The Gulf of Guinea Large Marine Ecosystem
J.M. McGlade, P. Cury, K.A. Koranteng and N.J. Hardman-Mountford (Editors)

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Environmental Forcing and Fisheries Resources in Côte d'Ivoire and Ghana: Did Something Happen?

P.Cury and C. Roy

Abstract

The main environmental characteristics off the coasts of Côte d'Ivoire and Ghana are reviewed. Seasonal variability as well as long-term environmental changes observed during the last three decades are presented using a seasonal-trend decomposition procedure. Striking similarities are observed between changes in the Gulf of Guinea and the Pacific. This suggests that the observed changes are not the result of local processes but rather are induced by inter-oceanic teleconnection via the atmosphere. Fisheries productivity in the Gulf of Guinea appears to be quite important but is limited by the duration of the upwelling process. Thus, using comparative methods between several upwelling systems, relationships are identified between pelagic productivity and several environmental factors (wind, turbulence, and upwelling index) and only a weak relationship is observed when considering the demersal fish productivity and the upwelling intensity. Fisheries as a whole off Ghana and Côte d'Ivoire have been expanding during the last four decades: the total marine fish catch off Côte d'Ivoire and Ghana has been increasing from less than 50 thousand tonnes in the 1950s to around 400 thousand tonnes in the mid-1990s. For the pelagic species, there has been a noticeable increasing trend is observed since the 1950s and the total catch reached about 250 thousand tonnes in the 1990s. By contrast, the demersal fisheries in Côte d'Ivoire and Ghana have fluctuated between 30 and 50 thousands tonnes since the mid-1960s without any trend. Fishing effort by purse-seiners and trawlers has decreased significantly since the 1970s in Côte d'Ivoire. The abundance, estimated from cpue of both pelagic and demersal, does not appear to be related to fishing activity. Trends in several environmental time series are in phase with the observed trends in the cpue data of the demersal fisheries in Côte d'Ivoire. This suggests that in Côte d'Ivoire the abundance of the demersal fish stock is strongly related to large scale environmental changes.

Introduction

Catch statistics for the major pelagic and demersal fisheries have been collected in West-Africa and in the Gulf of Guinea since the 1960s. In Côte d'Ivoire and Ghana a large amount of information on the environment is also available (Arfi *et al.* 1991; Koranteng 1998; Roy *et al.* this volume). Until now, environmental data have been mostly used to relate pelagic fish stock dynamics to environmental variability (Mendelssohn and Cury 1987; Cury and Roy 1989, 1991; Pézennec and Bard 1992; Pézennec and Koranteng 1998; Durand *et al.* 1998) as pelagic resources tend to be highly variable. However the demersal communities which have been studied for several decades in many fisheries (almost forty years in the Gulf of Guinea) sometimes also exhibit patterns of drastic changes. A general concern in fisheries management is now to address ecological problems and fish population dynamics with an ecosystem perspective and to consider the long-term changes in the environmental or exploitation. Studies that link the different components of the trophic web or the spatial and temporal dynamics of the interaction between the environment and the resource are definitively needed as they have important implication for managing the resources. Recently, an effort to analyse the ecosystems off Ghana has been made which relates the environmental variability to demersal fisheries (Koranteng 1998). The present paper constitutes an attempt to link all the available environmental and fisheries information in order to discuss the observed global patterns in the pelagic and demersal fisheries since the 1950s off Côte d'Ivoire and Ghana.

The Côte d'Ivoire-Ghana coastal upwellings

Mean patterns

The Côte d'Ivoire and Ghana ecosystem is located between 1°E and 8°W at a low latitude (5°N). The wide continental shelf (80 km) east of Cape Three Points narrows on the western side of the Cape and is less than 20km wide off Côte d'Ivoire. The East-West orientation of the coast is a singular characteristic of this tropical upwelling ecosystem. However, the eastward flow of the Guinea current and the westward undercurrent make the structure of the surface and subsurface circulation quite similar to other upwelling areas. The depth of the thermocline is shallow, and varies seasonally between 10 to 60 meters. The seasonal amplitude of the sea surface temperature (SST) is large, SST varies between 21°C during the austral winter and more than 29°C in April (Table 18-1). The southwest monsoon wind is the dominant wind regime, wind speed is maximum (around 5 m/s) during the austral winter. On the eastern side of Cape Three points in Ghana and off Cape Palmas in Côte d'Ivoire,wind is upwelling favourable all year round. Maximum values of the upwelling index are observed during the austral winter. Due to the latitude dependency of Ekman transport, upwelling indices can reach large values in equatorial regions. Off the Côte d'Ivoire and Ghana ecosystem, the wind intensity remains below 5 m/s, but the value of the upwelling index is similar to values observed on other eastern boundary currents. Nutrient concentration is high and comparable to what is found in other upwelling areas. Perhaps, the most important feature of this ecosystem is the occurrence of two upwelling seasons: the main one from June to October and a second one of lesser amplitude in February-March.

Table 18-1 summarises the main characteristics of the Côte d'Ivoire and Ghana ecosystem; information on other upwelling areas are also given for comparison. The mechanism responsible for the occurrence of the seasonal upwellings in the Côte d'Ivoire and Ghana ecosystem remains unclear. For the summer upwelling, several processes are proposed (Picaut 1983; Roy 1995). The contribution of the wind induced Ekman transport to the summer upwelling remains unclear (Binet and Servain 1993). The Guinea current is thought to be an important contributor to the upwelling process (Ingham 1970; Bakun 1978); interactions between the coastal topography and the coastal currents may also be an important factor (Marchal and Picaut 1977). The remote forcing hypothesis is well documented and is

