The Gulf of Guinea Large Marine Ecosystem
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Environmental Variability at a Coastal Station near Abidjan: Oceanic and Continental Influences

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Abstract

Hydrobiological conditions (light penetration, temperature, salinity, chlorophyll biomass at six depths and bacterioplankton abundance at the surface) were measured weekly for six years (1992-1997) at a station located in a coastal area of the Gulf of Guinea (Abidjan, Côte d'Ivoire). Nutrient concentrations completed the data set from December 1994. This coastal area is strongly influenced by a major upwelling (July-September) and by a minor upwelling (short cold events during January-February). Continental inputs induced by local rainfalls (May-June and October) and river floods (September-November) have also pronounced hydrological effects. SST varied from 20.6°C (August) to 30.7°C (May), while surface salinity showed an obvious annual cycle with a minimum of 30.12 psu in June and a maximum of 35.87 psu in September. Bacterial abundance and phytoplankton biomass show seasonal cycles, with simultaneous peaks noted during the main upwelling (maximum: 1.9 10^6 cell ml^{-1} and 5.6 $\mu g\ l^{-1}$ respectively). Interannual fluctuations of upwelling intensity and of continental inputs explain the hydrological variability. Freshwater inputs are associated with oligotrophy, while upwellings contribute to the enrichment of the euphotic layer. As a consequence of the drought in the Sahel and of the decreasing rainfall on the coastal area, freshwater inputs are now considerably reduced, and the related impoverishment is less pronounced. At the opposite, the increasing duration of upwellings (and the importance of the short cold events) allows a higher primary productivity (and therefore a more active bacterial compartment). Combined, these two factors would explain the marked outburst of small pelagic fishes in this part of the Gulf of Guinea.

Introduction

Neritic ecosystems show high variability because they are influenced by major hydrological and biological fluctuations occurring on various time scales. Major upwellings or short cold events (SCE) induced by transient inputs of deep water within the euphotic layer increase seasonally the productivity of a coastal zone for months or days. Inputs of continental origin (large river floods or local rain) modify the coastal environment through salinity variation, organic enrichment and light attenuation. Such conditions are observed along the Gulf of Guinea, which is alternately under the influence of upwellings and continental inputs (Roy 1995). The forcing functions of these coastal upwellings (i.e. equatorial Kelvin waves, with local current and wind enforcement) are still under discussion. During the FOCAL/SEQUAL experiment, Colin and Garzoli (1988) reported high frequency variability for temperature and currents in the eastern equatorial Atlantic. From data recorded between 1964 and 1990, Binet and Servain (1993) have shown the interannual variation of SST and the progressive warming of the surface layer near Abidjan (0.07°C y^{-1}). They also reported a change in the apparent westerly wind stress in the Northern Gulf of Guinea, with increasing speeds and slight change in direction. However, Roy (1995) showed that the intensification of the wind is weaker than previously thought and is observed during the minor upwelling. Continental influence is linked to the freshwater inputs from numerous small rivers in the forest zone and large rivers in the Sahel zone. In the last decade, continental flows have sharply decreased, and even the humid forest area along the Gulf of Guinea shoreline can, in some years, be regarded as semi-arid (Mahé 1991; Servat *et al* 1996).

Oceanic water circulation in the northern Gulf of Guinea is dominated by the Guinea Current (GC), an eastward surface flow with high speeds usually observed from April to July (Colin 1988). This current overlays the Guinea Under Current (GUC) flowing westward. When the GC speed is low, the GUC becomes predominant and reversals of surface circulation are common. These currents show large fluctuations in speed and direction, both on a temporal and a spatial scale, but little data on a long term-scale are available. Binet and Servain (1993) explained that the change in the current system observed since 1980 is compatible with other major events, such as the Atlantic Niño (Philander 1986) or the circulation anomaly noted along the Namibian coast (Shannon *et al* 1986).

Along the Côte d'Ivoire continental shelf, environmental patterns were investigated using data collected from 1966 to 1984 (Morlière and Rebert 1972; Hisard 1973; Colin 1988). Characteristics of coastal upwelling and their interannual variability are well documented (Morlière 1970; Voituriez 1981; Colin 1988; Arfi *et al* 1993; Colin *et al* 1993; Pézennec 1994). Along the Côte d'Ivoire shoreline, this seasonal enrichment supports pelagic and demersal fisheries, both very sensitive to environmental change (Binet *et al* 1991; Pézennec and Bard 1992; Binet 1993). Continental influence is linked to four major rivers. Cavally, Sassandra and Bandama Rivers flow directly into the Gulf of Guinea, while the Comoé River flows seaward through the Ebrié Lagoon and the Vridi Canal. These large river inputs are high during the flood season, from October to December. Rainfalls in the coastal forest area induce local river floods during the rainy seasons, from April to June and from October to November (Binet 1983; Mensah 1991).

