Northward migration of small pelagic fish off West Africa:The barrier of the Sahara Bank in the context of climate change

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Summary

1. **INTRODUCTION**: Different small pelagic fishes dominant along the upwelling system

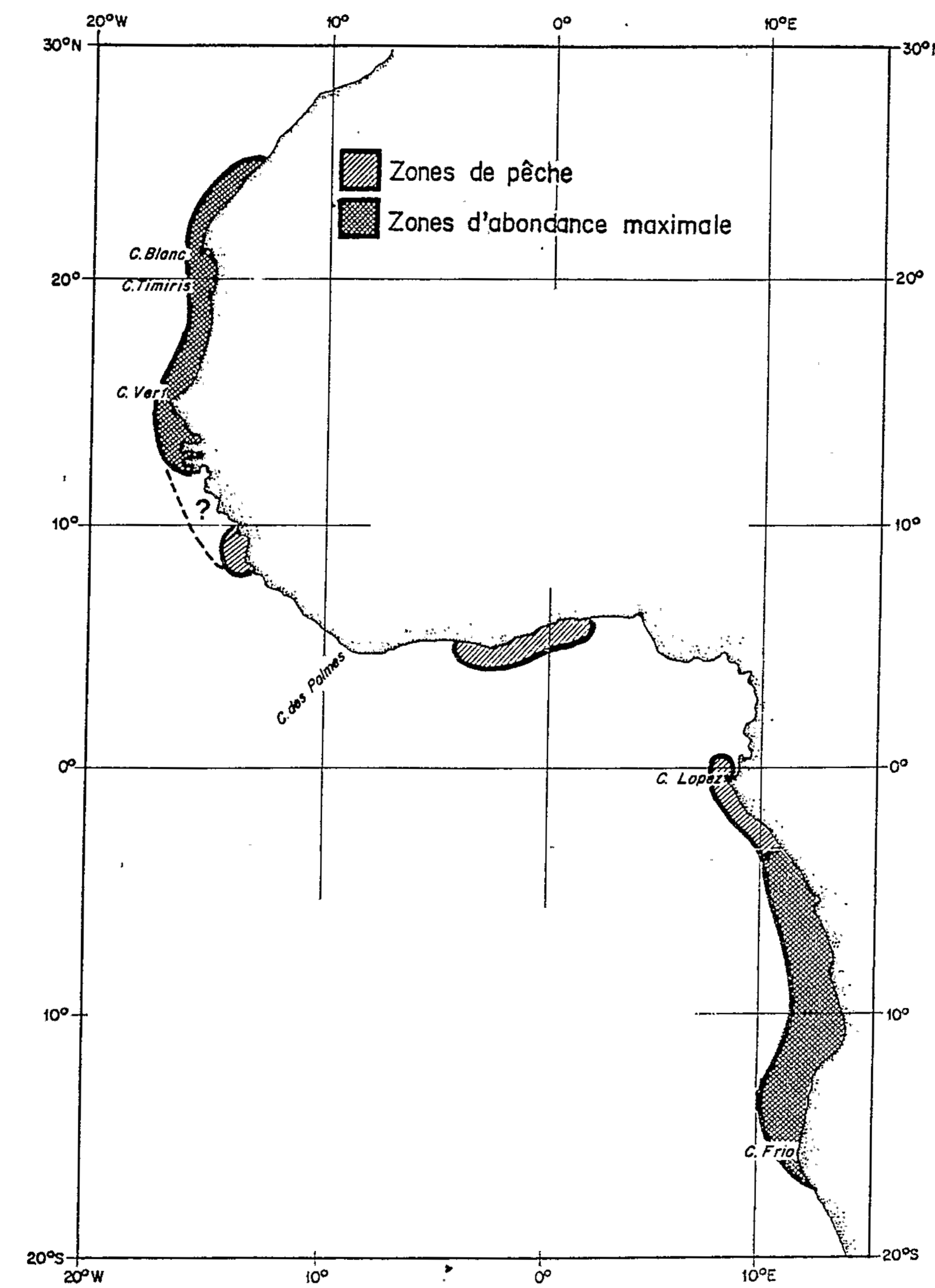
2. **What makes the Sahara Bank a barrier?**
    - Phyto/zoo-plankton assemblages,
    - Sea surface temperature/salinity,
    - Hydrodynamics

3. **Simulating the northern boundary of the S. aurita population** with a bio-physical model

4. **Discussion**
    - Connectivity between small pelagic fish populations north and south of the Sahara Bank

INTRODUCTION

- Few Small pelagic fish species (<10) dominate the biomass in upwelling ecosystems off West Africa
- Discontinuous spatial distributions within upwelling areas, separated by relatively stable limits
- Climate Changes may impact these limits and thus the associated ecosystems
- Exemple : Northward and Southward limits for Sardinella spp.



Sardinella aurita populations along West Africa
(Boely and Fréon, 1979)

Dominant small pelagic fish species along the Canary Upwelling system

~10-26°N

model **Sardinella**

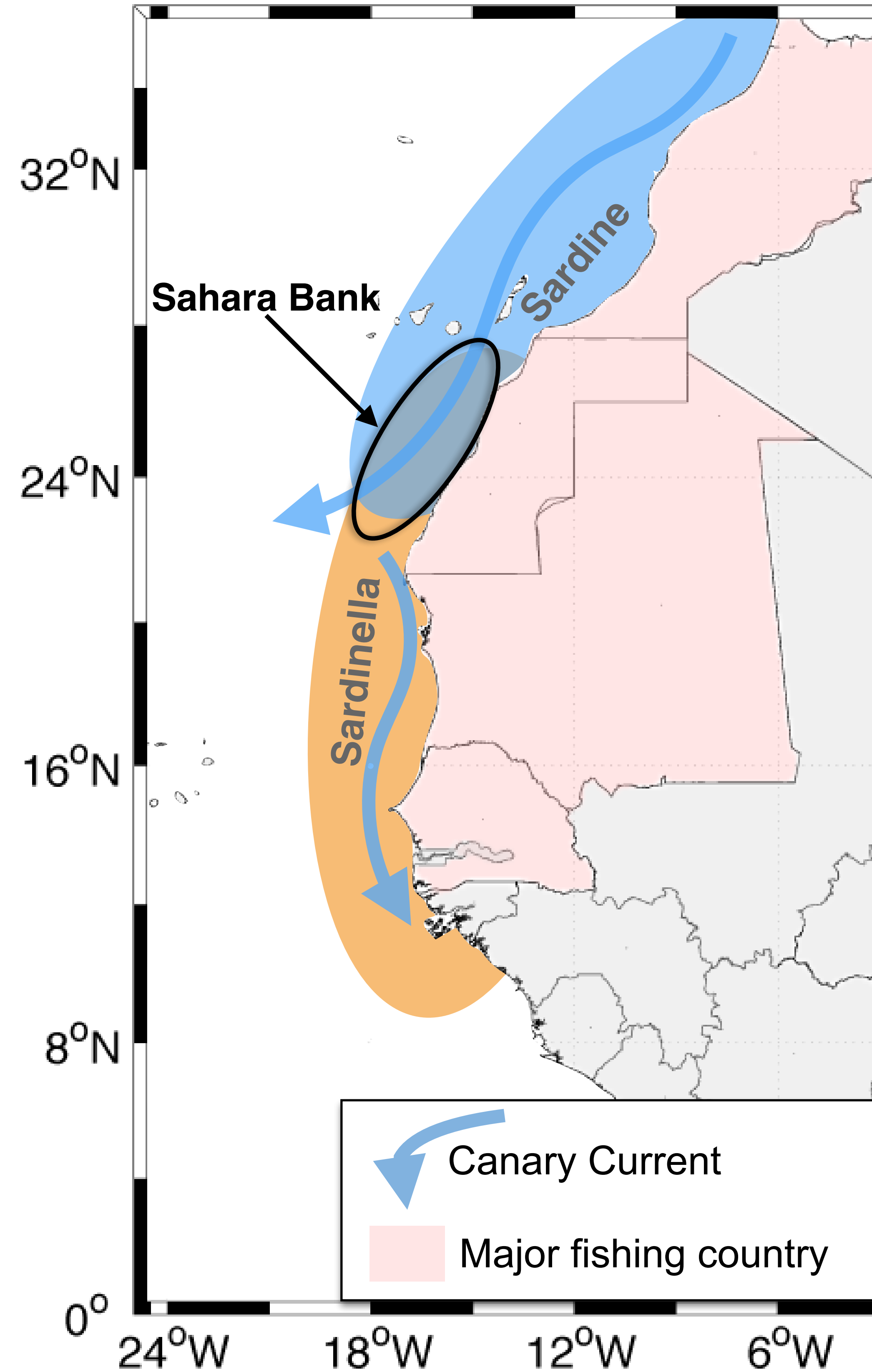
- *Sardinella aurita*
- *Sardinella maderensis*
- *Ethmalosa fimbriata*