	LATITUDE	UPWELLING	SST (°C)	WIND SPEED (m/s)	UPW. INDEX (m3/s/m)	WIND MIXING (m3/s3)
		JAN-FEB	**27.8**	**3.7**	**1.0**	**95**
COTE			21.4 30.0	1.7 6.1	-0.3 2.6	8 359
D'IVOIRE	5°N	JUNE-OCT.	**27.8**	**3.7**	**1.3**	**95**
-GHANA			21.4 29.9	0.5 6.7	-0.5 3.6	1 335
SENEGAL	15°N	DEC.- JUNE	**25.8**	**4.8**	**1.0**	**197**
(Cap Vert)			17.9 29.2	2.6 7.8	-0.6 2.6	50 683
CAP BLANC	21°N	PERMAMENT	**19.3**	**7.2**	**1.7**	**627**
			16.9 24.9	4.0 10.7	0.5 3.9	160 1548
BAJA			**18.7**	**5.9**	**0.7**	**359**
CALIFORNIA	27°N	PERMANENT	15.1 25.4	4.1 8.7	0.1 1.5	137 1017
(Punta Eugenia)						
Trujillo			**20.4**	**4.9**	**1.2**	**188**
PERU :	8°S	PERMANENT	16.3 28.4	1.6 7.9	0.1 3.3	10 613
Callao	12°S		**19.3**	**5.5**	**1.0**	**276**
			15.0 26.7	2.6 8.3	0.2 3.2	28 789
NAMIBIA	23°S	PERMANENT	**15.9**	**6.0**	**1.1**	**432**
			12.8 20.0	1.7 12.0	0.1 4.4	19 2698

Table 18-1 The physical characteristics of several upwelling areas. For each parameter, minimum, median and maximum values are given. Source COADS data set (Roy 1995).

supported by some numerical models and data analyses but the offshore scale of the thermocline oscillations along the coast suggests that local processes should be considered (Moore *et al.* 1978). Due to the equatorial location of the area, a combination of both remote and local forcing is more likely to be at the origin of the upwelling process.

The winter upwelling has received less attention than the summer upwelling. The intensity of this secondary upwelling has its is maximum in the vicinity of Cape Palmas and sharply decreases toward the east to become almost unnoticeable in the SST time series from the Ghanaian coastal stations (Arfi *et al.* 1991). Using satellite SST images, Hardman-Mountford and McGlade (this volume) provide evidence that the extension over the continental shelf of the winter upwelling is much more pronounced off Ghana than Côte d'Ivoire. The intensification of the Guinea current in January and February is thought to contribute to the upward movement of the thermocline associated with this secondary upwelling (Morlière 1970). Local winds are also an important contributor to the winter upwelling off Côte d'Ivoire: increasing wind induced offshore transport enhances coastal upwelling. As a result coastal SST decreases (Roy 1995).

The climatic variability of the Gulf of Guinea and of the tropical Atlantic has been quite extensively studied during the last decade (Arfi *et al.* 1991; Koranteng 1998; Koranteng and Pézennec 1998; Servain 1991; Carton *et al.* 1996; Bojariu 1997). In the following sections, both the seasonal and the long term variability of the Côte d'Ivoire-Ghana upwellings are investigated using SST data extracted from the COADS database (Woodruff *et al.* 1987) using the CODE software (Mendelssohn and Roy 1996). Mean monthly time series of SST were constructed by combining the COADS data from 7°W to 2°E and from 4°N to the coast from 1963 to 1995. A seasonal-trend decomposition procedure consisting of a sequence of smoothing operations that employ locally-weighted regression or loess (STL) of the monthly time series is performed using the S-Plus statistical package (Cleveland *et al.*

1990). This procedure allows decomposition of the different environmental time series into trend, seasonal, and remainder components. It is used in the following sections to investigate the main patterns of the variability of the Côte d'Ivoire-Ghana marine environment over the last 30 years.

Change in the seasonal cycle of COADS SST time series

Figure 18-1 presents the seasonal component given by the decomposition of the SST monthly time series. The predominant pattern is an intensification of the secondary upwelling (January-February) during the last 20 years. The thermal signature of the minor upwelling is almost unnoticeable in the late sixties and becomes more and more apparent during the late seventies. The amplitude of temperature signal associated with the minor upwelling events reaches 0.8°C in the late nineties. The increase in the amplitude of the seasonal component results from an increase of the warming before and after the minor upwelling and from an accentuation of the cooling in January (Figure 18-2). The intensification of the minor upwelling was previously noticed by several authors (Pézennec and Bard 1992; Koranteng 1998). An intensification of the upwelling-favourable wind is thought to have contributed to the intensification of the secondary upwelling (Roy 1995). Changes in the strength of the Guinea current may also have contributed to the strengthening of the minor upwelling (Binet and Servain 1993).

Another pattern highlighted by the SST seasonal decomposition is a slight shift in the phase of the major upwelling. From 1975 to 1995, there is a pronounced increase of the intensity of the SST drop between June and July (1.7°C in 1975 to 2.8 in 1995, Figure 18-2). Simultaneously, the rate of warming between August and September appears to intensify; the maximum cooling resulting from the upwelling remains in August. These patterns in the seasonal component of SST indicate that the timing of the major upwelling season may have changed during the last 30 years and that upwelling now tends to start earlier than in the early 1960s.

Changes in the seasonal behaviour of a time series are difficult to address, as they require advanced statistical techniques. Minor changes in the timing or the intensity of the seasonal cycle of an environmental variable can have an important ecological impact by

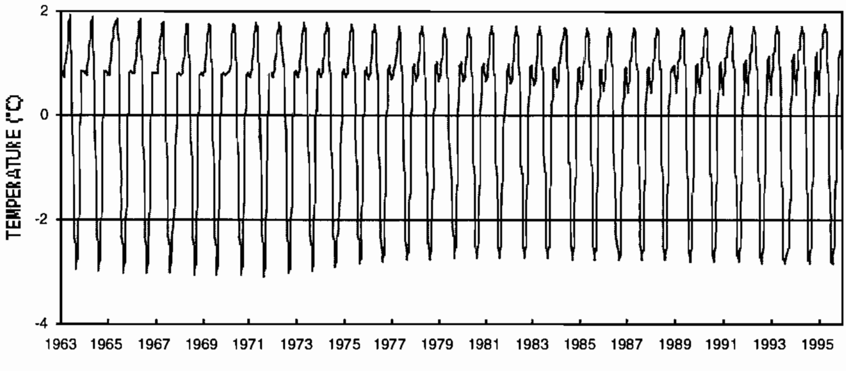

Figure 18-1 Seasonal component of the SST from 1963 to 1995 given by the STL decomposition of the monthly SST time series off Côte d'Ivoire and Ghana (source COADS data set).