Several studies have been conducted on relating the effects of upwellings on the structure of the marine ecosystem, particularly on bacterioplankton and phytoplankton (Hanson *et al.* 1986; Fiala and Delille 1992; Painting *et al.* 1993; Wiebinga *et al.* 1997). In the coastal area of the Gulf of Guinea, no recent information is available on plankton productivity. Along the Côte d'Ivoire, coastline, phytoplankton (Dandonneau 1973; Binet 1993; Sevrin-Reyssac 1993) and zooplankton (Leborgne and Binet 1979) data were collected during the 1965-1979 period. Therefore, very little is known on the recent planktonic productivity and on the relationships existing between planktonic communities, and especially, how bacteria biomass responds seasonally to the changes in phytoplankton abundance.

A sea sampling programme was initiated in the mid-sixties in the Abidjan coastal zone. But the station location has changed several times, although globally, the same area was studied. Since 1982, a weekly hydrological sampling (temperature, salinity and Secchi disk measurements) has been maintained at the same site (Bakayoko 1990; Cissoko *et al.* 1995, 1996).

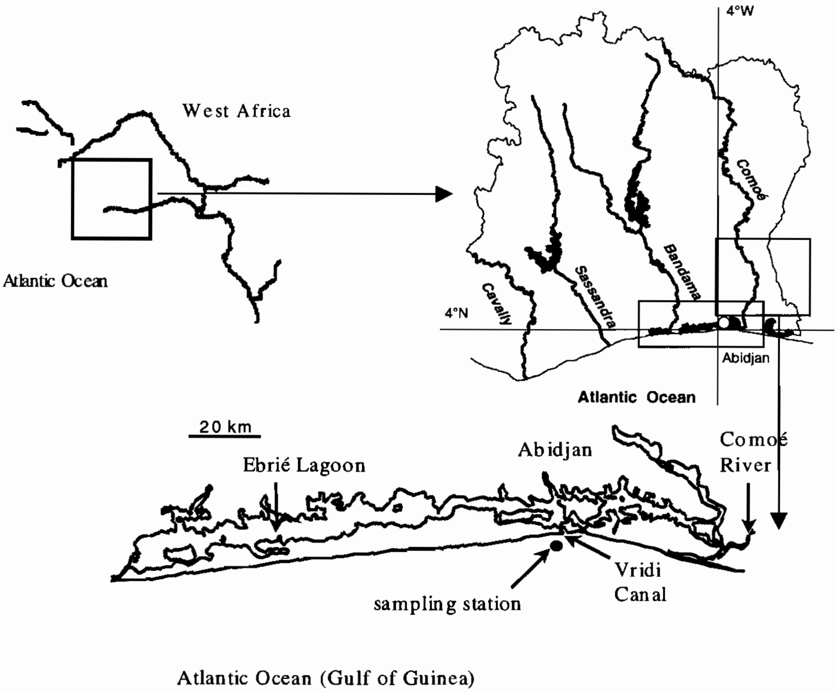

Figure 9-1 Location of the sampling station in the Gulf of Guinea.

This station is located four miles southwest of the Canal de Vridi (5°11N 4°04W, 80m depth, Figure 9-1). From May 1992, bacterial and phytoplanktonic biomasses were added to the parameters studied, while nutrients (PO_4-P, NH_4-N, NO_2-N and NO_3-N) completed the data set from December 1994. Local rainfall and monthly discharges of the main rivers were also collected, when available.

The aims of the study were to describe the seasonal and interannual fluctuations of physical parameters in relation to major continental (rain, river floods) and oceanographic events (upwellings) in the northern Gulf of Guinea during the 1992-1997 period and to compare these data to older information; and to assess the respective importance of these hydrological factors on the pelagic system (bacteria and phytoplankton) in that coastal station.

Materials and Methods

Rainfall was recorded daily at a meteorological station located 17 km west of Abidjan. River discharges (monthly average flow at the last gauge station before the estuaries) were obtained from the Côte d'Ivoire Water Authority.

