4 • The influence of climatic changes on the coastal oceanography of Ghana

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ABSTRACT
Monthly means of amounts of rainfall recorded at two stations in Ghana over the period 1979-1981 and 1987, rates of river flow and sediment transport recorded at seven stations quite close to the sea and monthly means of zooplankton displacement volumes taken off Tema (Ghana) are analysed. Two patterns of annual rainfall occur in Ghana. In pattern 1 which is dominant, major rains occur during the period May - July but mainly in May and June, while minor rains take place between September and October but most often in October, as it happened in the years 1979-1981. In pattern 2 which is rare, major rains occur in September while the minor rains take place during the period March - May, as it occurred in 1987. The rainfall patterns correlate with the patterns of river flow and sediment discharge into the sea. Rainfall pattern 1 correlates with the major coastal upwelling and is, therefore, more likely to exert immediate positive influence on biological production in Ghanaian coastal waters. Thus, rainfall patterns should be considered in modelling the effects of the environment on coastal pelagic fisheries.

RÉSUMÉ
Les moyennes mensuelles de la pluviométrie relevée à deux stations du Ghana sur la période 1979-1981 et 1987, les débits des rivières et des sédiments transportés pour sept stations situées près de la mer, ainsi que les moyennes mensuelles des déplacements de volumes planctoniques devant Tema (Ghana), sont analysés. Deux schémas annuels différents sont observés au Ghana. Le premier est dominant et les pluies apparaissent entre mai - juillet (principalement entre mai et juin), tandis que la petite saison des pluies a lieu entre septembre et octobre (plus souvent en octobre comme cela se produisit durant les années 1979-1981). Pour le second schéma qui est peu fréquent, les pluies ont lieu en septembre alors que les pluies secondaires ont lieu entre mars et mai, comme cela apparaît en 1987. Le premier schéma des pluies est corrélé avec l'upwelling et est ainsi plus susceptible d'exercer une influence positive sur la production biologique des eaux ghanéennes. Ainsi, les schémas des pluies devraient être considérés lorsque l'on modélise les effets de l'environnement sur les pêcheries pélagiques côtières.

INTRODUCTION

The coastal oceanography of Ghana has been sufficiently described by several authors (Howat, 1946; Mensah 1973, 1974; Houghton and Mensah 1978; Mensah and Koranteng; 1988). It is dominated by a seasonal coastal upwelling which occurs for approximately three months (July - September) of the year. For the rest of the year a strong thermocline exists, except for a few weeks in January, February or March, when a minor upwelling

occurs. This thermocline fluctuates in depth between 10 and 40 metres.
Several authors have also described the linkage between the Ghanaian coastal oceanography and abundance and availability of the coastal pelagic stocks especially, *Sardinella aurita*. Among these authors are Mensah (1973); Ofori-Adu (1975, 1977); FRU/ORSTOM (1976); Houghton and Mensah (1978); and Mensah and Koranteng (1988).
Until the near-collapse of the sardinella stocks in 1972 due to overfishing of the adult stocks, the relationship between the *Sardinella* landings, plankton production and upwelling indices has been linear and positively correlated. This relationship has broken down since 1973, though the linear relationship has been maintained between upwelling index and plankton production.
The mechanism of the coastal upwelling has been the subject of research by several authors (Ingham, 1970; Pople and Mensah, 1971; Houghton, 1976; Bakun, 1978; Houghton and Mensah, 1978; Adamec and O'Brien *et al.*, 1978; Clarke, 1978; Philander, 1979; Citeau, Piton and Voituriez, 1981; Picaut, 1983; Houghton, 1983). In summary, the driving force for the Ghanaian coastal upwelling is non-local and not related to the local wind force. The current prevailing view is that low frequency waves observed over the shelf and on the equator in the Gulf of Guinea may provide a non-local driving mechanism for this coastal upwelling.
Very little work has been done on relating the abundance and availability of coastal pelagic fish stocks to the local climatic factors. Using river flow data recorded in Ivory Coast since 1966, Binet (1982) has related the *Sardinella aurita* fishery of Ivory Coast and Ghana to coastal oceanography and climatic changes. This paper describes the correlation between the patterns of rainfall, river discharge and sediment transport into the sea, zooplankton production and the sort of relationship it may have with the Ghanaian coastal fisheries.

THE DATA

Three series of data have been used: (a) amounts of rainfall; (b) rates of river flow and sediment discharges into the sea; (c) quantities of zooplankton.

Rainfall data: These were monthly means of amounts of rainfall recorded at two stations (Axim and Saltpond) on the coast for the period 1979-1981 and 1987 by the Meteorological Services Department of Ghana. They are presented in table 1 and figure 1. These data were selected from data available for eight stations on the coast during 12 years when rainfall data were regularly available within the 1971-1987 period (tab. 1 and 2).

River discharges and sediment transport: These data records of rates of river flow and sediment transport into the sea were taken by the Water Resources Research Institute of Ghana. They were recorded at seven stations quite close to the sea (fig. 2) and for the period 1987-1988 (tab. 3 and fig. 3).

Fluctuations in zooplankton abundance during the period 1973-1977: Monthly means of zooplankton displacement volumes in ml/1000 litres of sea water taken on the continental shelf along a transect off Tema were used. The gear used in collecting the zooplankton was ICITA net operated step-obliquely from approximately 8-32 metres to the surface. These data are presented in figure 4 and table 4.

OBSERVED PATTERNS

Patterns of rainfall

The two stations (Axim and Saltpond) and the period 1979-1981 and 1987, were chosen in order to illustrate the patterns of rainfall and any changes in the patterns (fig. 1, tab. 1). For every month there is some amount of rainfall in one part of the country or the other. The amounts of rainfall vary from month to month producing two main peaks - major and minor. The timing of the peaks also varies. The major peaks occur between May and July while the minor peaks occur between September and October in some years such as in 1979-1981 but in other years such as 1987 the major peaks occur in September while the minor peaks occur between March and May. Further examination of the data for the eight stations and the 12-year period (tab. 1 and 2) showed that the major peaks occurred more commonly between May and July than in September or November. In fact, for the 12-year period, the major rainfall peaks occurred in September or November in only 1975 and 1987.

