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Ecological Studies in the Coastal Waters of Mauritania.

Wind, surface water temperature, surface salinity and pollution in the area of the Banc d'Arguin, Mauritania

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Key words: Banc d'Arguin, Mauritania, wind, water temperature, salinity, pollution

Abstract

Based on meteorological observations at Nouadhibou Airport, Mauritania, over the period 1953–1990 frequency distributions and averages are computed for wind speed and direction. Average wind speed reaches a maximum in May–June (9 m s^{-1}) and a minimum in November–December (6 m s^{-1}). About 85% of the time winds blow from northerly directions. Based on a data set collected since 1952 maps of surface water temperatures are constructed. Based on these maps and on observations on salinity an hypothetical current pattern for the shallow area between Nouadhibou and Cap Timiris, Mauritania, is proposed.

Introduction

Coastal areas are considered to be highly productive. The Baie du Lévrier and especially the area of the Banc d'Arguin (Fig. 1) in Mauritania are no exception to that rule. In the latter two areas the combination of water masses of different origins creates a highly diverse mixture of tropical and temperate plant and animal species. Moreover the shallow seagrass beds attract numerous species for their reproduction. This results in these areas being a nursery and it has even been suggested that these waters function as reservoirs for some West-African fish populations (Maigret & Ly, 1986). Also bird numbers are extremely high; with over 2 million wintering waders the Banc d'Arguin ranks among the principal wintering sites of the world (Trotignon *et al.*, 1980; Altenburg *et al.*, 1982).

The richness of the ecosystems of the Banc d'Arguin is due to the interaction of a great number of factors. To protect and manage these sys-

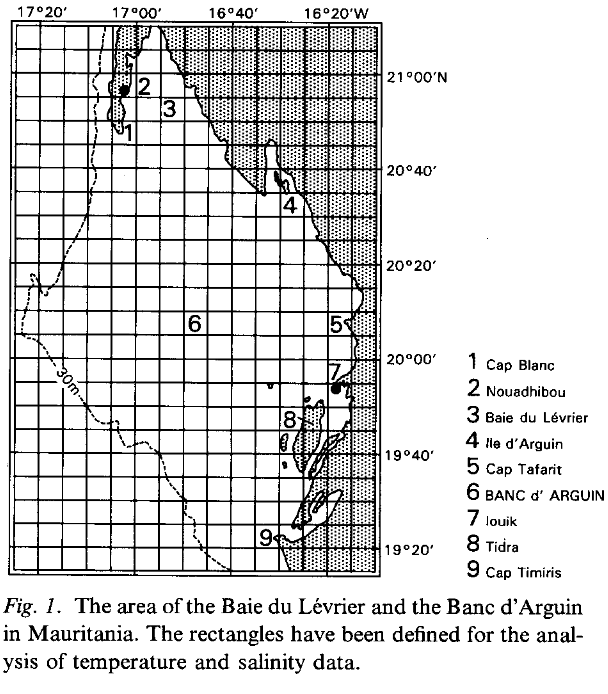

Fig. 1. The area of the Baie du Lévrier and the Banc d'Arguin in Mauritania. The rectangles have been defined for the analysis of temperature and salinity data.

Table 1. Frequency distribution of hydrographical rectangles (Fig. 1) according to the number of observations of surface water temperature per rectangle.

Number of observations	0	1–20	21–50	51–100	101–200	>200	Total
Number of rectangles	34	98	26	22	19	13	212
Percentage	16.0	46.2	12.3	10.4	9.0	6.1	100

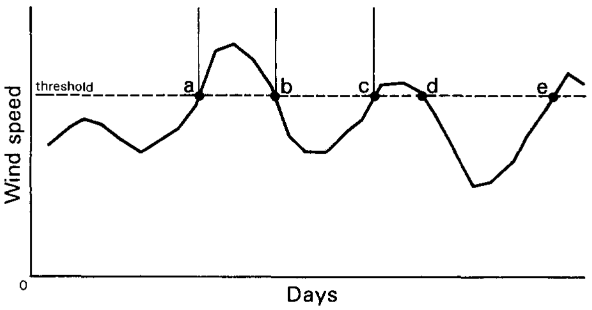

Fig. 2. Example of changes of wind speed and definition of periods of high wind (a-b, c-d), windows of quiet weather (b-c, d-e) and wind speed cycles (a-c, c-e).

tems in a sustainable way intimate knowledge of these factors is required. This paper is a contribution to the knowledge of the area of the Baie du Lévrier and the Banc d'Arguin and concerns a description of three major factors: wind, water temperature and salinity. In addition some data on local pollution are presented.

Material and methods

Wind data have been obtained from the meteorological station of Nouadhibou Airport for the period 1953–1990 and were made available by the Agence pour la Sécurité de la Navigation Aerienne en Afrique (ASECNA). In addition wind data for Iouik have been derived from Smit *et al.* (1989) for two spring periods in 1985 and 1986.

For the analysis of wind data we have calculated monthly frequency distributions of wind speed and wind direction. For the analysis of wind stability on a time scale of days we have chosen the approach of Matuschevsky & Nadeev (1987). Figure 2 shows an example how wind speed may change over time. Having fixed an arbitrary threshold value of 8 m s^{-1}, we can distinguish periods of high winds: a-b, c-d, and windows of quiet weather: b-c, d-e. Moreover we can define the length of a wind cycle: a-c, c-e. These data have been presented as frequency distributions. The threshold value has been based on Roy (1990) who observed a declining phytoplankton productivity at wind speeds over 8 m s^{-1}.

