FURTHER INVESTIGATIONS ON SOME ENVIRONMENTAL CHARACTERISTICS OF NORTH-WEST ARAB GULF

by HUSSAIN A. AL-SAADI, MASSOUD A. H. SAAD*, RAFIE A. HADI *and* NAJAH A. HUSSAIN, *Department of Biology, University of Basrah, Basrah, Iraq*

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Several environmental factors considered to be the most important for the biomass of the area were studied. Water samples were collected from eleven stations at different water depths in the months of October 1974 (autumn), January (winter), and March 1975 (spring). Transparency increased further away from the mouth of Shatt Al-Arab. Thermal stratification was absent, and only slight temperature variations occurred throughout the whole water column of each station in a given season. Salinity gradient was much more pronounced in stations I—V due to the direct effect of Shatt Al-Arab on these localities. The *p*H values were found to lie in the alkaline side, ranging from 7.30 to 8.39. The highest oxygen values were found in spring.

INTRODUCTION

The rivers Tigris and Euphrates join in Iraq forming Shatt Al-Arab which opens in the Arab Gulf. Both rivers transport to Shatt Al-Arab approximately 5,700 m^3 of water per second (Schott 1918). In August, the combined flow of both rivers decreases and reaches a minimum of 700 m^3 of water per second in October. The river Karun also opens in Shatt Al-Arab on its western side near Abadan.

The Arab Gulf lies within an arid climate region. The great loss of water through evaporation (annual mean 144 cm) is not compensated by precipitation and river inflow (Seibold 1973).

The hydrographical studies on the Arab Gulf are limited and some were cited by Al-Saadi *et al.* (1975). Mohammad (1972, 1975) also made some environmental measurements in the Gulf near Kuwait. Tokyo University of Fisheries and Kuwait Institute of Scientific research (1969) submitted a report on oceanographical survey of the water off Trucial Coast, Qatar, and Kuwait without providing any data. A summary of some investigations dealing with the temperature and salinity characteristics of the Gulf was reported by Dubach (1964). Bibik (1970) made some measurements and studies on some aspects of the biology of the Gulf. The present study was carried out to throw more light on some environmental conditions of the North-West Arab Gulf in order to provide the basic knowledge for further investigations.

*Permanent address : Department of Oceanography, Faculty of Science, University of Alexandria, Egypt.

Materials and Methods

The data of the present study were obtained in October 23–25 (1974), January 22–24 (1975) and March 25–27 (1975) from 11 stations (Fig. 1). The exact geographical location of each station is indicated in Table I.