Patterns of river discharges and sediment transport

Since there are no data available on river discharges and sediment transport for the period 1979-1981, patterns of river discharges and sediment transport cannot be described for that period.

River discharge patterns in 1987-1988: At five of the sampling stations (Jumoro, Dominase, Beposo/Daboasi, Okyereko and Ekotsi) in 1987, the rates of river flow reached their major peaks in October while at the remaining two sampling stations (Mankesim and Todizenu) the major peaks were reached in September (fig. 3, tab. 3). There were hardly any minor peaks except at two stations, Dominase and Todizenu, where the minor peaks occurred in March and July respectively. In 1988, three stations (Dominase, Mankesim and Ekotsi) registered major peaks in October, one station (Jumoro) in September, another station (Todizenu) in June; there was no identifiable major peak at one station, Okyereko, while no recording was made at the seventh station (Beposo/Daboasi). A weak minor peak was observed at only one station - Dominase-in June.

Sediment transport patterns in 1987-1988: Five of the sampling stations (Jumoro, Dominase, Beposo/Daboasi, Okyereko and Ekotsi) registered peak sediment loads in October of 1987 (fig. 3, tab. 3); the other two stations (Mankesim and Todizenu) recorded peaks in September. The timing of occurrence of minor peaks

Fig. 1

Rainfall pattern at Axim 1979-1981 (a); rainfall pattern at Saltpond 1979-1981 (b); mean rainfall at Axim and Saltpond 1979-1981 (c); rainfall pattern at Axim and Saltpond 1987 (d).

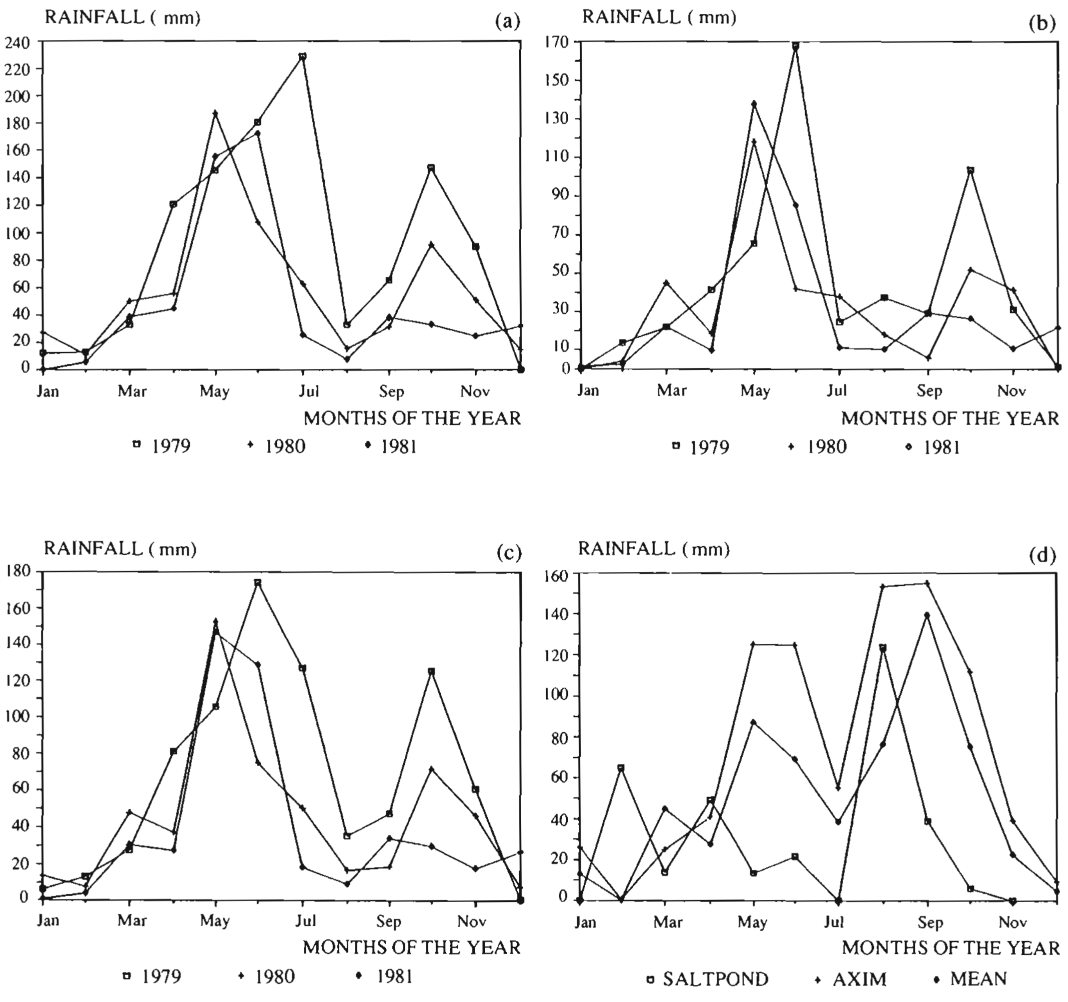
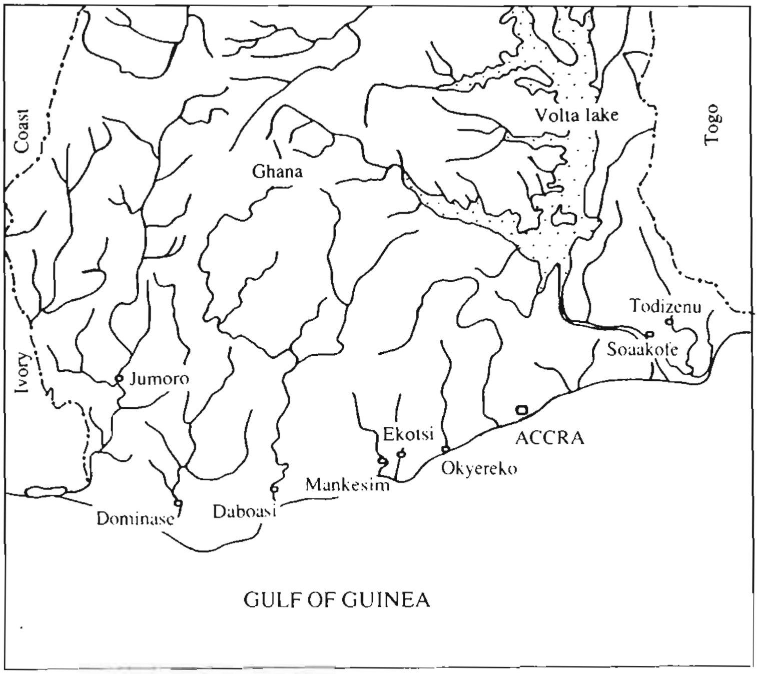


