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IMPLICATIONS OF CLIMATIC CHANGES ON THE COASTAL AREA OF FUKA-MATROUH

DRAFT

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EXECUTIVE SUMMARY

The study programme for the coastal zone management for Fuka-Matrouh area was planned to cover the climate, the geology, the hydrology, the ecosystem and the socio-economic aspects. Accordingly, the task team of experts was formed to match these discipline in order to establish a sound environmental management policy for sustainable resource development and land-use of the Fuka-Matrouh region. The study has revealed the following main conclusions:

Climate Change and Sea Level Rise

The scenarios of the global climatic change, adopted in the present study are based on the work of Wigley and Raper (1992) which takes into consideration the effect of sulphates and stratospheric ozone depletion. In all seasons the temperature change is more or less close to the global change (i.e. 1°C per degree global change). In Winter, Spring and Autumn, the predicted change is slightly below the global, i.e. 0.7°C to 0.9°C per degree of global change. On the other hand, in summer, the change is indicated to be around or slightly greater than the global change, i.e. 1.0°C to 1.1°C per one degree. The operative scenarios for the time horizons 2030 and 2100 show an increase in temperature in all seasons from 0.6°C to 1.0°C and from 0.5°C to 2.8°C, respectively. In fact. the change is expected to be greater during the Summer season.

The annual precipitation shows a decrease from the time horizons 2030 and 2100 by 0-4% and 0-10%, respectively. There would be a steady decrease in precipitation during Winter amounting to value from 5-20% and from 13-55% in the same time horizons, respectively. However, precipitation in Spring would be increased by a value from 20-65% in the year 2100.

The rise of the mean sea level in the coming century, due to global warming, would be a substantial acceleration over the local rise that has taken place during the present century along the Mediterranean coast of Egypt Several scenarios have been suggested to predict the rate of sea level rise in coming decades. The best-guess scenario, used in the present study, is based on the work of Wigley and Raper (1992) which appears to be 16cm and 48cm rise by 2030 and 2100, respectively.

Main Impacts of Climatic Changes

The present document reports the results of a performed investigation of the potential impacts of the climatic change including the sea level rise effects. The aim is to assess the impacts which the variation of the climate and the rising sea level may cause on each domain; ecosystem and/or human activities. The possible impacts were described qualitatively and wherever possible quantitatively, as well

The most important climatic change would be the northward shift of Winter cyclonic patterns affecting the western Mediterranean coast in Winter. There might be a deceleration of cyclonic activity more erratic rainfall, drier Summers and higher evapotranspiration. Moreover, the increase in the length of the Summer and the decrease of Winter precipitation may lead to extension of Summer aridity.

Due to rising sea level, the eastern part of the coast would be subjected to coastal erosion and flooding of backshore area and depressions, whereas slight impacts are expected to take place at the western port owing to its topography and high elevation. The coastal ridges surrounding the coast at some stretches will partly play an effective role in stopping flooding and damage to the coast.

Small pocket beaches and small bays will be the first to experience the impact of a gradual rise in sea level. The instability and breakup of barrier islands could become more frequent in the coming decades. Beaches in front of these barriers could be subjected to accelerated erosion. Low sandy coasts have the capacity to reform themselves with the rising sea level by gradual migrating landwards.

A consequence of rising sea level would also be a much increased statistical occurrence of extreme events like severe storms, waves, currents, high tides etc.

Increase of temperature is not expected to have an effect on the decomposition of organic matter in soils. Increase of air temperature will change the soil thermal regime. Higher temperature will reduce soil moisture and thus increase soil/wind erosion, soil fertility and soil salinity. Also, it would accelerate land desertification.

The increase of rainfall by 2030 will be very low and of insignificant effect on runoff. But, however, the rainfall decrease would cause a reduced ground water recharge and thus less thickness of fresh water layer in the plireatic ground water aquifers is expected. Therefore, the amount of drinking water may not be sufficient for people and animals.

Due to the rise in annual temperature and decrease in precipitation, the natural flora of the inland may shift northward. The flora of the present inter-dunal depressions may expand at the expense of the original endemic flora.

The decline in precipitation and increase in temperature may also lead to a shrinking in vegetation cover and hence decreasing the food available for herbivorous mammals and in turn decreasing their population and consequently the population of carnivorous mammals.

Global warming may alter the migration rhythm of the wintering migratory birds. The reptile community in the area may also have some alterations. The higher temperature may increase the probability of the appearance of jelly fish swarms, and in addition due to the higher salinity, may urge the lessepsian immigrants to inhabit the area.

Rainfall decrease and temperature increase will affect the pattern of cultivated crops. Change in rainfall and increase in evapotranspiration may lead to a reduction in the cultivated areas and agriculture is likely to change towards even more intensive farms. A change in crop productions and decrease of soil fertility are expected. Some tropical and sub-tropical plant diseases will move northwards and the distribution of insects and pests will be altered.

The impact of temperature increase could be significant in important fish species. Migration pattern of pelagic fish, as well as their spawning area, could be changed.

Marine grass meadows are particularly sensitive to reduced water transparency, as a result of sediment loads in the water due to rising sea level. On the other hand, a rise in water temperature may be expected to favour sea grass meadows.

Temperature rise will increase energy demand for air-conditioning in Summer. More demand for energy is expected for the new developments in the regular industry and for the expanding touristic industry sector.

Temperature increase may also favour the consumption of beverage and may encourage their production in the area.

The relatively serious problem may be the deterioration of the historical heritage located in the area due to the rise in water table elevation.

Increase in precipitation and temperature may affect the existing infrastructure of the area which would dictate more upgradings.

Climatic changes will result in corrosion of the water supply pipes. Increased temperature will speed up the rate of anaerobic decomposition of the organic matter in the sewage system which leading to dangerous levels of methane build-up and risk of explosion.

The change in the climatic conditions are expected to have only a limited impact on vital behaviour of populations, and will probably have insignificant effect on the ongoing evolution of population distribution and demographic pattern.

Measures to avoid, mitigate and adopt to the predicted affects

The following measures to avoid, mitigate and adopt to the predicted affects are proposed:

1. Using cleaner energy sources (solar, wind and wave energy) and technologies to reduce CO_2 emissions and emission of pollutants that cause environmental problems.

2. Design of coastal protection measures in critical coasts to the east. Suitable stabilisation methods (by using plants, wood fences, spraying, etc.) should be undertaken for the coastal dunes which act as barriers against sea attack.

3. Gradual landward transfer of some touristic projects which are located at critical coasts.

4 Carry out extension programmes to upgrade awareness of water users concerning scarcity of fresh water resources and introduce cultural practices of water conservation.

5. Select suitable tolerant without drought crops, shrubs and forage plants to maximise yield and minimise adverse impacts.

6. The laws protecting the wild life have to be strictly implemented.

7. Invest in fisheries and aquaculture research is currently inadequate. The technology of rearing fish in cages is simple and does not require much place or capital.

8. Matrouh airport should be widened to combat with the increase of the number of tourists and the investors for the new developments. Local roads should be also widened and paved to facilitate the motion in the study area. The railway line could be doubled.

9. Adoption of expected safety elevation for drainage and sewerage system.

1. INTRODUCTION

1.1 BACKGROUND

It became almost accepted, that the concentration of greenhouse gases would effect the pattern and the balance of the solar radiation in the atmosphere to the extent that a rise in the global mean surface air temperature would take place in the next century. Furthermore, the Second World Climate Conference, held in Geneva in 1990, has highlighted to long term implications of climate change which were considered as major scientific environmental socio-economic and political challenges. The Conference consensus, has put the expected global warming change in a range between 2°C and 5°C over the next century, if no effective action is to taken to reduce gas emissions in the atmosphere. This would lead to a sea level rise as much as 65 ± 35 cm. With such alarming figures in mind, many international and regional associations and organisations have set to work to establish an assessment for the possible impacts of the climatic changes and to explore ways and means to face it at the right timing. The Mediterranean Action Plan of UNEP, was one of the leading organisations to account for this threat and has guided and encouraged the execution of several case studies within the Mediterranean basin. One of these studies is the present one, made on Fuka-Matrouh region of Egypt.

The outlook of the socio-economic projection of the inhabited zones in Egypt, places a great importance on the role, the Egyptian coastal zone would be playing in the near future, as anticipated in the country global planning. Due to the present fast increasing population, and for certain security measures, the adopted strategy for demographic distributions calls for a balance between the heavily populated Nile valley and delta zone and the sparsely occupied coastal zone, specially the strip encroaching the Mediterranean.

This implies that these zones would accommodate in the coming years a sizeable part of the population and have to provide them with adequate working opportunities, food production, housing and other infrastructures and living facilities.

In the recent past, expansion in arable land development has caused reclaiming almost all the suitable lands lying within the lower Nile delta region, even some areas that were originally parts of the northern lagoons were already reclaimed. So, most of future land reclamation expansion would be positioned at the north western and the north eastern sides of that region.

With respect to industry and commercial activities, at the Mediterranean coastal region it has been expanding for the last few decades, but mainly concentrated around the main coastal cities, at the lower delta, and it is expected to keep on, the same way, at least for the next few decades.

The coastal touristic developments including erection of new Summer resort installations on the beaches, have enjoyed a booming time during the last decade, mostly at west of Alexandria till Matrouh and around El-Arish, in the East. Unfortunately, it took a hasty and uncontrolled development trend that lacked integration with environment and with land-use principles. However, the inertia with which this activity is moving now, shows that it will continue as such, for some time, unless virtual integrated coastal zone management based on deep studies becomes operative.

The area covered by the present study, which extends for some 72 km from Fuka; longitude 27° 55' to Matrouh, longitude 27° 10', and which overlooks the Mediterranean, is considered to be a virgin area with almost no industrial activity in the time-being. So, it forms a good pilot study area for the north western coastal zone. A zone that will become shortly at the top of the development agenda.