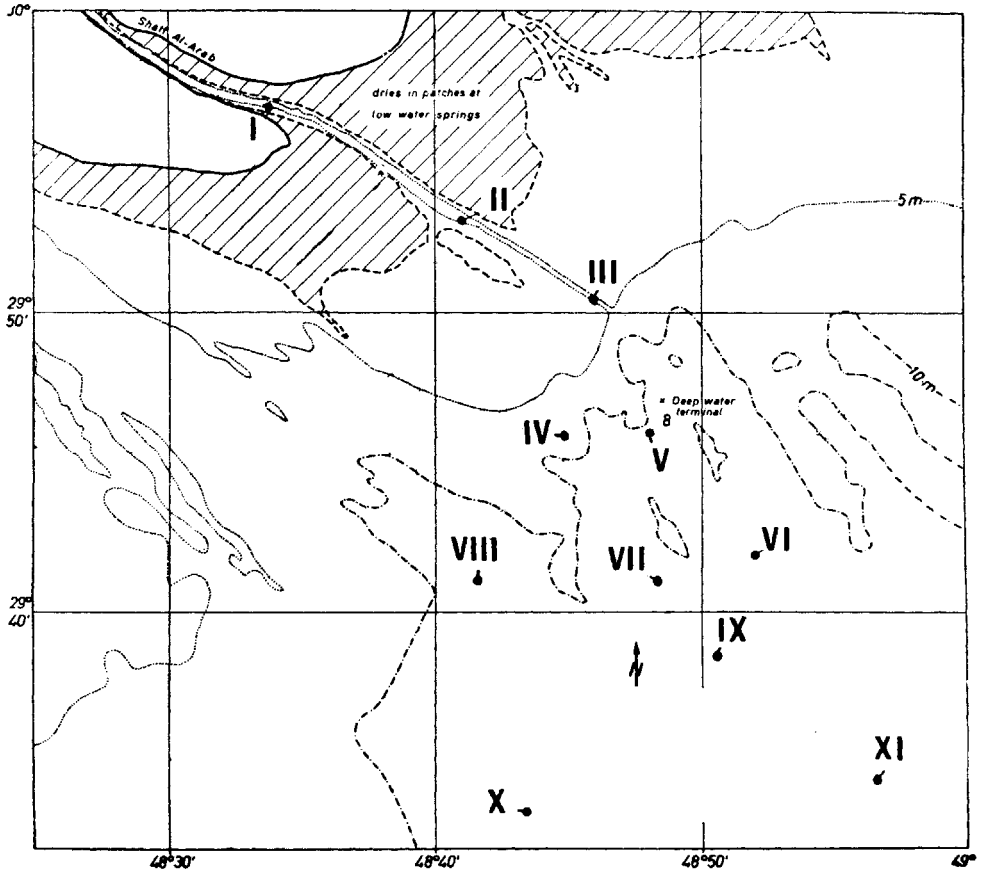

Fig. 1. Geographical locations of stations in the study region.

Table I

The locations of the different stations studied

I	48°	33.8′ E	,	29°	56.8′ N
II	48°	41.0′ E	,	29°	53.0′ N
III	48°	46.0′ E	,	29°	51.0′ N
IV	48°	45.0′ E	,	29°	46.0′ N
V	48°	48.0′ E	,	29°	46.0′ N
VI	48°	52.0′ E	,	29°	42.0′ N
VII	48°	48.0′ E	,	29°	41.0′ N
VIII	48°	41.5′ E	,	29°	41.0′ N
IX	48°	50.5′ E	,	29°	38.0′ N
X	48°	43.5′ E	,	29°	33.5′ N
XI	48°	56.0′ E	,	29°	34.5′ N

Light penetration was measured, using a Secchi disc 30 cm in diameter and an illuminometer (Rigo Submarine Illuminometer. Type 2501 A, Rigosha Co. Ltd. Japan). The Secchi disc extinction coefficient (K) was calculated from the formula "$K = 1.7/D$", where D is the depth of visibility in metres.

Water samples from different depths were collected by means of a van Dorn water sampler. The water depths were provided by the recording Echosounder of the ship.

The portable salinometer (Backman RS 5–3, U.S. Patent 2542057) was used for temperature and salinity measurements. The accuracies of salinity and temperature data obtained by this instrument were ± 0.05°/oo and ± 0.05°C, respectively. The values of temperature and salinity were checked by other methods, namely the thermometer connected with the sampling bottle and the silver nitrate titration respectively. All the data of temperature and salinity of the present study were obtained by the salinometer.

The pH values were measured, using a portable pH-meter (Model 30C, Electronic Instruments Ltd., Richmond, Surrey, England), with an accuracy of $\pm$ 0.1 pH.

The concentrations of dissolved oxygen (mg/l) were determined according to the modified Winkler method as described by Strickland and Parsons (1972).

Results and Discussion

For further hydrographical investigations and also for comparison with the results obtained from previous studies some of the stations selected in the present study were taken from the same localities investigated previously by Al-Saadi and Arndt (1973) and Al-Saadi *et al.* (1975). Regarding the abiotic parameters (transparency, temperature, salinity and dissolved oxygen) the results obtained from the present study are, generally, in good agreement with those of the previous investigations.

The stations from I to V had more or less transitional estuarine characters, mainly at the surface. On the other hand, the rest of stations (VI–XI) were not much affected by the water of Shatt Al-Arab due to their position far away from the mouth of this estuary.

Transparency—Tables II, III and IV show the seasonal and regional variations of the Secchi disc extinction coefficient (K). The percentage light transmission at different water depths was measured only at stations II, IX, X and XI in January and also at stations V and VI in March (Fig. 2).