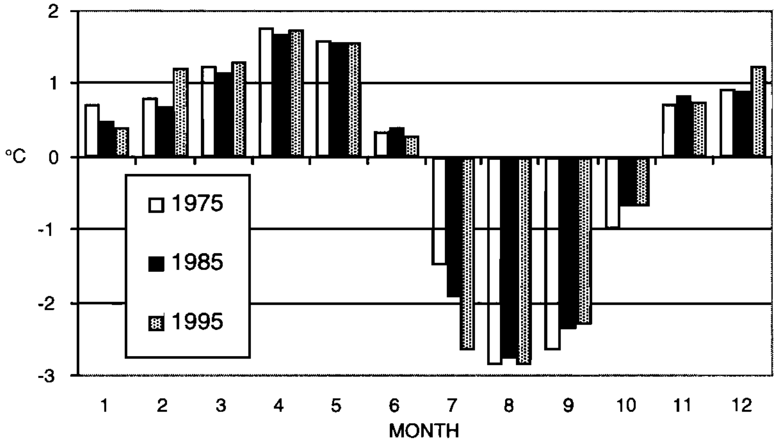

Figure 18-2 SST seasonal component in 1975, 1985 and 1995 given by the STL decomposition of the monthly SST time sereis off Côte d'Ivoire and Ghana (source COADS data set).

modifying the interactions between the physical and biological components of an ecosystem. The intensification of the minor upwelling season is thought to have favoured the increase in abundance of *S. aurita* off Côte d'Ivoire (Pézennec and Bard 1992). This intensification is almost unnoticeable on the raw monthly SST time series but its apparent consequence is, by far, the greatest change observed in the fishery pelagic catch data during the last twenty years.

Long term trend from COADS SST time series

The long-term trend of several environmental time series off Ghana was analysed in detail by Koranteng (1998). The major pattern, common to both surface and sub-surface time series of several environmental variables is a drastic change in the mid-seventies. The long term trend given by the seasonal-trend decomposition performed on the SST COADS data off Côte d'Ivoire and Ghana also shows that the seventies was a period of drastic changes within the ecosystem (Figure 18-3). A relative SST minimum is observed in 1966, then SST peaks in mid-1972 (27.4°C), and sharply decreased until mid-1977 when it reaches an absolute minimum (26.95°C). SST showed a continuous warming trend from 1978 to 1989 and then decreased slightly from 1990 to 1992. The variability of the trend component of the atmospheric pressure monthly time series extracted in the same area from the COADS data set is almost a mirror image of the variability of the SST trend component (Figure 18-4). The similarity between the trend of these two different variables gives strong confidence into the observed pattern of variability.

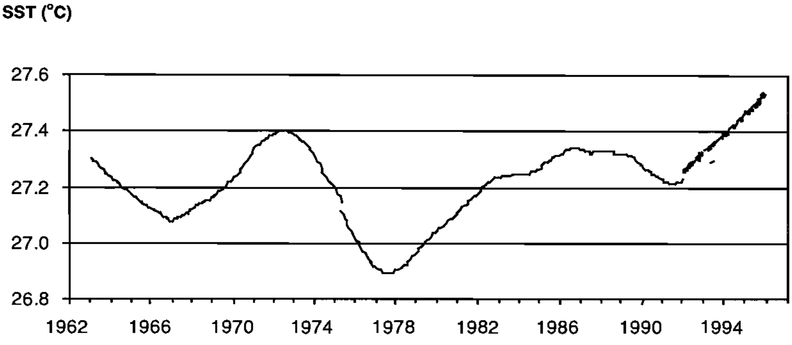

Figure 18-3 Long-term trend of SST off Côte d'Ivoire and Ghana given by the STL decomposition of the monthly SST time series (source COADS data set).

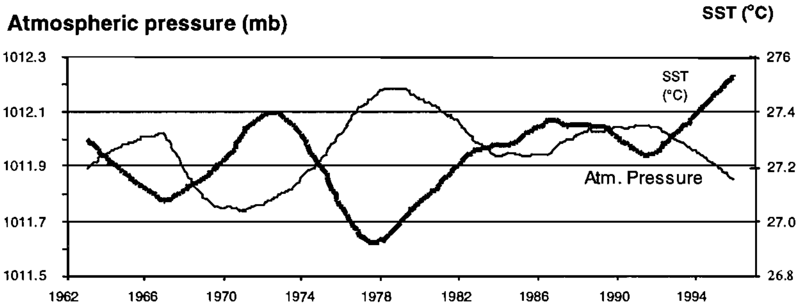

Figure 18-4 Long-term trend of SST and atmospheric pressure off Côte d'Ivoire and Ghana given by the STL decomposition of the monthly SST time series (source COADS data set).

This is also reinforced by the correspondence between the fluctuations of the SST trend and of the anomalies of Atlantic dipole (Figure 18-5). The dipole is an index of the inter-hemispheric gradient of SST anomalies in the tropical Atlantic (Servain 1991). This index is considered to reflect one of the major modes of climatic variability in the tropical Atlantic (Chang *et al.* 1997). The correspondence between the dipole and the SST trend indicates that the long-term climatic changes in the Côte d'Ivoire-Ghana ecosystem are related to basin wide fluctuations over the tropical Atlantic.