The area is arid and as being a coast encroachment, it is of a fragile nature but also bearing many valuable assets and resources, that call for reasonable development based on sustainability concept. Many natural environmental and managerial constrains are threatening this area, like scarcity of water in quantity and quality, soil salinity, availability of agricultural soil, probabilities of climate change and sea level rise due to the increase of concentration of greenhouse gases in the atmosphere, uncontrolled development trends, and hasty and unintegrated managerial policies

For all these reasons, this area was selected to be the venue for the present study and for these challenges, it exhibits its importance.

1.2 BASIC FACTS ABOUT FUKA-MATROUH COASTAL REGION

The terrestrial Fuka-Matrouh study area is almost square in shape. It extends for about 72 km along the Mediterranean between east longitudes 27° 55' and 27° 10', and is located in the middle of the northern part of Matrouh Governorate, with a width of about 70 km southward from the Mediterranean shore line, till the elevated south plateau, as shown in Fig. 1.

The climatic condition of the area ranges between a semi-Mediterranean in the North at the coastal plain, to an arid in the southern part. The average annual rainfall is around 140 mms in the north and decreases rapidly southward. The rain falls during Winter from mid-October to mid-March. The Summer season is warm and dry, with absolute maximum temperatures around 35°C and average maximum temperature of about 24°C, against absolute minimum and average minimum temperatures of 5°C and 9°C in Winter, with about 19.3°C as overall annual temperature average.

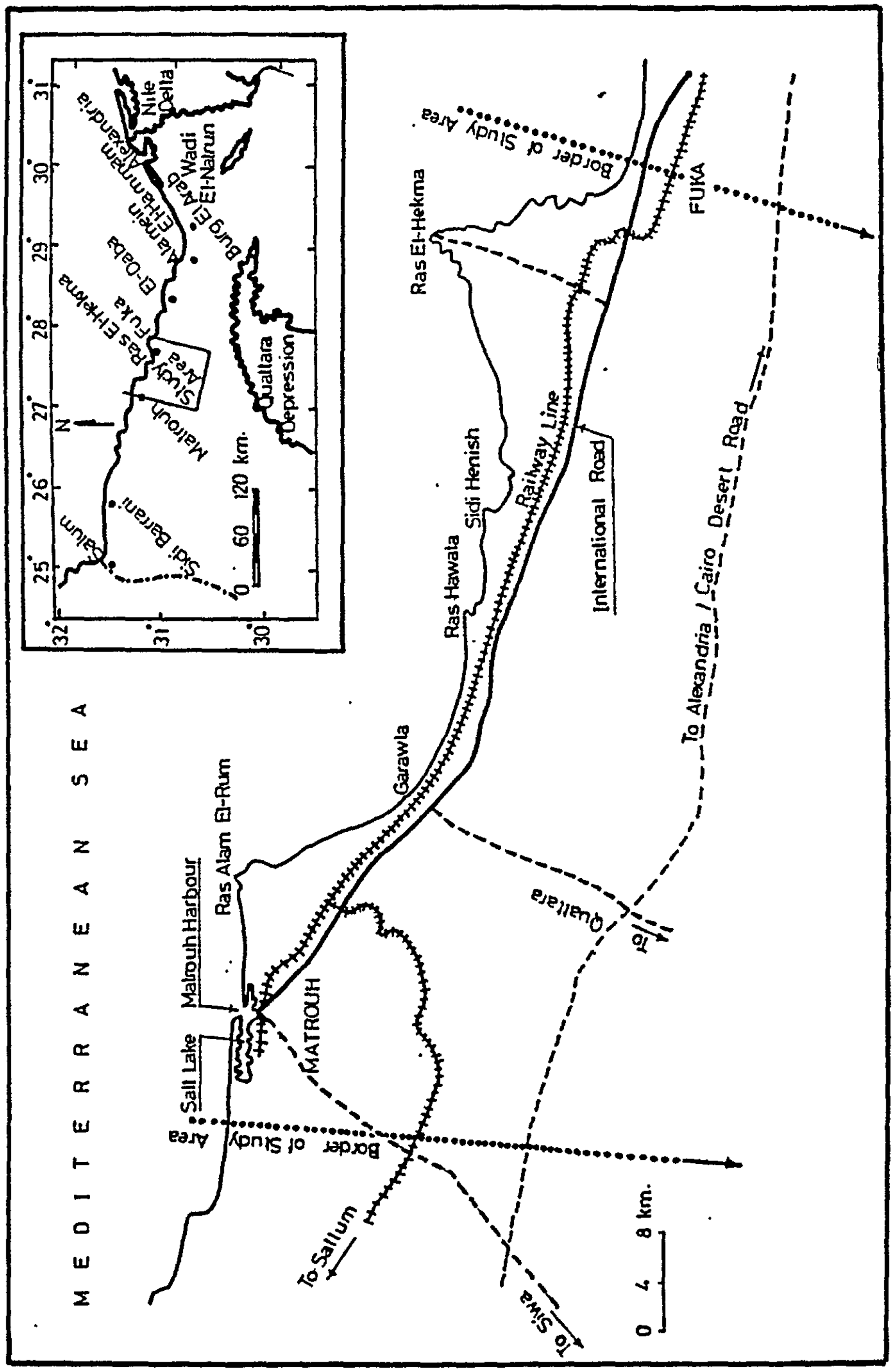


Fig. 1: General Location Map

The average relative humidity encountered in the study area is about 70% during Summer and could sometimes reach 90%, while it decreases to about 50% during Spring.

The area is covered mostly be sedimentary calcarious rocks, and in general terms, it could be regarded as composed from three conspicuous geomorphological units from north to south, i.e. the coastal plains, the northern plateau and the southern plateau. The coastal plains have a width ranging between 1 0 and 3 5 km and contain the foreshore plain, the frontal plain and the piedmont plain sub-units. The foreshore plain contains some ridges running parallel to the shoreline alternating with lagoons, salt marshes and alluvial deposits in-between The northern plateau has a width ranging between 13 and 19 km. It is an elevated rocky land of 30 to 80 ms high above sea level with a general northward slope. It has rocky soil batches in some localities with some 45 wadies cutting through, bearing alluvial sediments The southern plateau has about 50 km width and is characterised by its sand dunes, depressions and rocky soils. This plateau has an elevation ranging between 80 and 120 ms above sea level.

The present total population of the study area amounts to about 49,000 mainly concentrated in the coastal zone with average population density of about 10 persons per km^2. This density is against a figure of less than one per km^2 in the Governorate of Matrouh as a whole, and some 1,500 per km^2 in the delta and Nile valley. The average annual growth rate, in the study area is about 3.2% of which 10% is due to migration.

The area is served by reasonable transport facilities, the important ones being:

a. the Alexandria-Matrouh-Sallum highway road, which is dual way and crosses the area near the coast from east to west and is part of the North Africa international highway;
b. the railway line joining Sallum and Matrouh to Alexandria;
c. the single way road which is located at about 15 km south of the international highway and which joins Sallum to Alexandria-Cairo desert road at the 70 km land-mark from Alexandria; and
d. a group of unpaved roads running mostly from north to south, serving the local communities and settlements scattered in the area.

Grazing and cultivation are the main income source of the natives which are named the Bedouins. The cultivated land which constitutes 3.2% of the total land area is about 40,000 feddans (one feddan = 4,200 m^2) and is distributed between fig, olive and almond orchards, barley and wheat fields and range-land. Agriculture depends mainly on winter rainfall, whose annual average amounts to about 33 x 10^6 m^3, and which varies a great deal from one year to another. This water is harvested through a group of cisterns, dykes and sawani constructions However, some limited underground water is also used for human, agricultural and animal consumption as in Fuka, Ras El-Hekma and Burbeta. Most of the orchards are located in the wadis deltas, where the fine grained soil cover is deep enough. Grazing was entirely depending on the natural vegetation cover batches, but recently some attempts are made to grow certain types of trees for grazing.

In the last few years, an unconventional economical resource has begun to develop in the area, with the emerge of summer resort tourism activity with its huge infra-structures along the coastal zone. This new investment activity seems to keep its expanding momentum, in the coming years and eventually would play a major role in the socio-economic system and in the social structure of the natives.

1.3 HOW COULD GREENHOUSE GASES EFFECT THE CLIMATE?

Knowledge of how the land, oceans and atmosphere interact and how they might respond to increased concentrations of greenhouse gases is not complete. However, computer models can simulate, to some degree, these complex relationships and their effect on climate. These computer models use estimates of future greenhouse gas emissions level to model possible future concentrations of atmospheric greenhouse gases, global temperature, environmental conditions and climate.

Changes in the concentration of atmospheric greenhouse gases can alter the way they interact with the atmosphere, oceans other features of the Earth's surface, and this will, in turn, have further effects on greenhouse gas concentrations. Such changes are known as greenhouse gas feedbacks. Although feedbacks are not yet fully understood, it is likely that, in a warmer world, feedbacks would increase rather than decrease greenhouse gas concentrations.

A conference on the role of carbon dioxide and other greenhouse gases in climate change held by the World Meteorological Organization (WMO), the International Council of Scientific Unions (ICSU) and UNEP in 1985 concluded, on the basis of the information available at that time, that current trends in emissions of CO_2 and other greenhouse gases would lead to a warming effect equivalent to a doubling of CO_2 (in relation to pre-industrial levels) by about 2030. This would lead to global warming of 1.5-4.5°C and sea level rise of 20-140 cm during the next century. WMO/UNEP held two workshops in 1987 to examine the conclusions of the 1985 conference in the light of new scientific research, and to discuss the possible effects of climate change on the environment and society. The workshops produced three scenarios for future greenhouse gas emissions and corresponding temperature rises by 2050 On the basis of a large rise in greenhouse gas emissions, the forecasts estimated a temperature increase of 0 8°C per decade. If there were no change in emissions trends, the increase would be 0.3°C per decade. And if restriction on emissions were introduced, the rise would be only 0 06°C per decade. Temperature changes in these ranges were estimated to lead to a sea level rise of between 30 and 150 cm by 2050.