Fig. 2

Locations of sampling stations



was rather variable, taking place either in April or May or July. The situation was more variable in 1988. Major peak transport of sediment load occurred in April at one station (Todizenu); in May at one station (Dominase); in June at one station (Okyereko); in September at another station (Jumoro) and in October at two stations (Mankesim and Ekotsi) (fig. 3, tab. 3). Five weak minor peaks were observed - three occurred in June (Jumoro, Mankesim and Ekotsi) while the remaining two occurred in October (Dominase and Okyereko).

Zooplankton production patterns

The period 1973 - 1977 was selected to illustrate the effect of rainfall patterns on zooplankton production because there were sufficient zooplankton data available during the period. Despite the lack of zooplankton data during August 1976 (fig. 4), it shows clearly that during the period 1973 - 1977, peak of zooplankton production occurred during the three-month period- July - September, especially in September in 1973, 1975 and 1977. For the rest of the year, zooplankton production was minimal.

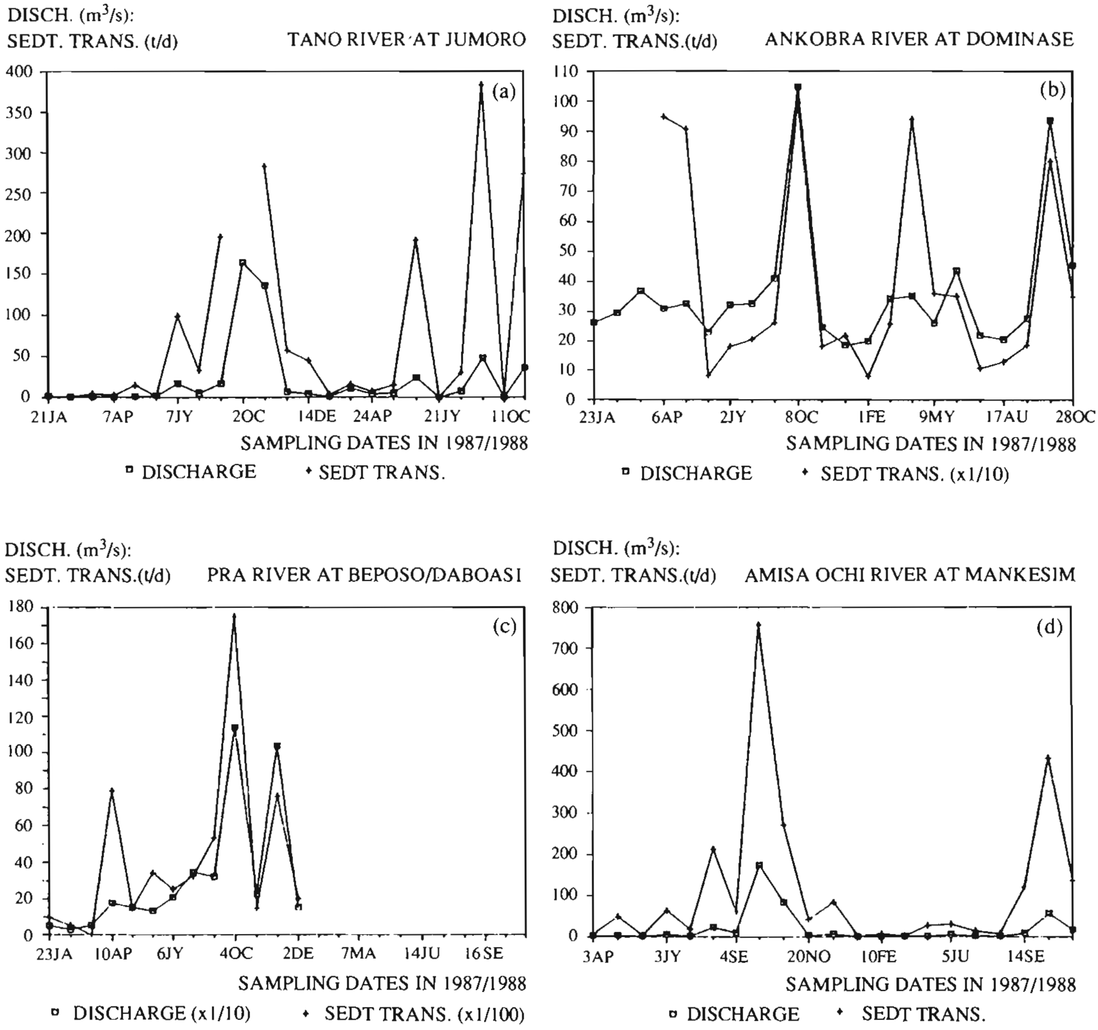
DISCUSSION

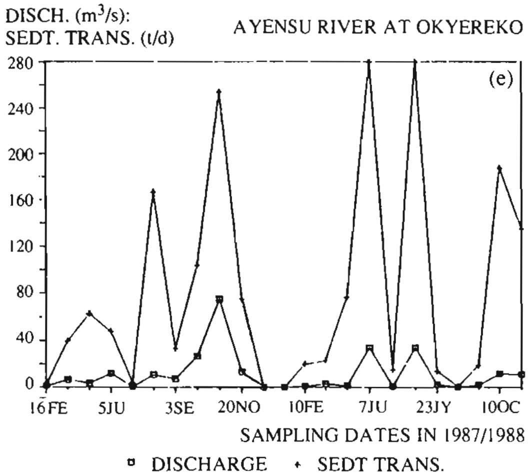
Correlation between the patterns of rainfall, river discharge and sediment transport and zooplankton production.

