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SEASONAL VARIATIONS OF ACOUSTIC PROPERTIES IN ROPME SEA AREA

By

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التغيرات الموسمية لبعض الخواص الصوتية في الخليج العربي وخليج عمان

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أستخدمت البيانات الهيدروجرافية المتاحة والمقاسة في الفترة من ١٩٦١ حتى ١٩٨٨ في منطقة الدراسة لدراسة توزيع سرعة الصوت في الفصول المختلفة . وقد نوقش في هذا البحث التوزيعات الأفقية لحيود متوسط سرعة الصوت عند الأعماق المختلفة عن ١٥٠٠ متر/ث وكذلك التوزيعات الرأسية في خليج عمان . وقد أظهرت هذه النتائج أن متوسط سرعة الصوت تكون أكبر ما يمكن في الخليج العربي في فصل الصيف عند إرتفاع درجة الحرارة وتكون أقل ما يمكن في فصل الشتاء . أما في خليج عمان فإن الاختلافات الموسمية صغيرة نظراً لأن الطبقة السطحية المتأثرة بالتبادل الحراري تكون صغيرة بالنسبة لعمق الماء . وقد أمكن تتبع القناة الصوتية عند عمق ١٥٠٠ - ٢٠٠٠ متر.
هذه الدراسة لها تطبيقات هامة في عمليات المسح البحري وكذلك الاتصالات تحت سطح الماء .

Key Words: Acoustic, ROPME sea area.

ABSTRACT

Hydrographic data collected in the periods from 1961 to 1988 are used to investigate sound speed distribution in the Regional Organization for Protection of Marine Environment (ROPME) sea area in the Gulf, during four seasons. The horizontal distributions of the anomaly of the vertically averaged sound speed from 1500 m/s showed a minimum deviation (5-10 m/s) in the area delineated by 22-24°N and 60-62°E, i.e., in Gulf of Oman where the depths exceed 2000 meters. The seasonal temperature variations are reflected on the sound speed changes especially west of Hormuz Strait with shallow depths. The vertical sound speed profiles at deep stations in February, March, May, September, November and December, in the Gulf of Oman, manifested a sound channel at 1500-2000 m depth.

In winter, the thermocline layer was not identified west of Hormuz Strait, but in March it starts to develop and was detected in other seasons. In the Gulf of Oman, the thermocline was deeper in winter than in summer. Sound speed was similar in the upper 60 meters. From an acoustic point of view, the basin west of 56°E is considered as a shallow area while the Gulf of Oman is a deep area. Although the thermocline was clear in the shallow part of the study area in summer, the salinity increase with depth cancelled the influence of temperature decrease on sound speed and the profiles became homogeneous.

INTRODUCTION

The sound speed distribution, vertically and horizontally, in the oceans and seas is relevant for several marine applications in both times of peace and war. It is important in the determination of the topographic features and underwater communications, where sound channel detection is of great interest for the submarine operations. The oceans and seas are called acoustically deep when the bottom has a negligible effect on underwater sound propagation. In practical applications of echo-ranging and sonic listening, the bottom reflected sound cannot return an echo if the depth exceeds 400meters. A depth of 200-300 meter is considered a boundary between deep and shallow waters. At supersonic frequencies, most of the ocean areas are effectively deep for practical purposes (U.S. Department of the Navy, 1968 & 1969).

The sound propagation and the percentage of energy reflected and absorbed by sea water and the bottom depend on the oceanographic conditions: the vertical temperature distribution, the type of bottom material, the water depth and the sea state. The seasonal changes of temperature distribution are a major factor affecting the sound speed and its intensity.

Higher temperature is associated with higher sound speed. A sharp thermocline causes loss in transmission below the thermocline layer, and the temperature gradient greatly affects the sound wave ray diagram. The transmission loss is least and the horizontal sound ranges are longer when the surface layer is reasonably isothermal and deeper than 33 meters. Experiments with different types of bottom material showed that transmission over a sand bottom is efficient, i.e., it has a high reflectance. Rock and sand- mud bottoms behave much like a sandy bottom, but the transmission is not as good as for sand. Finally, a mud bottom is not a good reflector of sound rays (U.S. Department of the Navy, 1988).

