DETERMINATION OF THE RETENTION AREAS OF PELAGIC SPECIES IN IVORIAN COASTAL WATER USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM (GIS).

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ABSTRACT- Infront of the threat of overfishing in the Gulf of Guinea, this study has been involved in the continental shelf of Côte d'Ivoire to have a better knowledge of pelagic species availability according to upwelling prevalency.

This study is based on combined analysis of in situ data and remote sensing data. The concentration of chlorophyll from the SeaWiFS and the Sea Surface Temperature (SST), derived Multi-Channel Sea Surface Temperature algorithm (MCSST) based on channels 4 and 5 of the AVHRR sensor. From the SST data, it calculated the Coastal Upwelling Index (CUI) and the Coastal Retention Index (CRI) The stability of water column due to the wind or turbulence has been calculated from the wind's speed of ERS I and ERS II data.

The coupled use of satellite and in situ data in a Geographic Information System (GIS) helped to define idealfishing areas based on analysis of environmental factors which contribute to the retention of larvae.

The incorporation of these parameters in a GIS from multicriterion analysis by balance permitted to obtain a pelagic species availability map in the Ivorian costal sea (1998-2004). This map allows distinguishing three areas of pelagic species availability which are: great availability in the Center and in the East, middle availability in the Center-West and weak disponibility in the extreme West of the littoral.

Keywords: Remote sensing, Geographic Information System (GIS), Sea Surface Temperature (SST), coastal upwelling index, chlorophyll concentration, Côte d'Ivoire

RÉSUMÉ- Devant la menace que constitue la surpêche dans le Golfe de Guinée, cette étude a été initiée sur le plateau continental ivoirien pour mieux comprendre la disponibilité des espèces pélagiques en fonction de la prévalence de l'upwelling. Cette étude est basée sur l'analyse combinée des données in situ et des données de télédétection. La concentration de la chlorophylle obtenue à l'aide du capteur SeaWiFS est calculée au moyen de l'algorithme bio-obtique OC4v4 par l'application de la projection azimutale à l'aide de SeaDAS v4.7. Quant à la température de surface de la mer, elle est obtenue à l'aide de l'algorithme Multi-channel Sea Surface Temperature (MCSST) basé sur les canaux 4 et 5 du capteur AVHRR. La stabilité de la colonne d'eau due au vent ou turbulence a été calculée à partir des données de la vitesse du vent de ERS I et ERS II. L'utilisation couplée des images satellitaires et d'un Système d'Information Géographique (SIG) permet de définir des zones propices à la pêche à partir de l'analyse des facteurs environnementaux qui concourent à la rétention des larves.L'incorporation de tous ces paramètres dans un SIG à partir de l'analyse multicritère par la pondération a permis d'obtenir une carte de disponibilité des espèces pélagiques du littoral marin ivoirien (1998-2004) qui permet de distinguer trois zones de disponibilité des espèces pélagiques qui sont : forte disponibilité au Centre et à l'Est, disponibilité moyenne au Centre-Ouest et faibles disponibilités dans l'extrême Ouest du littoral.

Mots-clés: Télédétection, Système d'Information Géographique (SIG), Température de Surface de la Mer (TSM), Indice d'upwelling côtier, concentration de la chlorophylle, Côte d'Ivoire.

1- INTRODUCTION

The Gulf of Guinea (GG constitute one of the large marine ecosystems that are home to most of the living marine resources and are the object of a vast multidisciplinary scientific approach, Sherman et al., [1]., The coastline of the Côte d'Ivoire (CI), is part of this great ecosystem that, is characterized by a seasonal upwelling which differs from the upwelling of the Ocean borders in several aspects, [2].

The originality of the Ivorian upwellings also lies in the existence of two Cold seasons,a primary and a secondary, well differentiated, [3]-[4]. Upwelling ecosystems provide 40% of global fisheries catches while they represent less than 3% of the surface of the ocean. They are at the origin of a biological production strong but subject to significant interannual fluctuations.

That of Côte d'Ivoire does not escape this constraint.

therefore Knowledge of spatio-temporal variation of this marine environment is essential for a better management of fisheries resources. It is indeed establish the practice of fishing which fits in the context of the challenge of food security for sustainable development. This study contributes by characterization and monitoring of areas of upwelling for the determination of the retention areas of pelagic species using remote sensing and the Geographic Information System in the seacoast of Côte d'Ivoire.

