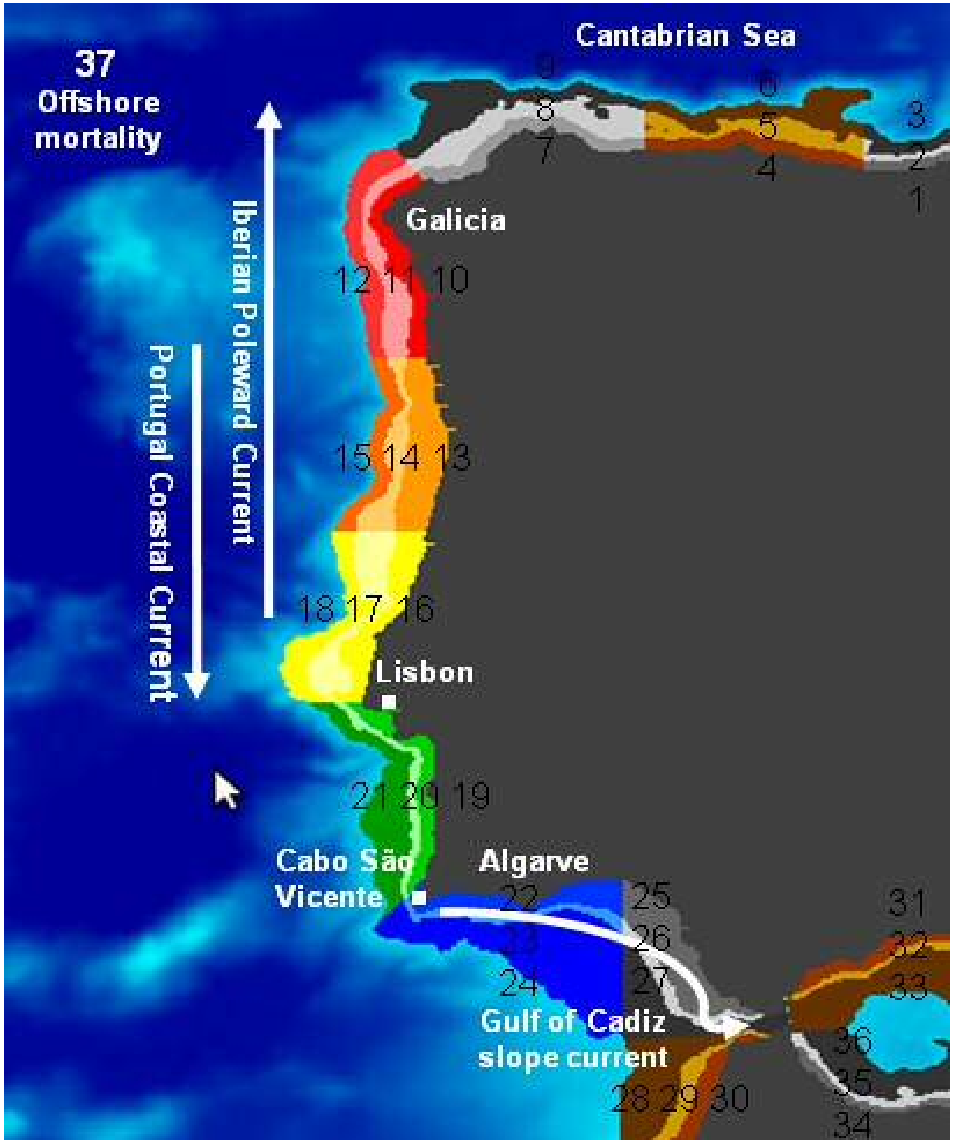
- **ROMS** (Regional Ocean Modeling System**)** with 2-way nesting capabilities.
- smallest grid at a resolution 2.3 km .
- forced with a 27 km resolution WRF dynamic downscaling of an ERA-Interim reanalysis (Soares et al., 2012. Clim. Dyn., 39: 2497–2522).
- high resolution simulation from 1989-2008; archive time of 5 days
- climatological mean year at 5 day time intervals over the 20 years of simulations.
- Temperature, salinity and three dimensional velocity fields are stored in full spatial resolution to be used by the Lagrangian tool.