The data on water temperatures and salinity have been extracted from the data base of the Centre National de Recherches Océanographiques et de Pêches (CNROP). These data have different origins. Part of these derive from measurements made by the Laboratoire des Pêches (now CNROP) since 1952. Another part is derived from measurements during scientific expeditions and by vessels engaged in industrial

Table 2. Comparison of wind speeds (m sec^{-1}) and standard deviations at Nouadhibou Airport and Iouik. Data from ASECNA and Smit *et al.* (1989).

Period of observations	Number of days	Nouadhibou		Iouik		Correlation coefficient
		Mean	s.d.	Mean	s.d.	
March-May 1985	34	9.50	1.83	9.07	2.03	- 0.15
Febr.-April 86	69	9.58	2.13	7.46	1.65	0.45
Total	103	9.55	2.03	7.99	2.93	0.22

Table 3. Wind speed (m sec^{-1}) frequency distribution (1984–1990), average monthly wind speed with standard deviation (1960–1988) and maximum wind speed ever observed (1953–1982) for Nouadhibou Airport. Data from ASECNA.

Wind speed	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
0	2.08	1.50	2.65	0.36	0.17	0.62	1.77	2.26	0.97	1.68	1.80	3.71
1	0.56	0.12	0.17	0.06	0.00	0.07	0.00	0.47	0.21	0.20	0.41	0.97
2	2.53	2.17	2.71	0.53	0.17	0.55	1.13	2.20	2.22	1.88	3.11	4.60
3	5.63	4.16	4.61	1.18	0.63	0.62	2.34	3.86	4.86	4.17	7.94	10.00
4	7.60	4.97	8.82	2.54	1.15	2.00	5.16	5.99	6.11	7.19	10.32	11.45
5	8.72	11.18	9.57	5.39	3.05	2.83	8.06	9.98	11.39	11.29	15.56	14.19
6	8.27	11.12	11.31	6.57	4.15	2.62	8.55	8.92	8.33	11.29	16.30	14.44
7	13.90	11.24	10.44	8.93	6.34	5.86	8.06	9.31	12.15	17.00	14.91	12.74
8	11.93	12.67	9.86	12.78	11.35	11.79	8.15	10.85	13.89	14.65	11.55	9.84
9	10.19	13.35	8.48	11.95	12.73	13.93	9.19	9.45	11.88	10.01	6.55	7.10
10	14.07	13.17	10.27	16.99	22.07	22.28	14.68	11.71	13.40	11.56	6.55	4.35
11	7.20	5.90	8.07	11.12	16.24	16.69	11.61	10.58	8.68	6.25	2.62	4.19
12	4.90	5.03	6.52	8.64	13.25	11.72	9.11	8.45	3.96	2.02	1.39	1.53
13	1.52	2.05	3.69	6.39	6.05	6.28	6.45	3.26	1.46	0.67	0.82	0.73
14	0.56	0.87	1.79	3.49	2.25	1.79	3.06	2.13	0.35	0.07	0.16	0.08
15	0.34	0.50	1.04	2.07	0.40	0.28	2.33	0.60	0.07	0.07		0.08
16				0.65		0.07	0.16		0.07			
17				0.18			0.08					
18				0.12			0.08					
19				0.06								
Mean	6.68	7.14	7.96	8.57	9.00	9.06	8.30	7.67	7.39	6.93	6.10	6.02
s.d.	1.75	1.29	1.70	1.73	1.40	1.76	1.57	1.34	1.27	1.47	1.09	1.24
Max	31	45	50	36	41	32	55	65	33	27	34	31

Table 4. Frequency distribution of wind directions for Nouadhibou Airport for the period 1984–1990. Data from ASECNA.

Direction	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
231–250		0.9	0.5	0.1			0.7	1.2	1.0		0.3	0.7	0.4
251–270	0.1	0.5	1.0	0.3		0.7	1.6	1.2	1.7		0.7	0.4	0.7
271–290	0.8	0.3	3.0	1.0	0.2	0.1	2.8	2.2	2.2	0.6	2.7	1.3	1.4
291–310	1.9	4.0	4.3	1.2	0.1	1.5	5.5	5.3	4.2	2.4	4.6	3.0	3.0
311–330	5.4	7.2	11.2	7.3	8.9	10.0	19.2	18.0	15.8	14.8	13.4	7.8	11.5
331–350	8.8	15.8	17.7	27.8	35.5	33.0	36.1	31.1	27.0	26.3	15.1	9.0	23.5
351–10	17.2	24.3	27.0	37.0	43.5	38.0	24.5	28.1	26.4	30.8	24.5	16.1	28.1
11–30	20.8	22.7	16.8	18.7	8.8	14.8	5.1	7.6	12.3	16.3	18.7	11.6	14.6
31–50	21.4	11.8	10.3	4.6	2.6	1.3	0.3	1.0	2.5	4.9	10.2	15.7	7.3
51–70	11.4	4.8	2.8	0.6	0.2		0.3	0.2	0.7	1.1	2.4	14.4	3.3
71–90	5.9	2.6	1.9	0.5			0.1	0.2	0.4	0.9	1.5	9.1	2.0
91–110	3.0	3.5	1.2	0.1	0.1	0.2		0.1	0.6	0.4	0.8	5.0	1.3
111–130	1.0	0.4	0.3	0.1	0.1	0.2	0.2	0.2	0.6	0.2	0.4	2.6	0.5
131–150	1.0	0.4	0.3	0.2			0.3	0.6	1.3	0.3	0.9	1.0	0.5
151–170	0.6	1.0	0.7	0.1		0.2	0.7	0.6	0.6	0.4	1.5	1.5	0.6
171–190	0.6	1.1	0.3	0.1			1.7	1.1	0.9	0.3	1.0	0.4	0.6
191–210	0.1	0.7	0.6	0.2			0.7	0.8	0.3	0.3	0.4	0.3	0.4
211–230	0.1	0.5	0.3	0.1		0.1	0.3	0.7	1.5	0.2	1.2	0.2	0.4

Table 5. Length and standard deviation of periods of high wind, windows of quiet weather and wind cycles for Nouadhibou Airport. A wind speed of 8 m.sec^{-1} is considered to discriminate between high winds and quiet weather.