2 MATERIAL AND METHODS

2-1. Data and treatments

The data cover the period from 1998 to 2004. The first four (4) years (1998 to 2001) were used for the design of the model and the last three (3) years (2002 to 2004) for validation. The parameters used are turbulence, the chlorophyll concentration (CHL), the upwelling and coastal retention because of their significant influences on the availability of pelagic species. We also used data from fisheries of *Sardinella aurita*, species whose landings are the most spectacular. They were obtained from the fisheries Direction (Ministry of Productions of animal)

Turbulence or mixing due to wind in the superficial layer index is usually calculated by the cube of the wind speed according to the method of Bakun and Parrish [5]. These are weather data (wind speed) derived from the ERS I and ERS II.

The concentration of chlorophyll (conc.CHL) is obtained from the Orbview-2 SeaWiFS sensor images. This concentration is extracted using the bio-optical algorithm linking the concentration of pigment and reflectance normalized out of the water.

The Coastal Upwelling Index (CUI) is obtained from the Sea Surface Temperatures (SST) measured by the AVHRR/NOAA sensor and measurements obtained from conventional stations of the Oceanographic Research Centre (CRO). The index is thus given by the relation proposed in [6].

$$IUC = \frac{SST\max - SST\min}{SST\max - SSTup} \qquad (1)$$

SSTmin is the lowest temperature measured along a perpendicular to the shore parallel, *SSTmax* is the maximum temperature measured along the same parallel (that is the temperature offshore reference); *SSTup* is the theoretical temperature of resurgent waters observed, resulting from the measures in situ.

Coastal Retention index (CRI) is obtained by performing the integral calculation of the difference with the maximum temperature from the coast to the point where the lowest temperature was noted, Demarcq and Faure [6].

$$IRC = \int_0^{z\min} (SST(z) - SST\min)\,dz \qquad (2)$$

z is the coordinate along the radial oriented coast seaward (*z* = 0 corresponds to the coast); *SSTmin* is the minimum temperature; *zmin* is the location of the *SSTmin* along the radial. This index corresponds to the amount of heat stored between the coast and the minimum temperature point.

2-2. Merger of the criteria by the method of weighting

The method of aggregation by weighting, Jourda et al. [7]-[8], Saley [9]; Jourda [10], KOUAME [11], N'da [12] has been used to add all criteria for the preparation of a summary of the availability zones map. The weighting was to multiply each criterion by its 'weight'. Indeed, to determine the weight, the correlation coefficient is calculated according to the quantities of fish taken and the sum of different factors to determine the weight of each criterion according to table I.

The merger of the criteria is progressively made around indicators which are sets of criteria added characterizing a same theme.

2-2-1. Abundance of planktonic food indicator (*I 1*)

Turbulence and the coastal upwelling index crossed for this indicator. Indeed, winds that induce turbulence are actually at the origin of the upwelling so engine of the presence of planktonic food. Each criterion is multiplied by its weight to obtain the thematic map of this indicator is:

$$I1 = (T \times t1) + (U \times u1) \quad (3)$$

T = Turbulence, *U* = Upwelling, *t1* = turbulence weight, *u1* = upwelling weight.

2-2-2. Productivity indicator (*I 2*)

By the same method, the criteria IRC and concentration of CHL are cross. It retains that CHL concentrations are more suitable for productivity, so decisive in food for species recovery. The equation of the association is as follows:

$$I2 = (R \times r1) + (C \times c1) \quad (4)$$

R = Retention, *C* = Chlorophyll concentration, *r1* = retention weight, *c1* = chlorophyll concentration weight

2 2-3 Map of availability uncommitted

For the development of the map of provisional availability of species, both indicators are crossed according to the following equation:

$$CD = (T \times t1) + (U \times u1) + (R \times r1) + (C \times c1) \quad (5)$$

With CD = availability map uncommitted.

2-2-4 Map of validation

All criteria from 2002 to 2004 are crossed. Here, fishing data will be not taken into account in the development of the map. They are an annual cumulation on all the ivorian coast; they can therefore be located at a specific point, so we reason in terms of area of availability covered for each year. For example if the surface covered by the "high availability" is more than half of the total area of the year concerned, this year is characterized by strong production. Similarly, if one has an almost equal distribution of different proportions, the availability is average. Subsequently, it is compared for the same year, the quantity of fish stock fished with the covered surface to assess the spatial distribution of the availability.