(Teles-Machado et al. (2016). Prog. Oceanogr. 140: 134-153)

MODEL

(Santos et al. (2018). Prog. Oceanogr. 162: 83-97)



- Ichthyop - Lagrangian transport model (Lett et al. 2008. Environ. Modell. Softw. 23: 1210-1214)
- Release (10-24), recruitment (1-36), and “mortality” (37; offshore transport)
- Nearshore (0-100 m), mid-shelf (100-200 m) and offshelf (200-1000 m)
- Zones were created to be as equal as possible in terms of the length of coastline (~165 km)
- Zone 37 bathymetry > 1000 m (mortality after dispersal period 30 days)

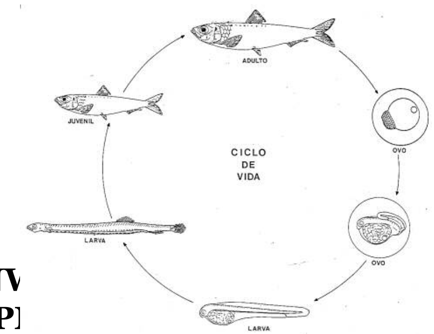
MODEL

Table 1
Summary of the parameters tested in the simulations.

Parameters tested	Summary	References
Release area	– Zones 10–24 (Fig. 1) Bathymetry: onshore (0–100 m), shelf (100–200 m), offshelf (200–1000 m) –	Ré et al. (1990) Cunha et al. (1992) Garrido et al. (2009) Checkley et al. (2010)
Period	– Climatology of 20 years 1989–2008 –	–
Month	– All months –	–
Frequency	– Every 10 d at 21:00 –	Bernal et al. (2001)
Transport duration	– 30 d –	Ré et al. (1986) Santos et al. (2007) Garrido et al. (2016)
Patchiness	– 1, 10, and 100 particles per patch –	Brochier et al. (2008a)
Release depth	– 0–20 m, 20–40 m, 40–60 m, 60–80 m, 80–100 m –	Matsuoka and Konishi (1996) Fletcher and Sumner (1999) Dopolo et al. (2005) Ganias and Nunes (2011)
Egg density	– 1.023, 1.024, 1.025, 1.026, 1.027, 1.028 $g\,cm^{-3}$ –	Coombs et al. (2004)
Diel vertical migration	– DVM1 – Day: 25 m, Night: 0 m DVM2 – Day: 100 m, Night: 0 m DVM3 – Day: 0 m, Night: 45 m –	Santos et al. (2006) Olivar et al. (2001)

(Santos et al. (2018). Prog. Oceanogr. 162: 83-97)

- Biological parameters from the literature.
- ROMS velocity fields interpolated at 3 h time steps.
- Horizontal dispersion factor ($1 \times 10^{-9}\ m^2\ s^{-3}$) was included following (Peliz et al. (2007). J. Mar. Sys. 68: 215-236)
- 15,000 eggs released every 10 days (spawning frequency of sardine) (Bernal et al. (2001). Prog. Oceanogr. 74(2–3): 210–227)

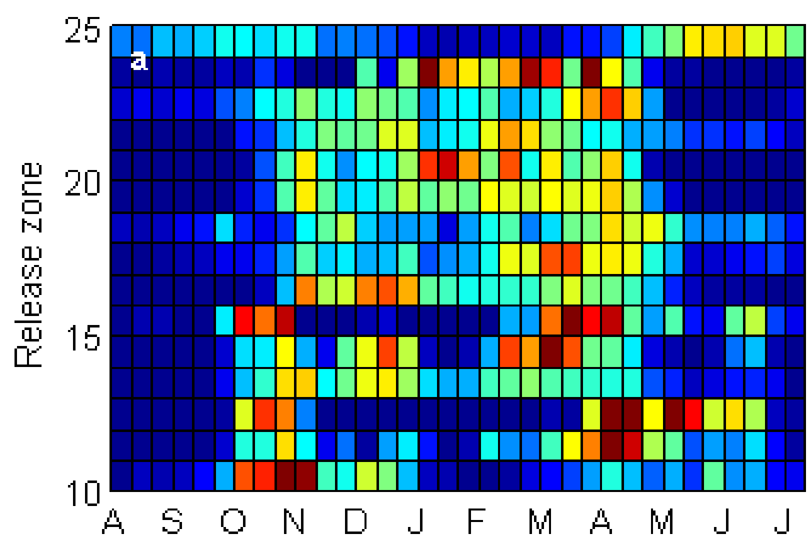


Simulation 1: Patchiness

The coefficients and calculated probability (p-value) of each explanatory variable on retention (Ret) and recruitment (Rec) for simulation 1 (Sim 1: patchiness) as derived from a Generalized Linear Model (GLM Binomial).