	Jan–March		April–June		July–Sept		Oct–Dec	
	Mean	s.d.	Mean	s.d.	Mean	s.d.	Mean	s.d.
Period of high winds (>8m sec^{-1})	4.5	3.5	14.3	10.1	3.6	3.1	3.9	3.2
Quiet weather window (<8m sec^{-1})	4.7	4.5	2.7	2.0	2.8	2.3	8.7	9.2
Cycle length	8.7	4.7	16.3	8.9	6.4	3.6	12.0	9.4

fishing. The CNROP data base now contains about 65% of all available data. In total we have used 8590 observations on surface water temperature and 4220 observations on surface salinity from the area within the 30 m isobath (Fig. 1).

For the analysis we have divided the sea area between 19°20′ and 21°20′ N and East of 17°25′ W into rectangles of 5 degrees latitude and longitude each. Only rectangles containing seabed shallower than 30 m have been considered (Fig. 1). The data show an inequal distribution in time and in space (Table 1). Many data are available for the regions West and North-East of the Banc d'Arguin proper as well as for the Baie du Lévrier. On the other hand, due to difficult access to some areas, we have no data for 16% of the rectangles, especially West of the Cap Blanc peninsula, in the Baie d'Arguin and around the island of Tidra.

For each rectangle we have computed the mean temperature and mean salinity per month. Through these monthly means for each rectangle we have fitted manually a curve and the monthly values thus obtained have served as the basis for all further calculations. The temperature maps have been based also on other available information such as some satellite pictures, the coastal and submarine topography of the area, and the temperature regime at the continental shelf, which is fairly well known. Based on the maps we have developed a subdivision of water masses and computed temperature characteristics per region.

Table 6. Annual development of average surface water temperatures for six subdivisions of the area of the Baie du Lévrier and the Banc d'Arguin (compare Fig. 13), for the entire area of the Baie du Lévrier and the Banc d'Arguin (BdA), and for the Mauritanian continental shelf between 19° 20′ and 21° 00′N (shelf).

Area	1	2	3	4	5	6	BdA	shelf
January	17.5	17.6	17.7	18.3	18.4	18.7	18.0	18.4
February	18.0	18.5	18.6	18.5	19.0	18.2	18.4	18.1
March	18.2	18.7	19.6	19.4	20.3	19.1	19.1	18.2
April	17.8	18.5	20.1	19.8	21.5	18.4	19.1	17.9
May	17.6	18.5	21.2	20.8	22.7	18.4	19.5	17.9
June	18.7	19.3	22.1	22.0	23.7	20.3	20.8	18.8
July	22.0	21.5	23.8	24.6	25.4	23.8	23.5	21.4
August	23.3	23.4	24.9	25.6	26.9	26.1	24.9	23.7
September	23.4	23.8	25.1	26.1	27.3	25.7	25.6	23.0
October	21.5	22.0	23.3	24.4	25.4	23.1	23.2	21.0
November	19.3	19.2	20.3	21.8	22.3	21.0	20.7	19.6
December	18.4	18.1	18.3	19.4	19.9	19.6	19.1	18.8

The subdivision has taken into account the pattern of seasonal development of temperature, the shape of the temperature curves, the maximum and the minimum values.

Because of time constraints the salinity data have not been put on maps. We did, however, establish temperature – salinity diagrams for each month.

Results

Wind data

Table 2 shows a comparison of wind data for Nouadhibou Airport and Iouik for two periods in which meteorological observations were made at both stations. Average wind speeds for the two