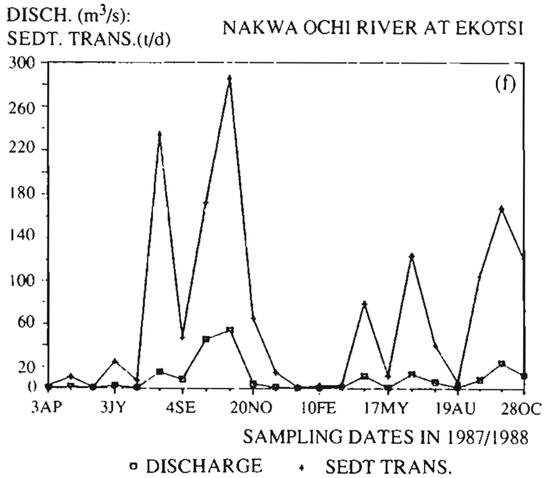
The results show that two main patterns of rainfall occur in Ghana; one pattern is more common than the other. In pattern 1, the more common pattern, major rainfall takes place generally during May and July but mainly during May and June and the minor rainfall occurs between September and October but most often in October. This pattern of rainfall took place during the period 1979-1981 (fig. 1) and in all years during the period 1971-1987 except in 1975 and 1987. In pattern 2, major rainfall takes place during September and November while the minor rainfall occurs between March and May, as occurred in 1987 (fig. 1d). and also in 1975 (tab. 2). The pattern of rainfall in 1987 (pattern 2) is very consistent with the pattern of river flow and sediment transport into the sea in 1987. The river flow pattern in 1988, to a large extent, is consistent with the pattern in 1987, though the transport pattern is rather variable in 1988. Analysis of rainfall data for 1988, whenever available, will explain the situation more clearly. Based on the results of the 1987 data analysis, even though there are no river discharge and sediment transport data available for the years 1979-1981, one could fairly assume, that the patterns of river discharge and sediment transport would be consistent with rainfall pattern 1.

It is generally known that nutrients and other chemical elements that are used in the process of photosynthesis in the sea are replenished from land sources through river run off as a result of rains. Where a nutrient element is a limiting factor in photosynthesis, its depletion in the sea will limit photosynthesis and consequently limit phytoplankton and zooplankton

Fig. 3
Discharge and sediment transport




DISCH. (m3/s):
SEDT. TRANS. (t/d)
AYENSU RIVER AT OKYEREKO
(e)
280
240
200
160
120
80
40
0
16FE
5JU
3SE
20NO
10FE
7JU
23JY
10OC
SAMPLING DATES IN 1987/1988
DISCHARGE
SEDT TRANS.


DISCH. (m3/s):
SEDT. TRANS.(t/d)
NAKWA OCHI RIVER AT EKOTSI
(f)
300
260
220
180
140
100
60
20
0
3AP
3JY
4SE
20NO
10FE
17MY
19AU
28OC
SAMPLING DATES IN 1987/1988
DISCHARGE
SEDT TRANS.

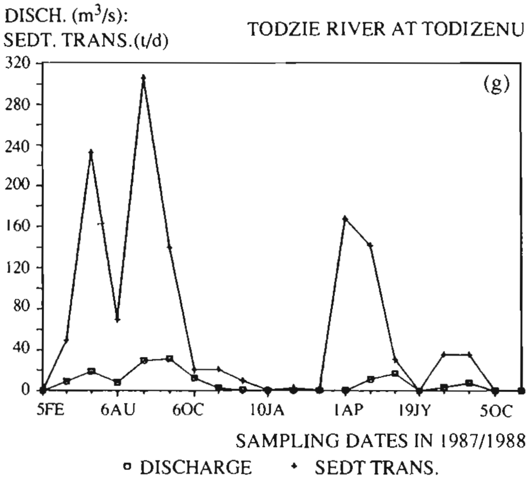
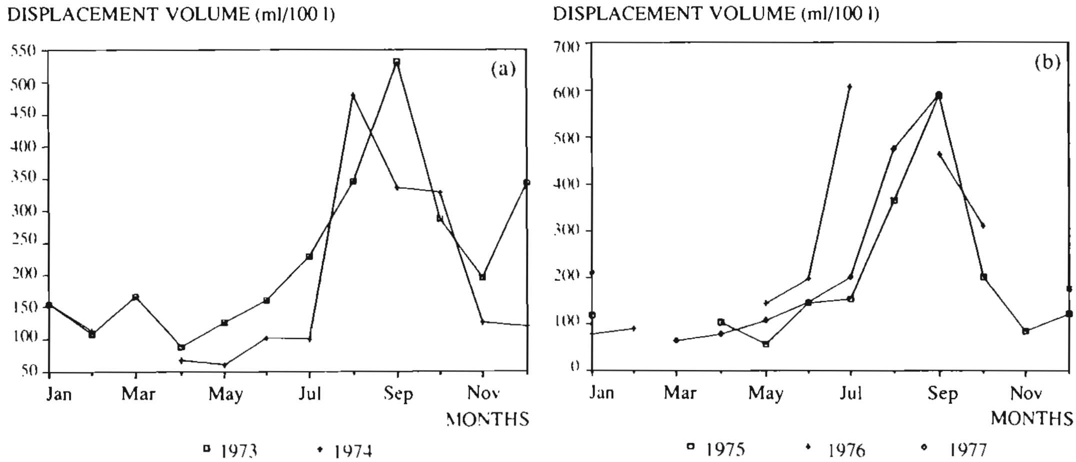

DISCH. (m3/s):
SEDT. TRANS.(t/d)
TODZIE RIVER AT TODIZENU
(g)
320
280
240
200
160
120
80
40
0
5FE
6AU
6OC
10JA
1AP
19JY
5OC
SAMPLING DATES IN 1987/1988
DISCHARGE
SEDT TRANS.