In 1988 WMO and UNEP created the Intergovernmental Panel on Climate Change (IPCC). Three panels were appointed to make a scientific assessment of the climate change issue (Working Group I), to assess the impacts of climate change (Working Group II) and to formulate response strategies (Working Group III). Working Group I developed four scenarios for future greenhouse gas emissions (see Fig. 2) The first assumes that few or no steps are taken to limit emissions, and is termed Business as Usual (BaU). The other three scenarios - referred to as scenarios B, C and D - assume that increasingly strict controls will reduce future emissions. The CO_2 levels and their corresponding temperature rises projected in these four scenarios are shown in Fig. 2. Under the BaU scenario, average global temperature was calculated to increase by approximately 0.3°C per decade, resulting in a temperature rise of about 1°C by 2025 and about 3°C by the end of the next century. Sea levels would rise by about 65 cm by 2100. Scenarios B, C and D would lead to temperature increases of about 0.2°C, a little more than 0.1°C and about 0.1°C per decade respectively. These predictions are based on average values obtained by a number of different computer models.

Discussion of the possible effects of greenhouse gas emissions on climate is complicated by the fact that Working Group II - the group that studied the impacts of climate change - concluded that an effective doubling of CO_2 by 2025-2050 would cause an average global temperature increase in the range of 1.5-4.5°C.

Computer models indicate that warming will not take place uniformly over the planet: it will be more intense at higher than at lower latitudes, and greater in the winter than in the summer. In some areas in high northern latitudes in winter, warming could be 50-100 percent greater than the global average. Air temperatures rise more rapidly over land than oceans, and there is likely to be a time lag between increased greenhouse gas concentrations and increased air temperatures, particularly in areas influenced by deep water circulation such as the northern North Atlantic and the southern oceans near Antarctica.

The atmosphere is a self-renewing resource. The oxygen we use is ample in supply and is continuously replaced through photosynthesis at the expense of (partly man-made) carbon dioxide. Natural processes, mainly precipitation, normally act to cleanse the atmosphere of undesirable gases and dust particles, but some of the gases and particles dissolve in the cloud and rainwater, altering their chemical make-up and creating what has become known as acid rain. Cleansing is not always achieved before the gases and particles noticeably interact with sunlight, which causes visibility to decrease the atmospheric turbidity to increase. It came to be recognised, therefore, that the environment could be seriously and dangerously impaired by steadily increasing industrial production and individual consumption.

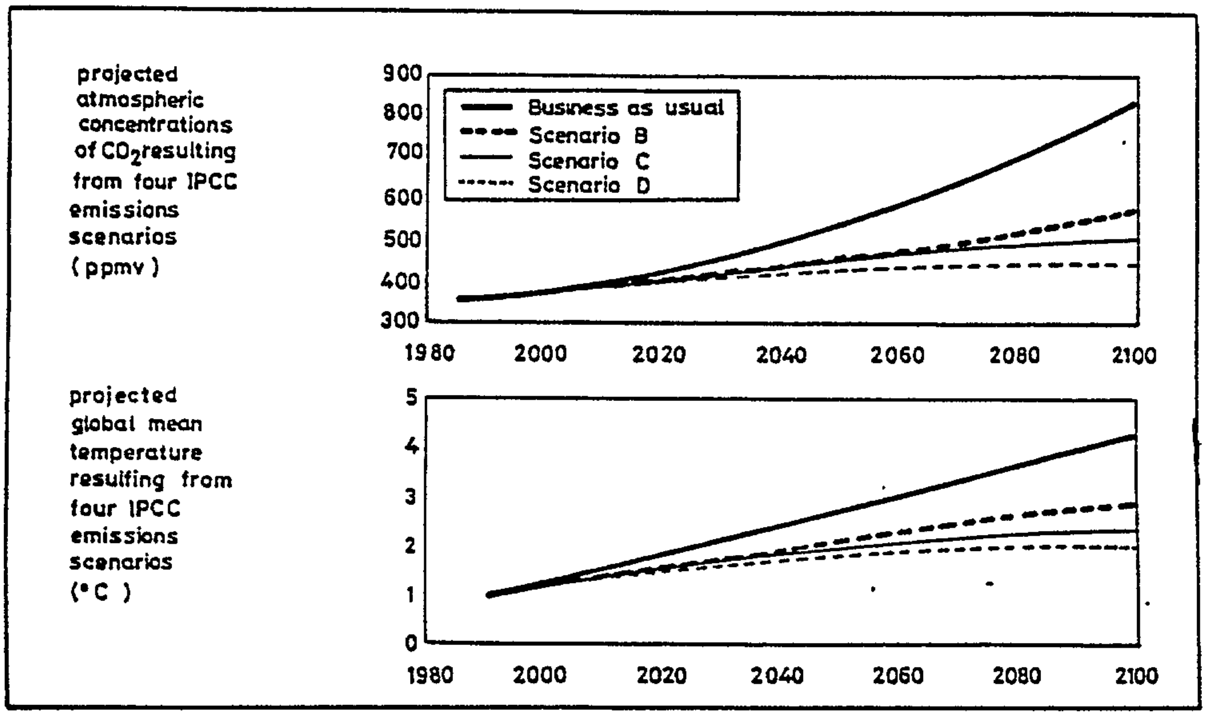


Fig. 2 Projected CO_2 concentrations and temperature change according to four IPCC emissions scenarios.

Scenario A

Mainly coal-based energy generation, only modest improvements in the efficiency of energy use, deforestation continues and only partial participation in implementing the Montreal Protocol.

Scenario B

More lower carbon fuels used in energy generation, large increases in energy efficiency, deforestation reversed and full participation in implementing the Montreal Protocol.

Scenario C

Shift towards renewable energy sources and nuclear power during 2050-2100, CFCs phased out.

Scenario D

Shift towards renewable energy sources and nuclear power during 2050-2100, CO_2 emissions reduced to half 1985 levels by 2050.

The atmosphere and the ocean interact at the sea surface by exchanging fluxes of momentum, heat and moisture across the air-sea interface. The oceans, besides, play a key role in determining the earth's climate. Indeed any possibility of predicting the evolution of weather systems beyond a few weeks demands that ocean behaviour be taken into account.

When it is heated the ocean responds by storing some of the heat and by increased evaporation. Because the heat is mixed down for some metres in the water by the wind, temperature rises much less than it does on dry land under the same heating conditions. The evaporation has profound effects on the atmosphere and on climate. Water vapour released into atmosphere increases the greenhouse effect in the atmosphere. When it recondenses (sometimes far from where it evaporated) the resulting heating of the air is a major source of energy for atmospheric motion.

1.4 METHODOLOGY AND ASSUMPTIONS USED IN THE STUDY

The study programme for the coastal zone management of Fuka-Matrouh area was planned to cover the following ten aspects; *i.e.* atmosphere, lithosphere, hydrosphere, natural and managed ecosystems, energy, industry, tourism, transportation, sanitation and demography. Consequently, a task team of experts was formed to match these disciplines and each member of the team was assigned to one or more of these aspects, appendix I; and entrusted to carry out a full investigation of all elements of this aspect - for these aspects - for establishing, with the other team members, a sound environmental management policy for sustainable resource development and land-use of the Fuka-Matrouh region The study has taken into consideration the conditions in the area under the anticipated climate changes. To achieve this objective, the task team has adopted an inter-disciplinary approach in carrying out the studies and investigations for:

- identifying and assessing possible implications of the adopted scenario for climatic change on the study area ecosystems, populations, land and sea use practices and other human activities;

- determining the domains that would be most vulnerable to climatic changes;

- giving recommendations for planning and designing of major infra-structure systems;

- providing input into other studies related to the present subject, especially those related to further work on CZM studies; and

- providing information for public, economists and policy and decision makers, to account for protecting the environment and investments on the long term.

The study task team was formed of eight national and two international experts. The national team has held frequent bilateral and trilateral to discuss the obtained results and to exchange information and date. Also, the whole national and international team has held three plenary meetings. To start the study, a kick off meeting was held at the study site in Matrouh between 28 November and 1 December 1993. The second general meeting of the team was held in Alexandria between 30 August and 1 September 1994 to review the first draft of the experts texts and to form a general structure for the final report. A third general meeting was held at Alexandria (to be completed afterwards).

Two temporal horizons are considered in the study; *i.e.* the years 2030 and 2100, while the conditions in the year 1990 are taken as basic datum for comparison.

The scenarios of global climatic change, adopted in this study are based on the work of Wigley and Raper (1992), which take the effects of sulphates and stratospheric ozone depletion into account. They estimate global warming of 0.9°C and 2.5°C between 1990-2030 and 1990-2100 respectively, which works out at 0.23°C per decade; assuming the changes are linear.

The sea level change, according to Wigley and Raper (1992), who incorporate beside the oceanic thermal expansions, the effects of land-based ice sheets and small glaciers also, is estimated to be +48 cm between 1990 and 2100, while it would be +16 cm between 1990 and 2030, as the change could not be scaled linearly.

Based on the methods developed by Kim *et al.* (1984) and Wigley *et al.* (1990), annual and seasonal scenarios for temperature and precipitation change for the Fuka-Matrouh region, have been produced by the Climatic Research Unit, School of Environmental Science, University of East Anglia, (Nov. 1993, Report) which are presented hereafter.

For 1°C global warming, the changes at the coast of NW Egypt between 27° and 28°E would be as follows:

Annual	Temperature	0.8 to 0.9°C
	Precipitation	0 to -4%
Winter	Temperature	0.7 to 0.9°C
	Precipitation	-5 to -22%
Spring	Temperature	0.7 to 0.9°C
	Precipitation	+8 to +26%
Summer	Temperature	1.0 to 1.1°C
	Precipitation	not applicable (no rainfall in summer)
Autumn	Temperature	0.7 to 0.8°C
	Precipitation	0 to -14%

Also according to Wigley and Raper (1992), the operative scenarios of sea level rise for time horizons 2030 and 2100 for Fuka-Matrouh region would be as shown in the following table:

		Time Horizon	
		2030	2100
Annual	Temperature Precipitation	0.7 to 0.8°C 0 to -4%	2.0 to 2.3°C 0 to -10%
Winter	Temperature Precipitation	0.6 to 0.8°C -5 to -20%	1.8 to 2.3°C -13 to -55%
Spring	Temperature Precipitation	0.6 to 0.8°C 7 to 23%	1.8 to 2.3°C +20 to +65%
Summer	Temperature Precipitation	0.9 to 1.0°C not applicable	0.5 to 2.8°C not applicable
Autumn	Temperature Precipitation	0.6 to 0.7°C 0 to -13%	1.8 to 2.0°C 0 to 35%
Sea level change		+16 cm	+48 cm

2. IDENTIFICATION OF PRESENT SITUATION AND TRENDS

2.1 CLIMATIC CONDITIONS AND ATMOSPHERE

2.1.1 Climate Conditions

2.1.1.1 Pressure Distributions

The climate prevailing along the north-western coast of Egypt is qualified as "arid Mediterranean with mild winter", characterised by subtropical temperature conditions and a typical winter rainfall pattern. This climate is basically created by the latitudinal position and by the general circulation of the atmosphere but is modified by the interaction between land and sea.