Drastic changes in the environment have also been recorded in the Pacific during the seventies (Kerr 1992; Trenberth 1990; Graham 1994). In 1972, the whole tropical Pacific was affected by an intense ENSO event. Later, a major shift in the ocean-atmosphere system occurred during the winter of 1976-1977. In the tropical Pacific, SST and westerly winds suddenly increased after the 1976-1977 winter. These changes were viewed as a shift in the background state of the climate (Graham 1994). The pattern of the climate remained altered up to 1989 when it appeared that pre-1976 climate pattern had been restored. This climate shift has had drastic biological consequences in the Pacific (Hayward 1997); it affected,

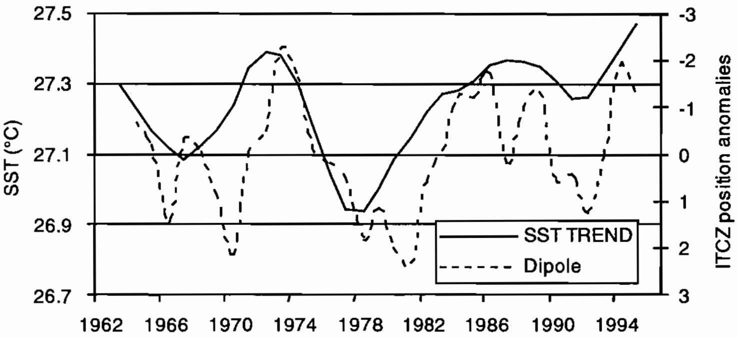

Figure 18-5 Long-term trend of SST off Côte d'Ivoire and Ghana (source COADS data set) and monthly values of the Atlantic dipole index (Servain, 1991) from 1963 to 1995.

sometimes positively and sometimes negatively, zooplankton abundance (Brodeur and Ware 1992) and the production of several commercial species (Ware and McFarlane 1989; Polovina *et al.* 1994; Beamish *et al.*1997).

There are striking similarities between the timing of the major climatic events (1972, winter 1976-1977, 1989) in the Pacific and the timing of environmental changes off Côte d'Ivoire-Ghana as indicated by the SST trend. Such a coincidence between the climatic pattern in the Pacific and the SST trend off Côte d'Ivoire-Ghana indicates that the observed environmental changes are not the results of local processes but rather are induced by inter-oceanic teleconnection through the atmosphere. When considering the interannual SST fluctuations in the tropical Atlantic, Enfield and Mayer (1996) showed that there is a link between these fluctuations and ENSO related anomalies in the Pacific. On the decadal time scale as considered here, the mechanisms involved in the inter-oceans teleconnection are not yet well understood.

Fisheries Productivity

Pelagic fish productivity

Pelagic fish productivity, calculated in different upwelling systems reveals important disparities (Table 18- 2).

Three national fisheries have annual catches of more than one million tonnes: Peru, Chile and Namibia. The Peruvian ecosystem clearly distinguishes itself with a maximum total pelagic catch productivity exceeding the others (Cury *et al.* 2000). Mean total pelagic catch productivity never reaches more than a few hundred thousand tons in Côte d'Ivoire, Senegal or in Morocco. Large ecosystems should *a priori* be able to produce more fish than small ones; however the size of the continental shelf appears to be only one among various important factors (Figure 18-6). Vast upwelling areas might yield relatively unproductive fisheries and vice versa. Thus the pelagic fish productivity in West-Africa and in the Gulf of Guinea appears relatively low compared to that of Peru or Chile (which are both located in the Humboldt Current).

Upwelling areas		Total pelagic "catch productivity index" Time period Considered	Mean (tons)	Maximum (tons)	Maximum per unit of surface (tons /km²)
1	**California**	1924-1991	200901	609979	6.0
2	**Peru**	1958-1993	5299183	12286264	142.0
3	**Chile**	1966-1993	1540109	3708071	59.3
4	**Spain-Portugal**	1937-1989	331839	368893	6.1
5	**Morocco**	1950-1991	192885	362023	3.1
6	**Senegal**	1964-1991	77234	194693	5.9
7	**Côte d'Ivoire – Ghana**	1966-1993	120414	270570	5.0
8	**Namibia**	1966-1992	507663	1561300	17.3
9	**South-Africa**	1950-1992	274312	623200	3.5
10	**Venezuela**	1957-1989	38032	80079	4.7
11	**India**	1948-1988	249382	448206	6.4

Table 18-2 Mean and maximum total pelagic fish catch fish catch observed in different upwelling areas and maximum catch per unit of surface of the continental shelf .

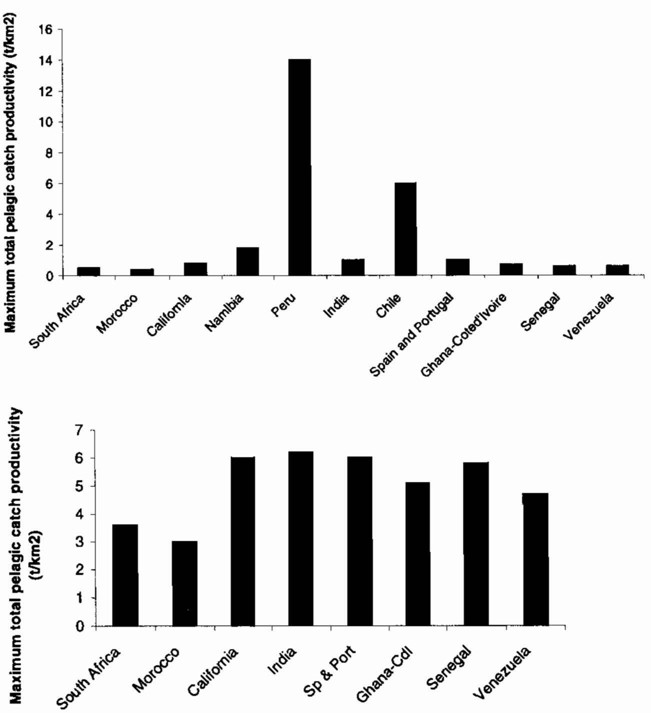

Figure 18-6 Maximum total pelagic catch productivity per unit of surface (t/km²) with and without the Chilean and Peruvian values (upper and below).

