Linking shrimp recruitment and environmental variability in French Guiana

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INTRODUCTION

Southern brown shrimp (*Farfantepenaeus subtilis* or *Penaeus subtilis*) is a Penaeid shrimp with a 36-month life span, distributed from the Caribbean Sea to Cabo Frio, in the Brazilian state of Rio de Janeiro (Fig. 1).
It has been exploited industrially since the early 1960s on the Guiana Shield and in northern Brazil.
Reproduction occurs all year long, with two periods of higher intensity, during the dry and rainy seasons.

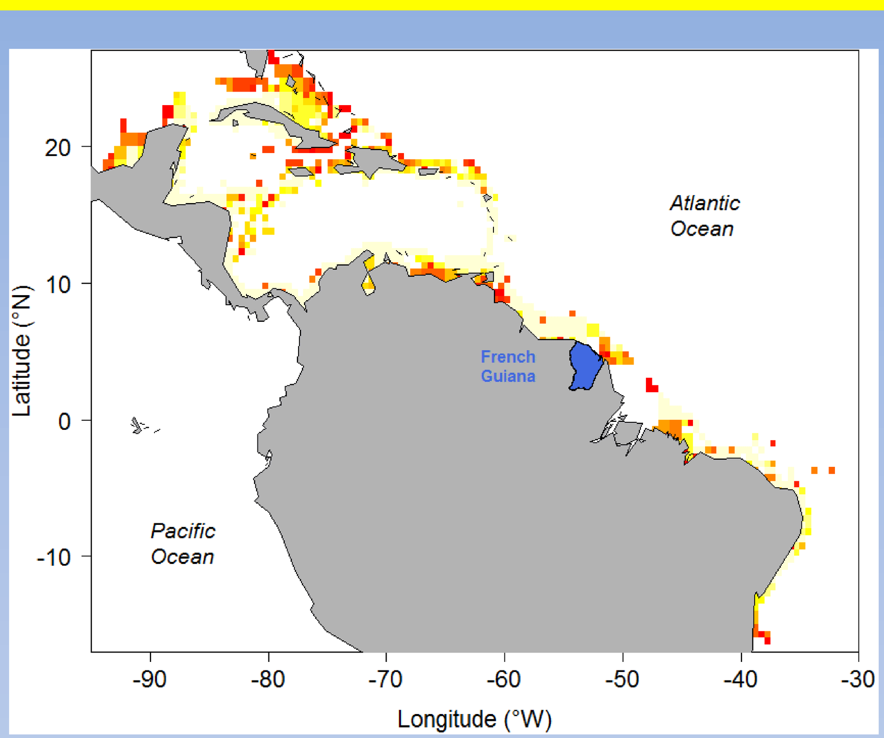

Fig. 1 Distribution of *F. subtilis* (source: Aquamaps)

In French Guiana, stock assessment of southern brown shrimp has been carried out since 1989. The stock went through two successive drops in the recent years: a first one in 1999 and a subsequent one in 2007.
Stock biomass and recruitment reached their historical lows in 2013 (Fig. 2).

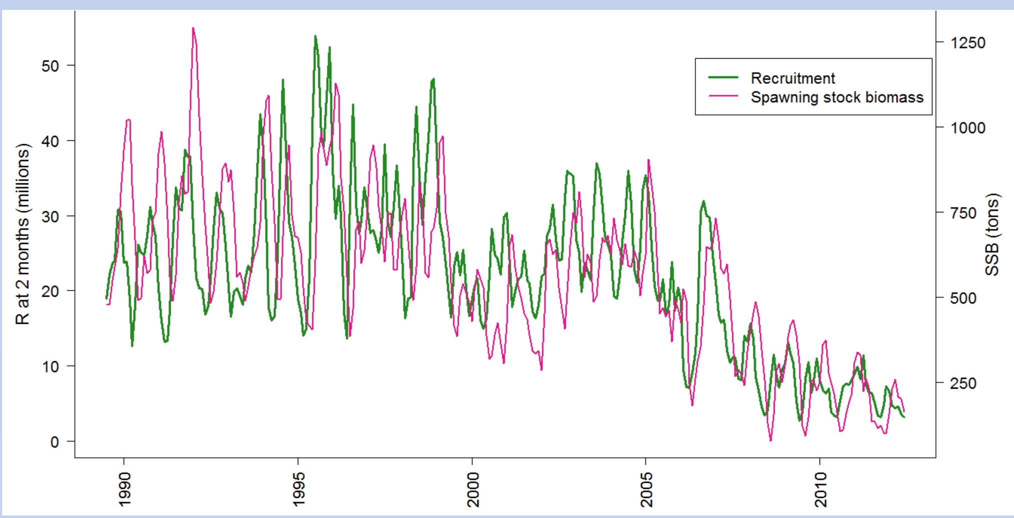

Fig. 2 Recruitment and Spawning Stock Biomass series for *F. subtilis*

Despite the possibility of fitting a classical Beverton-Holt stock-recruitment model here without considering time, a closer examination of the data reveals a **succession of 2 periods** (Fig. 3). On each side of a breaking point, estimated as June 2007, an average regime around which recruitment fluctuates can be derived.