Due to the many processes contributing to the phenomenon, upwelling indices could not be derived from wind and Ekman transport relation (Picaut 1983). Because upwelling results in a drop of SST, a fortnightly index based on the daily deviation from 26°C of surface shore temperatures was calculated (Arfi *et al* 1991, 1993; Pézennec 1994).

Seawater was collected using Niskin bottles at different depths (-1, -10, -20, -30, -50 and -75 m). Temperature was recorded using reversing thermometers and salinity was determined with a salinometer. Water transparency was measured with a 30-cm diameter Secchi disk. From repeated measurements using a LiCor underwater quantum sensor, a relation between Secchi disk values (Z_s in m) and light attenuation coefficient (k in m^{-1}) was calculated:

$$\ln(k) = -0.64*\ln(Z_s) - 0.27 \ (r^2 = 0.77, n = 41) \qquad \textbf{Eq. 9-1}$$

Thickness of the euphotic layer (Z_{eu} in m) was estimated from the 1% light level ($Z_{eu} = 4.605/k$). Nutrient concentrations of GF/F filtered water were analyzed according to the methods proposed by Aminot and Chaussepied (1983): ammonia was measured with a spectrophotometer, while soluble reactive phosphate (SRP), nitrite and nitrate concentrations were measured using an AutoAnalyzer. Bacterial abundance at -1m was estimated from direct counts by the epifluorescence method after staining cells by DAPI (Porter and Feig 1980). Chlorophyll *a*, considered as an index of phytoplankton biomass, was analyzed fluorometrically (Yentsch and Menzel 1963). Each profile of nutrients and chlorophyll biomass was integrated over the euphotic layer and expressed in mg m^{-2}.

It was not possible to retrieve the original oceanographic data collected in the sixties and the seventies. Therefore, figures illustrating temperature and salinity at -10 m and Secchi disk values recorded at the coastal station (fortnight average for the 1966-1971 period) were digitized from Morlière and Rebert (1972). The same process was used for the chlorophyll fortnight average values corresponding to the 1966-1969 period (Sevrin-Reyssac 1993).

Results and Discussion

Freshwater Inputs

Rainfall shows an obvious annual cycle (Figure 9-2a), with high values recorded during the main (May and June, 300 to 500 mm) and the secondary (October and November, around 200 mm) rainy seasons. Low values (less than 50 mm) are usually observed in August and in January-February. In this coastal area, rainfall shows a decreasing trend, embedded within large interannual variations. Drought characterises the end of the 1955-1997 period (Figure 9-3), even though high precipitation rates were still recorded in the later years (1987, 1993 and 1996). Annual values calculated for the 1988-1997 period (average 1551 mm) are lower than those calculated for the 1955-1965 (2278 mm), 1966-1976 (1844 mm) and the 1977-1987 (1633 mm) periods. When the two extreme periods are compared, the main rainy season of the recent sequence shows a marked rainfall decrease, while an increase is observed

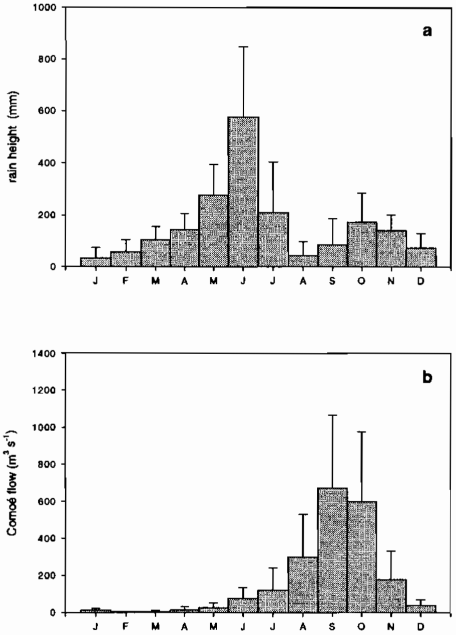

Figure 9-2 a Monthly rainfalls averaged over the 1948-1997 period and **b** Comoé flow averaged over the 1955-1995 period.

during the secondary rainy season. On several years during the 1990s, the main and the secondary rainy seasons showed comparable rainfalls.