3-RESULTS

Maps represent variations in time and space of the different parameters. All data are taken at the coast. Analyses are therefore related to longitude, not to latitude.

3-1. Abundance of planktonic food indicator

The figure 1 shows the abundance of planktonic food indicator. This map is the result of the turbulence criteria and IUC combination which give an idea of the recruitment of the species. This indicator shows that the low abundances of planktonic food located to the West while the strong are located east the same years (2000 and 2001). Medium planktonic food abundance occurs in Eastern (-5 ° W to –3 ° W) in 1998. In 2000 and 2001, around longitude - 6 ° W, observed these same means nutrients. This mean abundance is significant in 1999 on the entire coast.

3-2. Productivity indicator

The coastal productivity indicator results from the

combination of IRC and concentration of CHL criteria. It gives an idea on the distribution of the fish along the Ivorian coast (figure 2). High productivities are located at the Centre -6°W and -4°W in 1998 and 1999. In 2001, there is also high productivities in the West to the of the Cape. The average productivities are between-7 and -6°W and East of-4°W and to the Ghanaian border. Low productivity is located in the western part of the coast. They are very well marked in 2000 and 2001 at the Cap des Palmes and also around the longitude -6°W in 2001.

3-3. Availability non-validated species map

The availability non-validated species map (figure 3) is the result of the combination of the planktonic food abundance and productivity from 1998 to 2001.

Generally low availability are observed in the West of the coast in 1999, 2000 and 2001. Average availability of species are observed at the centre (-6 to - 5°W) in 1999 and 2001 and to the East at Cape three points in 2001. Species have abounded in the center between-6 and -5°W in 1998 and 2000, between -5 and -4°W in 2000 and 2001. This high availability is observed in the extreme is in 2000.

At the annual level, we note during 1998, low, medium and high availability share more or less equally coastline. So for this year, the availability is average. Low availability occupied the major part of the surface in 1999. Which indicates that in 1999, availability is low. During the 2000s, high availability occupy the whole of the territory since the longitude - 6°W to the Ghanaian border, with small areas of medium availability. Only the West has low availability. Availability is considered high for the year 2000. In 2001, there was an almost identica distribution of different availabilities (high between -5°W and -4°W, average in the east and centre between-6 and -5°W and low in the west). This year therefore presents average availability.

3-4 Validation of results

Figure 4 shows of high availability in the mid-coast in 2003 and 2004. During these three years, average availability occur between -7 and - 6°W and to the East at Cape three points. Low supplies are in the far West, that is to say the Cap des Palmes.

In 2002, low availability occupy the major part of the coastline. A small eastern part presents average availability. The year 2002 is considered as having low supplies. The year 2003 shows high availability which occupy an area larger than medium-sized and low availability. They occur in the centre and east after-4°W. For this year, the availability is relatively average. Finally in 2004, high availability occupy the centre of the coast. Average availability are the Cape three points and longitude - 7°W. The availability is so strong for 2004.

Table II shows the statistics of the areas occupied by the different classes of availability during three years.

Statistics from fishing for three years (2002, 2003 and 2004) reveal that fish stocks (quantities) are low in 2002 (2205 tons), high in 2004 with a value of 4234.242 tons and more or less important in 2003 (3857.1 tons). This observation is used to validate the selected criteria and therefore to make reliable results and their applications on the Ivorian seacoast fishing areas.

4. DISCUSSION

4-1. Availability of pelagic species in relation to upwelling and turbulence

The cold upwelling from the depths to the surface (upwelling) always brings with it the nutrients of the seabed.. Should include stability of water column or turbulence that is most often at the origin of this phenomenon.

Borja and al. [13] in a study on the relationship between anchovy (*Eugraulis encrasicolus*) and recruitment in the

environment of the Gascogne Gulf, precisely in the bay of Biscay, noted that oceanographic conditions caused by wind (turbulence) northeast of medium and low intensity in the Gascogne Gulf seem to induce a good level of recruitment to the population of anchovies. They also showed that this regime of wind pro-upwelling conditions generally low degree of turbulence (Figure 6). The intensity of upwelling and turbulence have submitted significantly correlated with an index of annual recruitment of anchovies. Two physical parameters explain approximately 70% of the variation of the recruitment index of the bay of Biscay.