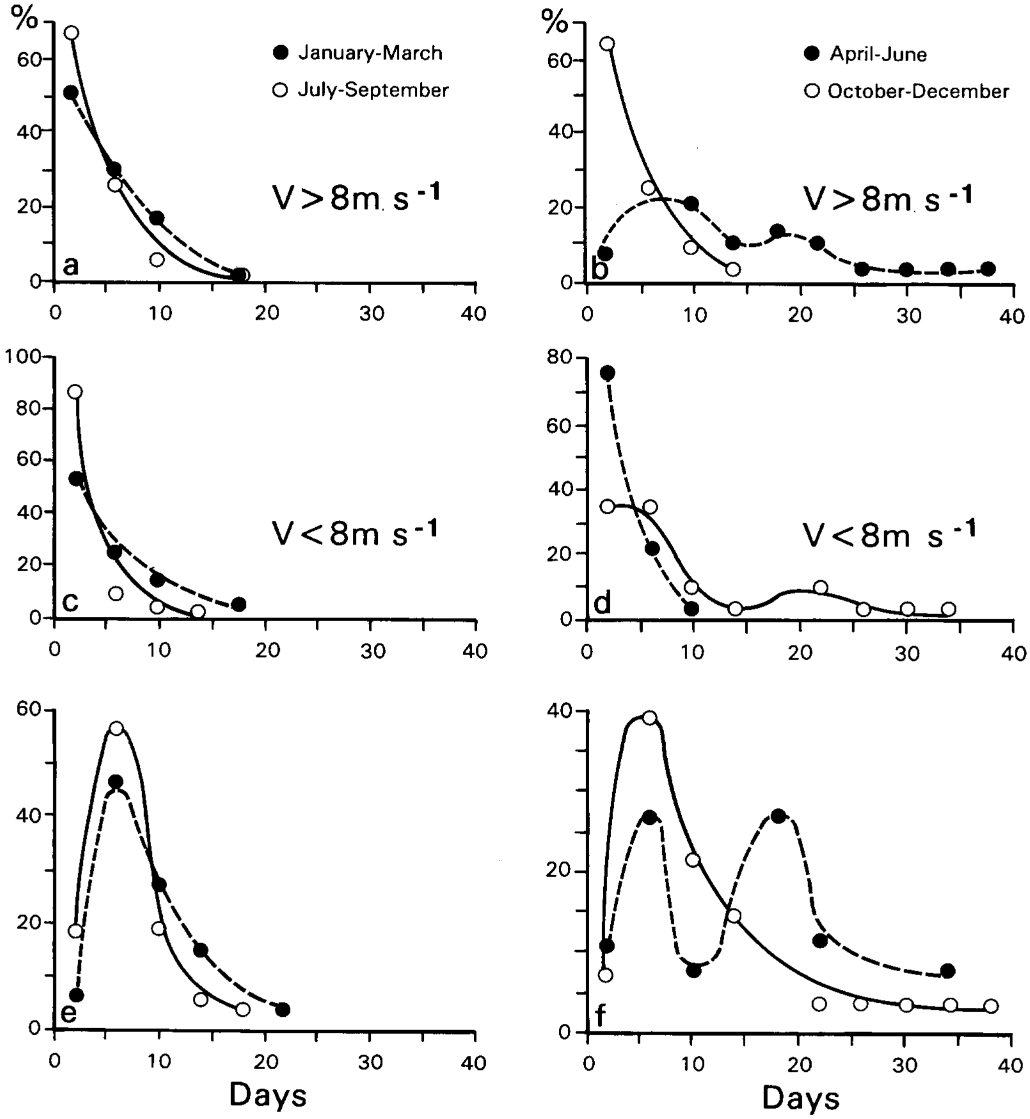

Fig. 3. Frequency distributions of periods of high winds, windows of quiet weather, and wind speed cycles for Nouadhibou Airport for the period 1960–1988.

stations do not differ significantly for the periods considered, so it may tentatively be concluded that the wind climates of Nouadhibou and Iouik are similar. On the other hand wind speeds on a day to day basis were not correlated significantly for the same periods.

Table 3 gives the wind speed frequency distribution per month for Nouadhibou Airport as well as the average wind speed per month and the maximum speed ever observed. It appears that there is a clear annual pattern with highest wind speeds in May–June and lowest values in November–December. The variability of the wind speed shows a similar pattern, but less clearly.

Table 4 shows the frequency distribution of wind directions per month for Noauadhibou Airport. Wind comes from the North (NW-N-NE) during nearly 85% of the year. In the period December–February northeasterly winds predominate. In spring the dominating winds shift to the North and in April, May and June northerly directions dominate. In July–September a northwesterly tendency becomes visible, but from October onwards a shift to the North-East develops again.

Table 5 shows the results of the analysis of wind stability. During the larger part of the year periods of high wind (>8 m s^{-1}) last only for 3.5–4.5 days on average. Only in the period April–June, when the trade winds reach maximum strength, the periods of high wind last for about 14 days on average. The windows of quiet weather (<8 m s^{-1}) are short from April to September and have their maximum duration in October–December. Figure 3 shows the frequency distribution of the various aspects of wind stability.

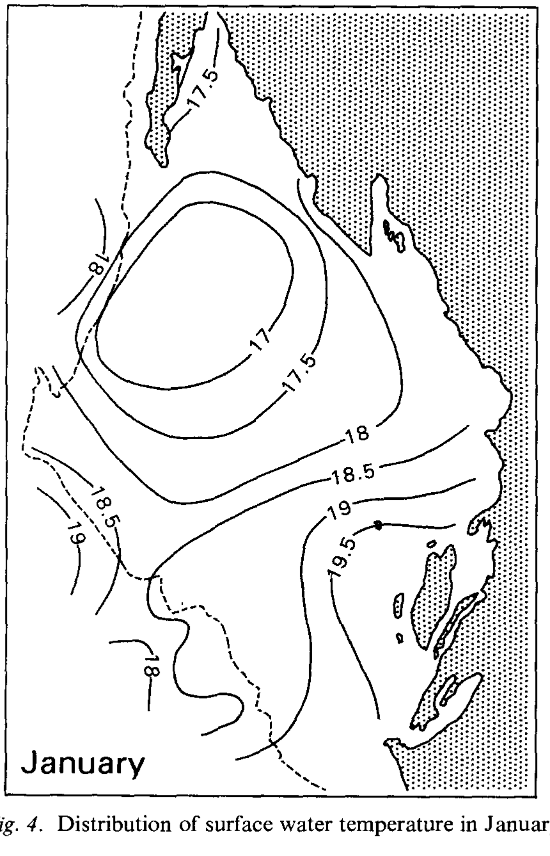

Fig. 4. Distribution of surface water temperature in January.