The highest turbidity was found at the estuarine station I, and the lowest at station VII. These results are in agreement with those found by Al-Saadi *et al.* (1975). The range of K values fluctuated between 0.32 and 6.80 Mohammad (1965) studied the transparency of Shatt Al-Arab estuary, and calculated K values slightly higher than the values of the present investigation, especially at the stations further away from the mouth of Shatt Al-Arab. Higher K values are expected in this estuary due to the large amounts of fine suspended sediments continuously entering into it, mainly from its feeding rivers, and increasing the turbidity of its water. K values as high as 10.43 (visibility depth = 16 cm) were measured during February 1974 in the lower reaches of Shatt Al-Arab (Arndt & Al-Saadi 1975).

TABLE II

Hydrographical data of the stations during October 1974

Stations and Time of sampling	Stations depth (*m*)	Sample depth (*m*)	*K*	Temp. °C		$S‰$	O_2 mg/l	pH
				Air	Water			
I		0			—	5.14	6.86	7.88
	9		1.55	28.5				
11 : 15 a.m.		5			—	35.13	6.86	—
II		0			—	22.47	6.86	8.00
	8		1.70	—				
10 : 00 a.m.		5			—	37.39	7.06	—
III		0			—	35.13	7.00	7.88
	6		0.76	5				
9 : 00 a.m.		5			—	39.85	6.86	—
IV		0			—	31.77	7.77	8.05
	12	5	1.17	—	—	39.72	6.96	—
2 : 30 p.m.		10			—	39.72	6.56	—
V		0			—	38.02	7.77	8.05
	16	5	0.79	—	—	38.93	7.06	—
1 : 30 p.m.		10			—	38.89	6.66	—
VI		0			—	40.37	7.16	8.05
	18	5	—	—	—	40.89	6.96	—
4 : 20 p.m.		10			—	40.89	7.06	—
VII		0			—	40.31	7.26	8.10
	12	5	0.32	—	—	40.21	6.96	—
12 : 00 noon		10			—	40.31	6.96	—
VIII		0			—	39.21	7.47	8.10
	21	5	0.32	—	—	39.76	7.26	—
9 : 00 a.m.		10			—	39.65	6.96	—
		15			—	39.56	6.96	—
		20			—	40.01	6.76	—
IX		0			—	40.36	7.06	8.05
	16	5	0.65	—	—	40.31	6.86	—
11 : 45 a.m.		10			—	40.31	6.66	—
X		0			—	39.41	6.76	8.10
	16	5	0.36	—	—	39.99	7.06	—
10 : 15 a.m.		10			—	40.58	6.76	—
		15			—	40.31	6.66	—

TABLE III

Hydrographical data of the stations taken during January 1975

Stations and Time of sampling	Station depth (*m*)	Sample depth (*m*)	*K*	Temp. °C		$S‰$	O_2 mg/l	pH
				Air	Water			
I		0			13.65	6.32	8.98	8.18
	9		4.25	14.50				
4 : 20 p.m.		5			15.33	30.88	8.17	8.08
II		0			15.18	24.13	8.58	8.28
	8		—	14.80				
6 : 00 p.m.		5			15.72	33.96	8.58	8.22
VI		0			15.37	37.34	8.68	8 10
	18	5	0.85	11.00	15.24	37.15	8.37	8.30
		10			15.31	37.77	8.27	8.20
9 : 00 p.m.		15			—	—	8.27	8.28
IX		0			14.85	38.40	8.52	8.22
		5			14.87	38.58	8.58	8.28
	16	10	—	14.00	14.87	38.38	8.58	8.39
10 : 15 a.m.		15			14.91	38.49	8.58	8.31
X		0			15.51	38.08	8.27	8.19
		5	0.43	—	15.50	37.72	8.27	8.15
	15	10			15.55	38.00	8.27	8.20
11 : 25 a.m.		15			—	—	8.27	8.21
XI		0			16.06	38.25	8.07	8.20
		5			16.14	38.18	8.07	8.05
12 : 35 p.m.	22	10	0.34	12.50	16.14	38.18	8.07	8.10
		15			—	—	8.07	8.09
		20			—	—	8.07	8.00