From the absence of relationship between spawning stock biomass and recruitment and the anteriority of the drop in recruitment over the drop in spawning stock biomass (SSB), it can be inferred that **harvesting is not the main driver of the current stock dynamics**.
Thence, the source of inter-annual **variability in recruitment was sought in fluctuations of the environment**.

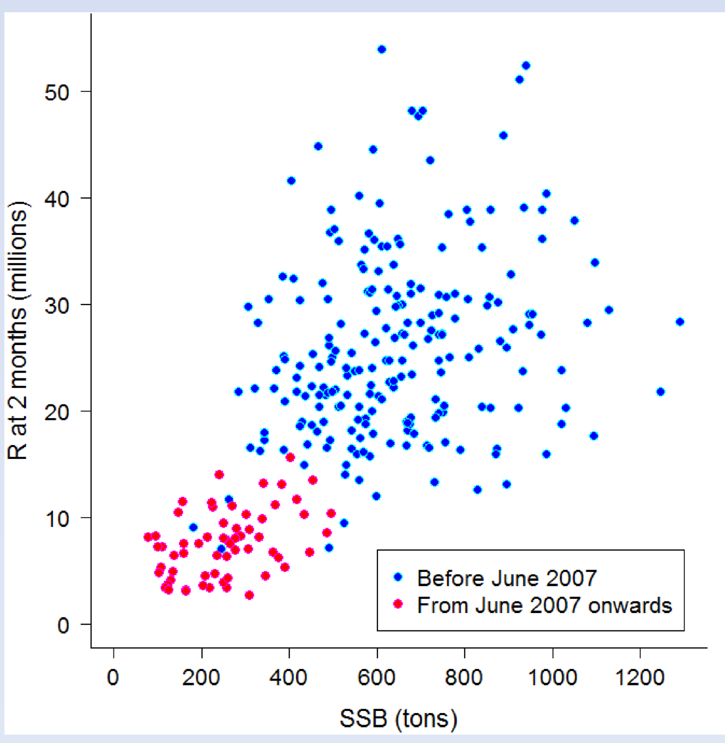

Fig. 3 Relationship between stock and SSB in *F. subtilis*

MATERIAL & METHODS

Recruitment at the age of 2 months was estimated through through virtual population analysis (VPA). Various series of environmental parameters were contrasted against the monthly recruitment series.

- In-situ data: wind force and direction, precipitations, river flow
- Remote-sensing data: sea-surface temperature, chlorophyll a, turbidity, suspended matters, Kpar
- Model outputs: swell, surface currents
- Large-scale synthetic indices: NAO and SOI

The series cover various periods, as summed up in Fig. 4.

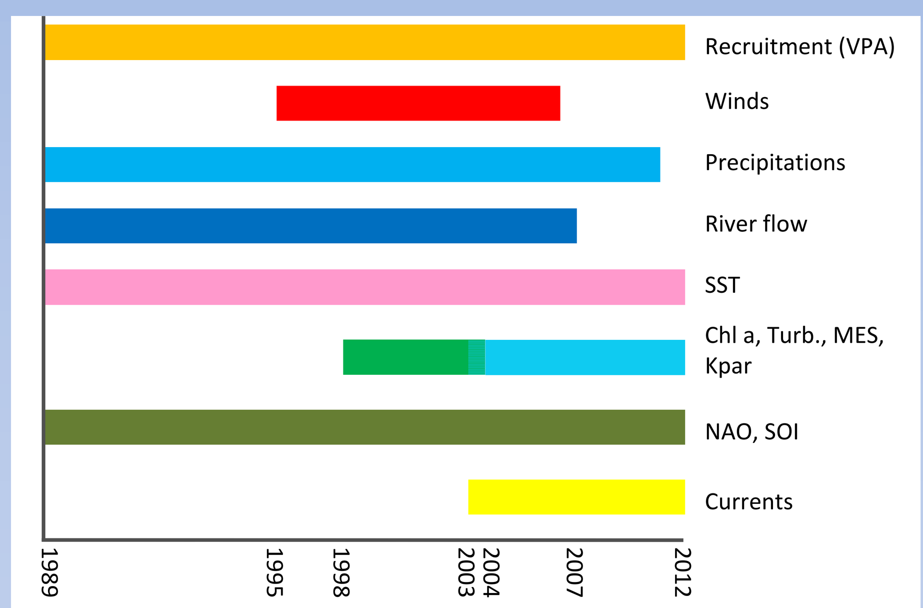

Fig. 4 Time coverages of the candidate environmental variables

Preliminary data processing

- Remote-sensing variables averaged within 23 spatial strata (Fig. 5).
- Deseasonalised signal to focus on interannual variability