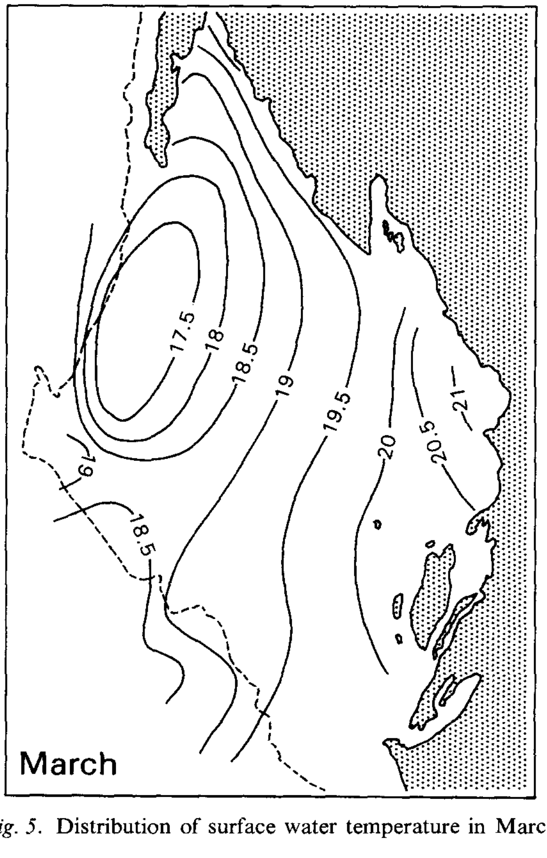

Fig. 5. Distribution of surface water temperature in March.

Surface water temperature

Figures 4–9 show the surface water temperatures in the course of the year. In January temperature conditions are rather homogeneous (Fig. 4), but in March on the one hand upwelling becomes more dominant whereas on the other hand insolation becomes more important (Fig. 5). Thus the temperature gradient across the area becomes stronger. The strongest gradient, however, is observed in May (Fig. 6). Lowest temperatures occur always South of Cap Blanc whereas the highest values occur in the coastal areas such as around the island of Tidra and inside the Baie du Lévrier.

The same pattern occurs in the annual average values of temperature (Fig. 10). The annual fluctuations of temperature are rather small with an increasing trend from the vicinity of Cap Blanc towards the area around the island of Tidra (Fig. 11).

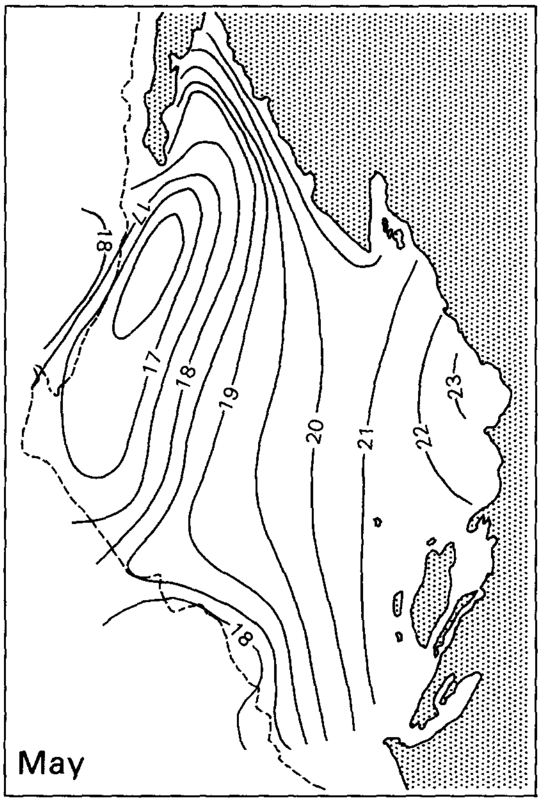

Fig. 6. Distribution of surface water temperature in May.

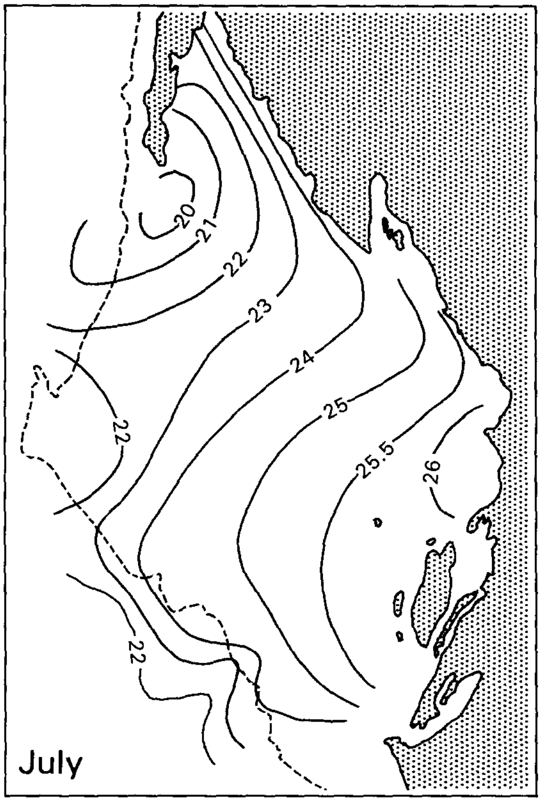

Fig. 7. Distribution of surface water temperature in July.

Surface salinity

The T-S diagrams (Fig. 12) demonstrate the existence of two different water types. One type with salinities between 35.5 and 37 is found at the seaward part of the area and in the entrance of the Baie du Lévrier. The other type with salinities over 38, occurs inshore. Both types change in the course of the year, apparently following the yearly cycle of insolation.