The Comoé River, close to the station, exhibits a period of low water from January to May and a flood period in September-October (Figure 9-2b). These waters arrive in the ocean after a gap close to one month corresponding to the transit in the Ebrié lagoon (Durand and Guiral 1994). The same seasonal alternation of low flow and flood periods characterizes other large rivers along the Gulf of Guinea (see Mensah, 1991 for the Ghana shoreline).

River discharges show marked interannual fluctuations. The recent drought in the Sahel, and dam construction in the 1970s for the Sassandra and Bandama Rivers explain the sharp decline of freshwater inputs reaching the Côte d'Ivoire coastal area during the last two decades (Table 9-1). For the Comoé River (not dammed), the annual flow (Figure 9-3) is much lower during the 1977-1987 and the 1988-1995 periods (respective averages: 120 and 128 $m^3 s^{-1}$) than during the 1955-1965 period (224 $m^3 s^{-1}$) or the 1966-1976 period (197$m^3 s^{-1}$). The main difference between these sequences is due to the flood flow decrease, but low waters recorded recently are nearly half those recorded 25 years ago. The annual average

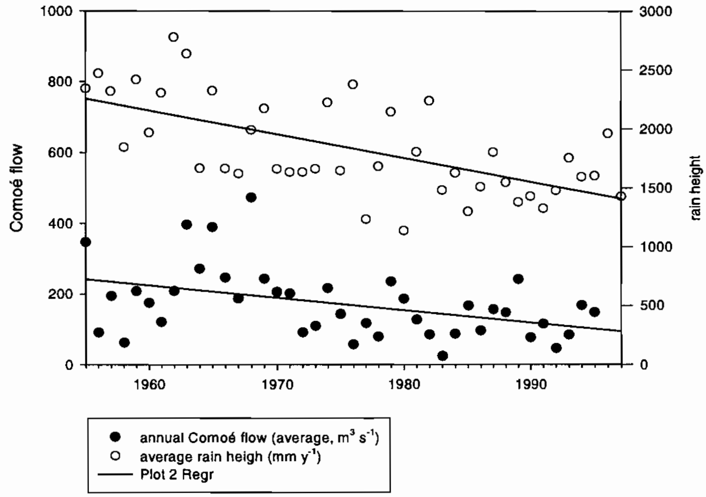

Figure 9-3 Annual rainfalls near Abidjan and Comoé flow for the 1955-1997 period.

Period	Cavally	Sassandra	Bandama	Comoé
1958-1969	Nd	Nd	Nd	248
1966-1969	689	663	372	287
1970-1981	456	390	165	147
1982-1993	462	364	154	110
1992-1995	Na	Na	Na	110

Table 9-1 Interannual variability of freshwater flow (yearly average, m^3s^{-1}) from main Cote d'Ivoire rivers reaching the Gulf of Guinea. (Nd: no data; Na: data recorded, but not available)

flow of the 1992-1995 period (3.5 10^9 m^3 y^{-1}) represents only 38% of the 1966-1969 value (9.1 10^9 m^3 y^{-1}). All these changes (decreasing of the freshwater and solid load inputs) have probably limited the continental influence on the neritic area.

Interannual change in upwelling intensity

The coastal upwellings occurring along the Côte d'Ivoire shore are under the influence of several physical, topographical and climatological factors (details in Arfi *et al.*, 1993). They show high interannual variability, and in recent years, the western part of the shoreline was characterized by events that were cooler and of longer duration than in the eastern part (Pézennec and Bard 1992; Pézennec 1994). Until the mid-80s, upwelling intensity was low from Assinie to Fresco and high west of Sassandra (6°W). From 1986, high intensity was also observed along the shoreline east of Fresco. In the last two years, a more classical pattern took over again, with very weak intensity at the extreme east of the coast (Assinie).

Seawater Characteristics

- Temperature and salinity

An obvious annual cycle characterises the upper 30 m of the water column, with low temperature during the main upwelling (from July to September) and high values from November to June (except a few weeks of possible cooling in January-February during a SCE). Fortnightly averaged Sea Surface Temperature (SST) ranged from 21.17°C to 30.50°C, while at -50 m, values were always under 26°C. Sea surface salinity shows also a seasonal cycle with two periods of high values alternating with two periods of low values. T-S plots at the various levels (fortnightly averaged data) show several features:

i. the deepest level (-75 m) features very low variability;
ii. continental influence is clearly perceptible at a depth of 30m but not perceptible below 50m;
iii. deep waters reach seasonally the intermediate levels, and its influence is still perceptible at 20m during the major cold event (temperature < 21°C from mid-July to end-September). At 10 m, deep water is present between mid-August and mid-September. Near the surface, cooling is induced by mixing of deep water and of superficial water;
iv. the short cold events are not perceptible in the average cycle. It can be very marked (1994, 1997), but its intensity can be very weak in this part of the shoreline. In the continental shelf of Ghana, Mensah (1991) reported a thermocline, which fluctuates between 10 and 40 m depth.