TABLE IV

Hydrographical data of the stations during March 1975

Stations and Time of sampling	Station depth (*m*)	Sample depth (*m*)	*K*	Temp. °C		$S‰$	O_2 mg/l	pH
				Air	Water			
I		0			19.30	2.50	11.27	7.93
	9		—	21.00				
8 : 00 p.m.		5			19.70	4.60	8.05	7.81
II		0			20.05	—	8.45	7.50
	8		6.80	26.00				
4 : 20 p.m.		5			20.30	7.52	12.68	7.30
III		0			19.90	18.45	10.45	7.70
	6		4.25	22.50				
3 : 15 p.m.		5			19.10	33.91	8.85	7.75
IV		0			18.20	—	11.07	7.80
	12	5	1.00	21.00	18.00	35.46	11.67	7.81
11 : 00 a.m.		10			17.90	—	10.46	7.80
V		0			18.90	35.37	9.26	8.05
		5			18.70	36.67	9.66	7.88
	16	10	1.55	20.00	18.30	37.13	8.85	7.80
7 : 00 a.m.		15			17.90	37.82	9.86	7.95
VI		0			18.60	—	11.07	7.80
		5			18.30	37.00	10.26	7.80
	18	10	0.38	22.00	18.00	38.16	9.46	7.80
9 : 30 a.m.		15			18.00	38.67	9.86	7.80

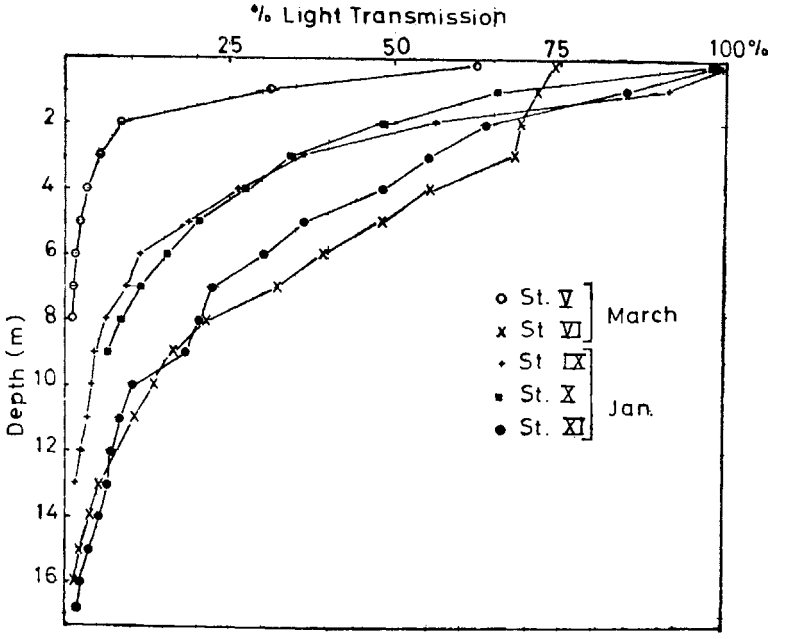

FIG. 2. Percentage of light transmission at different depths of some stations in January and March 1975.