This study aims to investigate sound speed distribution and its relation to water temperature changes in ROPME Sea Area. This region is limited by 22-31° and 48-62°E. It can be, according to topography, divided into a deep area east of Hormuz Strait (at 56°E) with depths exceeding 2000 meters and a shallow area west of the latter strait with an average depth of about 35 meters and maximum of 55-60 meters. The hydrographic conditions, including water temperature, have been previously studied by Hunter (1986), Hassan and El-Samra (1985) and others.

Data and method of analysis:

The data used in this work were supplied by the NODC at Washington and some of the data were collected by Mukhtabar Al-Bihar, Qatar University. In this analysis sound speed and water temperature are used. The positions at which data were considered are shown by Fig. 1. The number of positions, the years of data collection and the nationalities of the cruises are in Table 1. The number of the casts is in fact greater than the number of positions since 24 hours of observations were done at fixed stations.

In each season, the sound speed along the water column was averaged, by weighted means, at the stations where the measurements were taken to near the bottom. The deviations of the averages from 1500 m/s have been represented in horizontal sections.

The vertical sound speed profiles have been examined. In the shallow part of the area, the sound speed was nearly constant at the different depths. Therefore, only profiles in the deep area (i.e., Gulf of Oman), will be graphically represented.

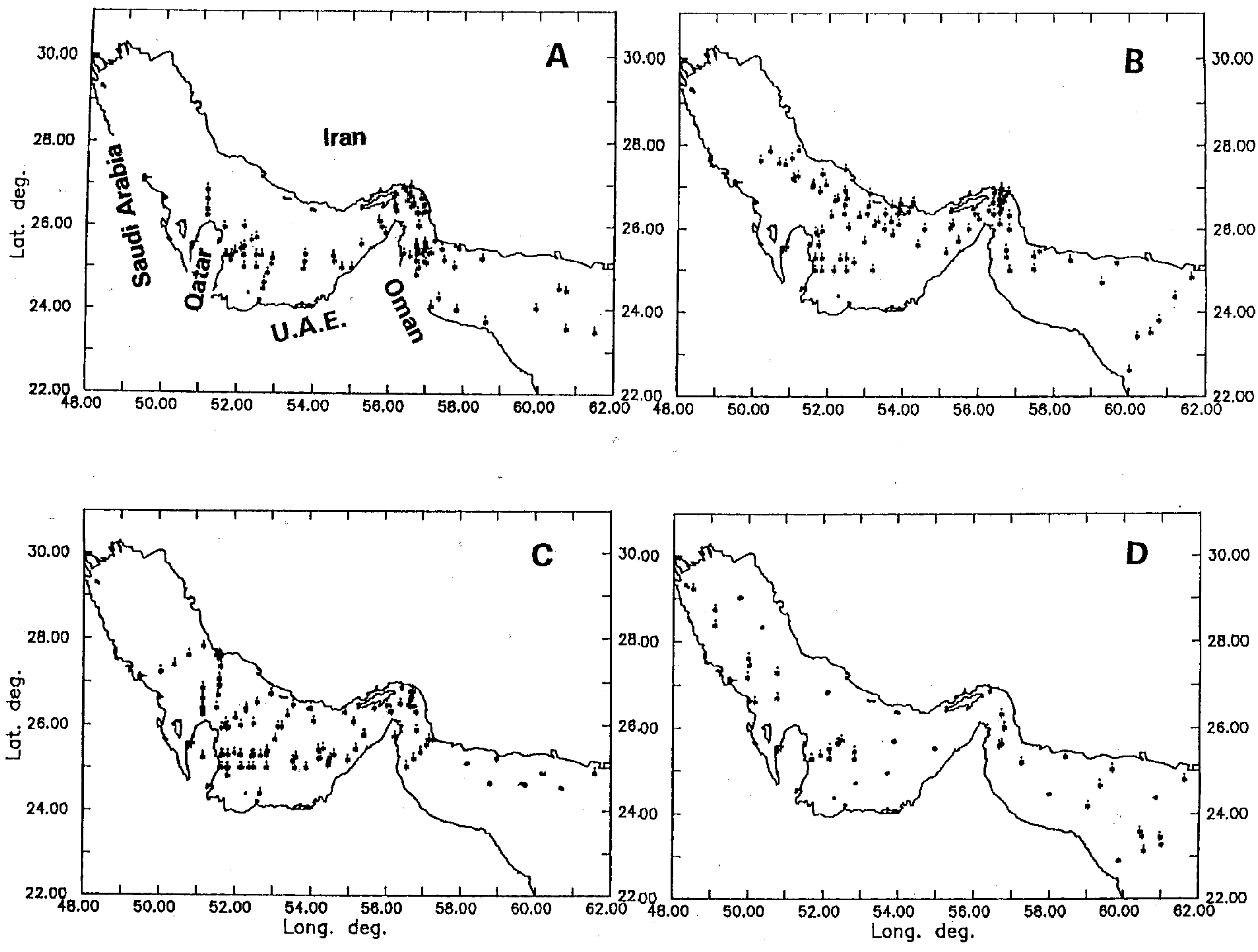

Fig. 1: The positions at which the data were collected in winter (A), spring (B), summer (C) and autumn (D).

Table 1