The climate of the region is determined basically by the following factors:

a. The semi-permanent pressure systems in each season, such as the cold Siberian anticyclone in winter, the heat lows of Africa in spring and autumn, and the huge low over southeast Asia in summer. These systems are air mass source regions in their respective season.
b The travelling depressions and associated weather in winter and the transitional seasons.
c. The Mediterranean as a source of water vapour, in addition to its being positive or negative thermal source (warm surface to cold polar masses, and cool surface to tropical air masses). In fact, the Mediterranean has a pronounced influence on the region.

The above factors (as well as the other minor ones) will be taken into consideration when discussing the situation on each season.

2.1.1.1.1 Winter Circulation

In Winter, the Mediterranean and the western parts of the Middle East are, except for short rare periods of extensive high-pressure systems, under the influence of Mediterranean depressions moving with the westerlies. The surface circulation over the eastern part of the Middle East controlled for long periods in winter by the Siberian high-pressure and dominated by north-easterly winds.

When the depression reaches the eastern mediterranean, cold moist north-westerly winds blow over the north of Egypt, and convective clouds appear during the daytime. When an upper cold low or steep trough exists above the depression, much cloud and rain results over the area under consideration by both day and night. The rain is sometimes heavy and accompanied by thunder. The depression may stay an average of two or three days over the eastern Mediterranean during which time the region experiences its worst winter weather. When the depressions are deep, the south-west winds may reach a gale force and cause severe sandstorms.

Between the passage of consecutive depressions, high pressure covers the eastern Mediterranean. This situation is responsible for the flow of north-easterly winds over the coast, a condition that favours the formation of radiation fog in the early morning, dispersing a few hours after sunrise.

2.1.1.1.2 Spring Circulation

The main feature of this season is the southward shift of the tracks of depressions. The centres of the depressions either move along the coastline of North Africa, or further south, where they are known as desert, or "khamsin" depressions. The average frequency of these latter depressions is three or four per month, but may vary between two and six per month. Khamsin depressions can be vigorous and cause severe sandstorms. When these depressions have become upper lows, they are often associated with large amounts of high and medium clouds as well as with thunderstorms, which can give very heavy showers of rain and hail.

In this season (spring), the sudan trough sometimes extends northwards to cover Egypt. The hot, south-easterly current of Arabia turns north-eastward over Egypt and moderate or severe heat waves are then experienced The air is hot and dry, except in the surface layers, where it picks up moisture from the Mediterranean, a feature that sometimes leads to the formation of early morning radiation fog. All record maximum temperatures are caused by this hot tropical continental air, which is at the same time the season for record low relative humidities.

2.1.1.1.3 Summer Circulation

Summer circulation in the Middle East is dominated by the north-westerly to northerly winds between the sub-tropical high pressure system over the Mediterranean Sea and southern Europe on one hand. and the low pressure system stretching from Arabia to Pakistan on the other. The general climate for the area in this season is hot, dry and rainless. Clear skies prevail, except for some coastal fair weather cumulus or early morning stratus clouds which disperse a few hours after sunrise. The climate of the area being affected by the cool Mediterranean water, is warm during the daytime, and rather cool by night.

2.1.1.1.4 Autumn Circulation

The climate in this season is similar to that in spring, for it is another transitional season. Khamsin-like depressions begin to cross Egypt during late October and cause a break-down of the settled summer regime. Early depressions in September are frequent and usually die out on arriving in Egypt from the west. The depressions at this time are much less vigorous than spring and are slower in their movement. On the other hand, the higher humidity in this season favours greater frequency of thunderstorms and heavier precipitation, a fact especially true in November.

2.1.1.2 Air Temperature

The air temperature in the region displays a simple annual curve and a mean annual value of 19.4°C

The Gorszinsky index of continentality in percent based on the difference between the mean minimum of the coldest month (January) and the maximum of the hottest month (August), and corrected according to latitude, has been calculated, the formula is:

$$C = \frac{1.3\,A}{\sin ¢} - 36.3$$

C is the continentality expressed in percent.
A is the mean for the period of records for the annual range between maximum temperature of the hottest month and the mean minimum of the coldest month.
¢ is the latitude.

The continentality for Matrouh and Dabbaa are 15.7 and 19.8 respectively. It is clear that the region enjoys a typical maritime climate, being strongly influenced by the presence of the sea.

Table 1 indicates the monthly mean daily, the mean monthly maximum and the mean monthly minimum air temperature in the two meteorological stations of the region.

Figs. 3A and 3B have - for Matrouh and Dabbaa stations - months of the year as abscissa and hours of the day as ordinates. Mean monthly values for each hour were plotted and isotherms were drawn, summarising in very compact and useful forms, and the values, gradients and trends of air temperature variations through the year.

Table 1

Mean monthly and annual values of the air temperature (°C) (1961-1990)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Ann.
Monthly mean daily temperature													
Matrouh	12.9	13.5	15.1	17.6	20.2	23.4	25.0	25.5	24.3	21.6	17.9	14.4	19.3
Dabbaa	12 8	13.7	15.0	17.8	20.6	23.6	25.4	25.8	24.5	22.0	18.2	14.4	19.5
Mean monthly maximum temperature													
Matrouh	17.7	18.5	19.6	22.9	25.3	28.1	28.6	29 5	28.5	26.5	22.8	19.3	23.9
Dabbaa	17.8	18.7	20.4	23.6	26.0	28.5	29.4	30.0	28.9	26.7	23.2	19.7	24.4
Mean monthly minimum temperature													
Matrouh	8.7	8.9	10.4	12.5	15 1	18.6	20.7	21.2	19.9	17.2	13.5	10.4	15.2
Dabbaa	7.8	8.1	9.7	12.1	14.6	18.2	20.7	21.0	19.5	16.6	13.0	9.3	14.7

The lowest temperatures are observed in January and February: the mean monthly minimum stays around 9°C and daily minimum seldom falls below 5°C (absolute minimum 2°C). Table 2 gives the number of days per year with minimum air temperature thresholds and its standard deviation.

Table 2

Mean number of days per year (N), minimum air temperature below certain temperature thresholds and its standard deviations (s d.) for Mersa-Matrouh station
(Period 1958-1967)

	Temperature Thresholds			
	5°C		10°C	
Station	N	s.d.	N	s.d.
Matrouh	2.3	1.25	78.3	12.91

No danger of frost, as observed in desert climate, is thus to be feared in the region, but cool nights, characterised by temperatures below 10°C, prevail from the last weeks of December until the middle of March. The maximum temperature during the winter is rather low and uniform, seldom exceeding 20°C.

Spring begins in the first weeks of March, and there is marked increase of the maximum day temperature (above 20°C). But the nights remain cool and the general trend of increasing temperature is often broken by cold spells lasting three or four days. April is characterised by frequent "khamsin" winds, bringing the maximum temperature to over 30°C or even 35°C for two or three days at a time. April nights are still cool (between 10 and 20°C). Table 3 gives the number of days per year with maximum air temperature thresholds and its standard deviation.

The summer lasts over 5 months, from May until the end of October. The day temperature is warm but temperature, fluctuating between 25 and 30°C. The minimum temperatures are rather high, mainly in August and September (more than 20°C).