~20-32°N

model **Sardine**

- *Sardina pilchardus*
- *Engraulis encrasicolus*

What makes the Sahara Bank a limit?



What makes the Sahara Bank a limit?

Hypotheses:

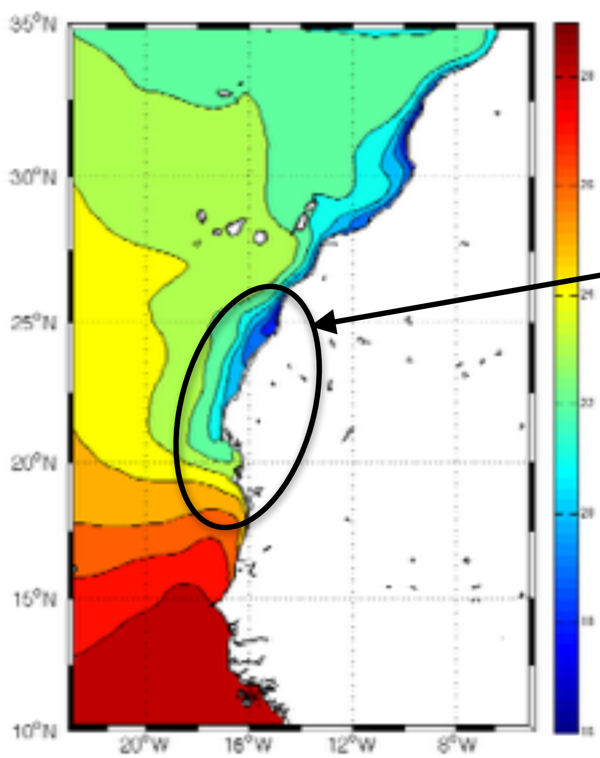
- Difference in plankton species assemblage and fish species diet :
  - Prey quality and size (phyto- and zoo- plankton species)
  - Prey abondance
- Different predators pressure
- Hydrodynamics constraints
- Differences in fish habitat (temperature and salinity)

What makes the Sahara Bank a limit?