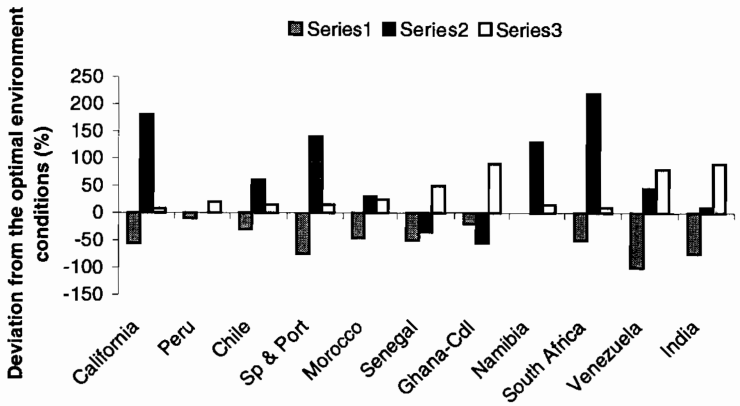

Figure 18-7 Relative deviation of the environmental values (%) from the optimal Environmental values; Series 1 CUI; Series 2 V3; Series 3 SST.

The relationship between estimates of pelagic fish productivity and environmental characteristics in upwelling systems, using non parametric regressive statistical methods, reveals that a combination of several factors are necessary to promote a high productivity:

- a high upwelling intensity (near to 1.28 $m^3/s^1/m^1$).
- a moderate turbulence (around 200-250 $m^3 3/s^3$).
- a medium sea surface temperature (15-16°C).
- a relatively extensive continental shelf (approximately 100 000 km^2).

The Peruvian ecosystem is the only one that combines all the optimal environmental conditions, which is what makes it so productive (Cury *et al.* 2000). A comparison of the environmental values of the upwelling areas with these "optimal environmental values" is presented on Figure 18-7. In Chile and Namibia, the upwelling index is favourable, however it is associated with a negative effect of a high turbulence index. The same high upwelling index is found off Côte d'Ivoire-Ghana and the area appears to be quite productive; in this area the short duration of the upwelling season certainly constitutes a limiting factor for the production. In South Africa, Spain and California, the turbulence index is high and associated with a low upwelling intensity therefore limiting the productivity.

Demersal fish productivity

Similar catch statistics and associated environmental data can be calculated for the demersal fisheries to that used for pelagics (Table 18-3). When one tries to relate them to the size of the continental shelf or the wind intensity or the turbulence or the sea temperature, no relationship can be found.

However it appears that there might be some links between the demersal productivity per unit of surface of the continental shelf and the upwelling index (Figure 18-8). One would expect such relationship to exist, as the global productivity of an ecosystem should be increasing with its global enrichment process. The demersal productivity off Ghana-Côte d'Ivoire appears to be quite high compared to other upwelling systems (with the exception of the very productive areas located in the Humboldt current). In upwelling areas the total pelagic and demersal fish productivity appears to be linked to environmental processes. However these constraints evolve through time, and seasonal as well as inter-annual fluctuations affect the overall resource dynamics.

Country	**Surface (km^2)**	**Catch (t)**	**Upwelling index**	**Wind mixing**	**SST**	**ratio**
Peru	86523	368267	1.20	225	19.1	4.256
Chile	62516	393575	0.93	346	16.5	6.296
Spain-Portugal	59864	81691	0.36	628	16.3	1.365
Morocco	118539	35487	0.66	306	19.6	0.299
Senegal	32887	68517	0.59	150	23.7	2.083
Côte d'Ivoire - Ghana	54647	67727	1.04	103	27.1	1.239
Namibia	90508	136872	1.28	517	16.8	1.512
South-Africa	178315	215818	0.65	723	16.9	1.210
India	70135	153738	0.40	240	28.1	2.192

Table 18-3 Surface of the continental shelf, maximum demersal fish catch, mean upwelling index, turbulence and sea surface and ratio (maximum demersal fish catch/ surface of the continental shelf). (environmental data from COADS and fisheries data from Fishstat95 FAO 1997).

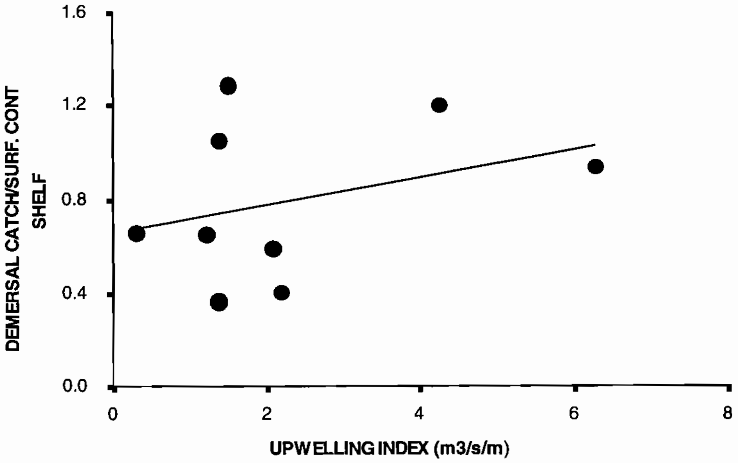

Figure 18-8 Relationship between upwelling index and demersal fish productivity per unit of surface for nine upwelling areas of the world.

Fisheries Variability

In West Africa and in the Gulf of Guinea several oceanographic institutes collect information on biology, fisheries and the environment, in order to support fisheries management. The FAO database (accessible through Fishstat95, FAO1997) also provides an interesting source of information as the fish catch statistics are summarised per year and available since the 1950s, even though the reliability may be sometimes doubtful before the 1970s. However the demersal fish catch from CROA (Centre de Recherches Océanographiques d'Abidjan) and from the FAO data-base appear to be in good agreement.

The global fisheries off Ghana and Côte d'Ivoire have been expanding during the last four decades: the total marine fish catch off Côte d'Ivoire and Ghana has been increasing from less than fifty thousand tonnes in the fifties to around four hundred thousand tonnes in the mid-nineties (Figure 18-9). Ghanaian catches represent 73% of the total catch, and are responsible for the observed trend as the Ivoirian catches have been stable since the 1960s.