Sim 1	Recruitment		Retention	
Variable	Coefficients	P	Coefficients	p
(Intercept)	1.69E+00	≪0.0001	−2.31E+00	≪0.0001
Patch	−3.52E−05	0.012	1.16E−06	0.920
Depth	2.89E−02	≪0.0001	1.08E−02	≪0.0001
month2	−8.36E−02	≪0.0001	3.18E−01	≪0.0001
month3	−4.88E−01	≪0.0001	3.80E−01	≪0.0001
month4	−9.89E−01	≪0.0001	4.35E−02	≪0.0001
month5	−1.13E+00	≪0.0001	6.91E−03	0.011
month7	−2.12E+00	≪0.0001	−5.37E−01	≪0.0001
month8	−1.52E+00	≪0.0001	−3.35E−02	≪0.0001
month9	−5.13E−01	≪0.0001	1.54E−01	≪0.0001
month10	6.60E−01	≪0.0001	−2.46E−01	≪0.0001
month11	4.20E−01	≪0.0001	−1.72E−01	≪0.0001
month12	2.13E−01	≪0.0001	−4.66E−01	≪0.0001
release11	−4.42E−02	≪0.0001	4.38E−01	≪0.0001
release12	−1.52E+00	≪0.0001	−3.43E−01	≪0.0001
release13	5.72E−01	≪0.0001	1.28E+00	≪0.0001
release14	−6.95E−02	≪0.0001	6.10E−01	≪0.0001
release15	−1.01E+00	≪0.0001	−2.27E−01	≪0.0001
release16	−7.00E−01	≪0.0001	8.27E−01	≪0.0001
release17	−6.95E−01	≪0.0001	9.44E−01	≪0.0001
release18	−2.05E+00	≪0.0001	4.67E−01	≪0.0001
release19	−5.98E−01	≪0.0001	4.89E−01	≪0.0001
release20	−1.11E+00	≪0.0001	2.09E−01	≪0.0001
release21	−2.31E+00	≪0.0001	1.07E+00	≪0.0001
release22	1.82E−01	≪0.0001	4.93E−01	≪0.0001
release23	−9.94E−01	≪0.0001	−3.03E−01	≪0.0001
release24	−3.16E+00	≪0.0001	−1.12E−02	≪0.0001
AIC	4,800,611		3,781,662	

- Patchiness has no effect on larvae recruitment.
- Successful recruitment occurred when eggs were released during the peak of the spawning season (October to January).



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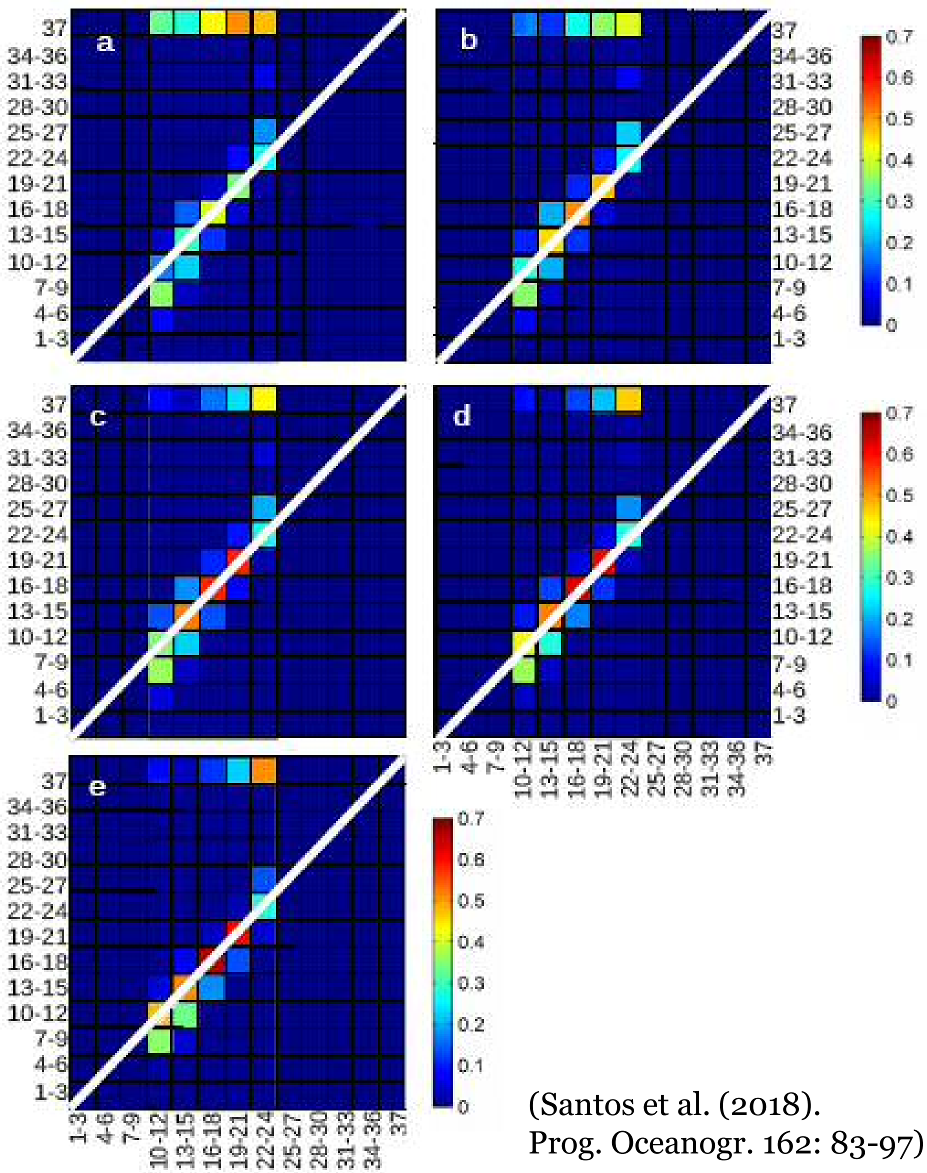