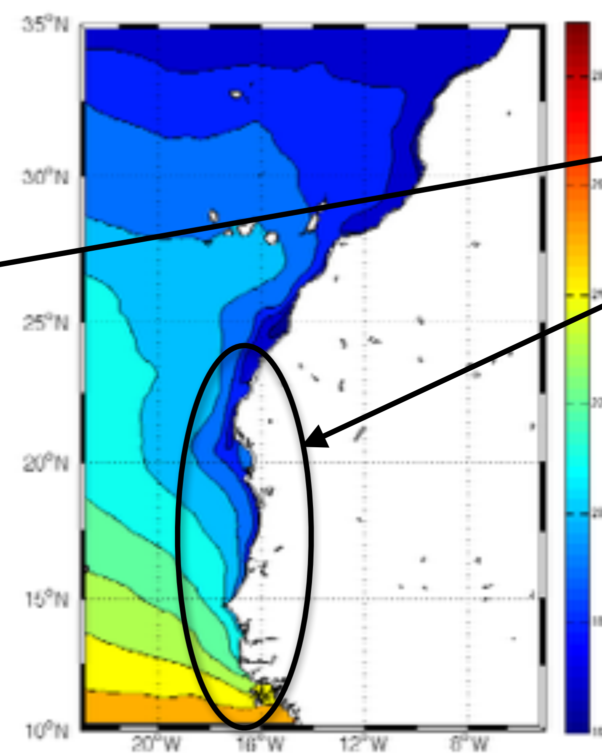
Differences in temperature

- Temperature

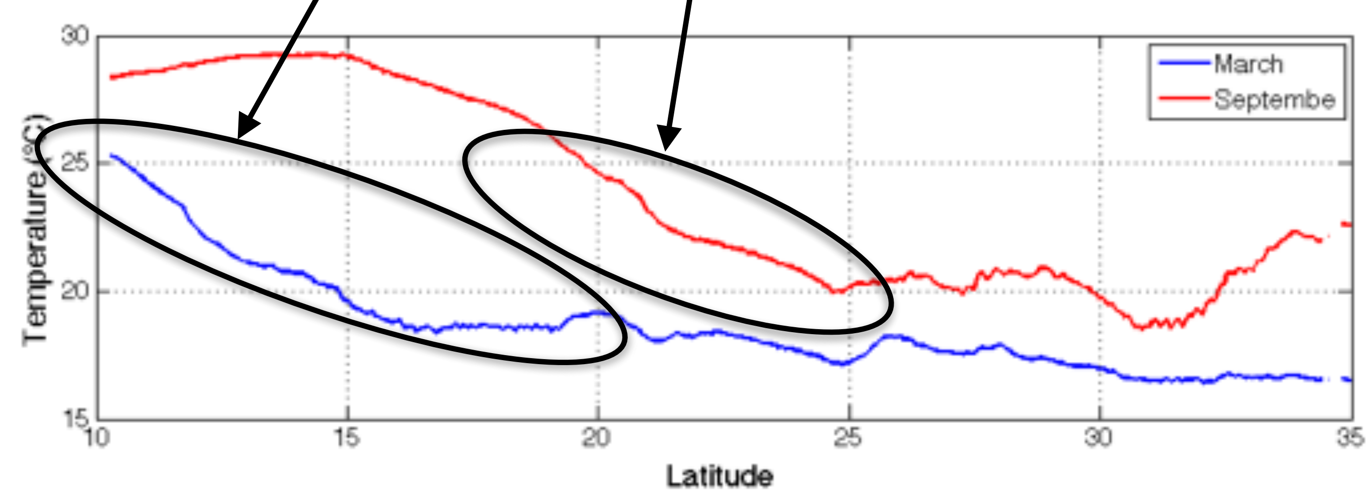
Month 8-11



Month 2-5



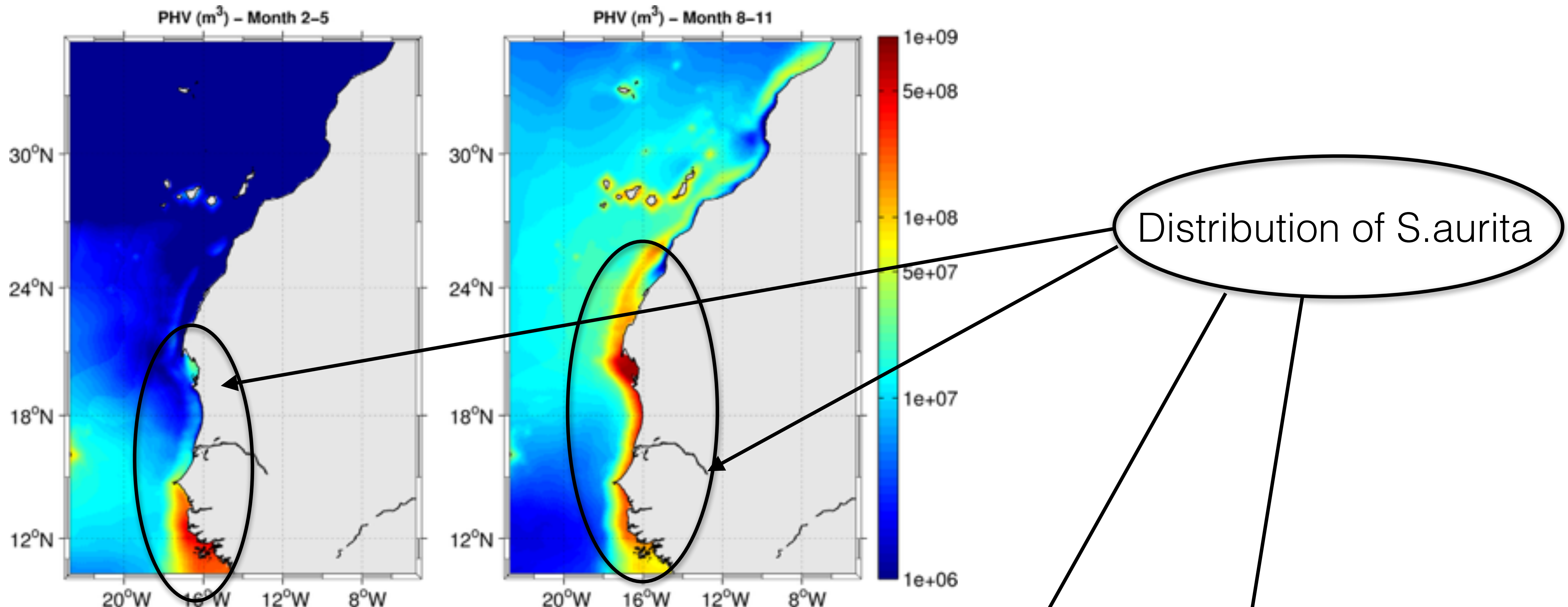
Distribution of S.aurita



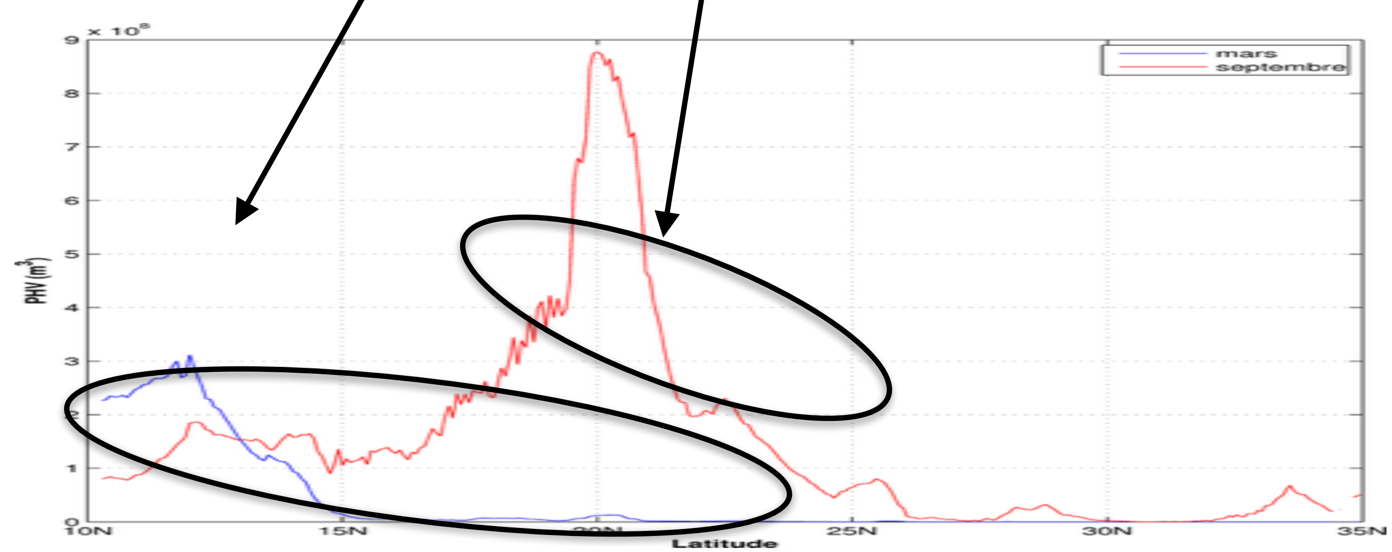
+Plot SALINITE
Habitat Baye/Eric?

What makes the Sahara Bank a limit?

Differences in Spawning Habitat Volume



Température : 22-26°C
Salinité : 35.5-36 psu

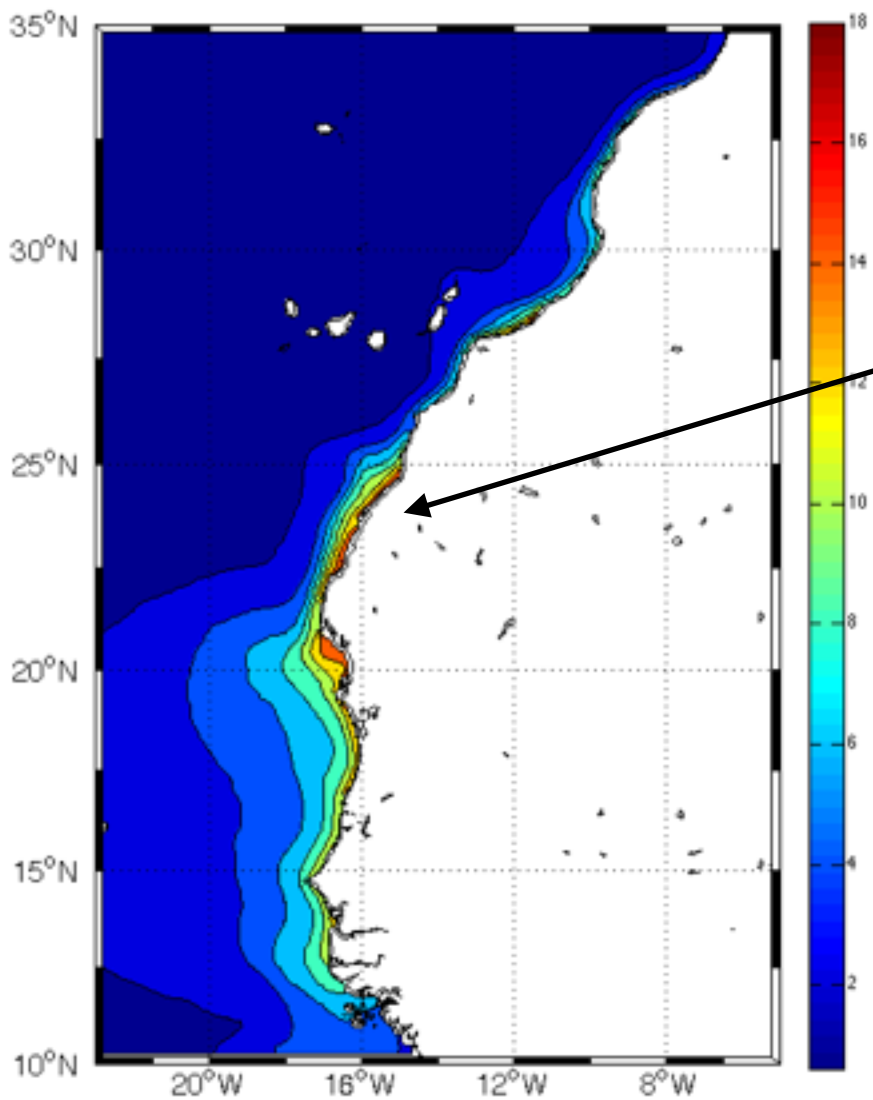


What makes the Sahara Bank a limit?