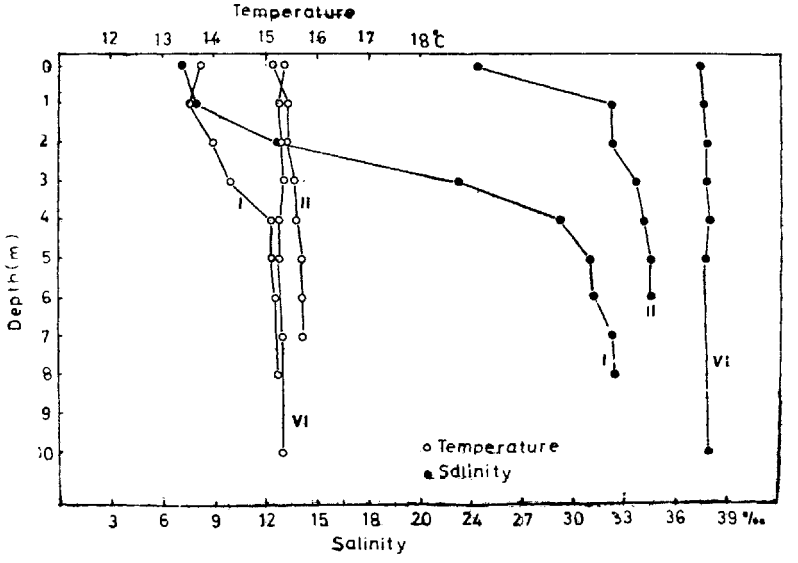

FIG. 3. Vertical variations of temperature and salinity at stations I, II and VI in January 1975.

The transparency increased towards the Arab Gulf (Al-Saadi *et al.* 1975). The depth of 1 % light transmission (penetration depth), which was cited by Lenz (1968) as the approximate compensation point ranged between 8 to more than 17.5 m (Fig 2). Lenz pointed out that the depth of 1 per cent 'ight transmission is equivalent

to 3 times the value of Secchi disc readings, whereas Aleem and Samaan (1969) used 2.5 times the value of the Secchi disc. The measurements of the present study correspond better with those of Lenz.

Temperature measurements—The data of air temperature and water temperature are given in Tables, II, III and IV. Several temperature measurements were recorded at each meter along the vertical profile of stations I, II and VI only in January, and the data obtained are represented graphically in Fig. 3.

The lower water temperature readings were recorded in January with a minimum of 13.65°C at the surface of station I. Bibik (1970) measured temperature values from 16 to 17°C during January in the Gulf. Unfortunately, the water temperature was not measured in October. However, it could be expected to be relatively higher than that of March, due to the relative rise in the air temperature. Dubach (1964) reported that the coldest water temperature in the Gulf was about 16°C during February and the warmest more than 31°C during August.

There were no significant vertical differences in the temperature measurements at all stations. However, the surface and bottom temperature readings gave a difference of about 1°C at some stations during the day as shown in Fig. 3.

Salinity—The data of salinity are given in Tables II, III and IV. Several salinity measurements were carried out along each one meter depth of stations I, II and VI only in January (Fig. 3).

Stations I—V showed estuarine characters as affected by the discharge from Shatt Al-Arab. A similar conclusion was also reported by Al-Saadi and Arndt (1973), although they indicated that station V did not show a pronounced vertical gradient in salinity values in November. As shown from Fig. 3, the vertical gradient of salinity was very clear at stations I and II and not at station VI.

Lower values of salinity were measured in March at stations I—V, especially in the upper water layers, due to the effect of the flood of Shatt-Al-Arab which began in this month and discharged huge quantities of the river water into the Gulf. The results of salinity obtained from stations VI—XI did not show a pronounced vertical gradient. This observation was also found by Enomoto (1971), Al-Saadi and Arndt (1973) and Al-Saadi *et al.* (1975). The salinity was relatively higher in October, and reached values slightly more than $40^{\circ}/_{oo}$ at some stations. Such increase in the salinity values may be due to the relative increase in the rate of evaporation during this month accompanied by less water discharge from the river flow (Schott 1918) and from precipitation. Evans (1966) reported that the salinity range of $37–38^{\circ}/_{oo}$ in the entrance of the Gulf to $38–41^{\circ}/_{oo}$ in the extreme northwest was found to depend upon the river inflow. A high value of salinity of $42.4^{\circ}/_{oo}$ was reported by Emery (1956) for Kuwait and Bahrein water. Meanwhile, Mohammad (1975) reported salinity values of $40\text{-}42^{\circ}/_{oo}$ near the coast of Kuwait. During the spring of 1965 high salinity values of $40^{\circ}/_{oo}$ were measured in the open areas of the Arab Gulf, due to high evaporation losses (Hartmann *et al.* 1971). Bibik (1970) stated that the maximum salinity in the Gulf reached 43–50°/oo at the southern part. Purser & Seibold (1973) pointed out that the surface salinities in the central parts of the Gulf reached averages from 37 to $40^{\circ}/_{oo}$. Such high salinity values in the Arab Gulf reported by several investigators depend, like in the Red Sea, upon the extremely limited supply of fresh water runoff (Dubach 1964).