In the surface layer, three steps can be distinguished in the annual T-S cycle (Figure 9-4):

Step 1 : After the flood period, there is a progressive salinity increase induced by mixing with the underlying water during the SCE and by the reduction of continental outputs (low water for the major rivers, local dry season). From January to May, a "coastal" situation can be defined.

Step 2 : From mid-May to June, warm and desalinated waters are observed throughout the West African coastal area (intrusion of "Guinean waters" (GW), a combination of oceanic water and freshwater originated from the coastal area and carried by the GC). From October to December, the main river floods reach the Gulf of Guinea, inducing a warming and a sharp salinity decrease: the hydrological situation is comparable to the GW sequence, but the salinity decrease is less pronounced.

Step 3 : The local rainy season ends when subsurface temperature decreases sharply (July to September). The thermocline reaches the surface, salinity increases rapidly and temperature decreases due to upwelling. This is the main cold period.

- Water transparency

In this coastal area, light attenuation is linked to three components:

i. non-living seston of continental origin (detritus and particles of various size and shape): the river plumes are flattened eastward along the coast, but small particles can be

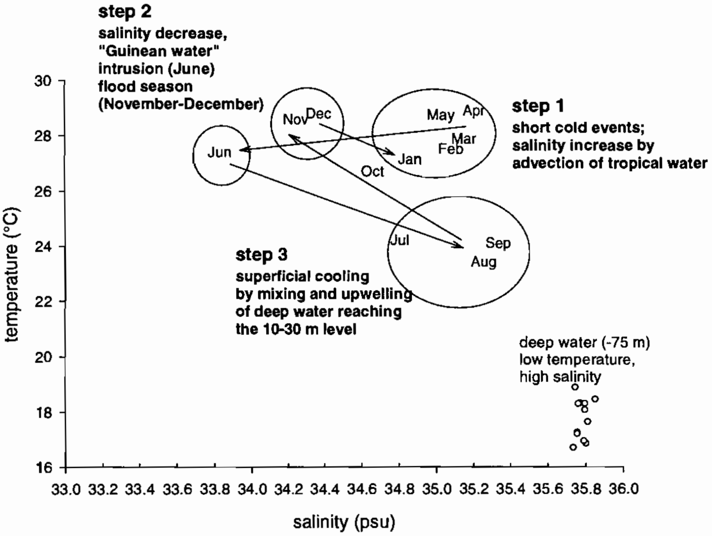

Figure 9-4 Annual T-S cycle in the surface layer.

mobilized by the currents while sedimenting-out, and can thus contribute to the local turbidity.

ii. living seston, essentially phytoplankton and bacterioplankton: this material is abundant just after the enrichment events in the neritic area.

iii. dissolved matter: lagoon and river waters have high concentrations of humic acids, conferring a yellow-brown color. Their effects, rapidly decreasing with the distance from the estuary, would be the most effective during the flood events.

Light attenuation is high from June to October (Secchi disk values: 4-15 m, average 9.3 m) and low from November to May (Secchi disk values: 10-29 m, average 17.6 m). The euphotic layer is 20-25 m thick during the high turbidity period, 35-40 m thick during the low turbidity period (Figure 9-5). Water transparency sharply decreases in June, when the GW invade the coastal area. From July to September, turbidity remains high (slow evacuation of continental particles from the superficial layer, then local phytoplankton production). Transparency slowly increases at the end of the upwelling event, reflecting the limited influence of flood water in the area.

Turbidity has markedly decreased between the 1966-1971 (interannual average Secchi disk value: 10.2 m, euphotic layer: 26.7 m) and the 1992-1997 periods (respective values: 13.9 m and 35.5 m). Turbidity is mainly related to the local rainy season: the decreasing rainfall in the last two decades have reduced the continental influence on the coastal water, so that the consequences of the GW intrusion are now less effective.