The number of the positions, periods of data collection and nationalities of cruises, executed in the ROPME Sea Area, whose data are used in sound speed analysis.

Season	Number of stations	Years	Nationality
Winter (January, February and March)	70	1960, 1 961, 1965, 1967, 1969, 1977, 1984, 1987.	USA, UK QATAR GERMANY
Spring (April and May)	81	1961, 1965, 1966, 1967, 1986.	UK, GERMANY USA, QATAR FRANCE, RUSSIA
Summer (June, July, August and September	72	1962, 1968, 1984, 1985, 1986.	RUSSIA, QATAR, INDIA
Autumn October, November and December)	34	1963, 1968, 1983, 1984,	UK, USA, QATAR

The distribution of sea water temperature are taken from previous studies as well as from the available raw data and they will be related to sound speed variations.

RESULTS

The horizontal distributions of the deviation of the average sound speed from 1500 m/s shown by Figs. (2, 3, 4 and 5) in winter, spring, summer and autumn respectively. In winter, the speed deviation west of Hormuz Strait lies between 20 and 30 m/s. In the Gulf of Oman, it lies between 5 and 20 m/s east of 59°E and 20-30 m/s in the region near the Strait. The minimum deviation is found in the region 23-24° N, 60-62°E. In spring, the region west of the Strait has a deviation between 25 and 35 m/s, which is greater than that in winter, but the region east of 56°E has the winter features with high speeds in shallow coastal parts. In summer, Fig. 4., the sound speed is significantly greater than spring with a range of 35-55 m/s, west of Hormuz Strait and 20-40 m/s in the Gulf of Oman. Finally, in autumn, Fig. 5, the speed deviation is between 30 and 45 m/s, west of 56°E, and similar conditions to winter are found in the Gulf of Oman.

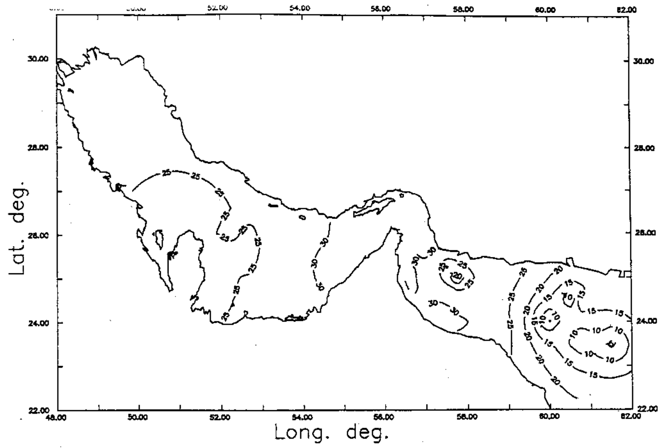

Fig. 2: Average sound speed deviation from 1500 m/s in winter in ROPME Sea Area.