For the pelagic species, a noticeable increasing trend has been observed since the 1950s; the total catch reached around 250 thousand tonnes in the 1990s (Figure 18-10). In contrast the demersal fisheries, in Côte d'Ivoire and Ghana have fluctuated between 30 and 50 thousand tonnes since the mid-1960s without any apparent trend.

The fishing effort of both the seiners and the trawlers has consistently decreased since the end of the 1960s in Côte d'Ivoire (Figure 18-11). The diagram of the cpue (catch per unit of effort) of the demersal species versus the fishing effort of the trawlers does not show any relationship which suggests that the link between the fishing activity and the abundance of the resource is not so strong, at least off Côte d'Ivoire.

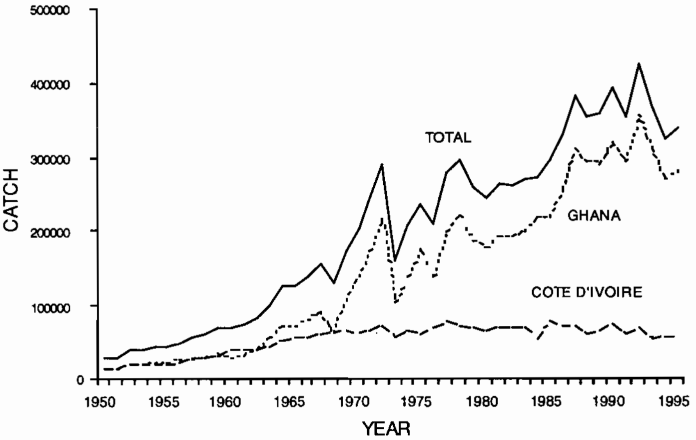

Figure 18-9 Total pelagic fish catch in Ghana and Côte d'Ivoire between 1950 et 1995 (source Fishstat95, FAO 1997).

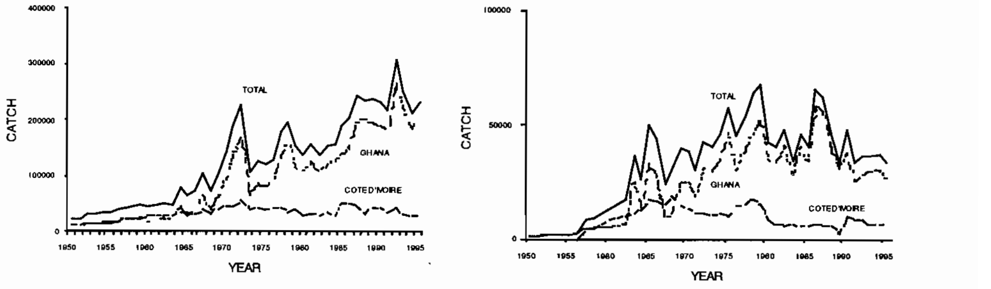

Figure 18-10 Total pelagic (left) and demersal (right) fish catch in Ghana and Côte d'Ivoire between 1950 et 1995 (source Fishstat95, FAO 1997).

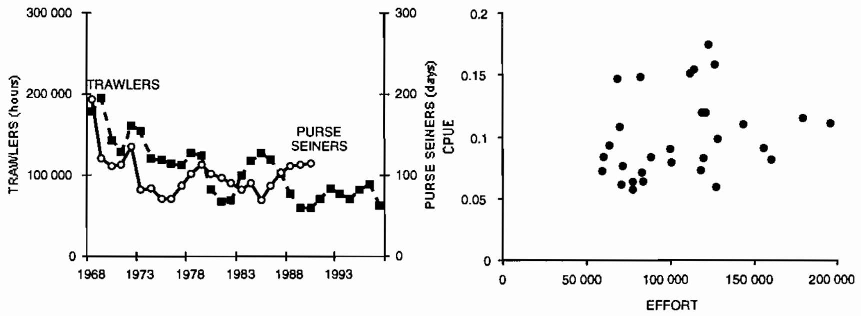

Figure 18-11 Fishing effort (time at sea in hours) between 1968 and 1997 for the trawlers and the purse seiners (source CROA) (left). Catch per unit of effort versus fishing effort for the demersal fishery off Côte d'Ivoire (right).

Ecosystem effects

It may be important to consider interactions between fish stocks, as drastic fluctuations have occurred in both the Ghanaian and Ivoirian ecosystems. *Scomber japonicus* exhibits a similar spatial and temporal pattern as *Sardinella aurita*: they are both found in upwelled waters during the minor and the major upwellings periods. *Scomber japonicus* are also caught seasonally in the purse seine fisheries and migrate into deeper waters during the warm season to join the deeper fauna at 200-300m depth (Longhurst and Pauly 1987), *Scomber japonicus* feed on juveniles as well as larvae of sardinella (Anon. 1976). After the collapse of the *Sardinella aurita* stock in 1973 it appears that two years later the *Scomber* stock collapsed. Despite the recovery of the sardinella in 1976, scomber reappeared only ten years later (Figure 18-12). It suggests that the abundance of prey, which is regulated by the environment, regulates the abundance of the predator. In this case, the *Scomber japonicus* may have collapsed due to the low abundance of sardinella and had, late on, difficulties in recovering from this depleted state.

The ratio of the pelagic predators (such as *Trachurus* sp., *Trichiurus* sp., *Scomber* sp., etc.) to small pelagic prey has decreased substantially since the late sixties, suggesting increasing catch of the small pelagics, which are at lower trophic levels. But this appears to be quite natural as the total small prey pelagic appeared to have increased in biomass over the last two decades.