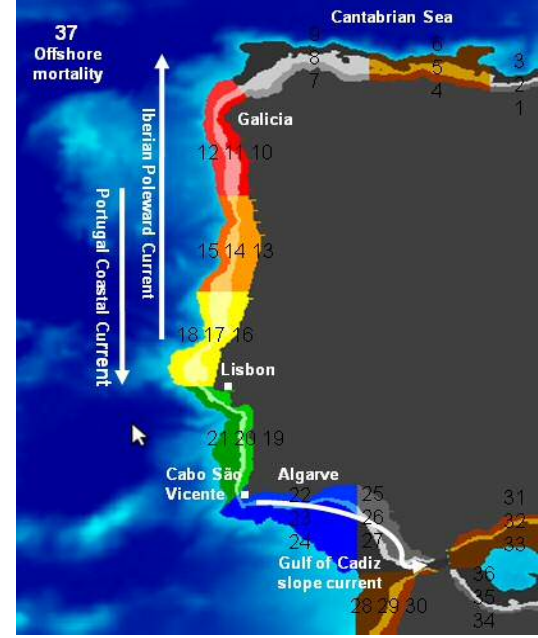

- Self-recruitment of larvae in the zone of release.
- Mortality lower in northwestern and central Iberian release sites (10-18).
- Eggs released from nearshore zones had the highest recruitment and lower mortality ((NW 10, 13 and ALG 22).

(Santos et al. (2018). Prog. Oceanogr. 162: 83-97)

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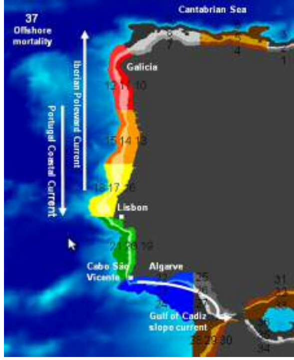
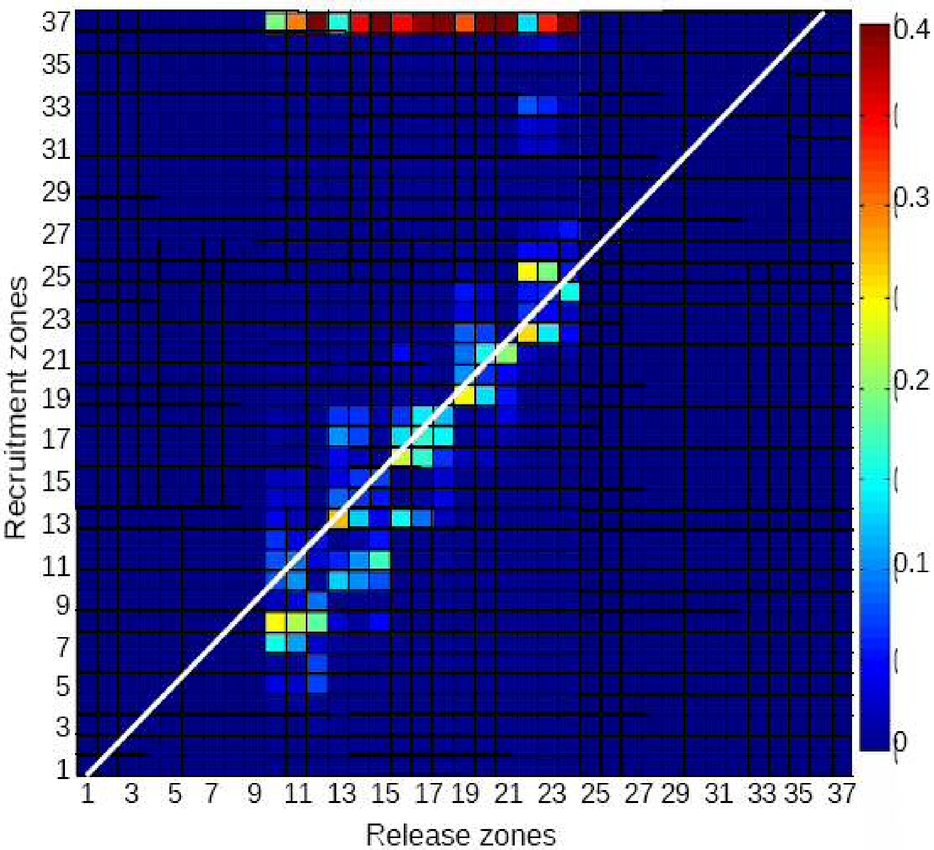