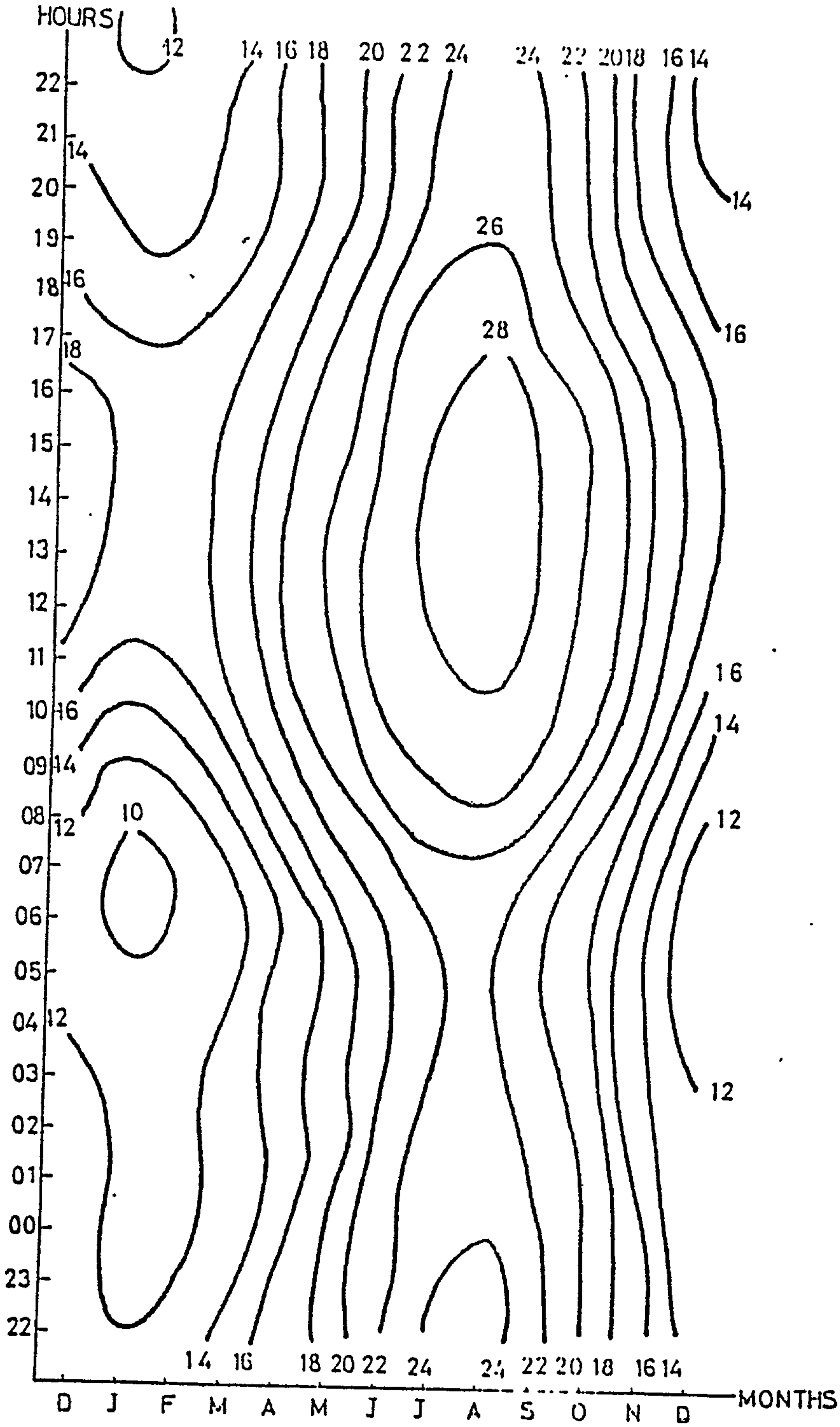


Fig. 3A Annual Hour Mean for Air Temperature - Matrouh

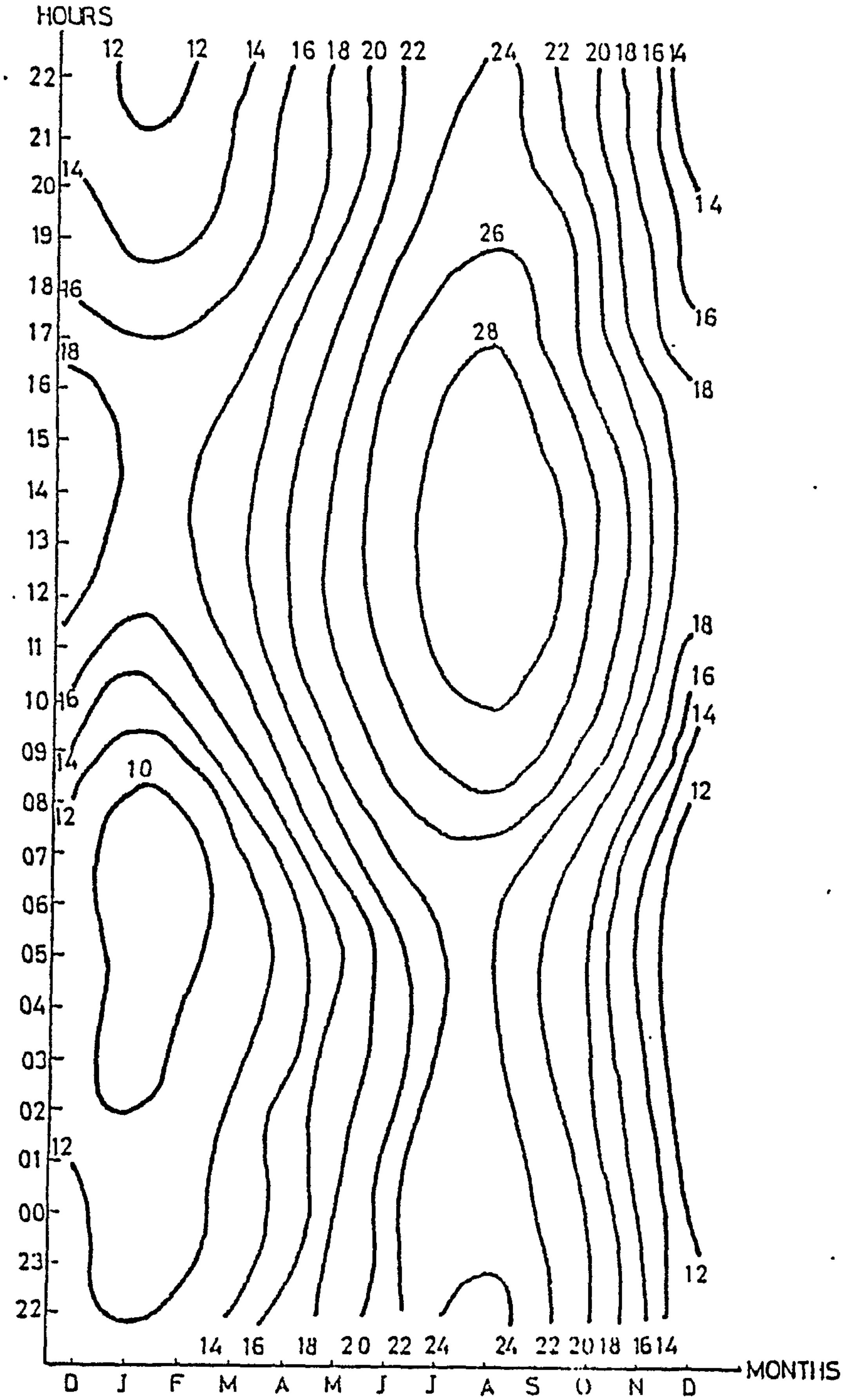


Fig. 3B Annual Hour Mean for Air Temperature - Dabbaa

Autumn begins with the first rains. Day and night temperatures slowly decrease, dropping to about 20°C (maximum temperature) and 10°C (minimum temperature) in mid December, the beginning of winter.

From Fig. 4 it can be clearly seen that the mean annual and seasonal values of air temperature for Matrouh have shown no trend over the period 1950-1992. Fig. 5 gives the annual variation of air temperature for Mersa-Matrouh.

Table 3

Mean number of days per year (N) with maximum air temperature greater than certain temperature thresholds and its standard deviation (s d.) for Mersa-Matrouh station (Period 1958-1967)

	25°C		30°C		35°C		40°C		45°C	
Station	N	s.d.	N	s.d.	N	s.d.	N	s.d.	N	s.d.
Matrouh	175.0	12 21	37.2	7.80	5.9	3.35	1.3	1.64	0.2	0.63

2.1 1.3 Relative Humidity

The relative humidity of the air in the region does not vary greatly through the year, staying between 45 to 60% at noon and between 65 and 75% in the morning (and also in the evening). Maximum and minimum values of relative humidity occur in July (75% for Matrouh and 69% for Dabbaa) and April (66% for Matrouh and 64% for Dabbaa) with mean annual value 70% for Matrouh and 66% for Dabbaa. Table 4 gives mean daily relative humidity, and mean relative humidity at 06, 12 and 18 U.T. Fig. 6 gives annual variation of relative humidity of Mersa-Matrouh.

Table 4

Mean Monthly and Annual Values of Relative Humidity (%) for Mersa-Matrouh and Dabbaa

Station	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Mean Daily Relative Humidity													
Matrouh	71	69	68	66	73	73	75	73	71	70	68	69	70
Dabbaa	67	65	67	64	66	67	69	69	66	65	64	64	66
Mean Relative Humidity at 06 U.T.													
Matrouh	75	72	67	65	64	64	72	72	69	70	77	72	70
Dabbaa	73	72	67	64	66	68	71	72	67	69	74	73	70
Mean Relative Humidity at 12 U.T.													
Matrouh	50	48	46	50	54	55	61	59	56	53	55	47	53
Dabbaa	48	47	46	47	51	56	58	58	56	53	55	51	52
Mean Relative Humidity at 18 U.T.													
Matrouh	68	68	67	71	75	75	76	73	70	71	72	66	71
Dabbaa	68	67	67	68	72	77	76	75	72	70	74	70	71