Hydrogen ion concentration — The values of the hydrogen ion concentration are give nin Tables II, III and IV. The pH values of October were only recorded from the surface waters. The values of pH were found to lie on the alkaline side, ranging from 7.30 to 8.39. In general, relatively lower values were measured at the stations near the mouth of Shatt Al-Arab. This is mainly due to the effect of the water of this estuary which contains extremely lower amounts of dissolved salts in comparison with those found in the Gulf water (White & Hartland-Rowe 1969).

The pH values recorded in March at stations I to VI were slightly lower than those found in the other seasons. This may be attributed to the diluting of the sea water with the flood of Shatt Al-Arab which began in this month. There were no pronounced vertical differences in the values at all stations. This may be due to the vertical mixing processes mainly induced by the tidal currents.

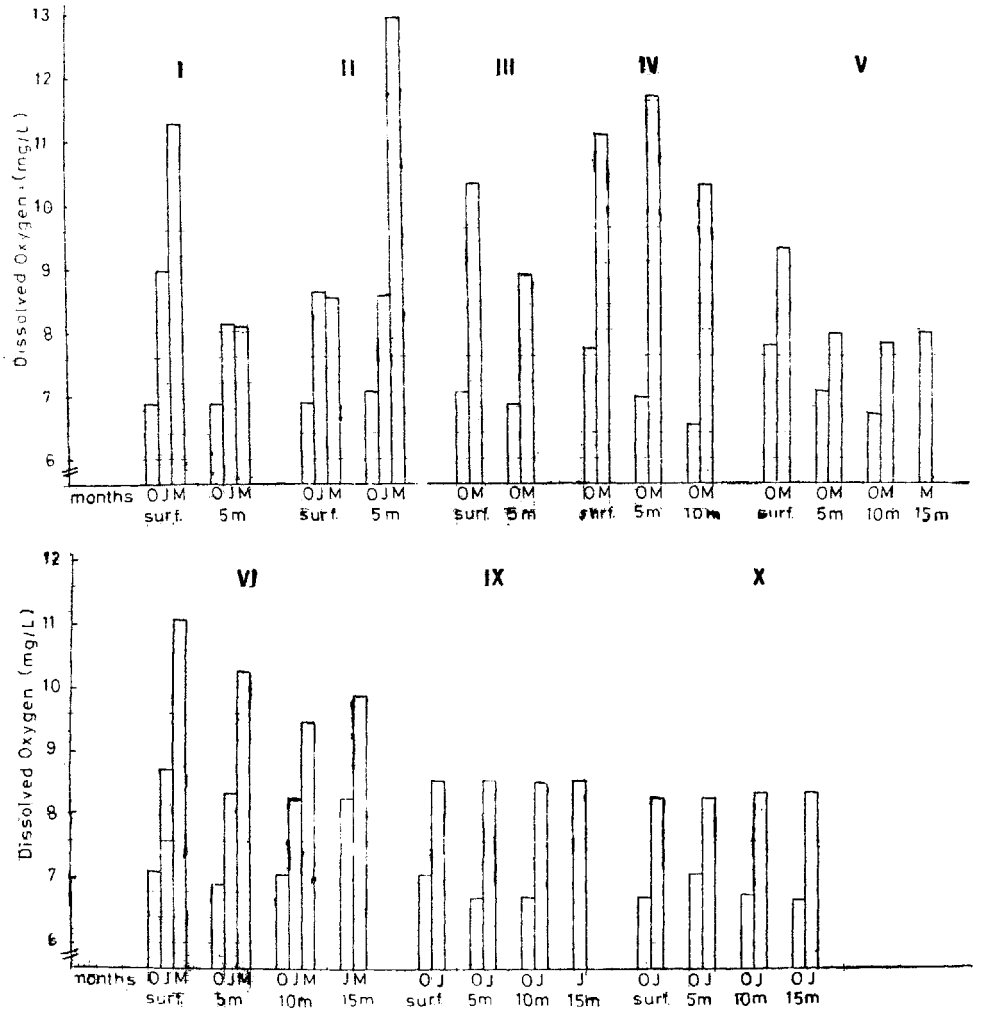

FIG. 4. Vertical and seasonal variations of dissolved oxygen at the different stations (O = October 1974, J = January 1975, M = March 1975).