- Substantial alongshore transport
- Large number of larvae advected northward into Galicia and the Cantabrian coast (1-9; up to 27%) from N Portugal (10-15).
- A large proportion of larvae are transported eastward (up to 36%) from the Algarve shelf (22-23) into the neighboring shelf zone in the Gulf of Cadiz (25), some (up to 8%) even enter the Mediterranean.
- A maximum of 1% of larvae are transported southward into northern Africa, and these were released from the offshore zone of Algarve (zone 24).

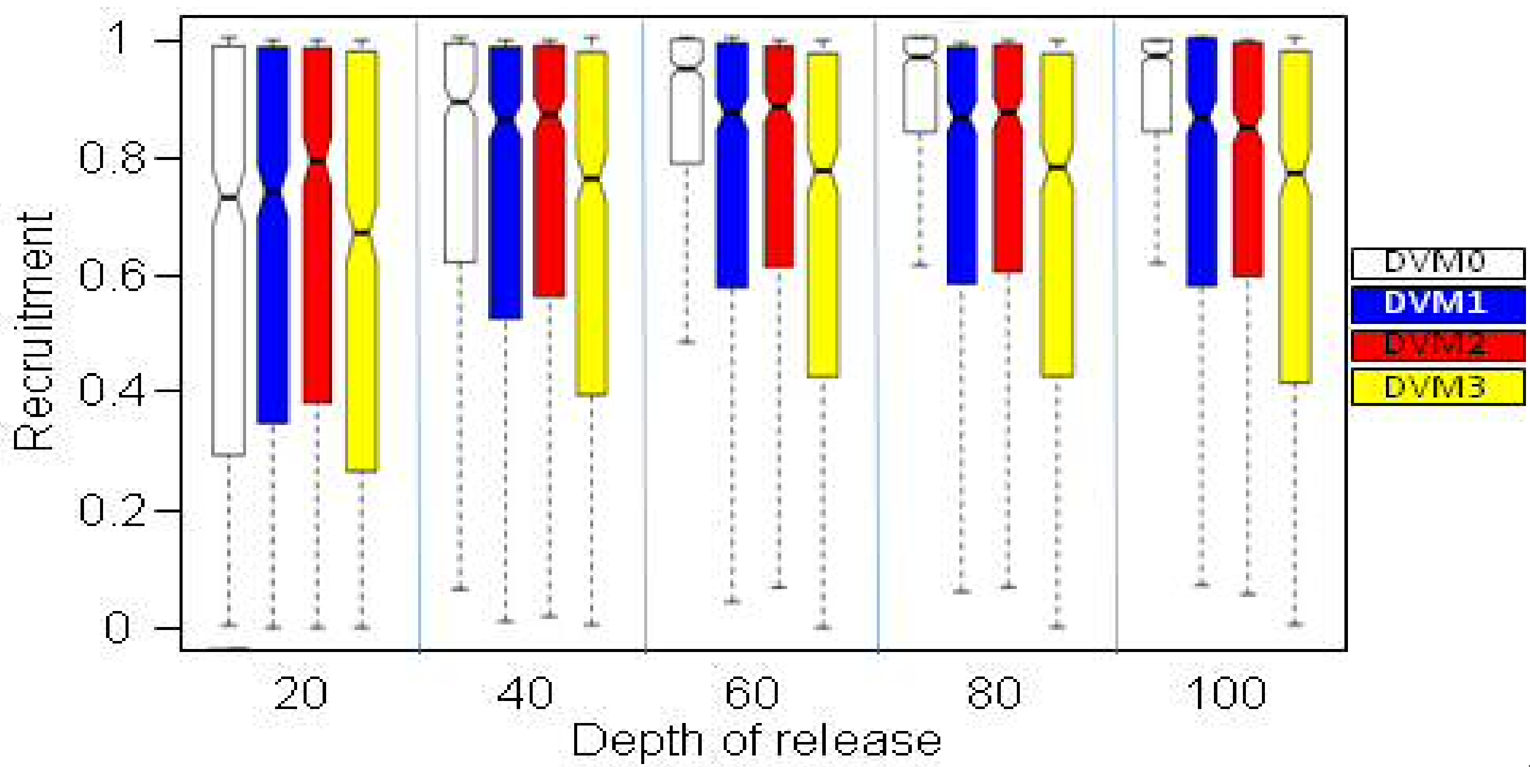


NWP Portugal Workshop
IPMA, Lisboa, 26-27 Nov 2018

Simulation 2: Vertical migration

- DVM1 (Day: 25 m, Night: 0 m) and DVM2 (Day: 100 m, Night: 0 m) are essentially the same in terms of recruitment.

