Sardinella spawning season matches coastal retention patterns in the senegalese-Mauritanian upwelling system

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1. Introduction

- Small pelagic fishes are the most abundant fish species in the Senegal-Mauritanian upwelling system and sardinella (*Sadinella aurita*) is the dominant species

Sardinella: key species for local economy (up to 6000, 000 tons/year, Deme et al., 2012), food security

- **Seasonal spawning**: Arguin Bank (northern Mauritania, **July-August**) and Petite Cote (southern Senegal, **April-May)**
- **Spawning reproduction** less studied compared to sardine (*sardina pilchardus*) in Morocco or anchovy in the Peru-Chili upwelling system

Context

Lack of information on early life stages (eggs and larvae): Migration (DVM), Growth and mortality

Spawning information based on old review: e.g. Boely et al. (1982) and Fréon (1988)

Need to update information on sardinella spawning

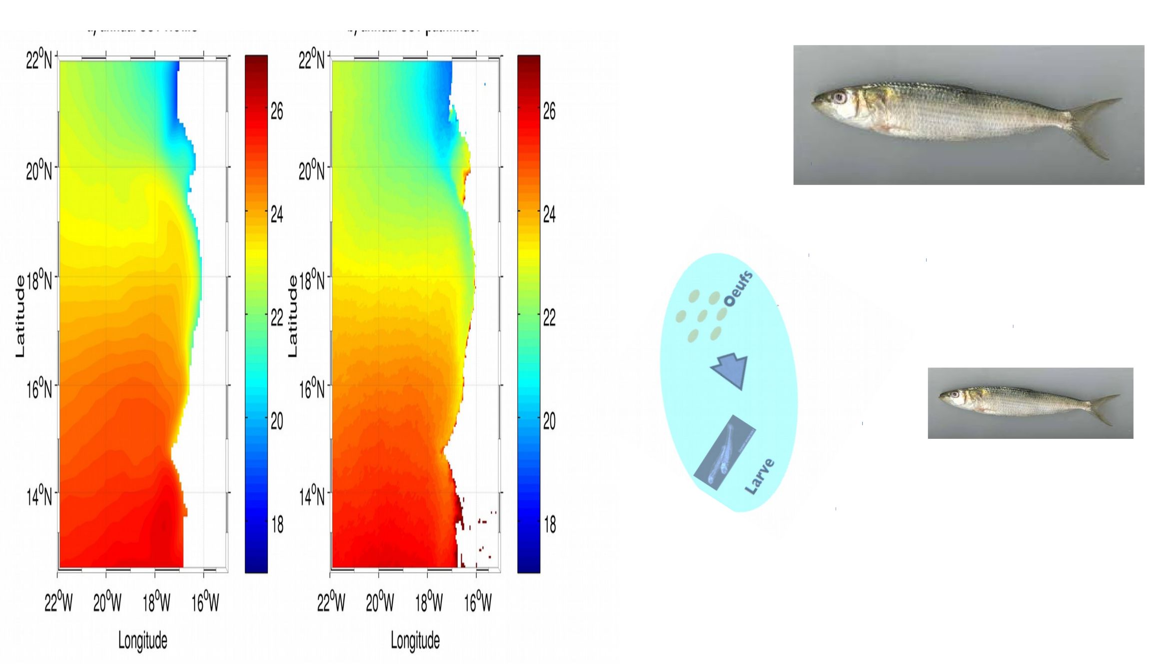
Questions

- **Do modelling larval distribution could help understand sardinella reproductive strategy by estimating coastal larval retention?**
- **What is the effect of model forgings and resolutions on coastal larval retention and the transport between spawning grounds?**

2. Methods

We used a set of 3 estimates of climatological ROMS simulations. The first 2 simulations (SM1 and SM2 respectively) have slightly same spatial resolutions (9km vs 8 km) with different forcing and focused on the Senegalese-Mauritanian shelf. The last simulation (SM3) encompassed the Senegalese coast at higher resolution (2km). ROMS simulations were used to force Individual based model (ICHTHYOP) to simulate larval retention

Figure 1: Presentation of of the system ROMS simulations - ICHTHYOP model



ROMS: hydrodynamic
Mbaye et al. 2015; Ndoye et al. 2018

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Individual-Based Model
ICHTHYOP (Lett et al., 2008)

- Simulate spawning
- Estimate larval retention
- Larval transport between spawning grounds