4-2. Availability of pelagic species from the chlorophyll concentration and coastal retention

According to Feldman [14], a marine ecosystem is productive when chlorophyll concentrations are greater than 1 mg.m-3. The concentration of chlorophyll pigments presents itself as an indispensable element for the determination of areas of availability for pelagic species.

The results showed that for the relevance of this parameter (CHL), need to include coastal retention index that corresponds to the amount of heat stored between the coast and the minimum temperature point (Figure 7).

Our results are in agreement with those of Djagoua et al. [15] who have studied the color of the ocean and the seasonal and interannual chlorophyll concentration variation in the Ivorian marine environment by the SeaWiFS images. They showed indeed that, images of the concentration of chlorophyll pigments provide information on probable retention and recruitment areas of small pelagic species in the marine environment of Côte d'Ivoire. But they note that the upwelling is the main engine of the enrichment of the coast of Guinea Bissau, the region Côte d'Ivoire - Ghana and Gabon sides.

5- CONCLUSION

The results of the study shows that the recruitment of the species can be quantified from the intensity of the upwelling, but that should be included for this stability of water column or turbulence which is most often at the origin of this phenomenon. The concentration of chlorophyll pigments presents itself also as an essential element in the determination of pelagic species availability areas

Also,The results provide information about the eventual retention and recruitment areas of small pelagic species by the presence of chlorophyll concentration:

During the great cold season, the entire entire coastline presents a greater or lesser availability. Availability of pelagic species map allows to discriminate three areas depending on availability of pelagic species in Ivorian waters: species are abundant in the Centre; Eastern availability is medium and low availability report in the West of the coast.

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Table I: Coefficient of correlation and weight of the criteria over the stocks of sardines from 1998 to 2001.

Criteria	Correlation coefficient	Criteria weight
Conc.CHL	0,95	0,35
Turbulence	0,94	0,34
IUC	0,47	0,18
IRC	0,31	0,11
Total	2,67	1

Table II: Statistics of the areas occupied by the availability from 2002 to 2004

	2002	2003	2004
Availability of classes			
High (%)	11	43	52
Average (%)	35	37	34
Low (%)	54	20	14

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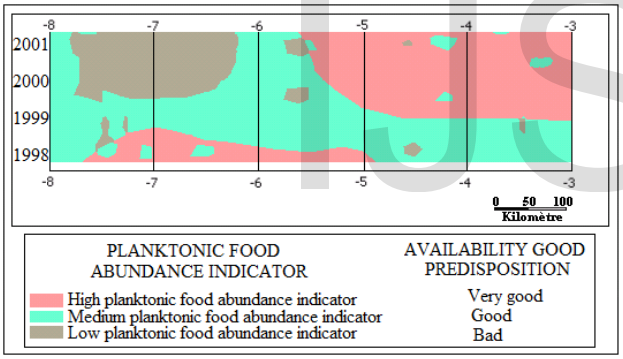


Figure 1: Spatio-temporal Variation of the indicator of abundance of planktonic food of the Ivorian seacoast from 1998 to 2001

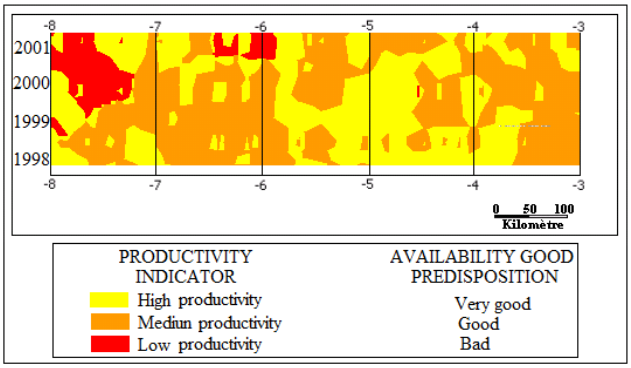
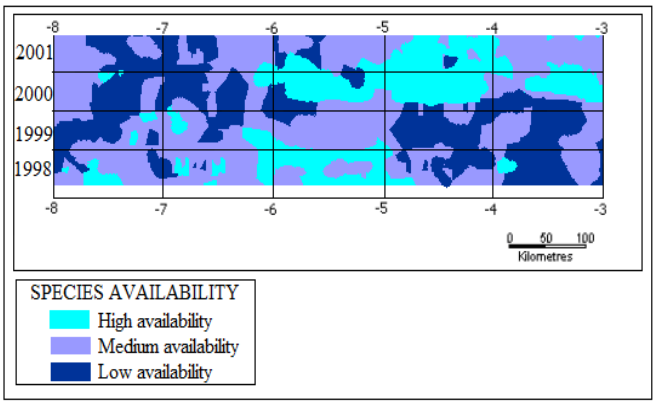