Oxygen variations — The results of dissolved oxygen found at the different stations are given in Tables II, III and IV and represented graphically in Fig. 4. Generally dissolved oxygen had normal concentrations and distribution in the North-West Arab Gulf. Bibik (1970) reported that the water of the Arab Gulf was characterized by high oxygen content.

The values of dissolved oxygen ranged from 6.56 to 12.68 mg/l. There were remarkable seasonal variations in the concentrations of dissolved oxygen in the studied region. The highest values were found in March and the lowest in October. The dissolved oxygen gave intermediate values in January. Mohammad (1965 *b*) reported few measurements in Shatt Al-Arab estuary and found actual oxygen concentration of about 5.2 ml/l during February 1975.

The highest oxygen values found in March are due to the abundance of phytoplankton blooms flourishing in the spring, especially in the presence of large amounts of nutrient salts transported to the Gulf by the flood of Shatt Al-Arab which began in this month. El-Wakeel and Wahby (1970) and Saad (1973) attributed the increase in the concentrations of dissolved oxygen to the abundance of phytoplankton and the increase of photosynthetic activity in the spring. Al-Saadi *et al.* (1975) attributed the higher oxygen content found in the Arab Gulf at the end of February 1974 in comparison with December 1973 to the higher primary productivity in the early spring.

The lowest oxygen values found in October can be related to the elevation of water temperature during this month (Neel 1951; Ruttner 1953; and Naquib 1958). With the decrease of water temperature in January, the oxygen content of the sea water increased.

Some stations did not show vertical differences in the concentrations of dissolved oxygen and the others had only slight differences. This may be due to the vertical mixing processes, mainly induced by the tidal currents. However, the differences ih the oxygen content between the surface and 5 m depth at stations I and II in March reached relatively higher values of 3.22 and 4.23 mg/I, respectively. This may be related to the direct effect of the flood of Shatt Al-Arab which began in this month on these localities.

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REFERENCES

Aleem, A. A., and Samman, A. A. (1969). Productivity of Lake Mariut Egypt. Part I. Physical and chemical aspects. *Int. Rev. ges. Hydrobiol.*, **54** (3), 313–355.

Al-Saadi, H. A., and Arndt, E. A. (1973). Some investigations about the hydrographical situation in the lower reaches of Shatt Al-Arab and the Arabian Gulf. *Wiss. Ztschr. Univ. Rostock, Math.nat. Reihe.*, **22** (10), 1169–1174.

Al-Saadi, H. A., Arndt, E. A., and Hussain, N. A. (1975). A preliminary report on the basic hydrographical data in Shatt Al-Arab estuary and the Arab Gulf. *Wiss. Z. Univ. Rostock, Reihe. Math. und Naturewissenchaften*, **24**, (6), 805–810.

Arndt, E. A., and Al-Saadi, H. A. (1975). Some hyrographical characteristics of the Shatt Al Arab and adjacent areas. *Wiss. Z. Univ. Rostock, Reine natn und Naturewissenchaften*, **24** (6), 797–904.

Bibik, V. A. (1970). Resuts of the investigations of the 3rd research expedition of Azcherniro on board the SRTM Myslited on the Arabian Gulf (December 1969—March 1970). The Azov-Black Sea research Institute of Marine Fisheries and Oceanography of the Fish Industry of the U.S.S.R. pp. 79.

Dubach, H. W. (1964). A Summary of Temperature-Salinity Characteristics of the Persian Gulf. National Geographic Data Conter, Publication G-4 in NODC General Series, pp. 223.

El-Wakeel, S. K., and Wahby, S. D. (1970). Hydrography and chemistry of Lake Manzalah, Egypt. *Arch. Hydrobiol.*, **67**, 173–200.