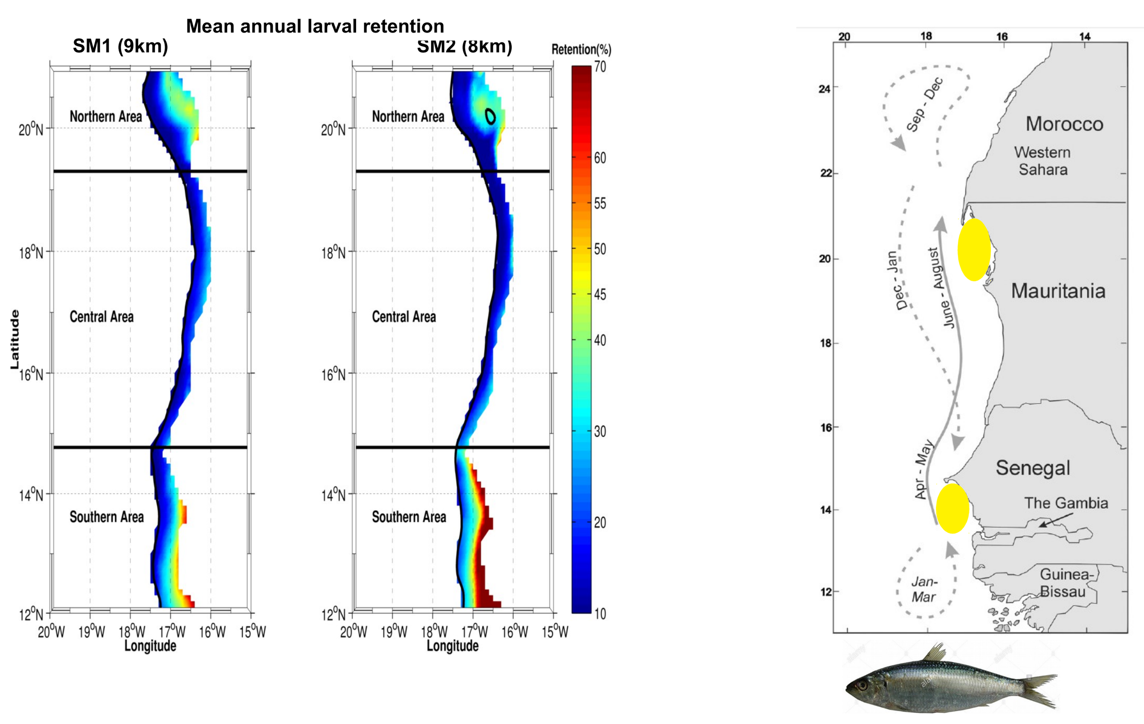
Table 1: Description of individual Based Models simulation configurations. Code names for vertical migration: PT=passive transport; DVM20 (DVM60): diel vertical migration between surface and 20 m (60 m) depth

Model configurations	**SM1**	**SM2**	**SM3**
Wind forcing	Quikscat	SCOW	Quickscat and SCOW
Spatial resolution	9km	8km	2km
Number of eggs	10,000	10,000	10,000
Release date	Each month	Each month	Each month
Release depth	0-20m	0-20m	0-20m
Release area	0-200m isobath	0-200m isobath	0-200m isobath
Diel Vertical Migration (DVM)	PT: no migration DVM20: migration 0-20m DVM60: migration 0-60m	PT: no migration DVM20: migration 0-20m DVM60: migration 0-60m	DVM60: migration 0-60m
Retention	Within release area after 28 days	Within release area after 28 days	Within release area after 28 days