Figure 2: Spatio-temporal Variation of productivity indicator



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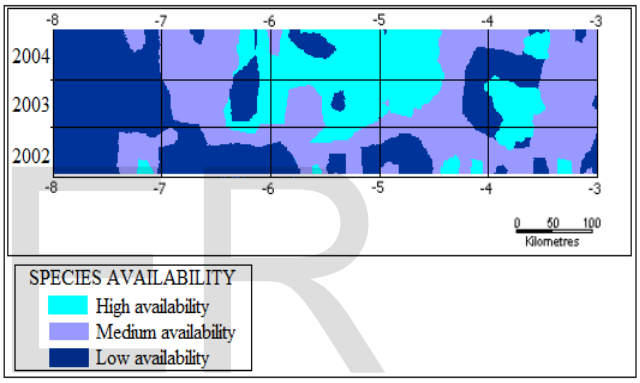

Figure 4: Map of the validated spatio-temporal variation of the availability criteria for pelagic species

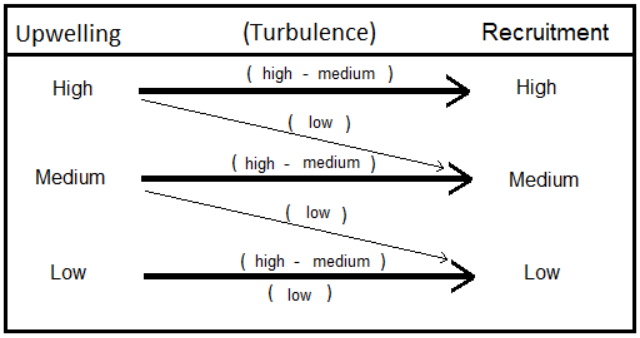

Figure 5: Relationship between the upwelling index, the water column stability and recruitment

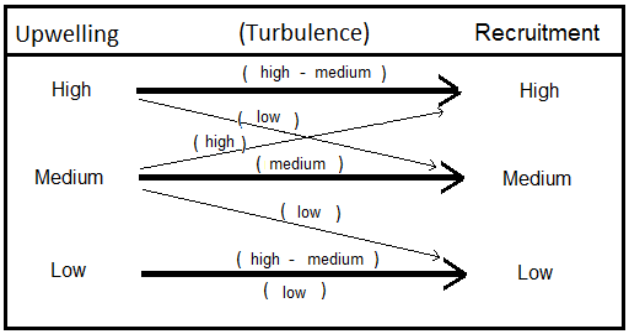

Figure 6: Relationship between the upwelling index, turbulence and the recruitment of anchovies (Borja et al., 1996)

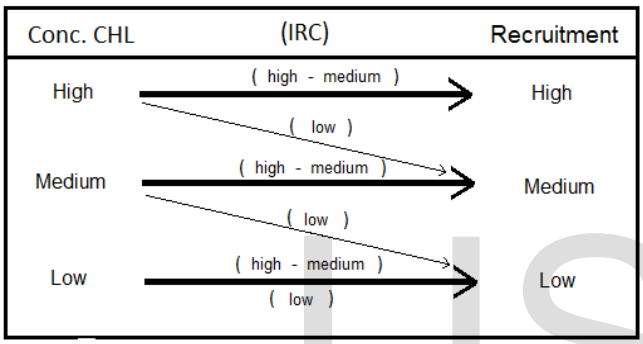

Figure 7: Relationship between Conc.CHL, IRC and recruitment