- DVM3 (Day: 0 m, Night: 45 m) has significantly higher mortality than the other two DVM schemes.

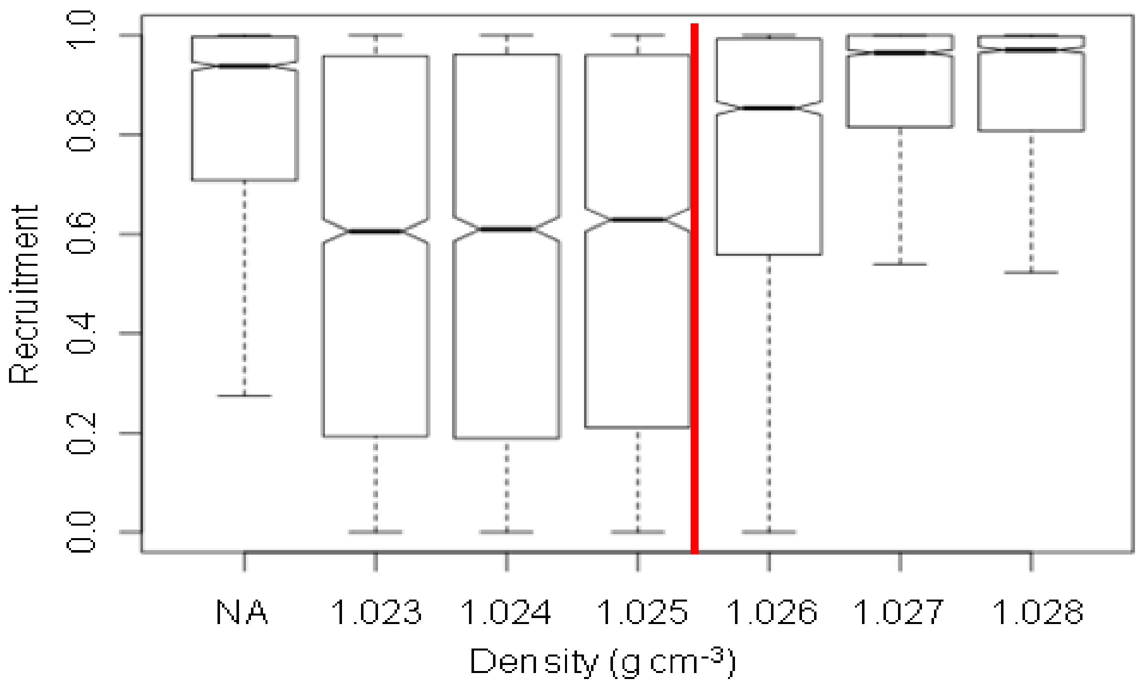


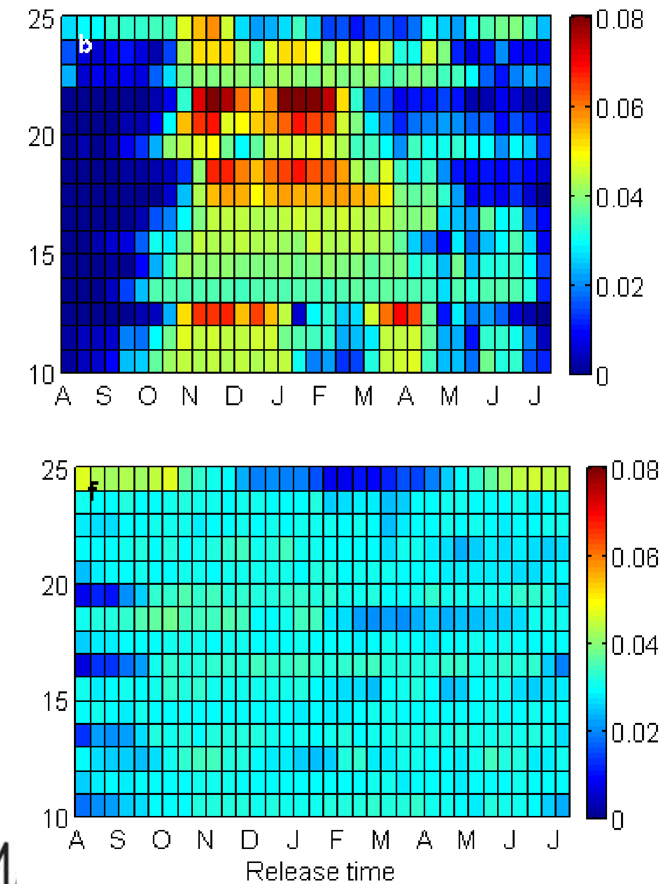
(Santos et al. (2018). Prog. Oceanogr. 162: 83-97)

Simulation 3: Egg density

- Recruitment and retention are higher for eggs of higher density.

