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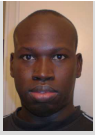

A surplus production model including the effect of environment: application to the white shrimps stocks in Senegal

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Abstract

Using a surplus production model which includes a additional effect of environment, we analysed changes in abundance of two main shrimps stocks of Senegal, over the past 10 years. We showed that the northern stock is still underexploited and that the driving force of abundance and catch is the upwelling intensity; conversely, the southern stock is strongly over-exploited and less affected by the environnemental variability.

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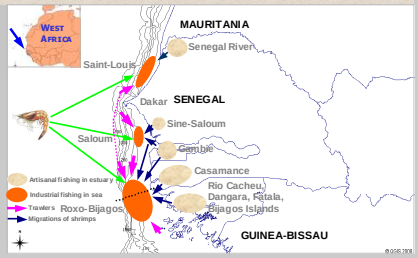
Scientific context

Exploitation of the white shrimps (*Penaeus notialis*) by trawlers recently became a major fishing activity in several Western African countries. In Senegal, two stocks are intensely exploited: the north one around Saint-Louis and the Roxo-Bijagos stock in the south (the largest stock). Life cycle of shrimps is very short and recruitment is usually considered highly dependant of the upwelling intensity. Thus, fisheries management has to take into account diagnosis based on stocks assessment, but also to adapt to environmental variability.



Location of the study

Objectives

- To understand and quantify the respective part of fishing and environmental effects on abundance of the Senegalese shrimps stocks;
- to establish a diagnosis on the stocks status and to estimate MSYs depending on environmental conditions.

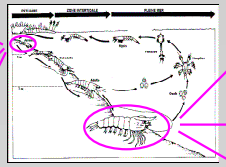
Life cycle and exploitation

Artisanal fishing

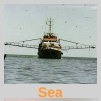

Estuary


Fixed net


Marked Products



Industrial fishing


Sea


Trawler

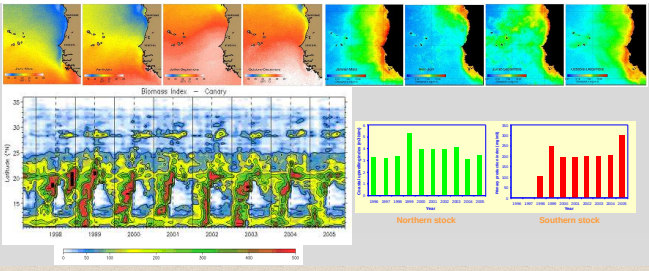

Marked products

Material and methods

Based on GLMs techniques, yearly abundance index are estimated from commercial catch statistics. Derived from these indices and from total catches, theoretical fishing efforts are calculated. Two environmental indices are alternatively tested in the model. One is measuring the coastal upwelling intensity from wind speeds provided by the SeaWifs database; the other is related to the primary production derived from satellite infrared images of chlorophyll a (NOA database, http://las.pfeg.noaa.gov).

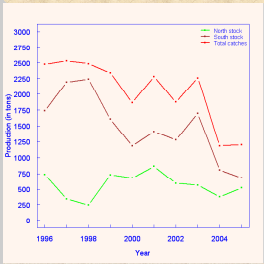
Fox Models are fitted to the 1996 to 2005 time series and express the abundance (**AI**) of each stock as a function of the fishing effort (**E**) and the environmental index (**V**), (Fréon, 1986, 1988, 1991; Fréon *et al.*, 1992) .

AI = a x (V^b) x exp(c x E) (**a, b, c**) are parameters



Seasonal climatology of sea surface temperature (top left) and sea surface chlorophyll (top right, given by SeaWiFS sensor) show seasonal dynamics of the coastal upwelling, with a maximum in winter. The local enrichment, which is maximum in winter, is cleary visible using biomass index derived from phytoplankton density (mg/m^3) (down).

Results

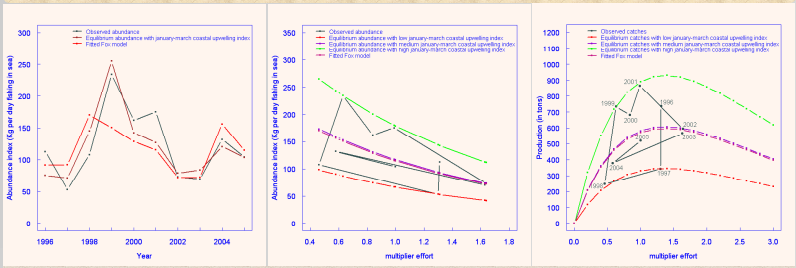


R^2	Northern stock		Southern stock	
	AI Fox	AI CUI	AI Fox	AI PPI
Observed AI	0.352	0.773	0.719	0.859

Variance explained by the various models: R^2 between observed Index of abundance and predicts based on the Fox model (without environmental effect) or based on the Freon model (tacking into account either the Coastal Upwelling Index (CUI), or Primary Production Index (PPI)

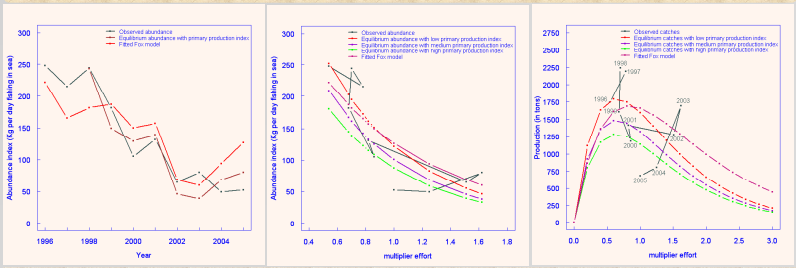
Shrimps catches in Senegal are significantly decreasing over the 1996-2005 period, and especially during the latest years. The decrease mostly affected the southern stock where landings were divided by almost three between 1998 and 2005. Conversely, catches on the Northern stock exhibited a high year-to-year variability, but no clear trend.

Northern stock



For the northern stock, the model based on the index of upwelling intensity explains 77.3% of the year-to-year variability. Fishing effort and abundance fluctuates over the period without any clear trends, and the stock seems to be still underexploited. The abundance of the stock mainly depends on the coastal upwelling index, which explains 42.1% of the total variance. MSY for instance varies from 300 to 900 tons for respectively the lower and the upper values of the observed interval of yearly upwelling indices.

Southern stock



For the southern stock, the best fit is observed using the primary production index (R^2 = 0.859). Fishing effort strongly increased during the period, while the abundance has been reduced by 4-fold over the past 10 years. The stock is nowadays significantly overfished, whatever the environment could be. Nevertheless, upwelling intensity explains 14% of the variance and results in significant changes in predicted catches. MSY for instance varies from 1250 to 1800 tons for respectively the lower and the upper values of the observed interval of yearly upwelling indices.

Conclusion

- The early-life planktonic stage of shrimps is known to be the main critical period of the life cycle. Recruitment especially depends on the productivity occurring in the reproduction area.
- In the north of Senegal, the seasonal upwelling is highly variable from year to year and constitutes the major factor determining this productivity.
- In the South, hydrodynamic processes seem to dominate and determine the primary production.

Acknowledgments

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