- Nutrients

SRP enrichment of the euphotic layer is obvious from mid-June to mid-October when the 0.6 μM contour line reaches the surface. Transient incursion of phosphate-rich water above the – 30 m level is observed from mid-December to mid-January. Working on fortnightly averaged data allows representation of time-depth variations in nutrients over an average year. The study of the whole time series versus the water density permits a discrimination of three homogeneous sequences: continental influence (σ_t at – 50 m < 25.25), coastal conditions (25.26 < σ_t at – 50 m < 25.80) and upwelling influence (σ_t at – 50 m > 25.81). Non parametric ANOVA on grouped data (Table 9-2) illustrates the trophic situation in the water column:

i. values > 1 μM below 50 m;
ii. values < 0.5 μM at the superficial level;
iii. higher concentrations in upwelling situation than under continental influence;
iv. nitrates show the same annual pattern as the SRP. Average concentration at the bottom level (14.4 μM) is four times higher than at the surface (3.7 μM). At these levels, there is no obvious seasonal cycle, while such a cycle is clear between –20 and –50 m, with a marked concentration increase from mid-June to mid-October. This increase is also significant in January at –50 m. In the three typical situations (Table 9-2), the euphotic layer shows higher concentrations during the upwelling situation than during the sequence under continental influence (respective average: 7.63 and 3.04 μM, $p < 0.001$).

An opposite scheme is observed for ammonia, with high concentrations from March to May and from October to December. High values reflect active mineralization process in the water column and occur simultaneously with the input of organic matter of continental origin.

Average concentrations of nutrients in the euphotic layer are significantly higher during the upwelling event than during the GW and the coastal phases (Table 9-3). GW clearly have low SRP and nitrate concentrations in the euphotic layer. In most of the cases, this situation is not different from the "coastal" situation. Therefore, upward movements induced by the currents carry nutrient-poor water in the productive layer. When this type water is no longer present (i.e. end of the rainy season), the rich deep water reaches the surface, and therefore, the system could be potentially more productive.

Biological Characteristics

For bacterial abundance and chlorophyll biomass, a typical year can be drawn. An obvious seasonal cycle is observed for each parameter, with several peaks noted during the upwelling periods (Figure 9-6). Isolated peaks are also observed at the surface level, either during the seasonal continental inputs (rain or floods) or during the SCE. The main difference between these processes is their duration. Each peak corresponds to the biological response to an intrusion of cold and nutrient-rich deep water into the euphotic layer. If such a phenomenon is repeated several times at a high frequency, the planktonic enrichment will be significant and sustainable (upwelling situation). If the process has a low frequency (SCE), the enrichment will be less important. In other situations, enrichment is sporadic, even if in some occasions (1994), real fertilization can be detected.

Bacterioplankton abundance fluctuated from 1.5 x 10^5 to 19.0 x 10^5 cells ml^{-1}, with an interannual average of 4.2 x 10^5 cells ml^{-1}. These data confirm the previous results obtained on bacterioplankton biomass in this zone (unpublished data) and are in agreement with those

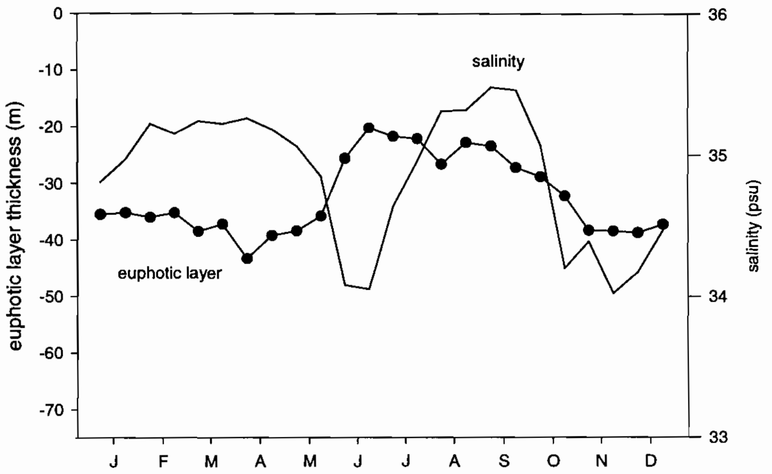

Figure 9-5 Surface salinity and water transparency: annual pattern based on fortnightly grouped data.