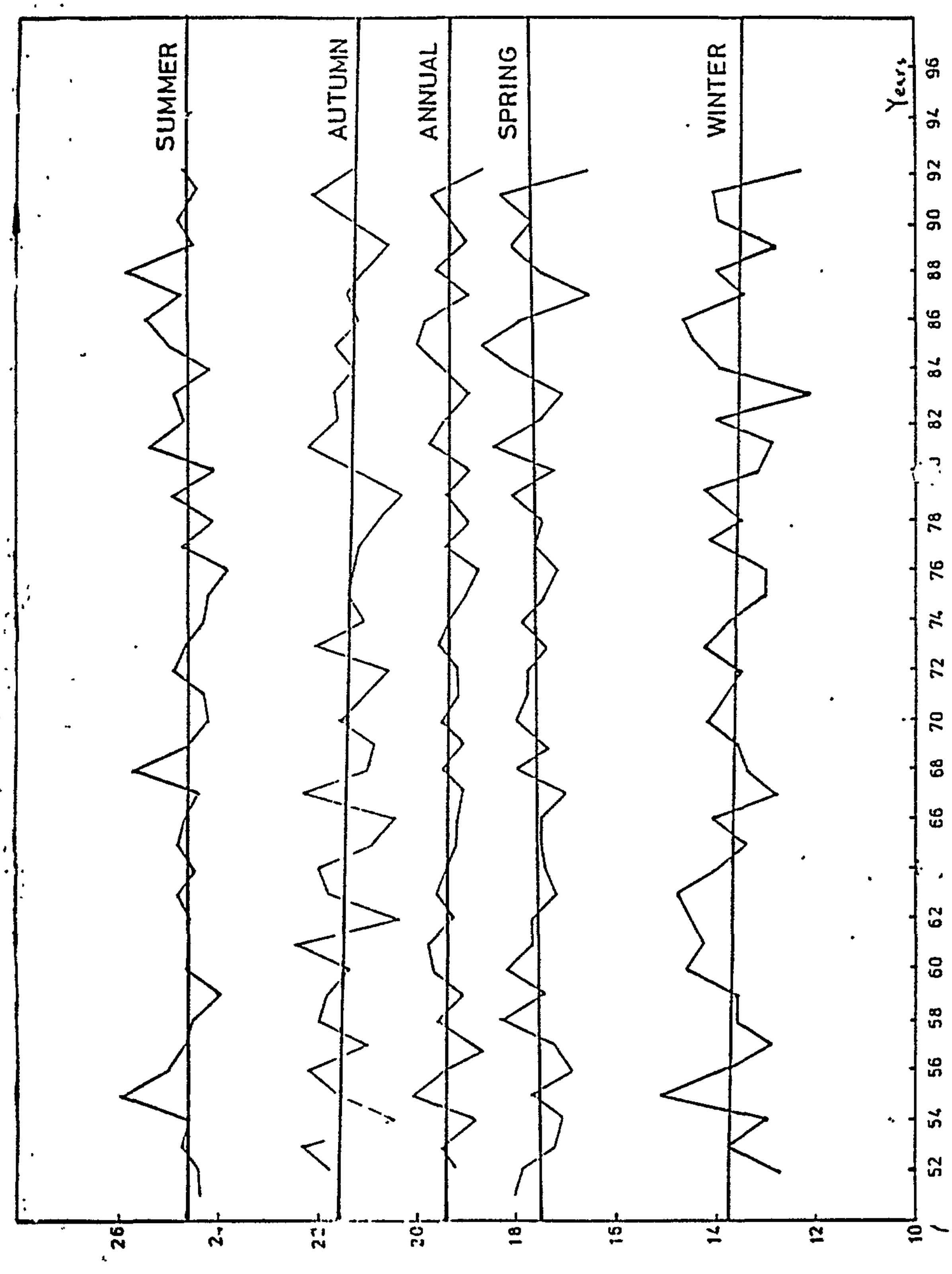


Fig. 4 Mean temperature

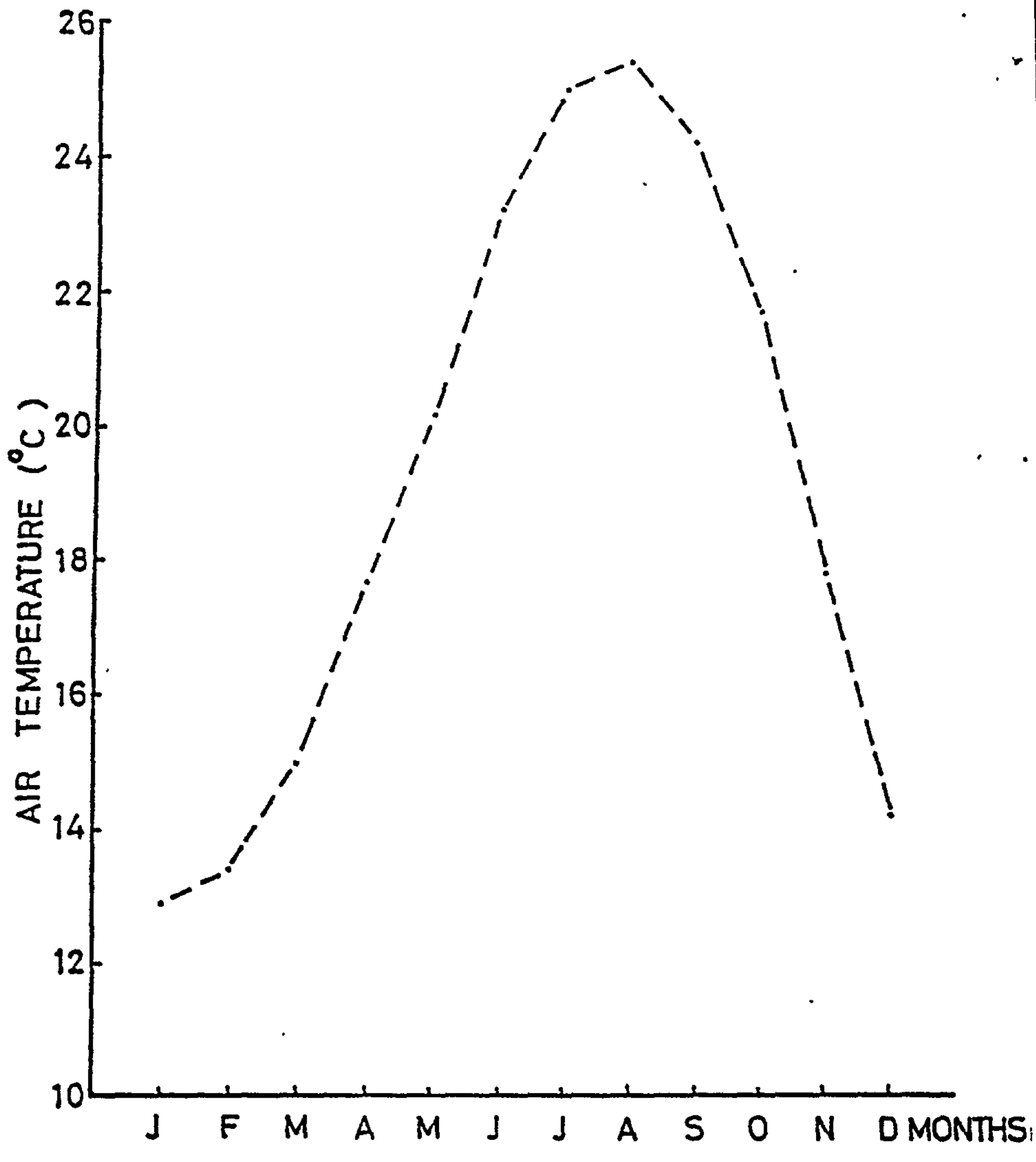


Fig. 5 Annual Variation of Air Temperature for Mersa-Matrouh

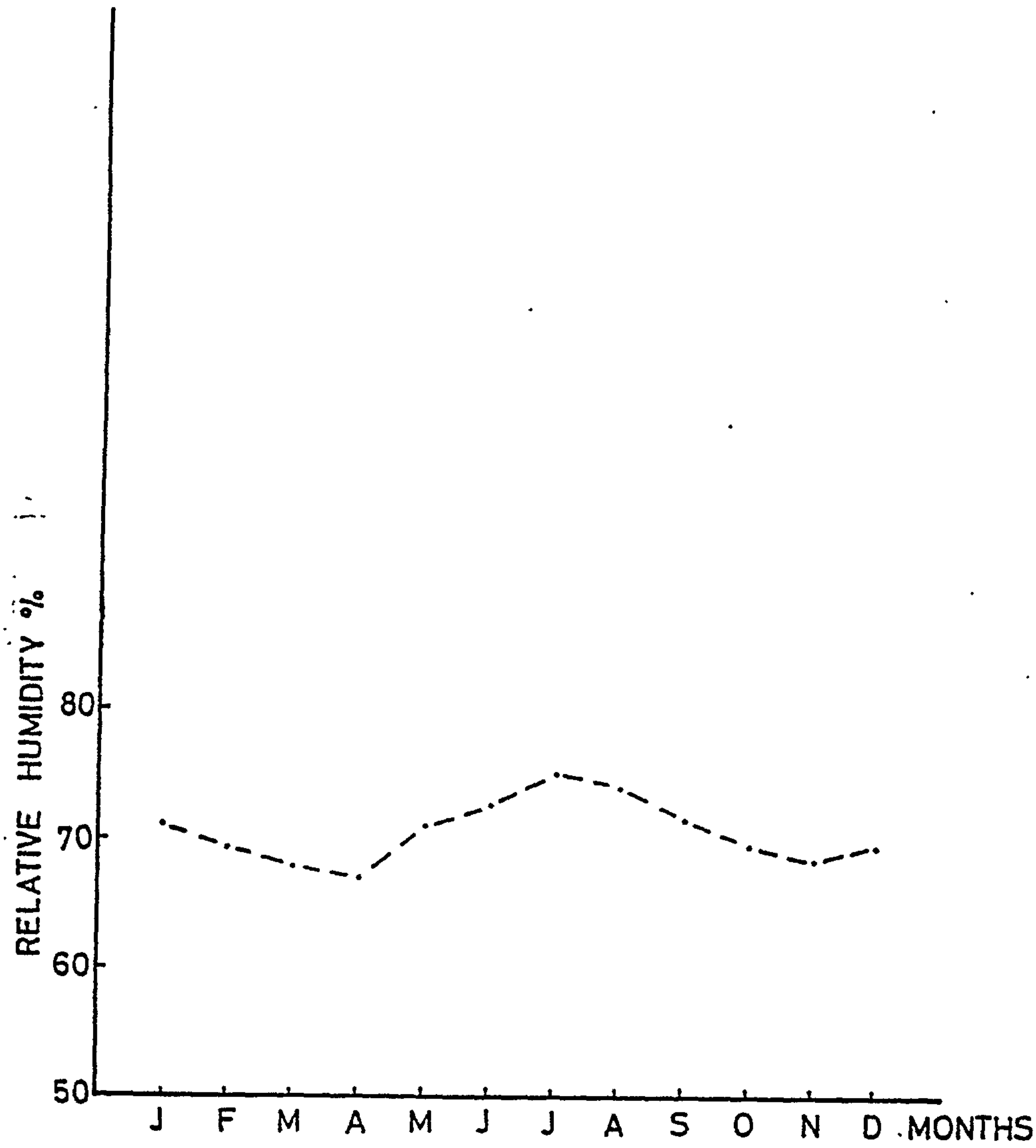


Fig. 6 Annual Variation of Relative Humidity for Mersa-Matrouh

2.1.1.4 Rainfall

2.1.1.4.1 Annual Rainfall Distribution

With regard to the rainfall condition, however, there is no doubt that the region is rather homogenous During the period October-November to April-May, the region is under the influence of the middle westerlies. The rain, which occurs over the region during these months, is mainly due to cyclones moving in over the area, after either in the Atlantic or the Mediterranean on a branch of the polar jet-stream in upper troposphere.