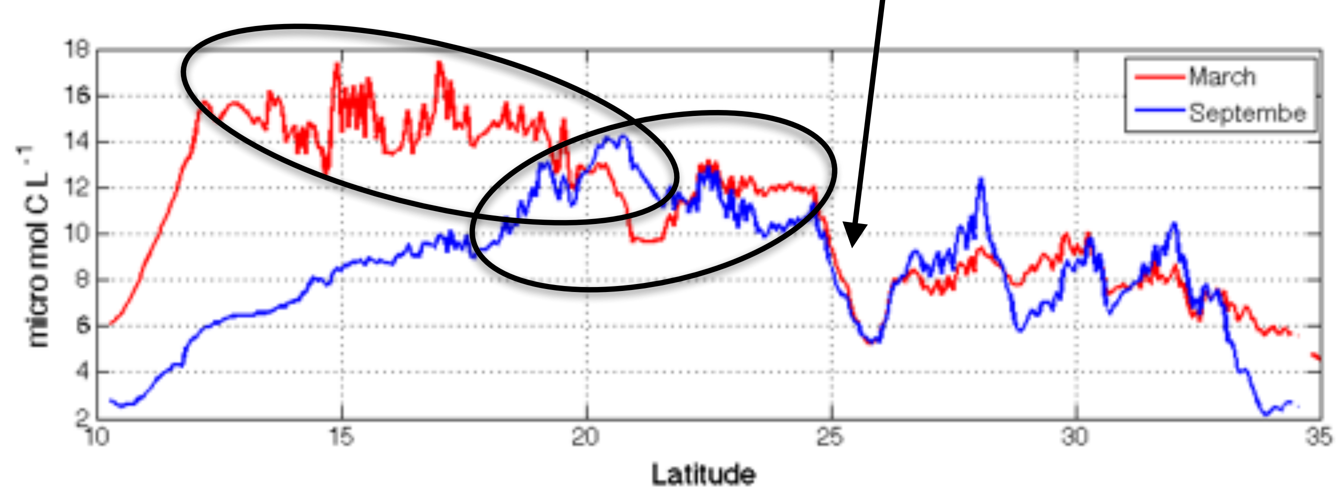
Difference in prey availability: biogeochemical simulations (ROMS-PISCES)

- Average modeled plankton biomass (ROMS-PISCES):

Abrupt change in prey abundance



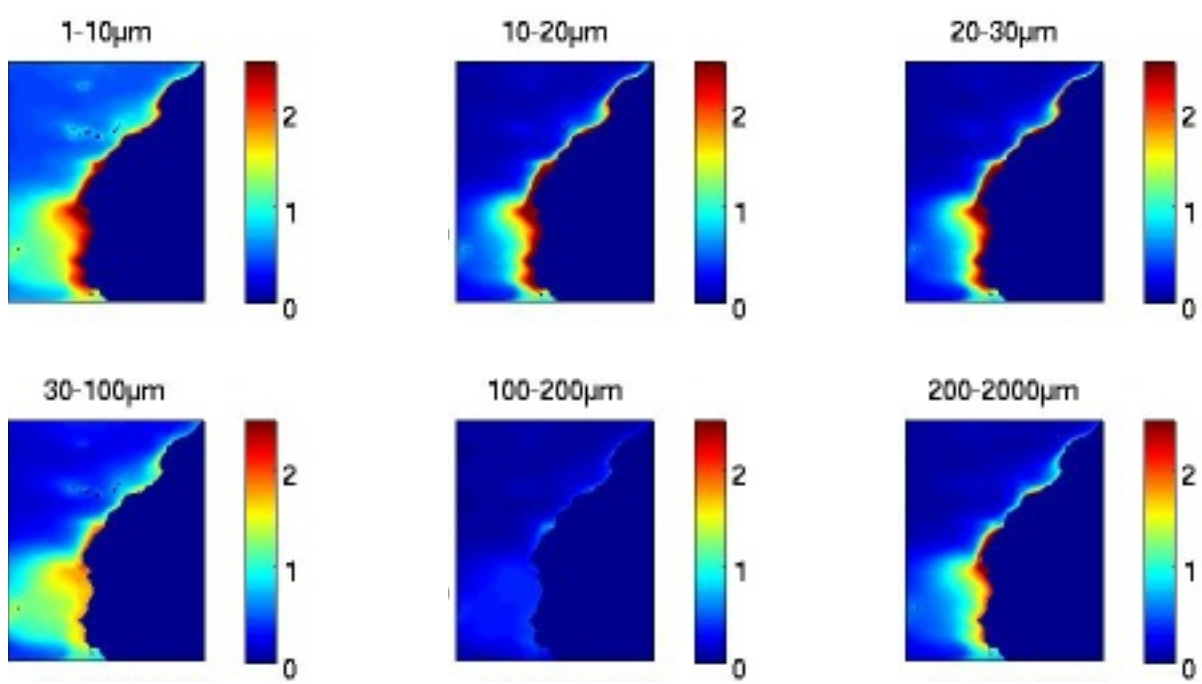
Average Zooplankton (A) and Phytoplankton (B) concentration over the continental shelf from 10 to 35°N



Average Phyto +Zoo plankton concentration over the continental shelf from 10 to 35°N

What makes the Sahara Bank a limit?
Difference in prey availability: biogeochemical simulations (ROMS-PISCES)

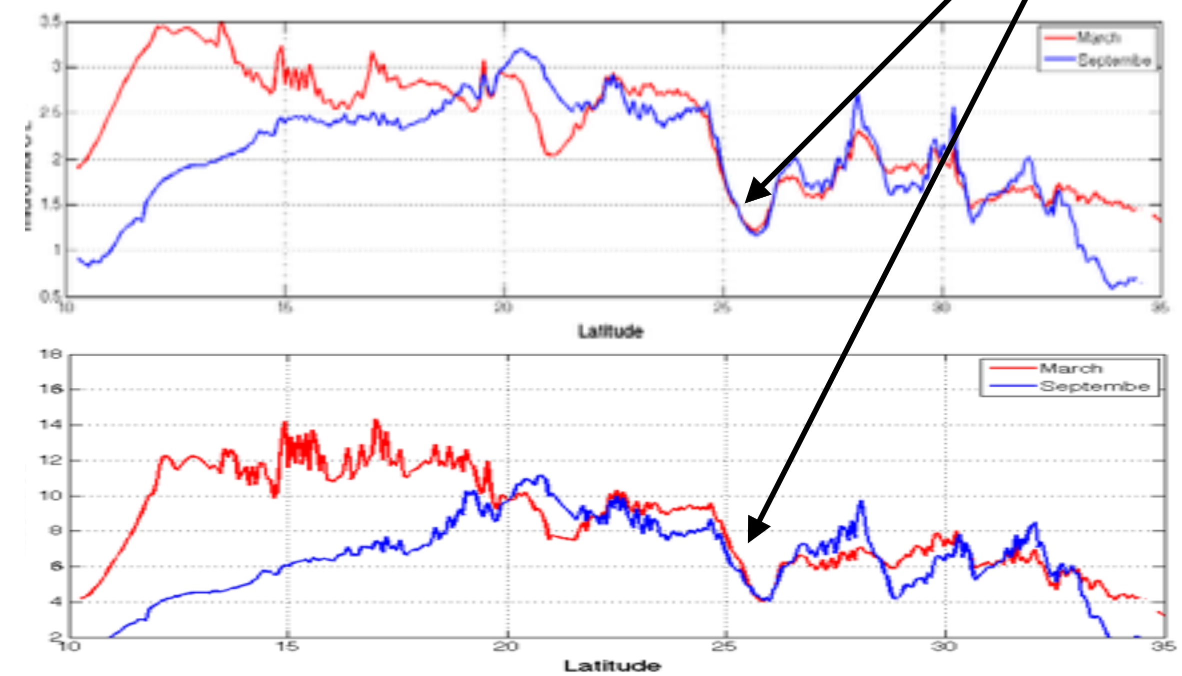
- By Size class:



All size class more abundant from 10 to 26°N…

- Phyto- and Zoo- plankton:

Abrupt change in prey abundance



Average Zooplankton (A) and Phytoplankton (B) concentration over the continental shelf from 10 to 35°N

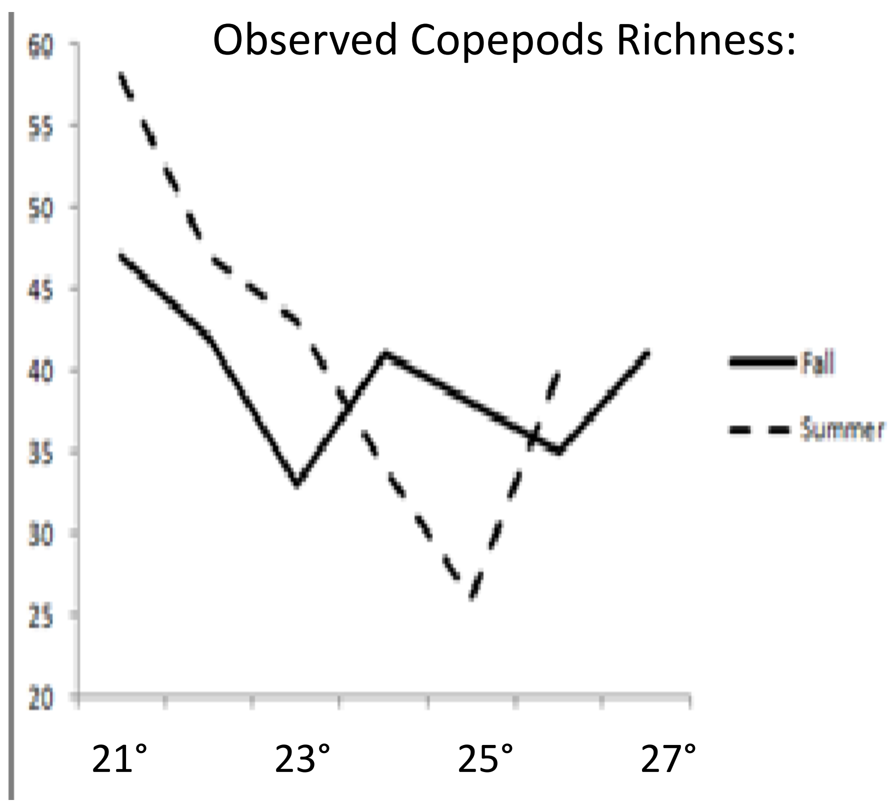
Binet 1998: Differences in plankton species not due to temperature fronts but to currents

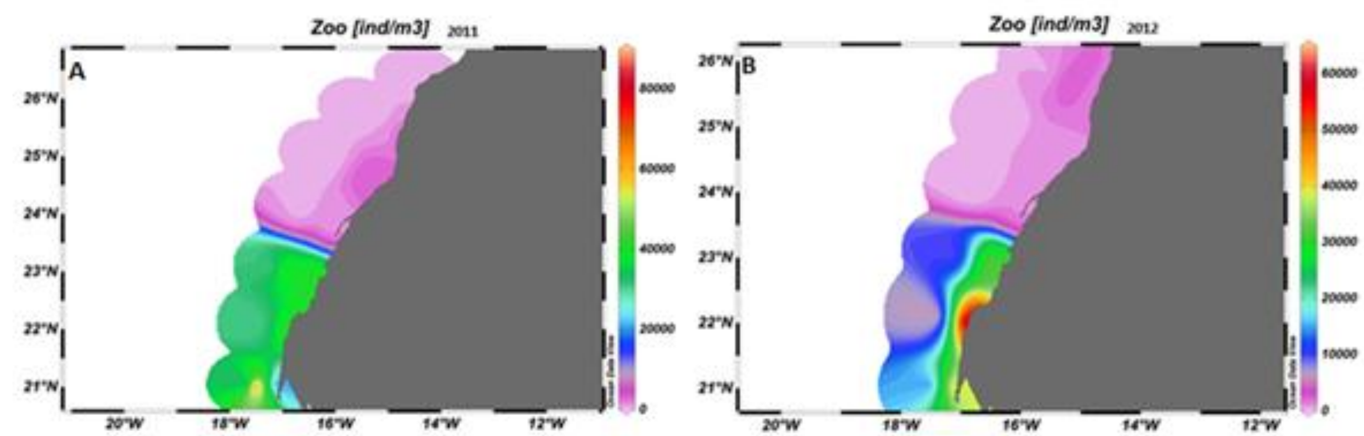
Drop in both Phyto- and Zoo- plankton

What makes the Sahara Bank a limit?
Difference in prey availability: Observations

Berraho, 2007: Higher zooplankton biomass south of 24°N from observations 1994 to 1999

El Arraj et al. 2015 : Higher zooplancton biomass and diversity south of 24°N





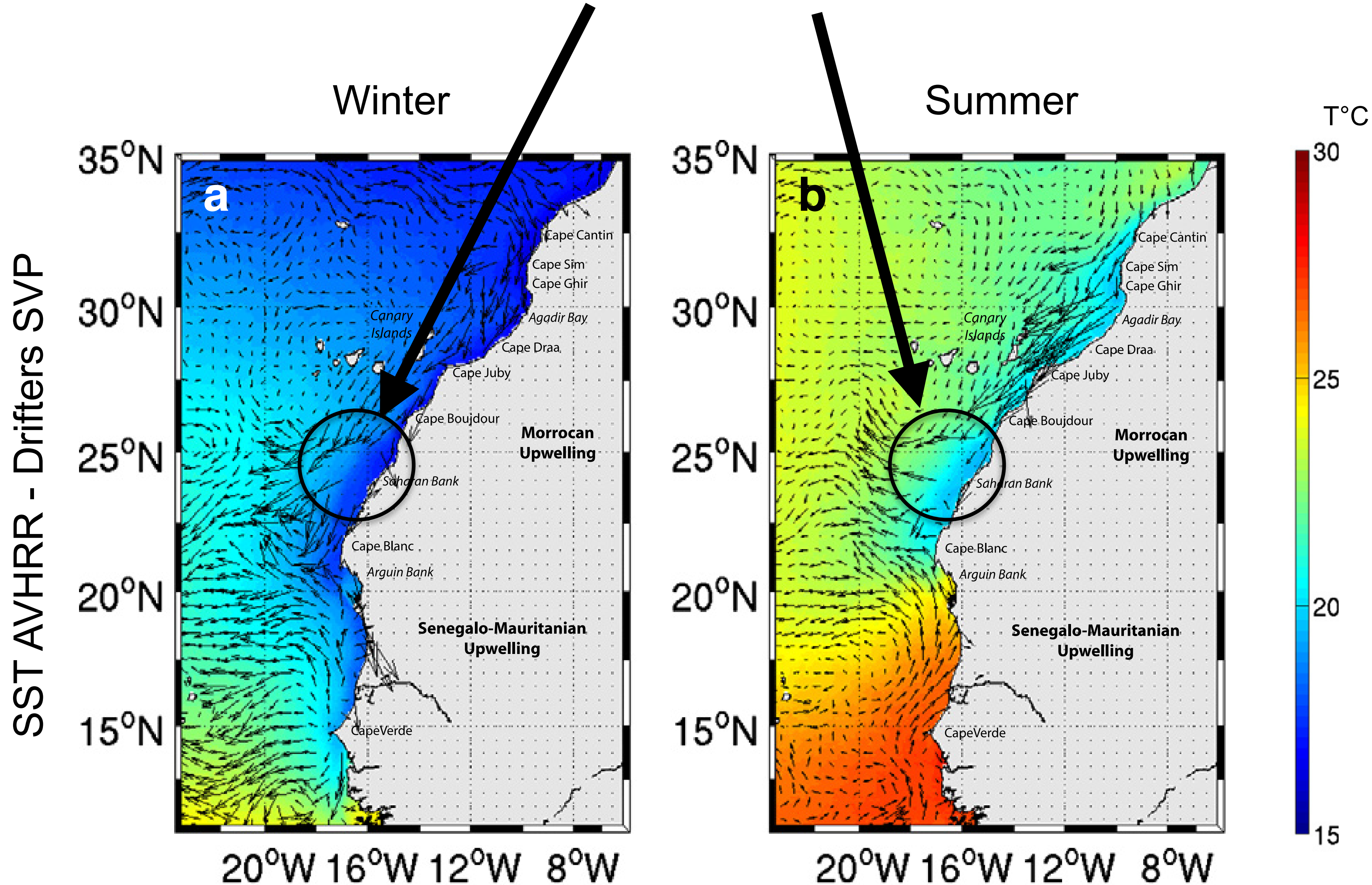
Mesozooplancton density in fall (A) and summer (B) (2011-2012)