PO_4-P, µM	**0 m**	**- 10 m**	**- 20 m**	**- 30 m**	**- 50 m**	**- 75 m**
Continental (n=59)	0.47	0.50	0.46	0.49	0.66	1.08
Coastal (n=40)	0.43	0.45	0.58	0.73	1.01	1.19
Upwelling (n=40)	0.45	0.61	0.79	0.94	1.17	1.29
P	H_0 nr	0.007	<0.001	<0.001	<0.001	0.002
NO_3-N, µM	**0 m**	**- 10 m**	**- 20 m**	**- 30 m**	**- 50 m**	**- 75 m**
Continental (n=59)	3.16	3.61	3.72	4.07	7.03	12.61
Coastal (n=40)	4.18	4.50	5.3	6.94	11.54	15.36
Upwelling (n=40)	4.21	6.30	9.12	10.92	14.50	16.25
P	0.005	< 0.001	<0.001	<0.001	<0.001	<0.001
Chlorophyll, µg l^{-1}	**0 m**	**- 10 m**	**- 20 m**	**- 30 m**	**- 50 m**	**- 75 m**
Continental (n=57)	0.62	0.55	0.63	0.68	0.55	0.27
Coastal (n=39)	1.05	1.02	0.95	0.88	0.59	0.28
Upwelling (n=38)	1.70	1.42	0.99	0.80	0.35	0.30
P	<0.001	<0.001	<0.001	H_0 nr	0.003	H_0 nr

Table 9-2 Nutrient concentrations and chlorophyll biomass: averages calculated on data grouped by water quality. A sampled day is considered as representative of "continental", "coastal" or "upwelling" situation following of the σ_t at – 50 m. Statistical significance: mean equality rejected (p value provided) or not rejected (H_0 nr).

	Continental (n=57)	**Coastal** (n=39)	**Upwelling** (n=38)	*p*
SRP (PO_4-P), µM	0.48	0.55	0.70	< 0.001
Nitrate (NO_3-N), µM	3.04	5.23	7.63	< 0.001
Chlorophyll, µg l^{-1}	0.65	0.97	1.22	< 0.001

Table 9-3 Nutrient concentrations and biomass integrated over the euphotic layer: averages calculated on data grouped by water quality. A sampled day is considered as representative of "continental", "coastal" or "upwelling" situation following of the σ_t at – 50 m. Statistical significance: mean equality rejected (p value provided) or not rejected (H_o nr).

encountered in oligotrophic sites of the Atlantic Ocean during the EUMELI cruises (Dufour and Torréton 1994). But they are lower than those observed during seasonal upwelling in the NW Indian Ocean (1.0-2.1 x 10^6 cell ml^{-1}, Wiebinga *et al.* 1997) or those reported in the southern Benguela (10^7 cell ml^{-1}, Painting *et al.* 1993). Knowing the rapid growth potential of bacterial communities, the fact that variations of bacterial densities do not exceed one order of magnitude might suggest a drastic control by grazing or nutrient availability in the sea (Azam *et al.* 1983). Low abundance could also be related to the transport to the surface of deep waters with low bacterial numbers.

Chlorophyll biomasses under the surface ranged from 0.1 to 5.6 µg l^{-1} (average: 1.0 µg l^{-1}) with marked seasonal variations. High values are noted during the main upwelling, with an average of 1.9 µg l^{-1} from July to September at the surface level. From October to June, values are fluctuating around 0.8 µg l^{-1}. On a vertical profile, the highest values are observed at a depth of 10 m to 20 m. Concentrations measured at a depth of 50 m and below are low throughout the year, most of them ranging between 0.2 and 0.5 µg l^{-1}. In the Côte d'Ivoire upwelling, chlorophyll biomass is lower than recorded in other coastal upwelling systems. In Somalia, Wiebinga *et al.* (1997) reported a range of 0.2-2.7 µg l^{-1}, with peaks at 15µg l^{-1}, while in Mauritania, Herbland *et al.* (1973) measured values between 5 and 35µg l^{-1}. In Peru values between 2-5 µg l^{-1} were measured near the coast (Minas *et al.* 1990). Chlorophyll values collected now are higher than those collected near the surface 25 years ago. Sevrin-Reyssac (1993) reported values fluctuating around 0.2 µg l^{-1} from February to May and around 0.6 to 1.0 µg l^{-1} from July to October. Algal biomasses are higher than the historical ones, for the oligotrophic season as well as for the enriched season. This process can be related to the combination of several factors:

a) higher enrichment linked to the SCE, now more intense and lasting longer in this area;
b) a decrease of the duration of the GW period with low nutrient water present in the euphotic layer in a context of enhanced water transparency, under the effect of reduced flow and particulate load from the rivers (drought plus dams);
c) since the system shows a marked gradient from poor (GW) to high production (upwelling situation), the longer the cold event and the shorter the GW intrusion would be, the more productive the euphotic layer would be;
d) short-term variability of physical events affects the distribution of chlorophyll biomass integrated over the euphotic layer;

e) the first peak (January-February) showed a high (1994, 1997) or low (1993) biomass increase, directly linked to the upwelling enrichment and/or to the drift or an advection of enriched superficial waters;

f) the same phenomenon is observed from July to October: the main upwelling allows a more (1994) or less (1992 and 1993) intense algal development, ending with the flood.

Biomass data can be integrated over the vertical; these values (mg m^{-2}) multiplied by time can be integrated over the time series, and expressed in mg d m^{-2}. Such an operation produces an assessment of the relative enrichment of each sequence. The respective average contribution of the various situations is: SCE and upwelling 55%; GW 13%; flood 15%; coastal 17%. The cold events produce more than half of the annual enrichment, while they occur, on average, for 174 days (Figure 9-7).

Conclusions

Hydrological conditions observed at the coastal station studied off Abidjan are strongly influenced by the seasonal variability of three major phenomena: rainfalls, river floods and upwellings. Upwelling enriches the neritic ecosystem, exerting an immediate influence on biological productions, on phytoplankton and consequently, on bacterioplankton. Therefore, during four to five months (main upwelling plus short cold events), the coastal ecosystem can be considered as productive. Freshwater influence can be considered as an impoverishing factor, and oligotrophic conditions are characteristic of this period.

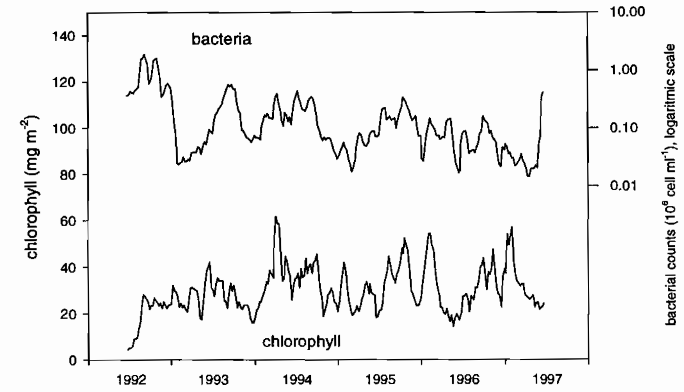

Figure 9-6 Chlorophyll biomass and bacterial abundance(4-term moving average) for the 1992-1997 period.

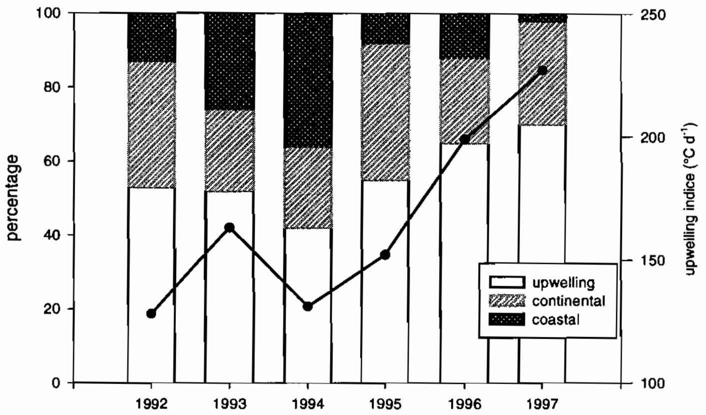

Figure 9-7 Respective percentage of the main hydrological situations for chlorophyll biomass integrated over the euphotic layer and over time (see text) and duration of the cold periods summed annually.

A first consequence of the lasting drought affecting the Sahel zone but also the coastal area is the decrease of continental influence and therefore, of the oligotrophic situation. Increased upwelling duration, and the recent major importance of SCE, enhances primary productivity and, in turn, the bacterial compartment. The neritic area along the eastern Côte d'Ivoire coastline can be presently considered as more productive than a few decades ago with the nutrient poor situation lasting less time, and the nutrient rich situation lasting longer. This change could explain the recent outburst of small pelagic fishes (such as *Sardinella aurita*) in this part of the Gulf of Guinea.

Acknowledgments

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