Subdivision of the study area

Our temperature data allow a subdivision of the area studied (Fig. 13). Table 6 gives the various

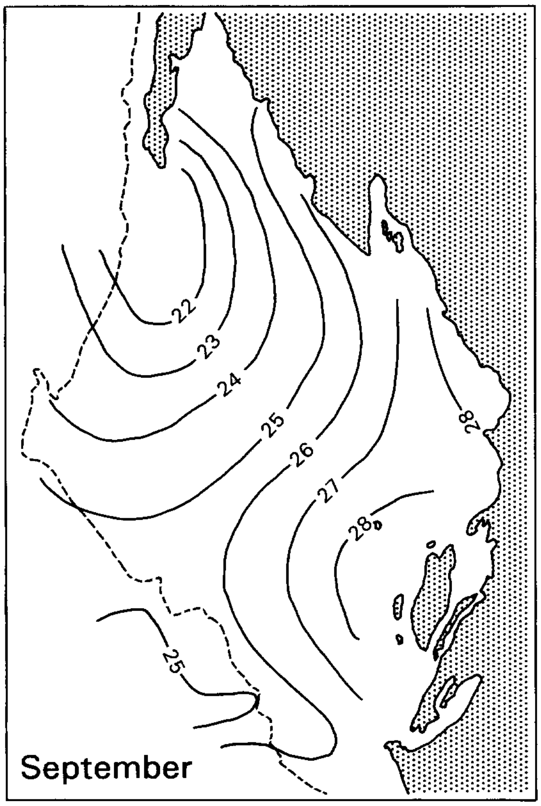

Fig. 8. Distribution of surface water temperature in September.

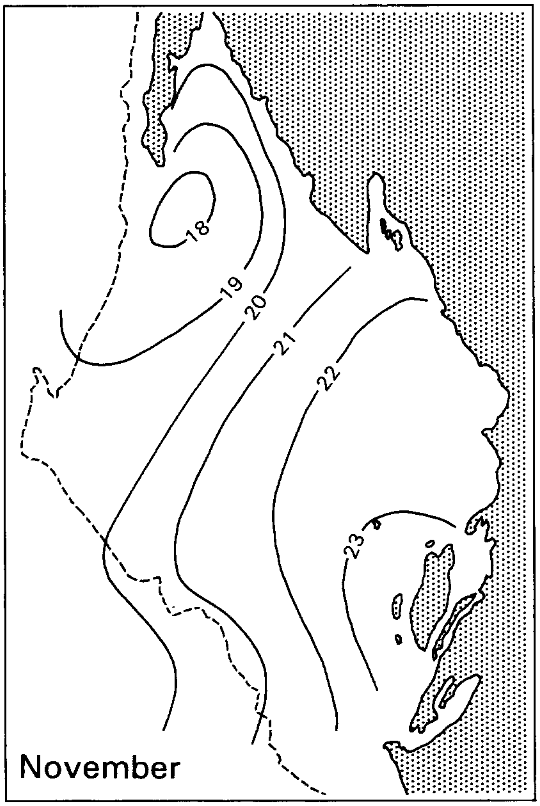

Fig. 9. Distribution of surface water temperature in November.

characteristics of these subareas and compares these with the Mauritanian continental shelf. Based on these data a pattern of water circulation is proposed for the Baie du Lévrier and the region of the Banc d'Arguin (Fig. 13).

Pollution

All domestic and industrial sewage of the city of Nouadhibou (about 50 000 inhabitants) are discharged untreated into the Baie du Lévrier. Particularly the fish processing industry discharges large amounts of oxygen demanding sewage.

Another source of pollution is the iron ore loading facility at Cansado. Dust from this facility is blown into the Baie du Lévrier by the strong northerly winds of the area. Quantitative data are lacking, however.

A major source of pollution are the ships on the roads of Nouadhibou. It is estimated that annually over 8 000 tons of oil are being lost or deliberately discharged into the Baie du Lévrier. The same ships also are the source of large quantities of solid waste. Because of the prevailing winds and currents floating wastes may be expected to drift towards the Parc National du Banc d'Arguin in the South. Indeed, according to observations of the Coast Guard during three periods in 1990 huge quantities of this material wash ashore in several bays near Cap Tafarit. Also South of Iouik solid waste obviously originating from ships is found along the shores (W. J. Wolff, pers. comm.).

Oil pollution may also result from accidents. Especially the vessels provisioning the country itself or the fishing fleet in Nouadhibou are likely candidates for collisions or strandings with serious consequences. Recently two vessels collided near La Guerra and another one ('Rosso II') with 500 tons of gasoil ran ashore on the Banc d'Arguin. Also the large number of abandoned vessels and wrecks (120 in 1989) in Nouadhibou roads constitutes a potential danger of pollution.

Finally oil pollution may result from the offshore transport of very large quantities of crude oil from the Arabian Gulf to Europe, but sofar no signs of this source of pollution have been noticed in the area between Cap Blanc and Cap Timiris. Operational discharges from these tankers are the most likely source of pollution, but the recent large oilspill off the coast of Morocco shows that the Mauritanian coast is also vulnerable to large-scale oil pollution resulting from accidents of oil tankers passing offshore.