Emery, K. O. (1956). Sediments and water of Persian Gulf. *Bull. Amer. Assoc,. Petrol. Geol.*, **40** (10), 2354–2383.

Enomoto, Y. (1971). Oceanographic survey and biological study of shrimps in the waters adjacent to the eastern coasts of the state of Kuwait. *Bull. Tokai Regional Fisheries Res. Lab.*, No. 66, page 1–74.

Evans, G. (1966). Persian Gulf in *The Encyclopedia of Oceanography*, pp. 686–695 (*Ed.* R. W. Fairfield) Reinhold Publishing Corp. New York.

Hartmann, M., Lange, H., Seibold, E., and Walger, E. (1971). Oberflachen-edimente im Persischen Golf und Golf von Oman. I. geologisch-hydrologischer Rahmen und erste sedimentologische Ergebnisse. *Meteor-Freschungsergeh*, C(4), 1–76.

Lenz, J. (1968). Produktionbiologische Unter suchugamethoden (Plankton) in "*Methodern der meeresbiologischen Forschung*". Hrsg. C. Schlieper. VEB Gustav Fischer Verlag Jena, S.256–270.

Mohammad, M. B. M. (1965 *a*). Preliminary observations on some chemico-physical features of the Shatt Al-Arab estuary. *Proc. Iraqi scient. Soc.*, **6**, 34–40.

———— (1965 *b*). Further observations on some environmental conditions of Shatt Al-Arag. *Bull. Biol. Res. Cent., Iraq*, **1**, 71–79.

———— (1972). Infestation of the pearl oyster *Pinctada margaritiferra* Linn. by a new species of *Polydora* in Kuwait, Arabian Gulf. *Hydrobiologia*, **39**, 463–477.

———— (1975). Competitive relationship between Balanus *amphitrite amphitrite* and *Pomatoleios Kraussii* with special references to their larval settlement. *Hydrobiologia*, **46** (1), 1–15.

Naquib, M. (1958). Studies on the ecology of Lake Qarun (Faiyum, Egypt). Part I. *Kieler Meeres-forsch*, **14**, 187–222.

Neel, J. K. (1951). Interrelations of certain physical and chemical features in a hardwater lime-stone stream. *Ecology*, **32**, 368–391.

Purser, B. H., and Seibold, E. (1973). The principal environmental factors influencing holocene sedimentation and diagnosis in the Persian Gulf. In *"The Persian Gulf : Holocene Carbonate Sedimentation and Diagnosis in a Shallow Epicontinental Sea"*, (*Ed.* by B. H. Purser), pp. 1–11. Springer-Verlag, Berlin.

Ruttner, F. (1953). *Fundamentals of Limnology*. Univ. Toronto Press, pp. 242.

Saad, M. A. M. (1973). Some Limnological characteristics of the Nozha Hydrodrome, near Alexandria, Egypt. *Hydrobiologia*, **41** (4), 477–499.

Schott, G. (1918). Ozeanographie and Klimatologic des Persischen Golfes and des Golfes von Oman, *Beil Zn. Ann. der Hydrographie und Maritimen Meteorologie*, **46**, 1–46.

Seibold, E. (1973). Biogenic sedimentation of the Persian Gulf. In *'Ecological Studies'*. Volume **3**, 103–114 : *"The Biology of the Indian Ocean"* (Ed. B. Zeitzschel). Springer Verlag, Berlin.

Strickland, J. D. H., and Parsons, T. R. (1972). *A Practical Handbook of Seawater Analysis*. Fisheries Research Board of Canada, Bull. 167, 2nd Edition, Ottawa, pp. 310.

Tokyo University of Fisheries and Kuwait Institute for Scientific Research. (1969). Arabian Gulf Fishery—Oceanography Survey only Umitaka Maru—Training Research Vessel. Progress Report, State of Kuwait.

White, G. E., and Hartland-Rowe, R. (1969). Temporal changes of physical and chemical factors in a shallow astatic saline lake. *Verh. int. Ver. Limnol.*, **17**, 440–446.