These cyclones are of two basically different types. The first type may be connected with shallow waves moving rapidly in the upper troposphere westerlies causing rainfall in the region. The second basic type of cyclonic is connected with the cold troughs in the upper air creating fairly stationary cyclones in favoured regions. One such region is the Cyprus area, where the influence of cold air often causes a cyclone to become fairly stationary. During the winter season, south-westerly/north-westerly winds connected with this cyclone which moves slowly over the Near East, considerable rainfall occurs over the region.

During the spring season, March-April, another cyclonic type of rain frequently occurs in the region, but of quite a different origin. These are the khamsin conditions. They generally cause rain in the region as the cyclones of the first type, but they occasionally meet a cold upper-air trough over the western part of the Middle East and consequently, in their further movement eastward, they behave as a regenerated slow-moving cyclone with a cold upper air trough. In these later conditions, they may give rise to considerable amounts of rain.

As during the summer, the region is under the influence of the sub-tropical high-pressure system, and winds are mainly from north-west, practically no rain occurs, except for some solitary drops.

All over the region, sometimes the autumn rainfall may be more, this is due to severe instability which occurs due to the upper-air depressions/trough which supply the region with cold air, while the surface may be under the effect of monsoon low which supplies the region with north-east warm and humid air.

Some of the annual rainfall can be precipitated as hail or snow. Hail occurs over the region two or three times per ten years near Matrouh. Hail could occur with the association of thunderstorms. Snow is a very rare phenomenon.

2.1.1.4.2 Amount of Annual Rainfall

The annual rainfall caused by the general circulation outlined above is thus concentrated within the period October-November to April:

a. At Matrouh annual rainfall for the period 1950-1951 to 1987-1988 is 130 mms, 48% of this quantity took place during December and January, while 61% took place during December-February (winter). The lowest amount of annual rainfall recorded was 37 mms in the season (1950-1951), while the highest amount was 277 mms (recorded in the season 1956-1957).
b. At Ras El-Hekma, 50 kms to the east of Matrouh, mean annual rainfall for the period 1956-1957 to 1982-1983 is 129 mms, 54% of this quantity took place during December and January, while 66% took place during winter. The lowest amount of annual rainfall recorded was 48 mms in the season (1980-1981) while the highest amount was 251.5 mms (recorded during the season 1968-1969).
c. At Fuka, 70 kms to the east of Matrouh, mean annual rainfall for the period 1948-1949 to 1963-1964 is 108 mms, 50% of this quantity took place during December and January, while 64% of this quantity took place during winter. The lowest amount of

annual rainfall recorded was 19 mms (during the season 1950-1951), while the highest amount was found to be 282 mms (recorded during the season 1956-1957).

d. At Dabbaa, 130 kms to the east of Matrouh, annual rainfall for the period 1950-1951 to 1987-1988 is 127 mms, 49% of this quantity took place during December and January, while 63% took place during winter. The lowest amount of annual rainfall recorded was 37 mms (during the season 195-1960), while the highest one was 266 mms (recorded in the season 1968-1969).

2.1 1.4 3 Distribution of Rainfall During the Year

Table 5 and give the monthly distribution of rainfall. The rainy season begins during the second half of October. Three quarters of the total amount falls from November to February. December and January are the rainiest months with the average of 35 mms per month Some showers are still observed in March, but the spring is dry and receives only 10% of the total.

Table 5

Mean monthly and annual values of rainfall and number of rainy days for Mersa-Matrouh and Dabbaa

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Rainfall (mm)													
Matrouh	29 6	17 9	9 8	2 7	1.7	1 6	0.0	0 5	2 0	14 3	18 3	31 2	129.6
Dabbaa	30.1	18 2	8 2	1.5	1.5	0.4	0.0	0 0	1.1	11 1	23.0	32 3	127.?
Number of rainy days (rainfall ≥ 0.1 mm) (days)													
Matrouh	8 5	5.8	5.1	2 1	1 3	0.1	0.0	0.1	0 3	3 5	5 9	7.5	40.2
Dabbaa	7 3	4.1	3.0	1 0	0 7	0 1	0 0	0.0	0 3	2.5	5.1	7.0	31.1
Number of Rainy days (rainfall ≥ 1 0 mm) (days)													
Matrouh	5 3	3 3	2 6	0 8	0 6	0.1	0 0	0 1	0.2	1.8	3 4	5 0	23.2
Dabbaa	5 4	2.7	1.7	0 5	0 3	0 0	0.0	0.0	0 2	1.7	3.3	5.9	21 7
Number of Rainy days (rainfall ≥ 5.0 mm) (days)													
Matrouh	1 7	0.9	0.6	0.1	0.0	0 1	0.0	0.0	0.1	0.7	1.3	1.9	7.4
Dabbaa	1.7	0.7	1 0	0.1	0 1	0.0	0.0	0.0	0.1	1.2	1 2	1 9	8.0
Number of Rainy days (rainfall ≥ 10.0 mm) (days)													
Matrouh	1.0	0 3	0 2	0.0	0.0	0.1	0.0	0.0	0.0	0 5	0.7	0.8	3.6
Dabbaa	1.1	0.4	0.2	0.0	0.1	0.0	0.0	0.0	0.1	0.5	1.1	1.3	4.8

The dry season lasts 6-7 months without precipitation except for a few stormy rains in April, May and September. This typical winter rain regime sets severe conditions for agriculture.

The mean annual number of rainy days according to the minimum amount, is given in Table 5 of the 38 rainy days per year, only a few bring enough water to moisten the soil. Twenty-four days recorded rainfall greater than 1 mm. A rainfall of more than 5 mms is observed 8 days per year. Rainfall of more than 10 mms/day, generally with an intensity high enough to produce run-off and fill the wadis, only occurs four or five times per year, mainly in December and January.

Fig. 7 gives the monthly rainfall for Mersa-Matrouh.

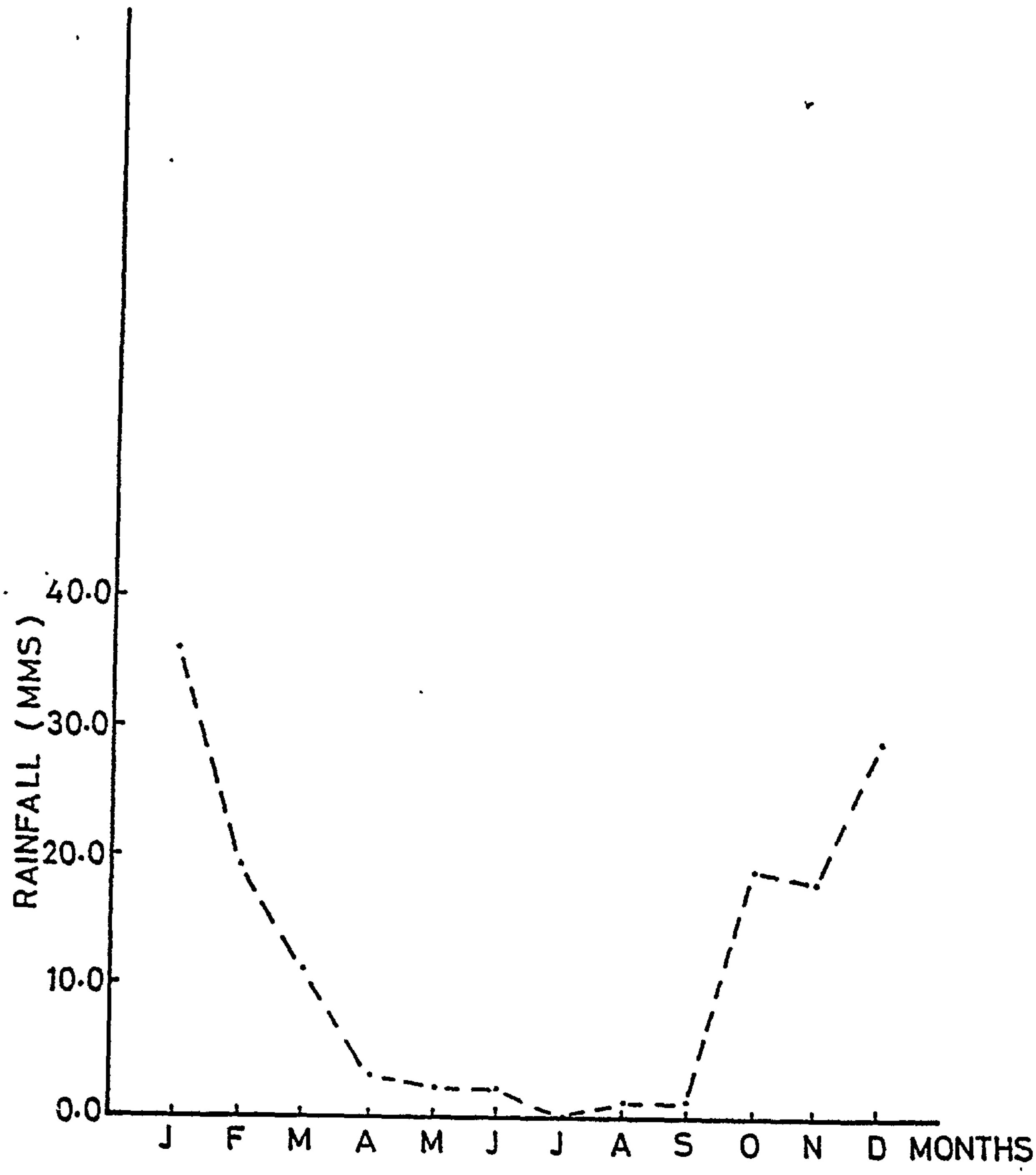


Fig. 7 Monthly Rainfall Mersa-Matrouh

2.1.1.5 Surface Wind

In winter, the Mediterranean depressions affect the region directly, causing surface winds to become variable, both in speed and direction. Since the tracks of the depressions are north of the coastline, the prevailing directions are, as expected, south and southwesterly in front of the depressions and west or northwesterly in the rear.