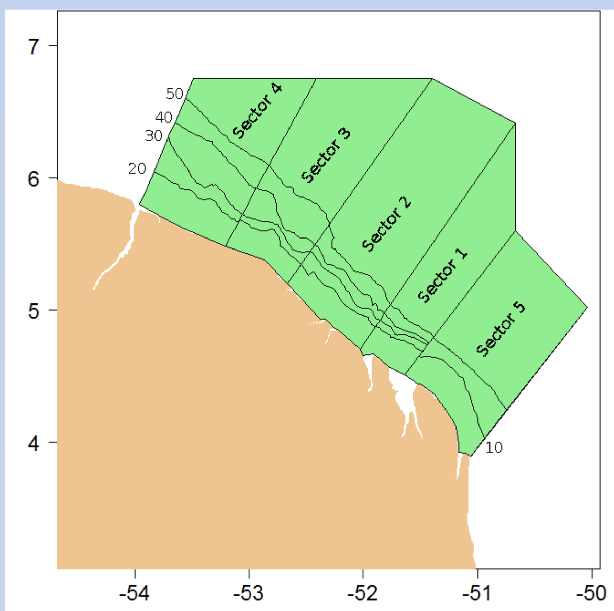

Fig. 5 Map of the strata defined to generate the series of variables obtained via remote sensing

Surface currents

Synthetic variables obtained by projection

- upon a SE-NW direction (corresponding to a straight trajectory from the suspected spawning zones to the main nursery areas).
- upon an orthogonal SW-NE direction (inshore-offshore) (Fig. 6).

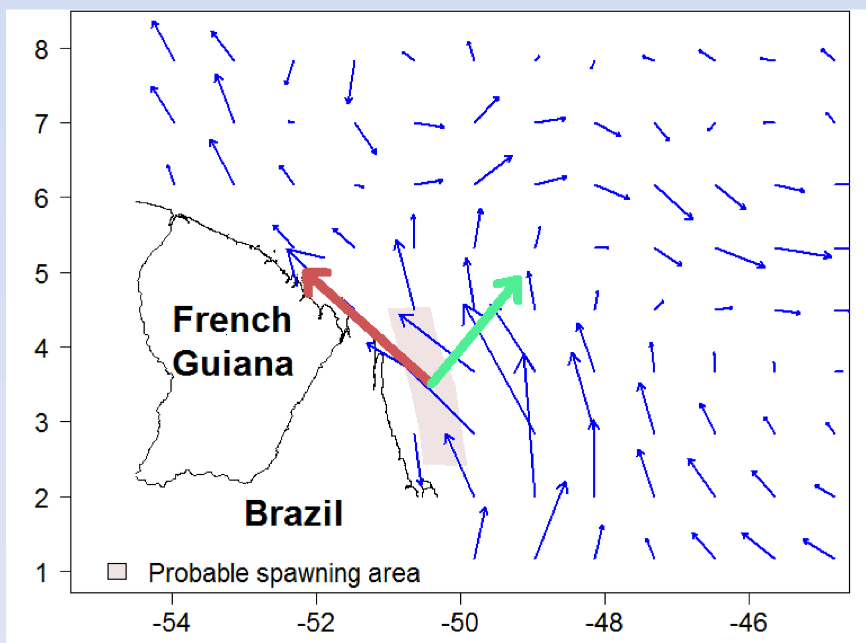

Fig. 6 Example of surface current vectors (blue)and their directions of projection (red and green).

Analyses

- Linear models of the type
$$R_{2months} = Cte + \alpha \cdot Var1 + \beta \cdot Var2 + ... + \varepsilon$$
- Statistical detection of time series ruptures

OUTCOMES

Results

Significant trends in environmental variables: SST, currents (Fig.7) and chlorophyll a.

Effect of sea-surface temperature (SST) significantly negative over the whole time series (1989-2012). However, it explained a maximum of 8.3% of the observed deviance and its significance vanished when only years after 2003 were considered.

The model $R_{2months} = Cte + \alpha \cdot SST + \varepsilon$ did not capture the observed drop in recruitment (R) occurring recently (Fig. 8).