Fig. 4
Monthly mean zooplankton



production and hence fish larval survival, no matter how excellent the upwelling is in a particular year. The annual major coastal upwelling in Ghana takes place during July, August and September, and so, considering the dominant rainfall pattern (pattern 1), the major coastal upwelling is always preceded by the major rains except in 1975 and 1987 when the major upwelling was preceded by the minor rains (rainfall pattern 2). However, the pattern of zooplankton production in 1975 was the same as in the other years when the major coastal upwelling was preceded by the major rains (fig. 4). Thus, the one year with a different rainfall pattern from the four years with other rainfall pattern did not adversely affect zooplankton production during the major upwelling.

The timing of the rainfall patterns is very important in the Ghanaian coastal pelagic fisheries, especially the *Sardinella aurita* fishery. The *S. aurita* fishery is described, in detail (see Binet, 1982; Koranteng in this volume). The fishery is seasonal and it takes place mainly during the three months period of July - September. For the rest of the year there may be few sporadic landings especially during the period January - March. The two periods mentioned coincide with the major coastal upwelling and the minor coastal upwelling respectively. It is during the upwellings that the nutrients brought into the sea as a result of the rains are utilised in the process of photosynthesis to provide food for the coastal pelagic fish stocks. Thus, rainfall pattern 1 gives an almost immediate positive effect on the success of the *S. aurita* fishery while the effect of rainfall pattern 2 may not be felt if it occurred only once in a number of successive years with rainfall pattern 1. Patterns of rainfall and their timing in relation to the occurrence of the coastal upwelling should be considered when modelling the effect of the environment on coastal pelagic fisheries. It is important to mention an observation made in Ghana in 1968. In that year, the rains were exceptionally heavy and extended from June to late August. In that year, the major upwelling was the poorest and coastal pelagic catches, especially *S. aurita*, were correspondingly very poor. It should, therefore, be noted that the timing of the end of the peak rainfall is important in reaping the benefits of the positive correlation between the rainfall pattern, river discharge sediment transport and zooplankton production.

CONCLUSION

It is concluded that patterns of rainfall correlate with the rates of river flow and sediment discharge into the sea. Rainfall pattern 1 correlates with the major coastal upwelling and so it influences high zooplankton production during the upwelling. The sediments replenish the nutrients consumed in photosynthesis which provides food for fishes. Thus, rainfall patterns are important climatic changes which affect coastal pelagic fisheries.

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Table 1

Monthly mean rainfall (mm) 1979-81 and 1987
Source: Meteorological Services Department, Ghana.

1979	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	0,83	0	14,17	26,1	54,47	103,7	4,4	5,7	10,23	61,07	16,67	0
Accra	0	0	17	13	55	85,4	17,2	18,63	26,17	57,9	20,13	0
Saltpond	0	13,7	21,97	41,63	65,93	167,9	24,77	37,67	29,17	103,77	31,33	1,17
Cape Coast	5,1	4,9	32,23	50,33	92,03	155,3	44,75	20,47	54,1	67,33	52,3	5,83
Komenda	0	39,1	8,9				63,5	31,4	24,1	74,47	38,73	12,87
Takoradi	0,43	3,8	41,23	31,43	67,7	147,23	69,65	18,23	72,4	57,5	47,17	15,9
Axim	12,3	12,97	33,37	121,07	145,77	180,87	229,4	33,2	65,7	147,57	90,33	0
Half Assini	0,27	0	0	46,9		125,6	86,23				90,47	0

1980	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	0	13,87	8,23	38,2	61,27	37,43	1,63	11,57	10,9	22,4	16,53	3,73
Accra	0	1,77	14,83	60,37	81,67	55,73	23,7	19,97	32,67	25,33	15,13	2,43
Saltpond	0,13	4,17	45,25	18,53	118,3	42,17	37,97	18,05	5,9	52,23	41,63	0,27
Cape Coast	4,57	1,13	18,9	23,07	115,57	55,37	36,97	28,45	24,43	46,07	24,57	
Komenda	1,6		11,4	61,3		26,9	29,8		85,2	47		
Takoradi	0,1	0,9	13,6	76,37	160,23	36,83	69,97	24,7	15,43	39,93	49	0
Axim	27,6	11,27	50,73	56,3	187,4	108,03	62,83	15,7	31,7	91,93	51,4	14,87
Half Assini	2,87	5,97		27,77	144,2	127,97	16,33			98,7	60,77	

1981	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	0,37	6,43	21,23	9,1	52,13	58,07	73,2	10,07	18,7	24,8	4,93	0,77
Accra	0,67	3,8	13,1	7,8	46,73	48,2	27,93	18,97	32,93	22,67	4,07	0,1
Saltpond	1,63	2,47	22,17	9,7	138	85,37	11,2	10,33	29,53	26,43	10,73	21,77
Cape Coast									21,47		15,17	
Komenda						98,37			18,73	21,93	20,77	10,17
Takoradi	13,67	4	22,2	43,87		118,17	16,63	7,83	24,37	28,27	11,63	9
Axim	0,1	5,67	39,13	45,03	155,63	172,5	25,63	7,87	38,63	33,5	24,97	32,23
Half Assini			57,63		231,33	363,6		16,5				