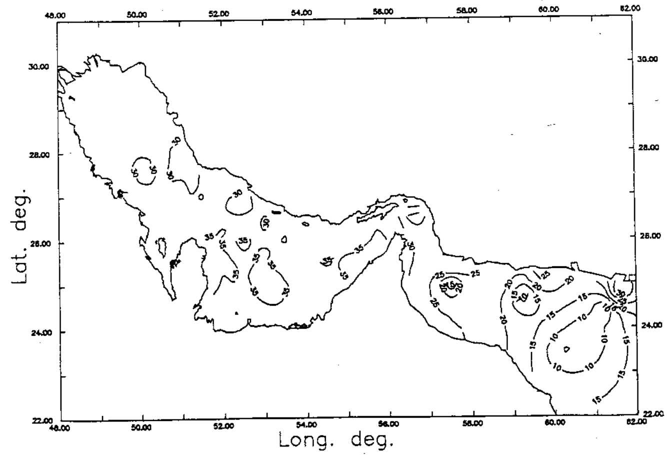

Fig. 3: Average sound speed deviation from 1500 m/s in spring in ROPME Sea Area.

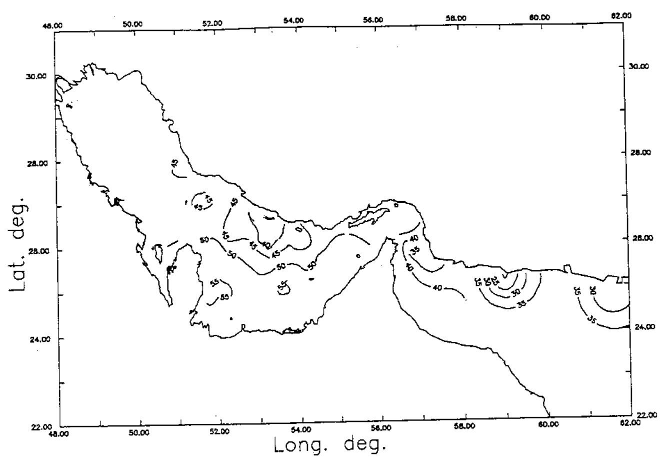

Fig. 4: Average sound speed deviation from 1500 m/s in summer in ROPME Sea Area.

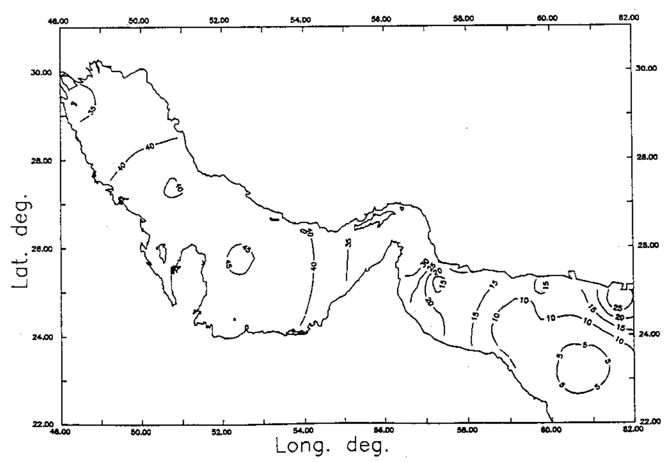

Fig. 5: Average sound speed deviation from 1500 m/s in autumn in ROPME Sea Area.