3. Results

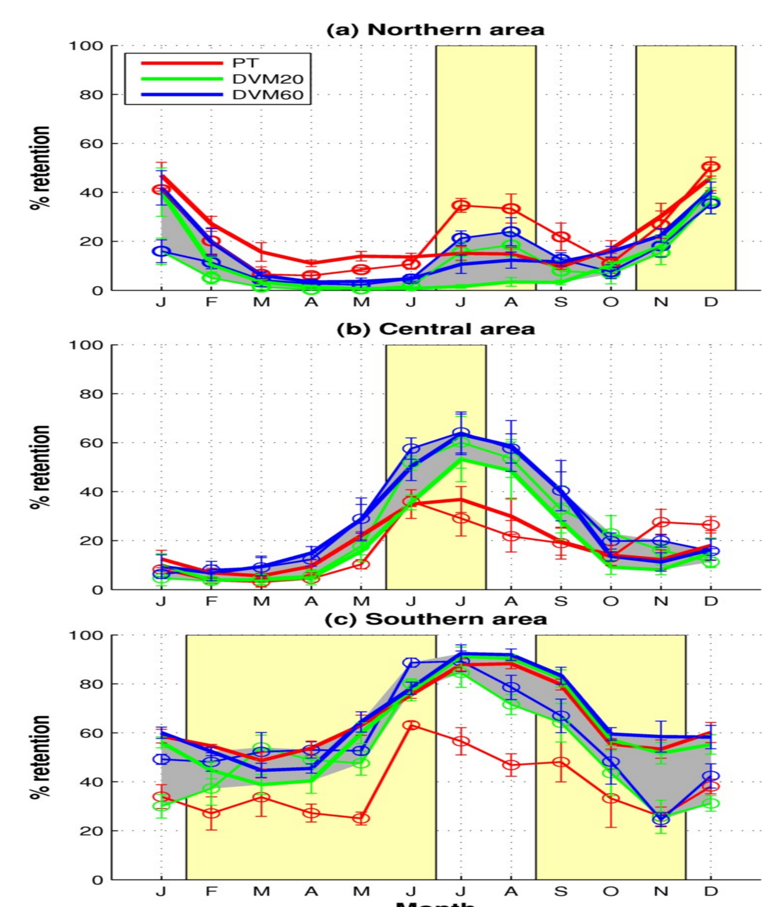
3.1. Spawning matches spatial and seasonal larval retention

Figure 2: Annual mean shelf retention for SM1 and SM2 simulations (left) and migration pattern and location of spawning grounds (yellow points; adapted from Zeeberg et al. 2008) of *Sardinella aurita* in Senegal-Mauritania upwelling system



3 different areas based on retention rates could be identified. Area of higher retention rates correspond to known spawning grounds

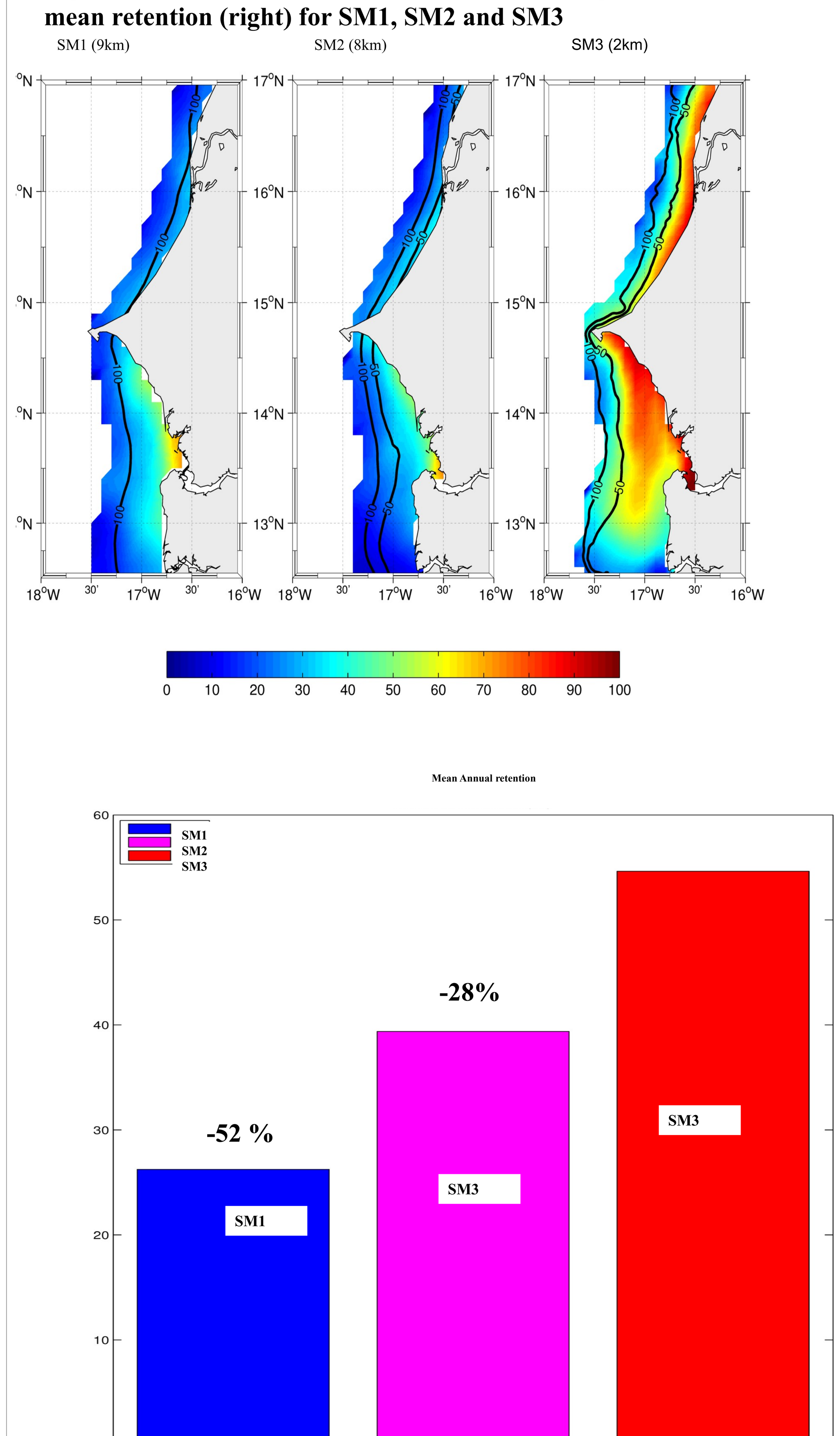
Figure 3: Seasonality of shelf retention rates in three regions of the Senegalese–Mauritanian coast, for SM1 and SM2. Results for PT (red), DVM20 (green), DVM30 (blue) are shown for the northern area (a), central area (b) and southern area (c). Error bars mark the standard deviation from monthly means. Yellow rectangles indicate *a priori* observed spawning periods.