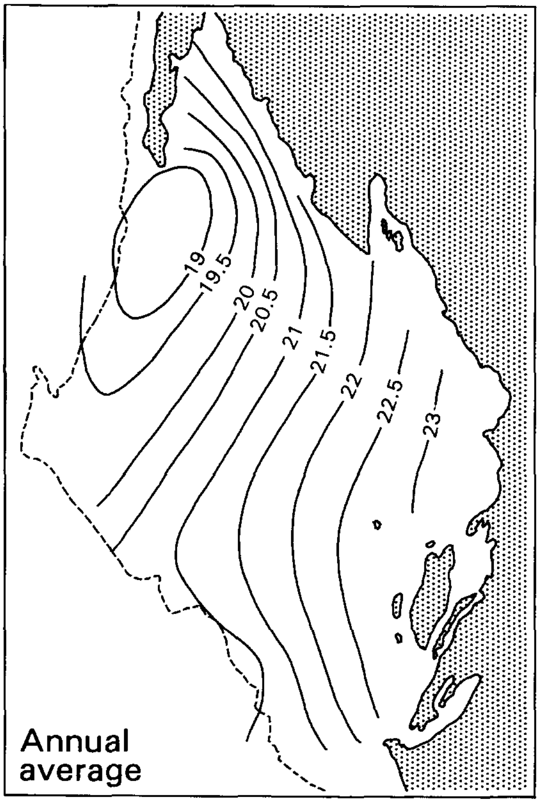

Fig. 10. Distribution of annual mean surface water temperature.

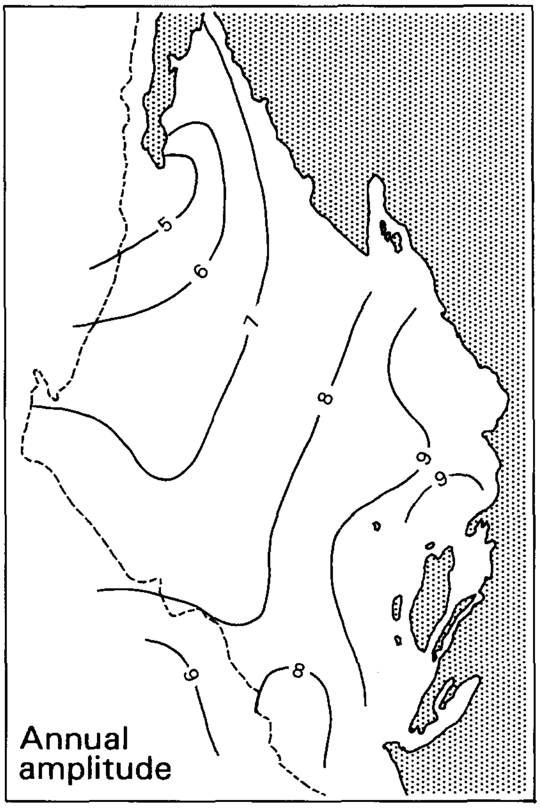

Fig. 11. Distribution of the annual surface water temperature amplitude.

Discussion

The major interest of the CNROP is vested in the large-scale fisheries off the Mauritanian coast. However, data have also been collected in the Baie du Lévrier and in the area of the Banc d'Arguin. Notwithstanding the shallow nature of this area and the fact that large parts are uncharted, it has proven possible for the first time to produce maps for an environmental factor for the entire area between Nouadhibou and Cap Timiris.

The analysis of wind data may be compared to the analysis of a similar data series from the same source by Smit (Smit *et al.*, 1989; Wolff & Smit, 1990). Although this author analysed data from periods different from ours his results are very similar to those of our analysis.

Our analysis of the hydrology of the Baie du

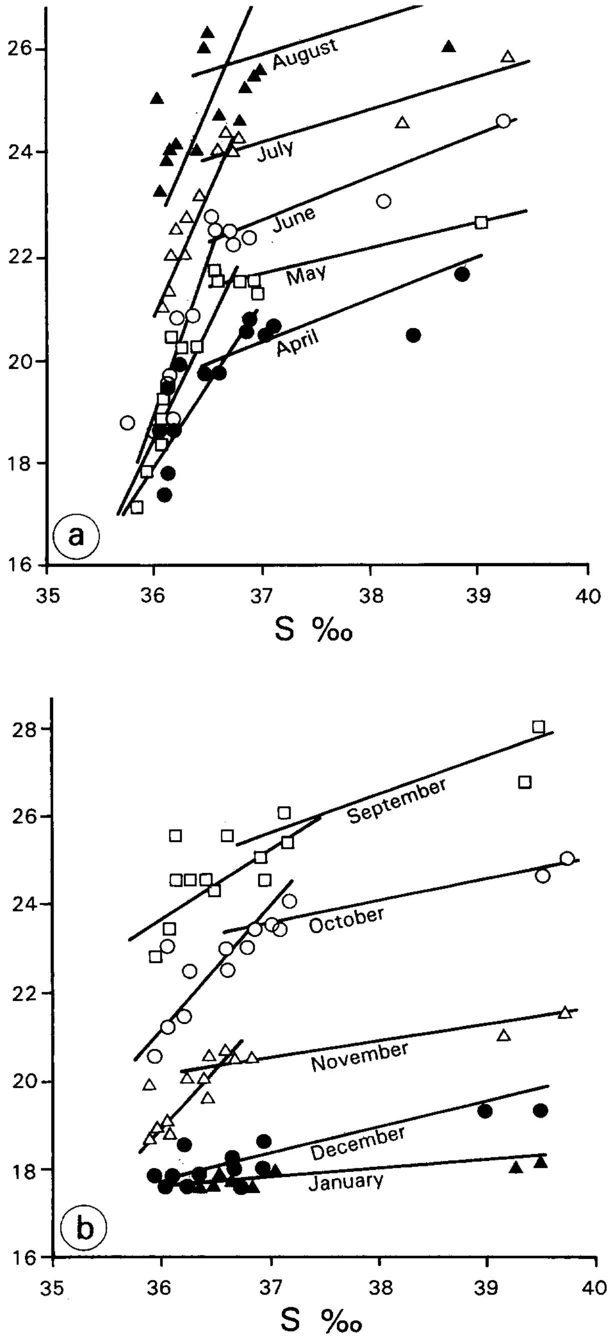

Fig. 12. T-S diagrams for the area of the Baie du Lévrier and the Banc d'Arguin per month.