Some variables were good descriptors of seasonal variability in R but had a poor explanatory power of interannual variability (i.e. river flow).

Surface currents (-) and chlorophyll a (+) concentration were the sole factors exhibiting a significant relationship with recruitment after 2003. These relationships arose only in the southernmost areas. When the 2 variables were combined, a maximum of 16% of total deviance was explained.

As to the detection of rupture in environmental time series, none of the most likely transition dates coincided with the observed transition between the 2 recruitment regimes (June 2007).

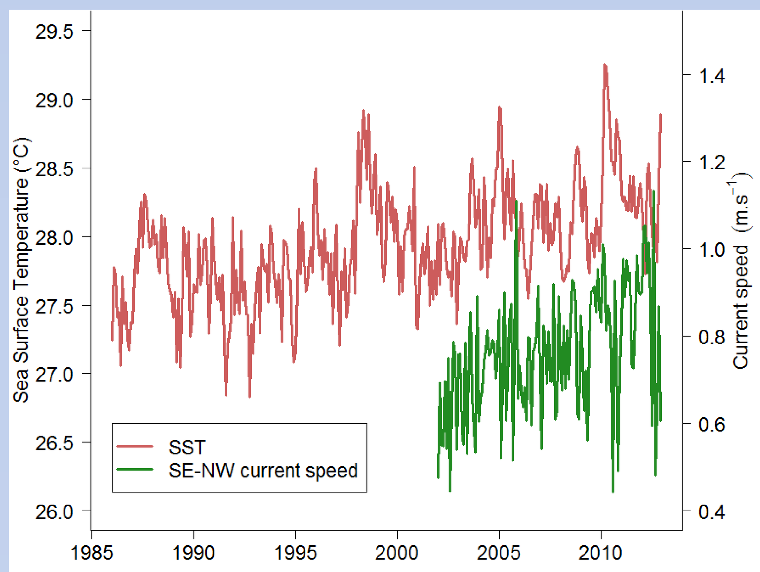

Fig. 7 Series of observed sea-surface temperature (SST) and SE-NW currents in the southernmost strata

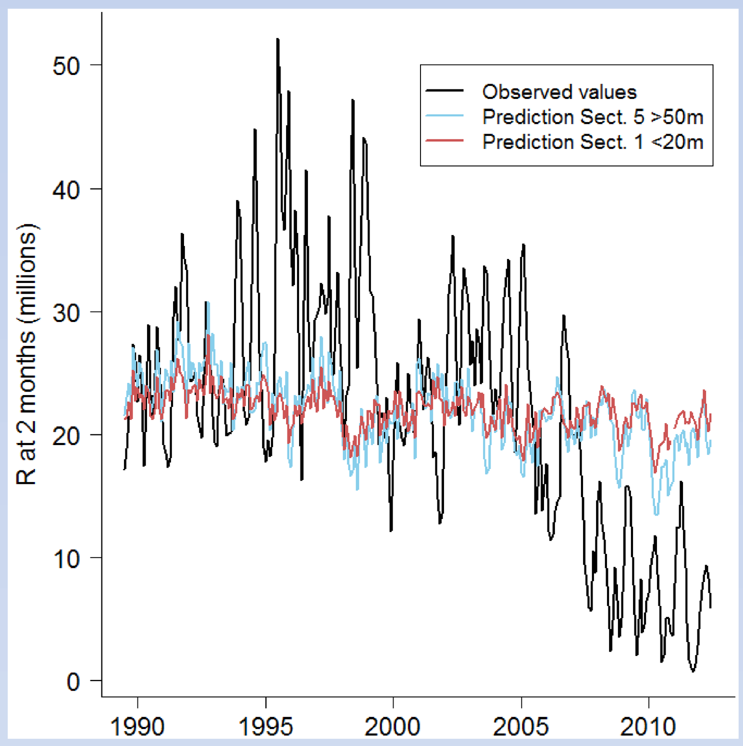

Fig. 8 Observed and predicted series of recruitment based on sea-surface temperature (SST)

Discussion & Perspectives

No satisfactory explanation of the decline in R based on the environment, but he lack of significance of most of the variables and the low explanatory power of the others may partly stem from the shortness of the available environmental series.

The assessment of the stock of *F. subtilis* would greatly benefit from the **exchange of information between countries sharing this stock** (Brazil , French Guiana, Surinam). This would among other things allow reducing the uncertainty as to the location of the spawning grounds and hence improving the accuracy of the stock-recruitment relationship.

With this objective in mind, a future development of this study will be the design of a **2D drift model** used to derive the origin of shrimp larvae settling on Guianese mangroves.

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