Period of higher retention rates correspond to known spawning season

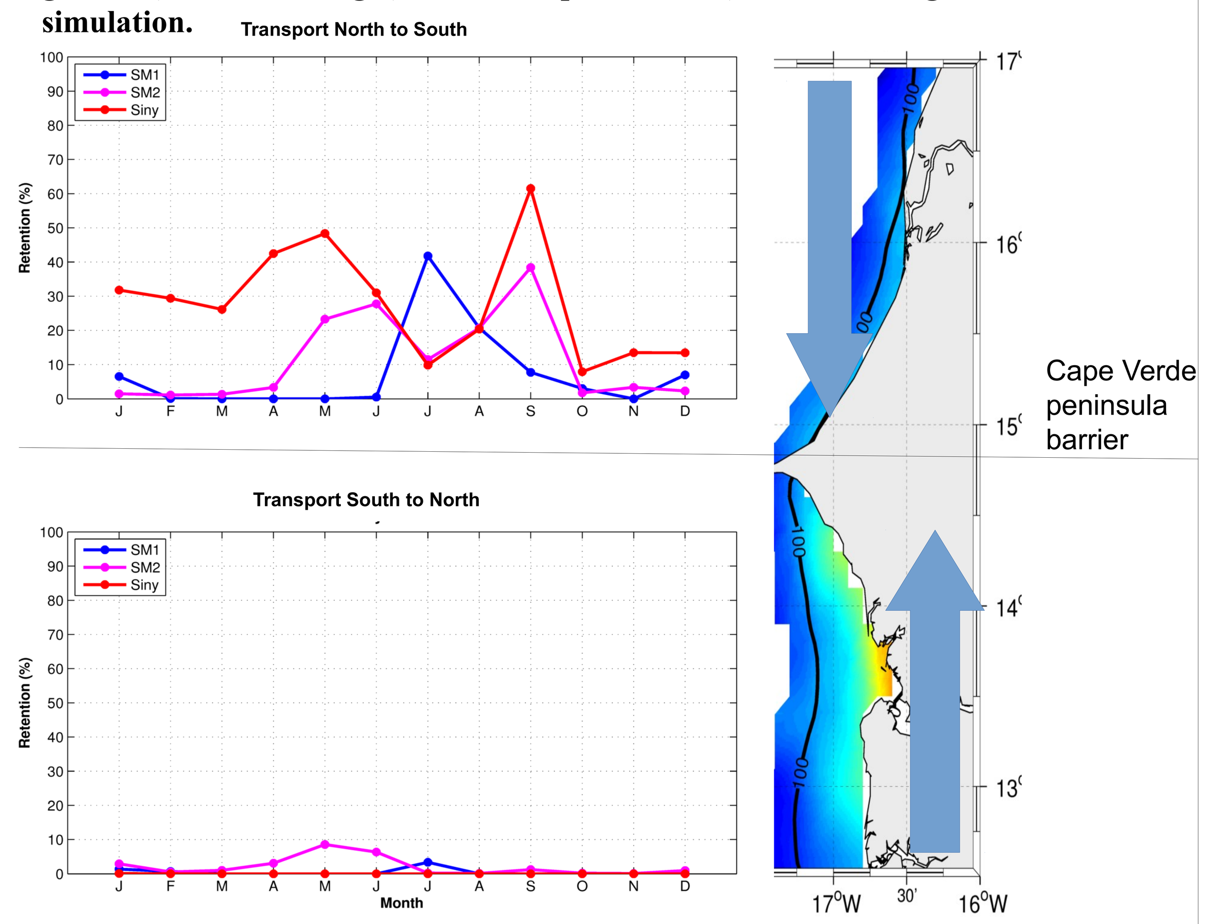
3.2. Increasing model resolution improve larval coastal retention rates