The total demersal catch appears to have increased consistently, but smoothly through time with a plateau since the 1970s. The appearance of the trigger fish (*Balistes capriscus*) at the beginning of the 1970s and its disappearance at the beginning of the 1990s apparently did not seem to have a

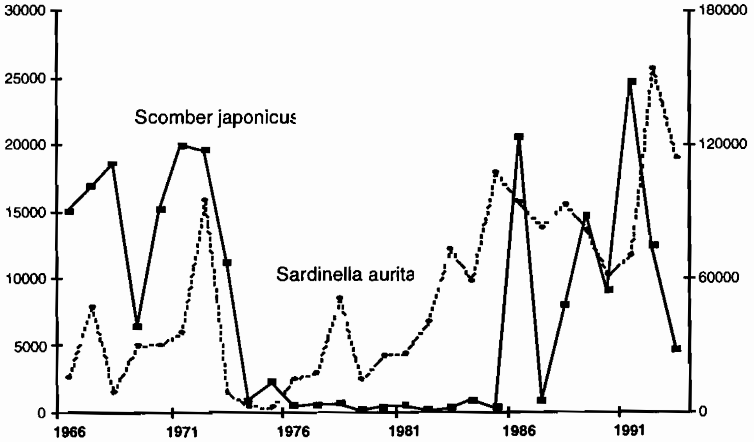

Figure 18-12 Catch of *Scomber japonicus* and *Sardinella aurita* in Côte d'Ivoire and Ghana from 1966 to 1994.

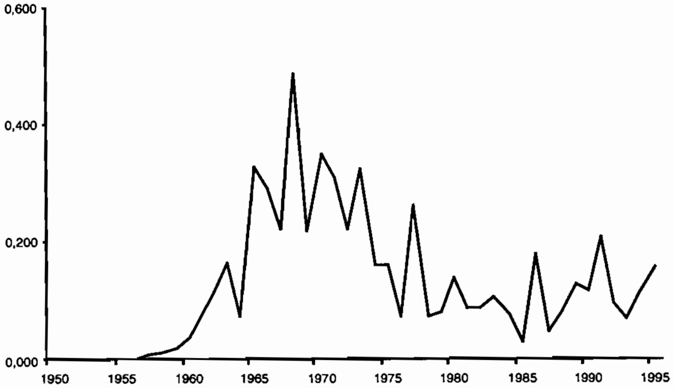

Figure 18-13 Ratio of the catch of pelagic predator (*Trachurus*, *Trichiurus*, *Scomber*, etc) on pelagic prey (sardinellas, anchovies, etc.) from 1960 to 1995.

major impact to the total demersal catch (Figure 18-14), even though it had some major effects on some demersal fish communities (Koranteng 1998, this volume)

Sardinella aurita alternates between periods spent as demersal schools at or near the edge of the continental shelf in the sub-thermocline, and as surface shoals closer to the coast during upwelling seasons (Longhurst and Pauly 1987). It may be worth noticing that the demersal fish abundance was high when the catch of *Sardinella aurita* was low (Figure 18-15). This may suggest a relationship between the two communities, or an environmental factor that favoured one and not the other.

In the ecosystem, strong patterns of fish variability have emerged in the last three decades and appear to be connected in some way, through interactions between species or communities or through environmental forcing.

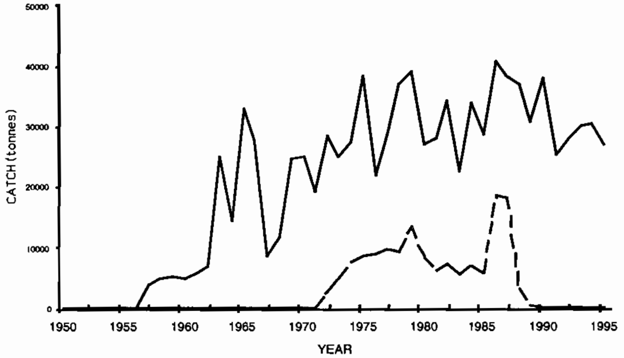

Figure 18-14 Total demersal catch of Ghana (without the trigger fish) and catch of the trigger fish (dashed line) from 1950 to 1995 (source Fishstat95, FAO 1997).

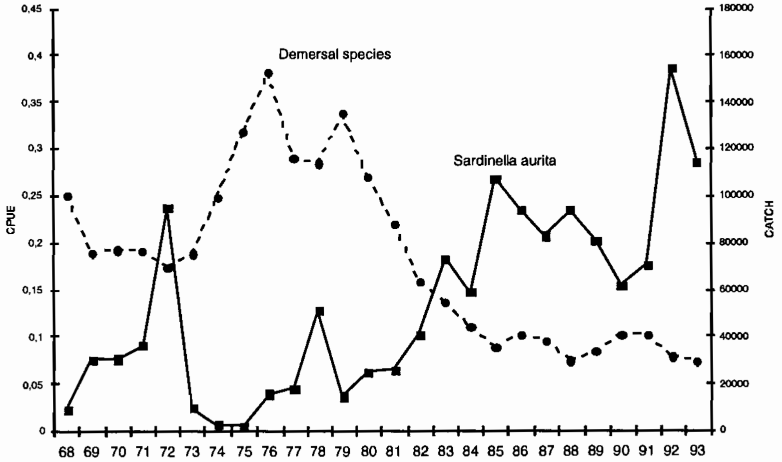

Figure 18-15 Catch of *Sardinella aurita* and CPUE (catch per time at sea) of the demersal species from 1968 to 1993 off Côte d'Ivoire.

Long-term variability and demersal fish productivity

Multi-annual changes were observed in the catch per unit of effort in Côte d'Ivoire for the demersal species. At the beginning of the 1970s a sharp increase was observed that lasted for about ten years, after which the cpue returned to a relatively low level (Figure 18-16). These changes had major effects on the results of the fisheries. In fact, the abundance did increase for many species during the 1970s (for example the sparids, *Pseudotolithus spp.*, rays...). It is also notable that the trigger fish appeared at the beginning of the 1970s (even though it was not fished by the Ivoirian fleet).

When the trends observed in the cpue and the SST (inverse plot) times series are plotted simultaneously, it appears that the two series are fluctuating in phase (a high cpue is observed for a low temperature and conversely) (Figure 18-17). This synchrony between the total demersal production and the SST trend time series suggests that the drop in temperature during the 1970s may have favoured the demersal fish communities. These environmental changes particularly affect the first six months of the year, which are not within the most productive major upwelling season. However they may act as an environmental forcing function for the resources. An enhancement of the productivity during the less favourable season certainly has a drastic effect on the whole sustainable production of fish. This "bottle neck" hypothesis was formulated for the pelagics by Pézennec and Bard (1992) and could perhaps hold also for the demersal community.