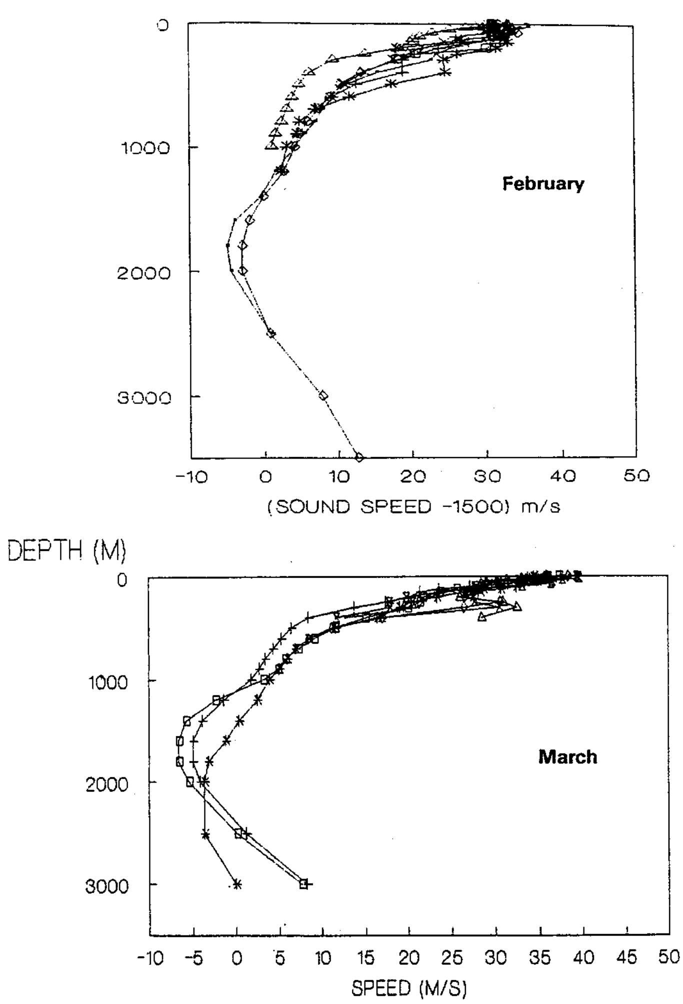

Fig. 6: Vertical distributions of sound speed at deep positions in the Gulf of Oman during February and March.

The vertical profiles of sound speed in the Gulf of Oman during february and March (Fig. 6) and during May, September and November / December (Fig. 7) show that the different profiles are convergent at different depths with only small variation (5 m/s). The existence of a deep permanent sound channel at 1500-2000 meter depth is well manifested, where the sound speed reaches 1495 m/s. The main variations occur in the upper 100 meters, which is a thin layer if compared to the total water depth in the area.

To explain the seasonal variations of sound speed, the NODC temperature records have been inspected to find the depth of the thermocline layer for different months. The temperature in the upper mixed layer was 14-22, 20-28, 28-34 and 20-28°C, in winter, spring, summer and autumn, respectively. During January, the thermocline in the Gulf of Oman was traced at 75-100 meter depth with no thermocline detected west of Hormuz Strait. An increase in temperature below 30 meter depth in the shallow part of ROPME Sea Area and below 50 meter depth in the deep area was often observed. In February and March, west of 56°E, the thermocline was not clear except near Hormuz Strait, where it was between 30 and 50 meter depth. In the deep part of Gulf of Oman a permanent thermocline was located at 150-200 meter depth. In the period from April to September, the thermocline west of Hormuz Strait was traced at 20-25 meter depth, while in the Gulf of Oman it was found at 30-100 meter depth. generally, the sharpness of the thermocline was less pronounced in the shallow areas of interest.