Lévrier and the Banc d'Arguin has to depart from the observation that this area is influenced by at least four different water types (Tixerant, 1966; Maigret & Ly, 1986; Loktionov, 1993).

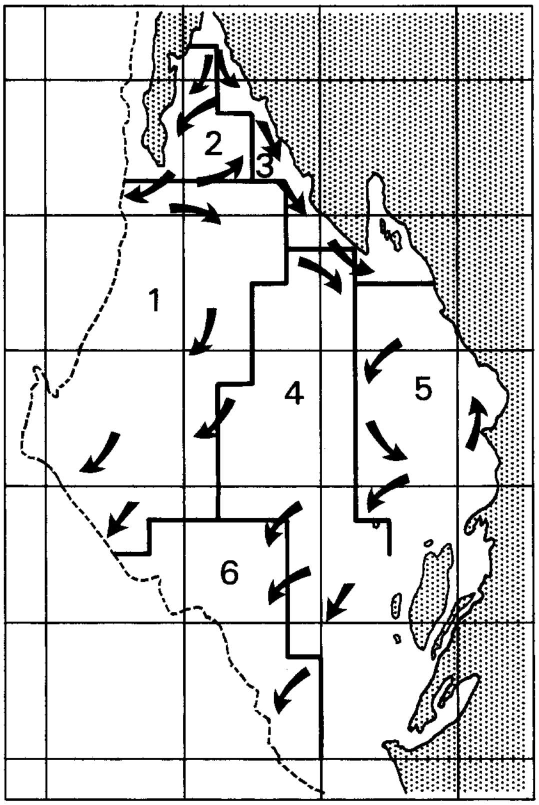

Fig. 13. Subdivision of the Baie du Lévrier and the area of the Banc d'Arguin based on temperature characteristics. The arrows denote our hypothetical pattern of water circulation.

Our maps of surface water temperature confirm hypotheses of earlier authors such as Peters (1976) and Sevrin-Reyssac (1983). In this respect the paper of Cuq (1993) more or less confirms our results.

Our work has also shown how many gaps in our knowledge still exist, particularly for the region of the shallow Banc d'Arguin. The collection of such data will form a major task for the years ahead.

References

Altenberg, W., M. Engelmoer, R. Mes & T. Piersma, 1982. Wintering waders on the Banc d'Arguin, Mauritania. Stichting Veth tot Steun aan Waddenonderzoek, Leiden, 283 pp.

Cuq, F., 1993. Remote sensing of sea surface and coastal features in the area of the Golfe d'Arguin, Mauritania. Hydrobiologia 258: 33–40.

Loktionov, Y., 1993. Hydrographical observations west of the Banc d'Arguin, Mauritania, in May 1988. Hydrobiologia 258: 21–32.

Maigret, J. & B. Ly, 1986. Les poissons de mer de Mauritanie. Centre National de Recherches Océanographiques et de Pêches, Nouadhibou, 213 pp.

Matushevsky, G. V. & V. V. Nadeev, 1987. Statistical laws for the distribution of wind-wave persistence characteristics. Meteorol. Hydrol. 9: 70–75. (In Russian).

Peters, H., 1976. The spreading of water masses of the Banc d'Arguin in the upwelling area off the northern Mauritanian coast. Meteor Forsch. Ergebnisse A 18: 78–100.

Roy, C., 1990. Reponses des stocks de poissons pélagiques à la dynamique des upwellings en Afrique de l'Ouest. Analyse et modélisation. Thèse Doct. Etat, Univ. Bretagne Occ., 149 pp.

Sevrin-Reyssac, J., 1983. Quelques particularités de la chaîne alimentaire marine dans la région des îles du Banc d'Arguin (Parc National du Banc d'Arguin, Mauritanie). Bull. Centr. Natl Rech. Océanogr. Pêches, Nouadhibou 11: 41–52.

Smit, C. J., A.-M. Blomert & L. Zwarts, 1989. Meteorological measurements. In: B. J. Ens, T. Piersma, W. J. Wolff & L. Zwarts (eds), Report of the Dutch-Mauritanian project Banc d'Arguin 1985–86. Report WIWO 25/RIN-rapport 89/6: 16–42.

Tixerant, G., 1966. Régime hydrologique de la Baie du Lévrier. Doc. Lab. Pêches, Nouadhibou, 62 pp.

Trotignon, E., J. Trotignon, M. Baillou, J.-F. Dejonghe, L. Duhautois & M. Lecomte, 1980. Recensement hivernal des limicoles et des autres oiseaux aquatiques sur le Banc d'Arguin (Mauritanie) (Hiver 1978/79). L'Oiseau et R.F.O. 50: 323–343.

Wolff, W. J. & C. J. Smit, 1990. The Banc d'Arguin, Mauritania, as an environment for coastal birds. Ardea 78: 17–38.