Copepods distribution patterns in an upwelling system off Northwest Africa (Southern Moroccan Atlantic coast)
Laila El Arraj, Ouadiaa Tazi, Ikram Hariss, Karim Hilmi, Serghini Mansour and Omar Ettahiri
International Journal of Advanced Research (2015), Volume 3, Issue 6, 1136-1149 1136

Binet 1998: Differences in plankton species not due to temperature fronts but to currents

What makes the Sahara Bank a limit?
Hydrodynamics constraints:

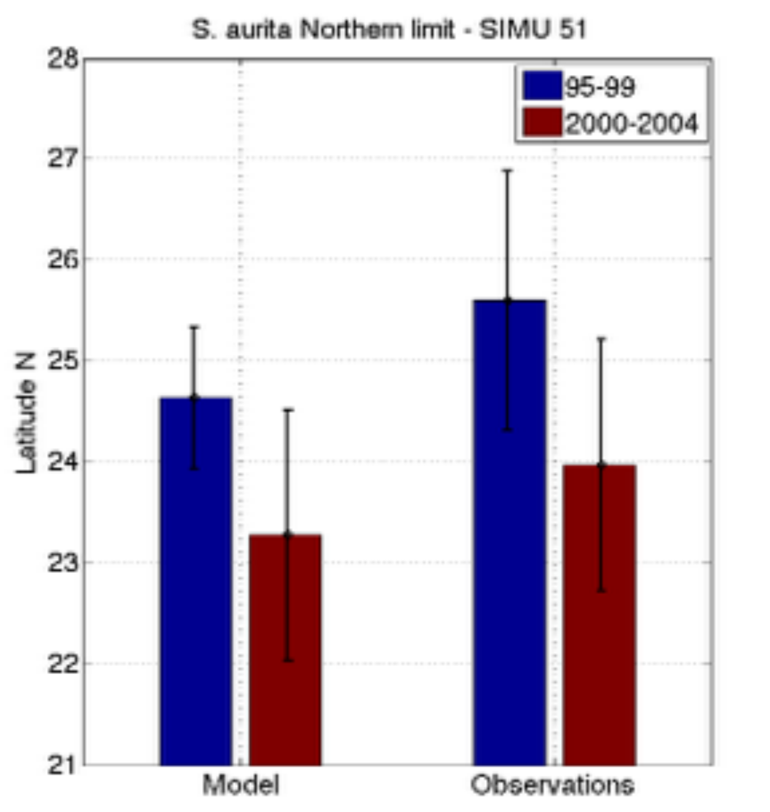
Year round particularly strong westward velocities



Seasonal climatology of sea surface temperature (SST in background) and near-surface currents (vectors) from AVHRR satellite data (1985–2009) and the Global Drifter Program (1979–present)
Auger et al., 2015

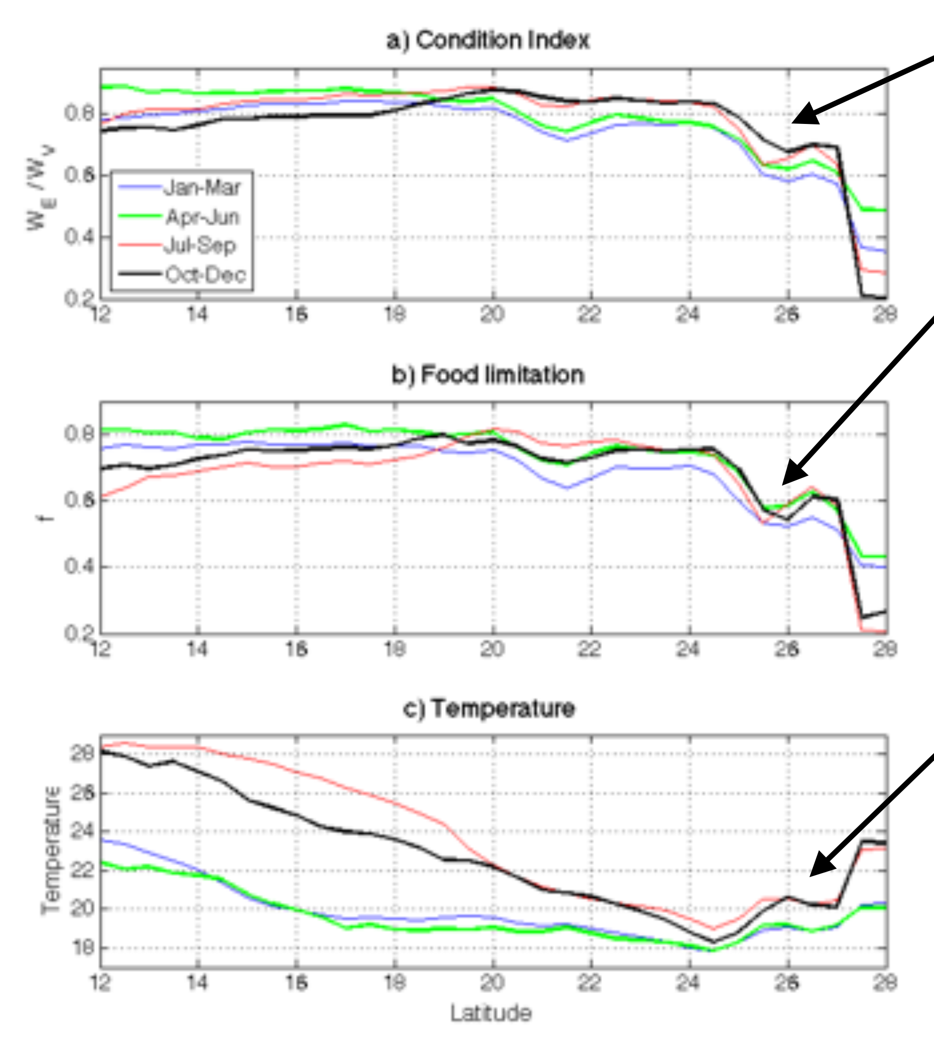
S.aurita EVOL-DEB model reproduce the variability of the northern extend of the population

1 - S. aurita population extend farther north in 95-99 than in 2000-2004 both in model and observations :



2 - What does limit the northward extend in the model?