Figure 4: annual mean retention rates in the Senegalese shelf (left) and average mean retention (right) for SM1, SM2 and SM3



Increasing model resolution increase coastal retention **up to 50%**

Figure 5: Percentage of larvae transported northern or southern limits of the Cape Verde peninsula marking the physical barrier between the main spawning ground (southern Senegal) and the dispersal area (northern Senegal for SM1 simulation.



Transport of larvae in the Senegalese shelf was mainly **southward** and was maximum during period of **higher retention rates in the main spawning ground** (southern Senegal)

4. Discussion and Conclusions

- Sardinella spawning matches spatial and seasonal larval retention in Senegal and Mauritania. Results confirmed the southern Senegal and the Arguin bank (Mauritania) as the main spawning areas of *Sardinella aurita*. These maximum retention rates appeared during upwelling periods therefore sardinella has adapted its reproductions strategy to the characteristics of the regional oceanography and seasonality of the upwelling system.
- Increasing model resolution improve larval retention due to better representation of shallow shelf and the presence of mesoscale structures at the coast (alongshore transport).
- Larval transport is mostly southward and maximum during the upwelling period corresponding to maximum retention rates in the the main spawning area in southern Senegal. This explains why northern Senegal was not identified as spawning ground for sardinella

5. Perspectives

Investigate the effect of resolving larval growth based on larvae feeding characteristics considering size of larvae and allocation of energy

- Size-structured opportunistic trophic interactions where phytoplankton and zooplankton from biogeochemical model are potential preys for larvae and where all larvae are considered to be potentially prey and predator at the same time (Maury et al. 2007)
- larval growth based on the DEB theory (Kooijman, 2010) to consider food availability (presently growth is only due to temperature change)

References

Boely, T., Chabanne, J., Fr#eon, P. et al. (1982) Cycle Sexuel et Migrations de Sardinella aurita sur le Plateau Continental Ouest-africain, des Iles Bissagos #a la Mauritanie. Rapport. P.V. Reunion du Conseil International pour l'Exploration de la Mer 180:350–355.
Deme, M. 2012. Etude des connaissances socio-économiques des pêcheries de petits pélagiques au Sénégal. Sub Regional Fisheries Commission, Dakar.
Kooijman, S.A.L.M., 2010. Dynamic Energy Budget Theory for Metabolic Organisation. Cambridge University Press.
Lagrangian tool for modelling ichthyoplankton dynamics. Environ. Model. Softw. 23, 1210-1214.
Lett, C., Verley, P., Mullon, C., Parada, C., Brochier, T., Penven, P., Blanke, B., 2008. A
Maury, O., Faugeras, B., Shin, Y.-J., Poggiale, J.-C., Ari, T. B., and Marsac, F. (2007). Modeling environmental effects on the size-structured energy flow through marine ecosystems. Part 1: the model. Prog. Oceanogr. 74, 479–499
Mbaye, B.C., Brochier, T., Echevin, V., Lazar, A., Lévy, M., Mason, E., Gaye, A.T., Machu, E., 2015. Do Sardinella aurita spawning seasons match local retention patterns in the Senegalese–Mauritanian upwelling region? Fish. Oceanogr. 24, 69–89. doi:10.1111/fog.12094
Ndoye, S., Capet, X., Estrade, P., Sow, B., Machu, E., Brochier, T., Döring, J., Brehmer, P., 2017. Dynamics of a "low-enrichment high-retention" upwelling center over the southern Senegal shelf. Geophys. Res. Lett. 44, 5034–5043
Zeeberg, J., Corten, A., Tjoe-Awie, P., Coca, J., Hamady, B., 2008. Climate modulates the effects of Sardinella aurita fisheries off Northwest Africa. Fish. Res. 89, 65–75.

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