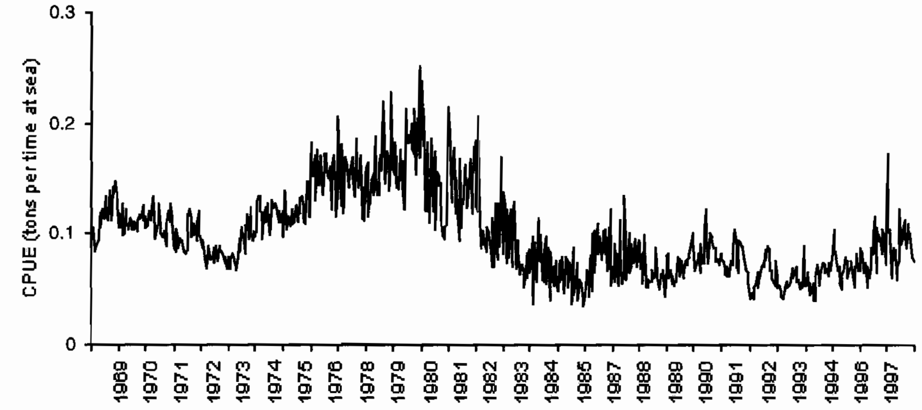

Figure 18-16 Catch per unit of effort for the demersal species off Côte d'Ivoire per fortnight from 1968 to 1995 (source CROA).

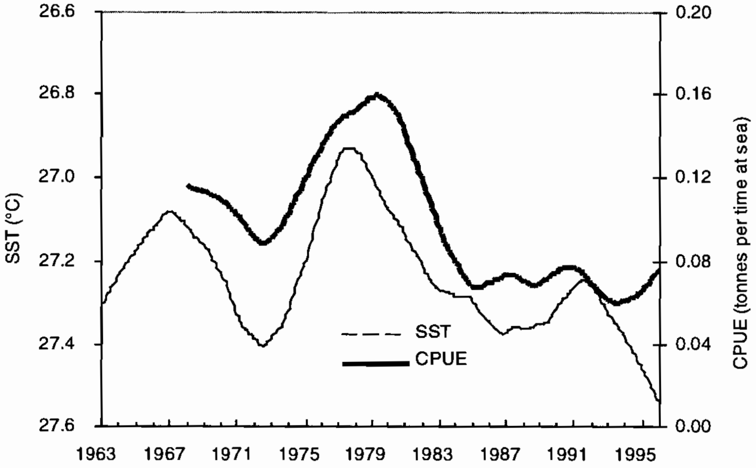

Figure 18-17 Trends in total CPUE of the demersal species (source CROA) and SST (inverse plot) off Côte d'Ivoire from 1964 to 1995 (COADS) calculated using STL.

Discussion: Environmental forcing and resources dynamics

In the Gulf of Guinea drastic changes in the demersal fish community have been observed during the last four decades. The abundance of *Sardinella aurita*, both in Ghana and Côte d'Ivoire, dramatically increased during the last two decades; the biomass of the trigger fish experienced an incredible expansion for eighteen years and, then disappeared; the abundance of the demersal fish community was higher during the 1970s and decreased at the beginning of the 1980s. All these changes were reflected in the demersal and in the pelagic fisheries; they may not be related to fishing effort, although the analyses of Koranteng (1998) and Koranteng and McGlade (this volume) suggest otherwise. The major environmental changes are mostly observed during the first semester of the year (and apparently disconnected from the major upwelling season). These environmental changes appear not to be the result of local processes but rather are induced by inter-oceanic teleconnection through the atmosphere as they are observed in different and independent environmental time series both in the Atlantic and the Pacific oceans. Relationships between the environment and pelagic fish populations have been documented in the Gulf of Guinea (Cury and Roy 1991; Binet and Marchal 1993; Koranteng 1998); however the impact on demersal communities has not been reported. It appears that the low frequency environmental signal is in phase with the demersal fish production. It is reasonable to think that these changes had a major impact in the Gulf of Guinea and consequently affect the total productivity of the ecosystem. According to these changes, cooler temperatures (stronger upwelling) during the 1970s would have increased the productivity in the area, particularly in the Gulf of Guinea which is quite stable from one year to another particularly during the first semester. Moreover, and as mentioned by Pézennec and Bard (1992) this time period constitutes an environmental bottleneck for fish production; consequently any particular favourable environmental events will have a major impact on fish production. Something did happen during the last thirty years in the environment of the Gulf of Guinea and had apparently major consequences on both pelagic and demersal fish abundance. Some drastic changes have sometimes been reported in several ecosystems and related to environmental changes (Arfi 1985; Beamish and Bouillon 1995; Rijnsdorp 1996), mostly in the North Pacific (Beamish 1995). Hallowed *et al.* (1987) examined recruitment variability in 59 stocks in the north-east Pacific, and found strong patterns at all time scales; they concluded that these long-term patterns were due to low frequency climate variability. Whether cyclic temperatures cause cyclic fisheries is a major issue when exploring low frequency environmental changes and their effects (Muter *et al.* 1995).

Relationships between environmental changes and demersal fisheries are not frequently observed. There might have several reasons for that, such as the number of age-classes within the populations which buffer any fluctuation, or the fact that most of the time, these resources are intensively or over-exploited and consequently the observed variability in fish population is mainly driven by the fishing effort. As suggested by Steele (1995), decadal changes in the physical environment are likely to have impacts on marine communities rather than on individual fish stocks. As a whole the dynamics of the demersal fisheries off Côte d'Ivoire may serve as a case studies as its resources were not intensively exploited during the last thirty years and located in an area subject to remote environmental effects. As stated by Longhurst and Pauly (1987) " The Gulf of Guinea upwelling serves as an excellent demonstration of what is frequently forgotten or ignored: that processes important for understanding coastal fishery dynamics may be driven by events a whole ocean away".

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