Drop in condition index due to **food limitation**

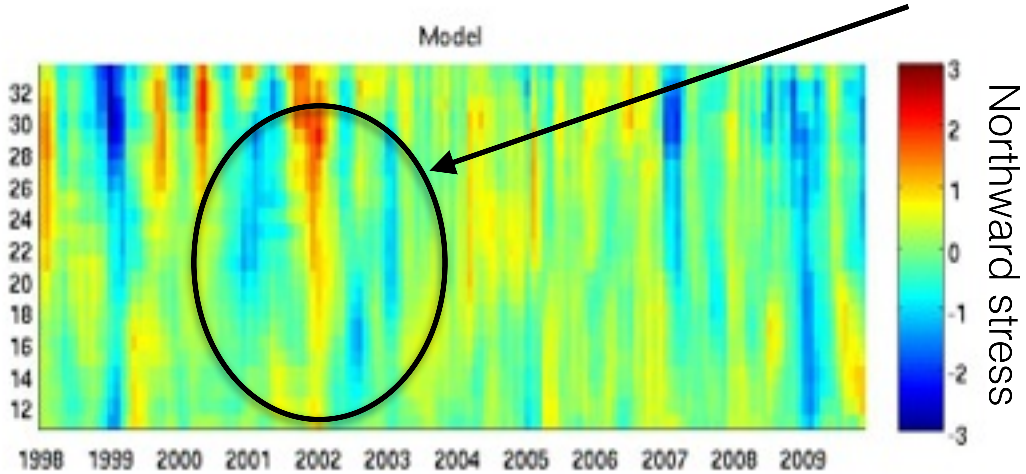


Mean temperature experienced remain within the optimal range (18-25°C)

S.aurita EVOL-DEB model reproduce the variability of the northern extend of the population

3 - What environnemental change between 1995-1999 and 2000-2004?

Stronger upwelling favorable wind during 2000-2004 :



Along shore wind (ROMS forcings)

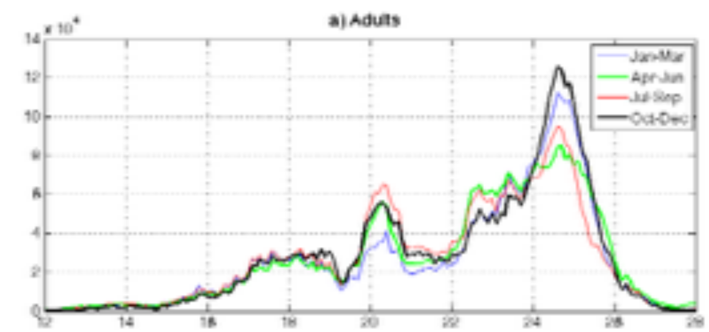
Impact on the continental shelf :

Temperature decrease but still in the acceptable range for S. aurita (SST: ~-0.5°C at 26°N)

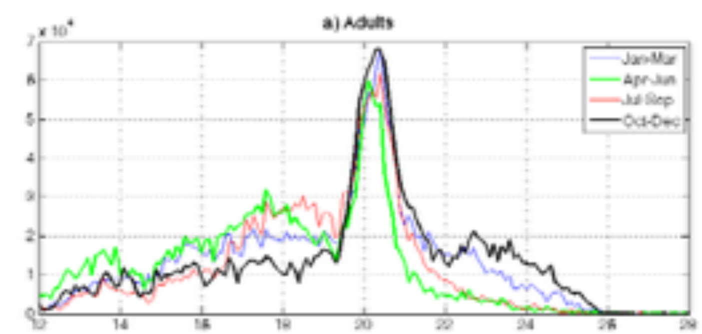
Enrichment and thus plankton production increase (+14% at 26°N) might be less limitant at the northern limit

The more favorable conditions in 2000-2004 should have allowed a northern migration but instead the population shifted south

4 - EVOLDeb : The **Southward current strongly impact the latitudinal distribution**:



Without advection (IFD)



With advection

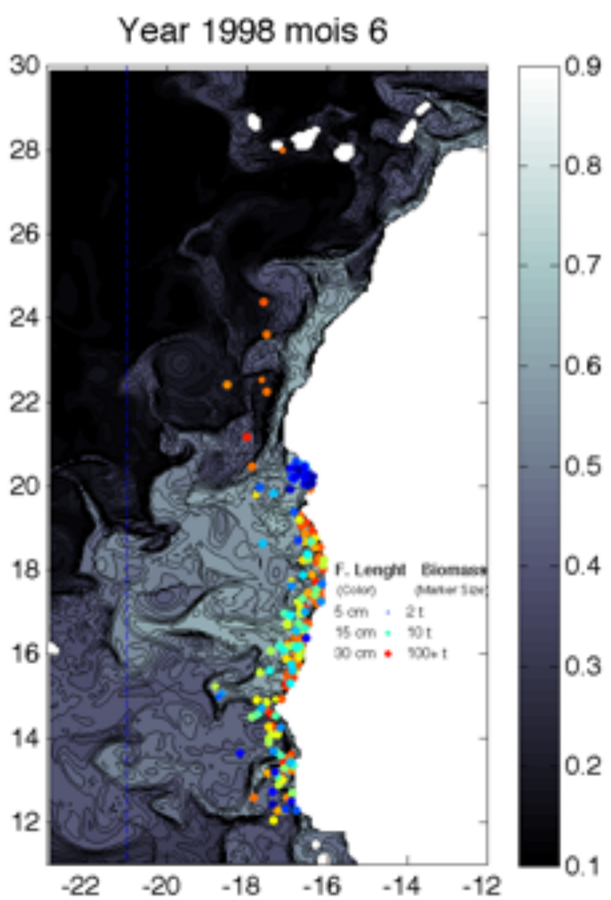
At inter-annual scale, fluctuations of the southward current intensity (model : +10% from 1995-1999 to 2000-2004)

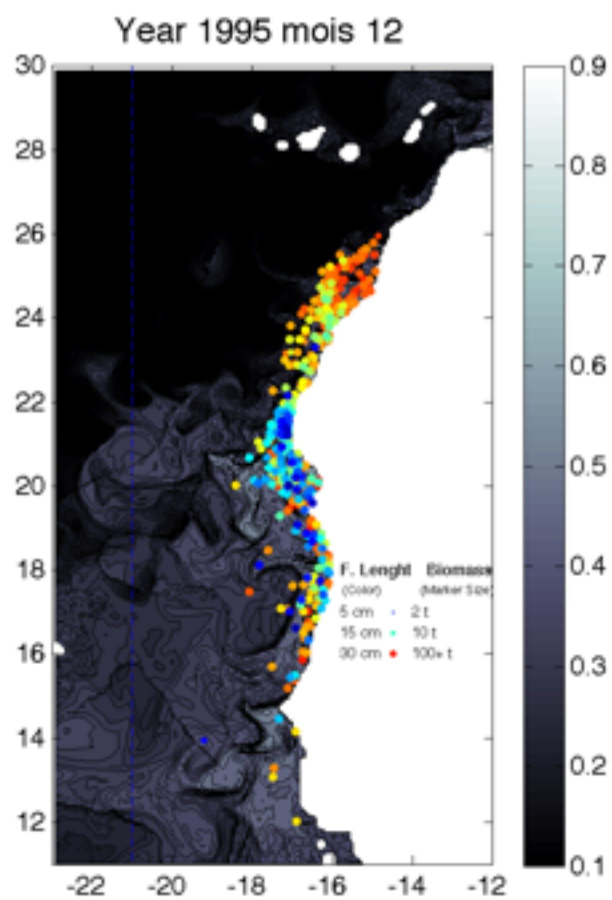
This cause the 2000-2004 southward shift of the population in the model