- Recruitment much more dispersed throughout the year for egg densities of 1.027 and 1.028 g cm^{-3}.





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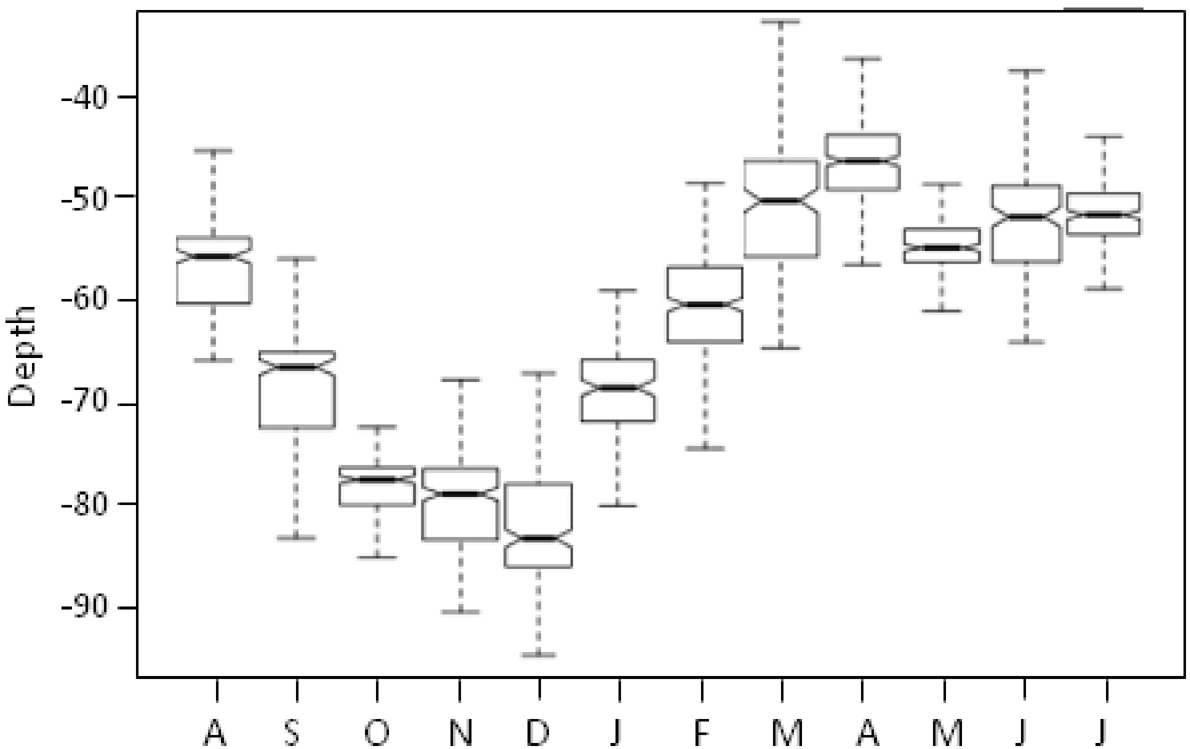
Simulation 3: Egg density

- Eggs of these densities settle at depths between 50-85 m and may be transported in weak undercurrents.
- A seasonal signal is evident in the depth to which larvae recruit:
  - at deeper depths in September to January (70-85 m)
  - shallower depths for the rest of the year (50-60 m).



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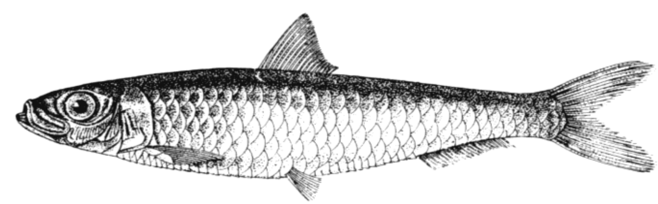
Main Remarks

- Results help explain how these small pelagic fish have adapted their reproductive strategies in a coastal upwelling system to ensure coastal retention and recruitment success.
- It is necessary to study the influence of other factors that are important for larval survival, such as food availability and predation.
- Conduct process oriented simulations that capture the fine-scale coastal circulation patterns and new biological parameterizations.
- The final goal is to develop an end-to-end model for sardine in the northern Canary Current Upwelling System to support sardine fisheries management decisions using a ecosystem-based approach.