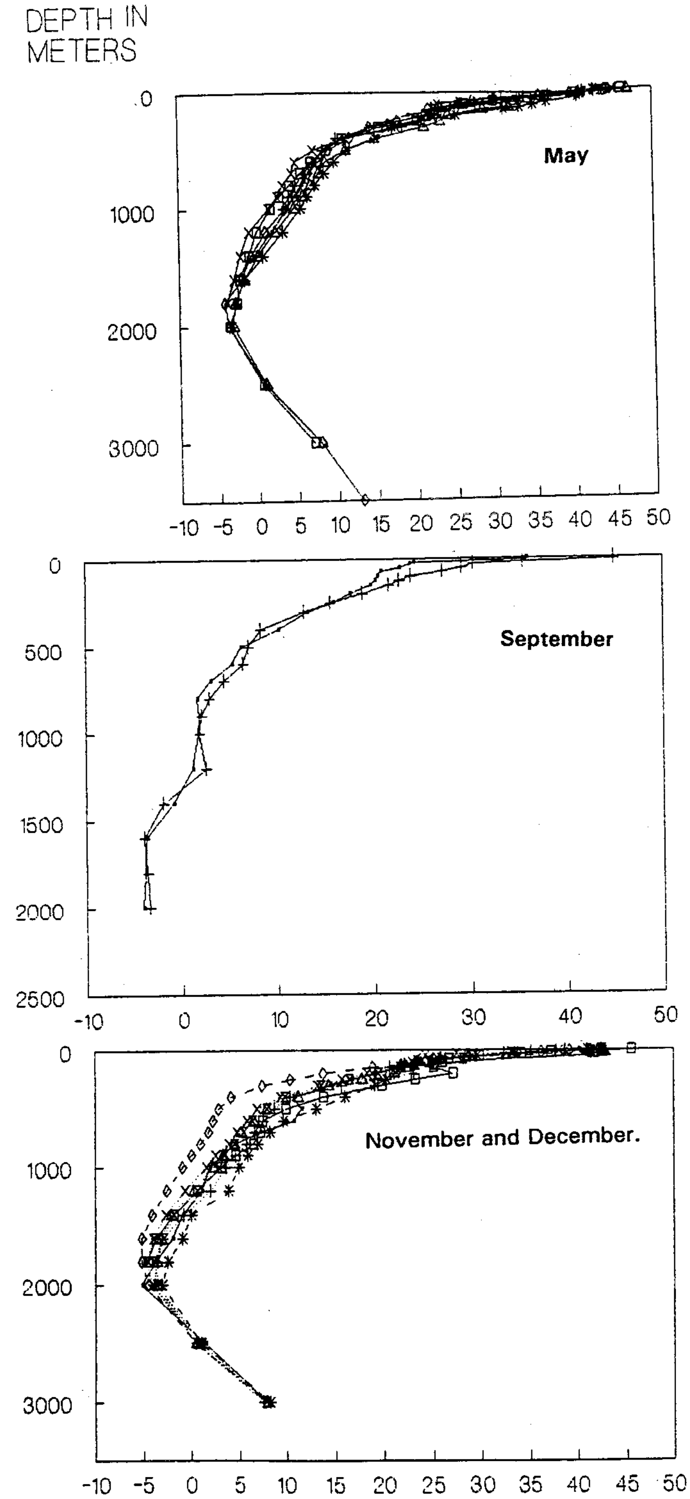

Fig. 7: Average sound speed deviation from 1500 m/s in winter in ROPME Sea Area.

DISCUSSION AND CONCLUSION

The ROPME Sea Area, west of 56°E, can be considered as a shallow region from acoustic point of view, while the Gulf of Oman is a deep area. The vertically averaged speed varies from one season to another with highest values in summer and minima in winter. These variations are more significant west of Hormuz Strait. This can be explained by the importance of the thickness of the upper mixed layer, modified by heat modified by heat exchange with atmosphere, relative to the total depth. The area west of 56°E is a shallow region. The thickness of the upper mixed layer reaches nearly the total depth in winter and early spring, while it exceeds 50% of the total depth in summer. Therefore, significant average seasonal temperature changes occur with parallel changes in sound speed. In the Gulf of Oman, the thickness of the upper layer is small compared with the total water depth and the seasonal temperature variations do not affect the average sound speed considerably. The shallowness of the area west of Hormuz Strait with the vertical mixing explain the small changes of sound speed along the vertical while in the Gulf of Oman, the sound channel is a permanent feature at 1500-2000 m, where only slow changes of water mass characteristics occur.

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REFERENCES

Department of Navy, 1968. Principles and applications of underwater sound. Summary Technical Report prepared by U.S. Department of the Navy, Vol. 7, Head Quarter, Naval Material Command, Washington, D.C. 20360.

Department of Navy, 1969. Physics of sound in the sea. Summary Technical Report, prepared by Department of the Navy, Vol. 8, Head Quarter, Naval Material Command, Washington, D.C. 20360.

Hassan, M.S. and **M. I. El-Samra, 1985.** Physical and chemical characteristics of the ROPME Sea Area. ROPME Symposium on Regional Marine Monitoring and Research Program, Al Ain, U.A.E.

Hunter, J. R., 1986. The Physical oceanography of the Arabian Gulf: a review and theoretical interpretation of previous observations. In Marine Environment and pollution, ed. R. Halwagy, D. Cleyton and M. Behbehani, Kuwait University, pp. 1-25.