1987	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	0	0	0		25,03		6,63	53,4	80,2	26,2		4,7
Accra		8,8	34,5	17,5	5,9	6,13	28,63	91,57	23,85	45,5		
Saltpond			65,13	14,07	49,5	13,7	21,8		123,93	39,05	6	
Cape Coast			31,67	14,8		3,75	42,7	48,8	162,87	67,6	13,73	0
Komenda			15,7	26,7		10,7	25,93	52,77	168,93	65,5	12,03	15,57
Takoradi	2,55	9,75	6,6	10,55	56,77	54,53	20,55	93,37	112,8	68		
Axim	26,37	0,53	25,15	41,3	125,4	125,03	55,4	153,57	155,27	112,13	39,47	9,4
Half Assini				25,3	105	83,2	8,9	42,7	211	93,8	24,95	
SALT	0	0	65,13	14,07	49,5	13,7	21,8	0	123,93	39,05	6	0
AXIM	26,37	0,53	25,15	41,3	125,4	125,03	55,4	153,57	155,27	112,13	39,47	9,4
MEAN	13,185	0,265	45,14	27,685	87,45	69,365	38,6	76,785	139,6	75,59	22,735	4,7

Mean monthly rainfall (mm)

Table 2(a):

1971	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	1,86	23,28	20,32	17,69	34,88	129,03	39,37	10,50	5,08	1,61	8,64	5,93
Accra	0,00	35,81	19,90	37,00	13,63	109,47	20,49	23,28	21,50	7,45	6,60	3,47
Saltpond	12,70	4,07	14,82	48,60	24,47	182,03	39,29	7,87	5,17	0,00	6,86	4,32
Cape Coast	5,50	12,19	25,65	16,76	50,88	260,94	51,81	38,69	8,89	0,00	20,20	1,10
Komenda						198,29	47,41	14,65	7,79	1,10	2,67	4,91
Takoradi	11,85	20,83	27,69	38,10	41,83	210,82	35,81	9,31	2,46	7,87	23,12	45,30
Axim	2,88	43,10	47,16	41,49	49,78	238,00	75,78	16,09	12,62	11,01	33,40	25,40
Half Assini						312,33	97,71	58,25	22,41	9,23	78,11	55,96

Table 2(b)

1972	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	0,17	7,20	20,40	96,40	11,43	159,26	1,18	0,00	5,08	0,56	9,99	0,42
Accra	0,17	12,45	20,32	74,55	13,63	75,44	0,93	0,51	11,77	17,10	7,45	0,51
Saltpond	0,00	23,20	40,98	53,60	18,29	98,64	6,60	3,34	8,21	16,09	11,18	17,02
Cape Coast		36,71	19,56	59,94	37,93	58,16	13,21	6,86	9,57	5,33	33,36	34,93
Komenda	0,00	12,09	29,64	39,88	18,88	54,61	12,53	11,30	13,29	17,69	3,39	44,79
Takoradi	0,25	21,34	41,23	34,93	34,63	25,23	36,24	3,18	15,15	87,04	14,14	12,45
Axim	0,93	28,11	76,20	82,04	126,83	66,29	116,25	9,65	26,93	53,85	44,28	27,35
Half Assini	4,83	27,26	72,64	61,60	108,71	123,78	141,22	10,03	8,47	70,70	60,45	12,62

Table 2(c)

1973	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	0,00	6,94	14,31	35,14	53,68	157,82	15,41	19,56	21,08	39,88	1,78	5,16
Accra	0,00	0,59	33,70	18,88	38,27	137,08	30,90	11,00	43,27	17,10	0,00	8,55
Saltpond	0,42	4,23	45,80	20,04	72,98	131,23	26,07	30,90	30,40	35,30	0,42	17,10
Cape Coast	16,34	15,07	51,56	28,87	51,65	146,13	25,40	32,13			0,00	0,42
Komenda	4,74	16,09	45,30	37,51	44,36	177,72	10,08	44,11	17,86	35,73	12,79	32,09
Takoradi	14,73	15,16	54,27	18,71	31,58	109,98	10,59	48,51	22,52	49,28	5,33	24,21
Axim	12,28	32,60	39,71	59,18	48,43	212,85	11,68	53,17	11,85	85,09	17,10	35,81
Half Assini	0,00	25,74	26,50	50,88	81,37	297,44	40,39	51,14	54,44	118,96	27,94	17,61

Table 2(d)

1974	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	3,38	0,17	8,80	21,25	79,88	276,10	19,90	2,11	18,88	7,28	0,00	2,03
Accra	2,62	0,51	26,25	15,58	71,20	114,89	39,37	3,98	32,60	2,80	15,24	6,94
Saltpond	3,81	20,32	26,67	33,02	62,95	217,51	20,40	7,36	72,39	19,64	1,69	11,43
Cape Coast	5,42	14,90	21,59	28,70	124,55	304,29	24,64	3,73	75,18	4,74	0,00	12,96
Komenda	6,27	14,39	32,68	17,53	78,06	305,73	46,40	1,95	93,90	11,18	1,86	14,73
Takoradi	26,84	7,28	36,15	45,21	78,99	212,01	46,99	11,77	69,00	14,82	6,35	9,40
Axim	1,27	21,08	57,57	17,27	107,10	396,66	154,94	8,98	57,49	43,27	22,86	31,92
Half Assini	14,31	12,28	43,09	25,40	65,19	299,72	177,29	21,76	50,63	30,40	43,10	5,67

Table 2(e)

1975	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	0,00	32,51	18,63	41,40	35,98	138,60	25,06	0,08	0,00	187,96	165,10	150,71
Accra	0,00	23,79	26,84	22,77	46,14	90,42	18,63	2,29	378,46	93,13	548,64	481,75
Saltpond	0,00	17,36	27,35	17,44	56,98	77,56	19,22	5,00	36,41	279,40	866,99	34,71
Cape Coast	0,00	32,51	30,99	17,27	60,79	83,57	29,21	8,64	269,24	559,65	657,86	324,27
Komenda	0,25	16,76	51,23	7,62	94,66	26,16	36,07	30,26	13,55	393,70	839,05	13,55
Takoradi	0,00	10,58	29,97	19,47	92,54	63,42	92,79	6,94	74,51	75,35	1111,67	23,71
Axim	5,25	23,88	51,90	25,15	86,62	210,65	147,06	10,58	156,63	572,35	1108,29	567,27
Half Assini	0,00	16,34	36,66	18,88	149,01	191,01	118,53	20,49	679,87	1115,91	1348,74	212,51