Relevant projects

- **OBSERVA.PT** (Mar2020; approved): To install several meteorological stations and oceanographic equipment (eg, thermosalinographs, fluorometers and/or ferrybox) on board cargo ships en route from Portugal Mainland to Madeira, Azores and Cape Vert Islands (**acquisition of 2-3 floats**).
- **OBSERVA.FISH** (FCT-Portugal2020; approved): To develop a totally autonomous system (no human action), integrating several new parameters (meteorological and oceanographic), to install onboard of all types of fishing vessels (trawlers, purse-seiners, longliners)..
- **Euro-Argo RISE** (H2020; approved): To enhance and extend the capabilities of the Argo network to provide essential ocean observations to answer new societal and scientific challenges. One of the tasks is to develop methodologies for efficient Argo observations in very dynamical ocean systems like the Gulf of Cadiz and the Gulf Current.
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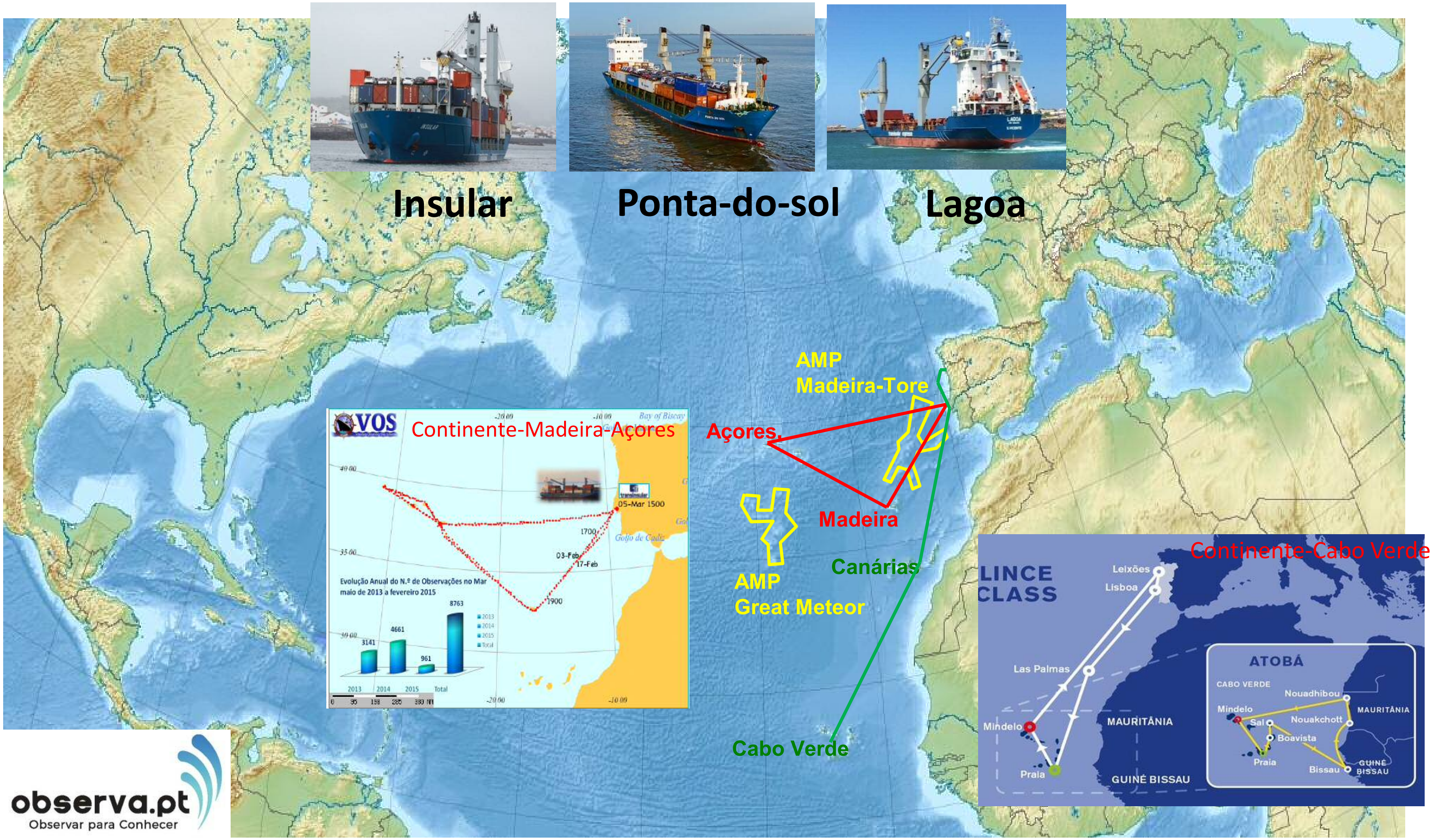
OBSERVA.PT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Ponta-do-sol
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Continente-Madeira-Açores
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Las Palmas
Mindelo
Praia
MAURITÂNIA
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