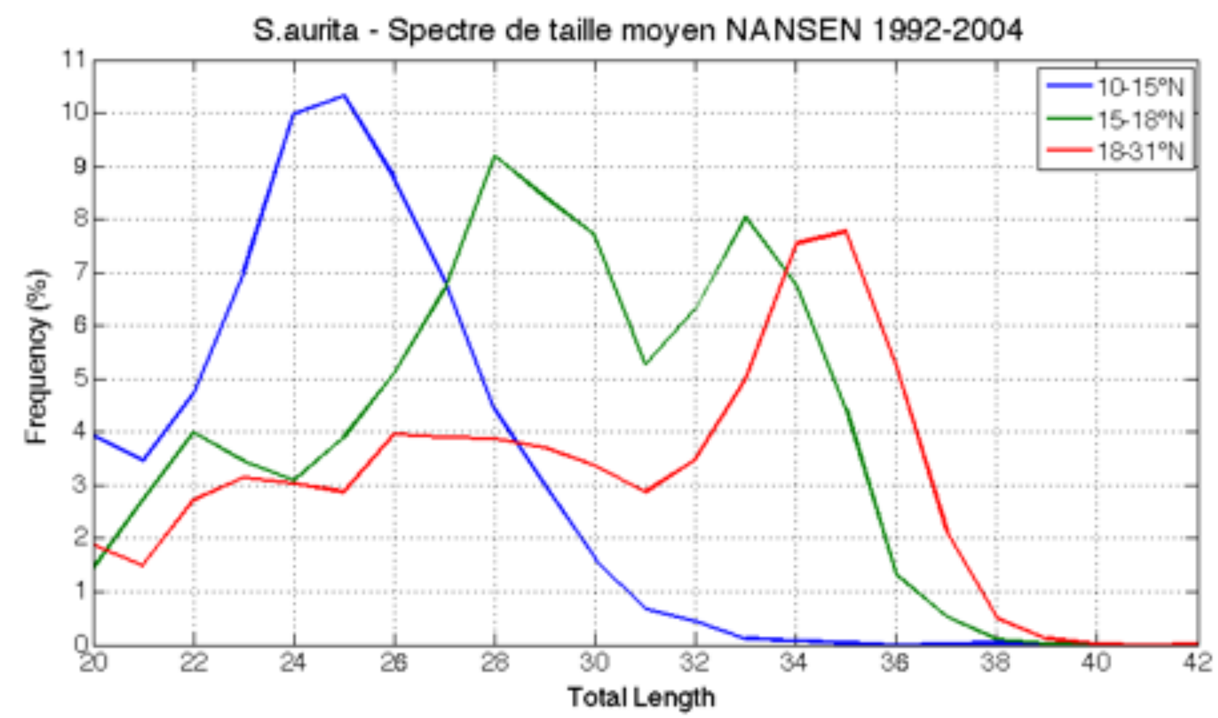
S.aurita EVOL-DEB model reproduce the variability of the northern extend of the population

The model predicted that only the large individuals (> 25cm) may be able to migrate northward until the Sahara Bank:

Such spatial length is observed (NANSEN cruses conducted in Nov-Dec from 1992 to 2004):







End of first semester : individuals distributed south

End of second semester: longest individuals in the north

In the model this size spatial structuration is related to the greater swimming efficiency of longer fish

—> The maximum size for sardine (~25cm) may not allow the seasonal northward migrations

Effect of current on fish movement/distribution was also proposed to explain the sardine migrations in south Africa (Van der Lingen et al., 2010)

CONCLUSION

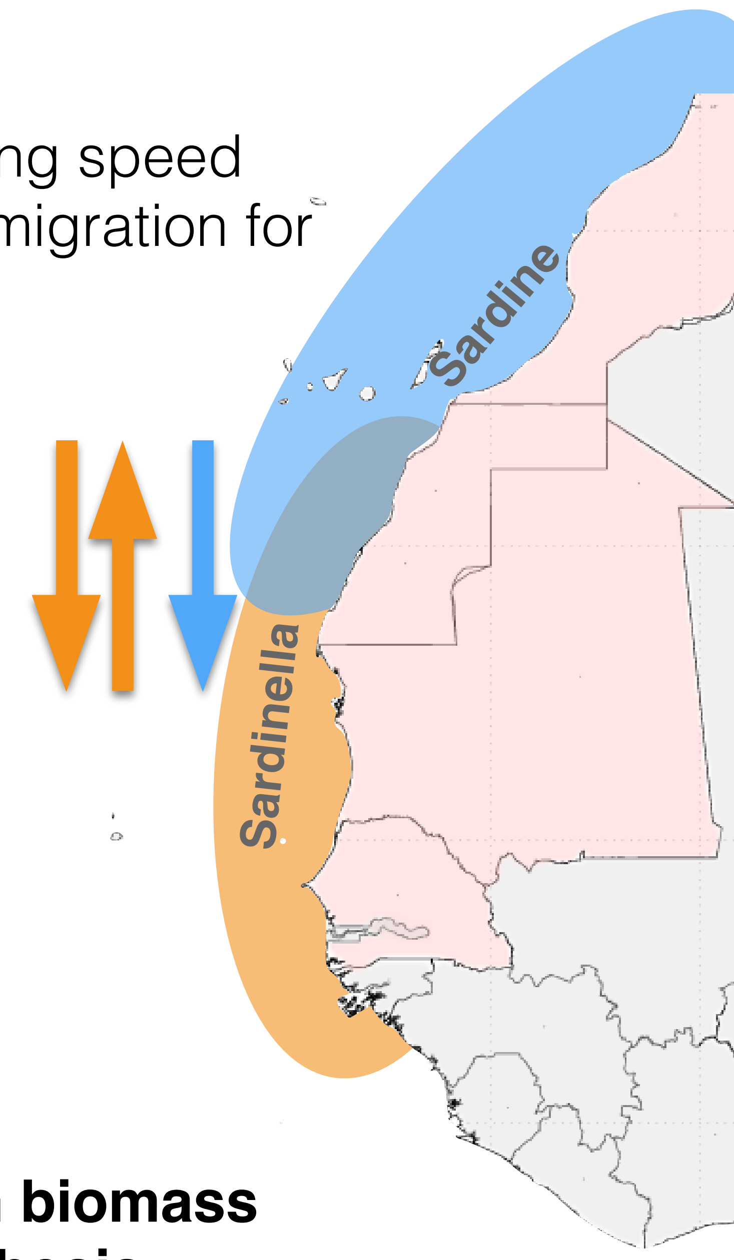
The Sahara Bank may act as a barrier:

For Northward extend of sardinella population:

- The main barrier : Food limitation north of 26°N :
- Southward transport of the juveniles

For Southward extend of sardine/anchovy population:

- No obstacle but impossible return due to smaller body length/swimming speed (hydrodynamic constraint too strong to allow the northward seasonal migration for feeding when the upwelling winds drop)



Consequences:

Connectivity among populations:

- Sardines « One way » connectivity

-**Sardinella**: « Two way for adults » (seasonal migrations) (but one way for juveniles)

Effect changes in upwelling favorable winds:

Changes in the current intensity on the Sahara Bank may be responsible for variations of the northern limit for *S. aurita,* but the drop in primary productivity is the main barrier

—> Need for in-situ measurement of current velocity and plankton biomass together with stock estimations in order to validate this hypothesis

Effect of climate change on this barrier?
Effect on transboundary exploited population?