Table 2(f)

1976	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	0,00	14,87	21,67	50,57	38,73	25,77	0,10	8,73	0,60	21,15	0,25	3,73
Accra	0,00	16,10	15,40	44,27	16,73	39,97	4,00	0,77	5,53	33,33	7,60	0,33
Saltpond	0,00	49,13	19,73	73,17	32,73	28,57	2,33	25,93	1,43	5,50	3,30	1,90
Cape Coast	0,00	23,37	46,25	40,30	65,20	44,67	1,33	20,67	0,20	12,90	22,20	4,30
Komenda	0,00	9,90	26,57	58,73	43,53	46,10	0,43	22,33	2,90	10,80	7,53	
Takoradi	0,17	15,93	22,53	61,57	77,20	84,27	37,13	17,30	0,77	12,73	18,40	16,70
Axim	2,47	38,27	65,47	111,70	179,80	177,40	9,40	24,20	0,80	18,47	60,87	38,10
Half Assini	0,77	18,97	34,47	155,50	155,80	273,47	23,00	0,30	1,55	28,13	33,60	56,30

Table 2(g)

1977	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	4,33	0,00	1,97	37,00	33,50	10,33	0,37	0,43	9.47	25,23	9,47	0,00
Accra	1,33	3,80	8,20	36,03	24,47	18,40	0,87	4,80	2,47	40,43	2,47	4,30
Saltpond	7,30	14,00	7,20	47,50	33,23	66,40	2,70	4,40	4,07	14,97	4,07	0,10
Cape Coast	28,70	3,07	25,45	20,10	18,95	90,93	3,63	2,20	2,97	13,17	2,97	0,93
Komenda		0,00	21,33	66,95	22,30	78,93	1,65	3,37		12,83		
Takoradi	22,50	3,90	21,07	21,27	39,73	63,10	1,70	4,17	20,50	4,53	20,50	5,93
Axim	8,60	3,77	55,17	54,30	68,13	99,17	2,40	1,97	47,20	35,33	47,20	12,37
Half Assini	0,33	13,95	31,00	30,83	36,60	222,93	3,90	4,37	76,77	26,53	76,77	13,50

Table 2(h)

1978	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ada	18,20	12,37	14,80	60,77	70,30	7,63	0,10	0,00	3,47	7,17	2,80	0,00
Accra	0,10	3,40	0,93	40,50	104,20	37,97	7,17	1,57	7,83	18,30	0,10	0,00
Saltpond		11,20	4,85	50,53	120,40	35,03	12,80	1,50	10,33	16,03	29,57	0,40
Cape Coast	18,47	20,70	5,00	38,03	75,00	65,17	7,13	3,10	3,45	39,27	12,10	2,30
Komenda				44,20		0,00	0,00	10,70	18,95	28,65	7,60	3,10
Takoradi	7,87	4,73	11,37	41,13	82,35	68,20	13,40	24,80	6,37	57,47	35,00	15,70
Axim	8,33	50,87	66,90	124,27	312,05	132,70	19,03	15,80	17,73	127,83	25,57	7,17
Half Assini		26,40	1,10	43,70	76,75	189,70	495,80	4,60	4,20	17,17		13,80

Table 3

River discharge (m^3/s) and sediment transport (tons/day) at seven (7) stations in Ghana

Source: Water Resources Research Institute, Ghana

(a) STATION : JUMORO
RIVER : TANO

WATER DATE	TEMP. (°C)	DISCHARGE (m^3s^{-1})	CONC. (mg/l)	S/TRANS (ton/day)
21JA	29	1,7	10	1,5
11FE	30	0,57	20	0,98
11MA	31	0,96	57	4,7
7AP	29	0,57	60	3
13MY	30	1,44	122	15
9JU	30	2,32	10	2
7JY	29	16,79	68	99
24JY	30	5,32	72	33
14AU	29	16,79	135	196
2OC	27	164,18	85	1210
22OC	28	136,32	24	283
27NO	30	6,99	94	57
14DE	30	4,36	120	45
12FE	29	1,19	36	3,7
16MA	25	10,99	17	16
24AP	30	4,36	20	7,5
18MY	31	5,32	32	15
16JU	29	23,87	93	192
21JY	27	-	53	-
18AU	27,5	7,59	46	30
15SE	27	47,8	93	384
11OC	26	-	40	-
27OC	28,5	36,1	88	274

(b) STATION : DOMINASE
RIVER : ANKOBRA

WATER DATE	TEMP. (°C)	DISCHARGE (m^3s^{-1})	CONC. (mg/l)	S/TRANS (ton/day)
23JA	22	26,34	115	262
13FE	30	29,74	993	2550
13MA	31	37,1	-	-
6AP	31	31,2	352	949
6MY	30	32,85	320	908
2JU	27	23,22	41	82
2JY	27	32,43	65	182
5JY	27	32,85	73	207
1AU	29	41,35	74	264
8OC	27	104,85	70	997
8NO	29	24,78	85	182
2DE	29	18,69	136	220
1FE	30	20,1	46	80
1MA	30	34,55	87	260
3AP	29	35,4	308	942
9MY	29	26,33	159	362
14JU	27	43,89	93	353
21JY	25,5	22,09	56	107
17AU	27	20,67	73	130
16SE	26,5	27,75	78	187
12OC	26,5	93,73	99	802
28OC	26	45,59	89	351

(c) STATION : BEPOSO/DABOASI
RIVER : PRA

WATER DATE	TEMP. (°C)	DISCHARGE (m^3s^{-1})	CONC. (mg/l)	S/TRANS (ton/day)
23JA	31	50,06	221	956
9FE	32	29,765	206	530
10MA	32	53,55	-	0
10AP	32	176,92	518	7920
7MY	32	154,2	112	1490
3JU	31	133,46	298	3440
6JY	29	209,26	141	2550
5JY	29	348,01	108	3250
5AU	27	323,38	192	5360
4OC	26	1139,89	178	17500
3NO	-	227,27	76	1490
8NO	31	1038,95	85	7630
2DE	31	154,21	152	2030
1JA	30	-	54	-
1FE	32	-	56	-
7MA	30	-	156	-
4AP	30	-	40	-
17MY	30	-	133	-
14JU	28	-	109	-
23JY	26	-	81	-
19AU	27,5	-	90	-
16SE	26	-	219	-
10OC	27,3	-	89	-
26OC	28	-	101	-

(d) STATION: MANKESIM
RIVER : OCHI AMISA

WATER DATE	TEMP. (°C)	DISCHARGE (m^3s^{-1})	CONC. (mg/l)	S/TRANS (ton/day)
3AP	32	2,94	32	8,1
7MY	30	3,45	166	49
5JU	30	1,93	31	5,1
3JY	28	6,28	120	64
25JY	28	2,27	96	19
7AU	27	23,53	106	215
4SE	28	10,42	69	62
24SE	29	175,25	50	757
15OC	29	85,21	37	272
20NO	31	3,88	124	42
12DE	29	7,11	139	85
21JA	32	1,1	39	3,7
10FE	30	1,42	60	7,4
15MA	31	1,93	21	3,5
17MY	32	2,66	123	28
5JU	27	5,97	61	31
22JY	26	2,66	65	15
19AU	29	1,93	48	8
14SE	26	9,32	152	122
10OC	27	56,38	89	434
26OC	28	17,08	93	137

(e) STATION : OKYEREKO
RIVER : AYENSU

WATER DATE	TEMP. (°C)	DISCHARGE (m^3s^{-1})	CONC. (mg/l)	S/TRANS (ton/day)
6FE	30	1,13	20	2
3AP	32	6,57	71	40
7MY	31	3,68	199	63
5JU	28	11,89	47	48
3JY	29	0,49	106	4,1
7AU	27	10,93	177	167
3SE	29	7,31	52	33
24SE	29	26,67	45	104
15OC	29	75,27	39	254
20NO	30	13,17	66	75
12DE	29	0	147	0
12JA	0	15	0	
10FE	2	0,99	230	20
5MA	30	3,09	87	23
22AP	29	1,44	618	77
7JU	28	34,09	95	280
17MY	30	0,85	207	15
14JU	28	34,09	95	280
23JY	26	2,29	73	14
20AU	26	0,14	84	1
18SE	26	2,12	105	19
10OC	26,5	11,75	185	188
26OC	28	11,19	140	135

(f) STATION : EKOTSI
RIVER : OCHI NAKWA

WATER DATE	TEMP. (°C)	DISCHARGE (m^3s^{-1})	CONC. (mg/l)	S/TRANS (ton/day)
3AP	32	0,88	38	2,9
6MY	30	1,90	65	11
5JU	30	0,88	19	1,4
3JY	29	2,80	105	25
25JY	27	0,88	100	7,6
7AU	27	15,35	177	235
4SE	29	8,66	63	47
24SE	28	45,62	44	173
15OC	30	54,26	61	286
20NO	30	4,53	166	65
12DE	28	1,39	127	15
21JA	31	0,54	34	1,6
10FE	32	0,54	61	2,8
15MA	33	1,10	30	2,9
22AP	30	11,84	77	79
17MY	30	0,99	141	12
14JU	28	13,54	106	124
23JY	26	6,03	76	40
19AU	29,5	1,39	49	5,9
16SE	26	8,41	144	105
10OC	26,5	23,65	82	168
26OC	28,5	12,40	113	121

(g) STATION : TODIZENU
RIVER : TODZIE

WATER DATE	TEMP. (°C)	DISCHARGE (m^3s^{-1})	CONC. (mg/l)	S/TRANS (ton/day)
5FE	29	0	59	0
3JU	27	9,09	64	50
2JY	27	18,97	142	233
6AU	29	8,18	99	70
3SE	28	29,73	119	306
13SE	28	31,71	51	140
6OC	29	12,52	19	21
9NO	29	2,83	87	21
10DE	29	0,85	142	10
10JA	32	0,42	82	1,1
9FE	32	0,42	82	3
4MA	33	0,48	25	1
1AP	32	0,48	40	168
1MY	29	11,36	171	142
10JU	28	16,99	97	31
19JY	26	-	77	-
15AU	26	3,54	100	36
12SE	27	7,65	54	36
5OC	27	-	92	-
25OC	28	-	88	-

Table 4

Monthly mean zooplankton displacement volumes (ml/1000 l)
(Number of samples in brackets)

	1973	1974	1975	1976	1977
JAN	154,4 (12)	155,93 (14)	119,25 (4)	78,88 (16)	211 (4)
FEB	108 (4)	112,75 (12)		90,43 (7)	
MAR	166 (1)				64 (4)
APR	88,79 (9)	68,08 (12)	104,13 (8)		78,75 (4)
MAY	125,88 (8)	61,5 (12)	57 (8)	144,43 (7)	107,75 (4)
JUN	160,33 (9)	102,14 (7)	145 (11)	198,25 (12)	147,5 (14)
JUL	229,9 (10)	100,67 (9)	154 (11)	607,25 (12)	201,25 (12)
AUG	346,67 (15)	480,25 (12)	365,25 (16)		475 (7)
SEP	532,13 (8)	336 (12)	587,63 (16)	463,24 (17)	590,5 (2)
OCT	287,25 (8)	328,3 (20)	201 (8)	310,58 (19)	
NOV	195,5 (4)	125,31 (16)	84,5 (8)		
DEC	343,47 (15)	119 (4)	121,71 (7)	180,75 (22)	173,19 (12)