Winter and early spring are the seasons of strong gale winds in the region, usually blowing from the western quadrant. Northeasterly winds become more frequent in the spring and autumn months because of the passage of the centre of Khamsin depressions south of the Mediterranean coastline This fact leads to the eastern Mediterranean becoming an area of relatively high pressure.

In summer, steady northerly winds prevail. Gales do not occur during this season.

Autumn, especially October, is the time of lowest wind speed.

Mean annual values of wind speed are homogenous through the region with small increasing trend from west to east. Annual means of wind speed are 10.3, 10.4 and 10.5 knots for Matrouh, Ras El-Hekma and Dabbaa respectively. Fig. 8 gives the annual variation of wind speed for Mersa-Matrouh. Figs. 9 (A-F) give the wind rose for the whole year (9A), January (9B) and July (9C) for Mersa Matrouh, and 9D, 9E and 9F are annual, January and July wind roses for Dabbaa respectively.

2.1.1.6 Human Bioclimate

The mean monthly values of both the cooling power of the air, **Cp,** in Kcal. $hr^{-1}m^{-2}$, and the effective temperature, **ET**, in °C were calculated.

The cooling power of the air, **Cp**, is expressed as:

$$(Cp) = 0.57\ U^{0.42}\ (36.5 - T) \times 36$$

where **Cp** in Kcal. $hr^{-1}m^{-2}$
T is air temperature in °C
and **U** is wind speed in m/sec

It combines wind and temperature conditions, without including a humidity term. Furthermore, the emphasis is upon the cooling power of the surrounding atmospheric conditions.

The effective temperature, **ET**, was determined by using the chart of **ET** as devised by Ellis *et al.* (1972). Table 6 and Figs. 10A and 10B give the values of both **Cp** and **ET**.

Classification of the cooling power of the air considers that cooling power from 396 to 540 Kcal. $hr^{-1}m^{-2}$ cool

and	from	541	to	790	Kcal. $hr^{-1}m^{-2}$	very cool
	from	791	to	999	Kcal. $hr^{-1}m^{-2}$	cold
	from	1,000	to	1,199	Kcal. $hr^{-1}m^{-2}$	very cold
	from	1,200	to	1,439	Kcal. $hr^{-1}m^{-2}$	biting cold
and	over	1,440			Kcal. $hr^{-1}m^{-2}$	exposed skin freezes quickly

By this classification we find that Matrouh is cold from December to the end of March, very cool in April, May, October and November, and cool in the period June-September (see Table 6a).

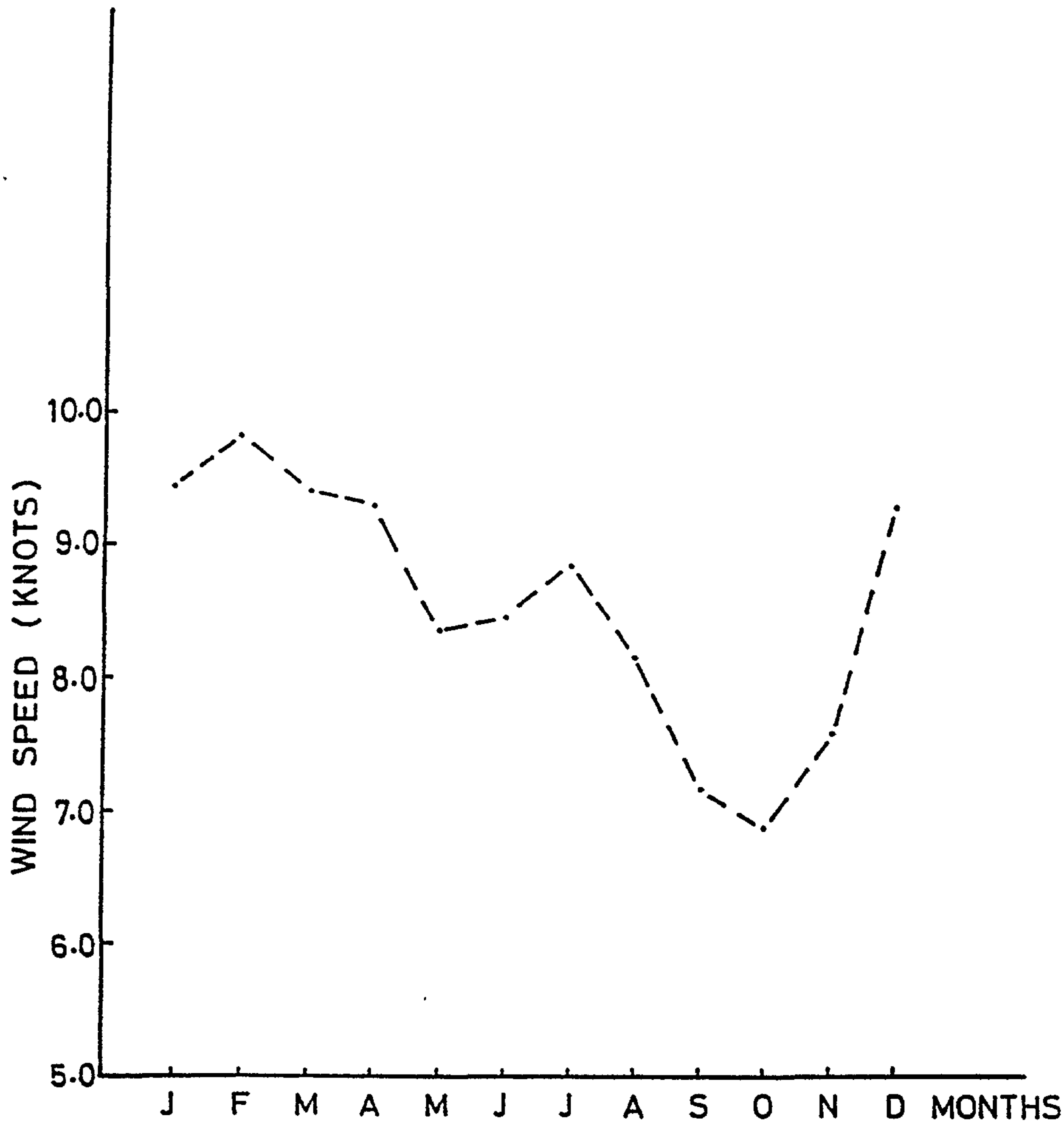


Fig. 8 Annual Variation of Wind Speed Mersa-Matrouh

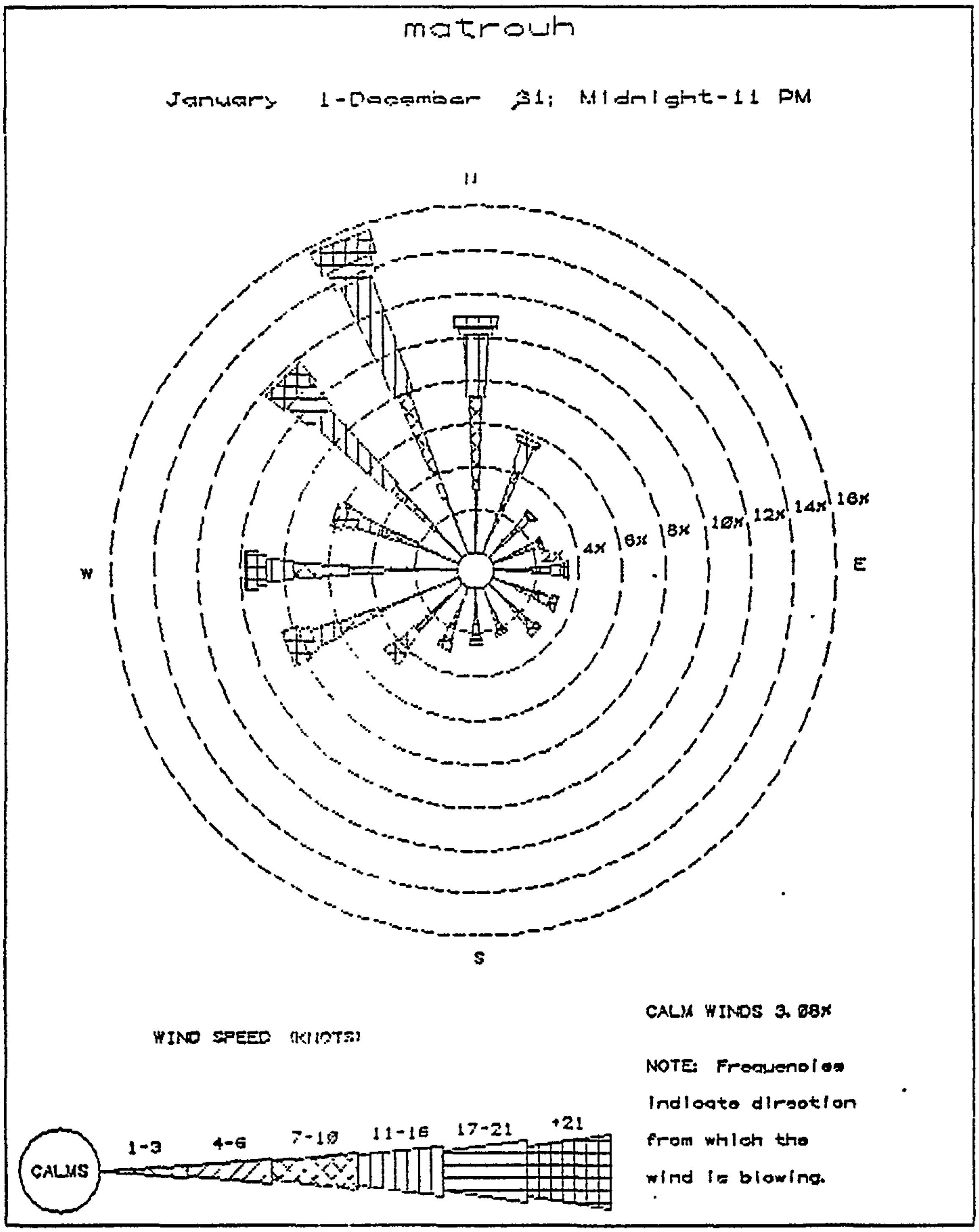


Fig. 9A Annual wind rose

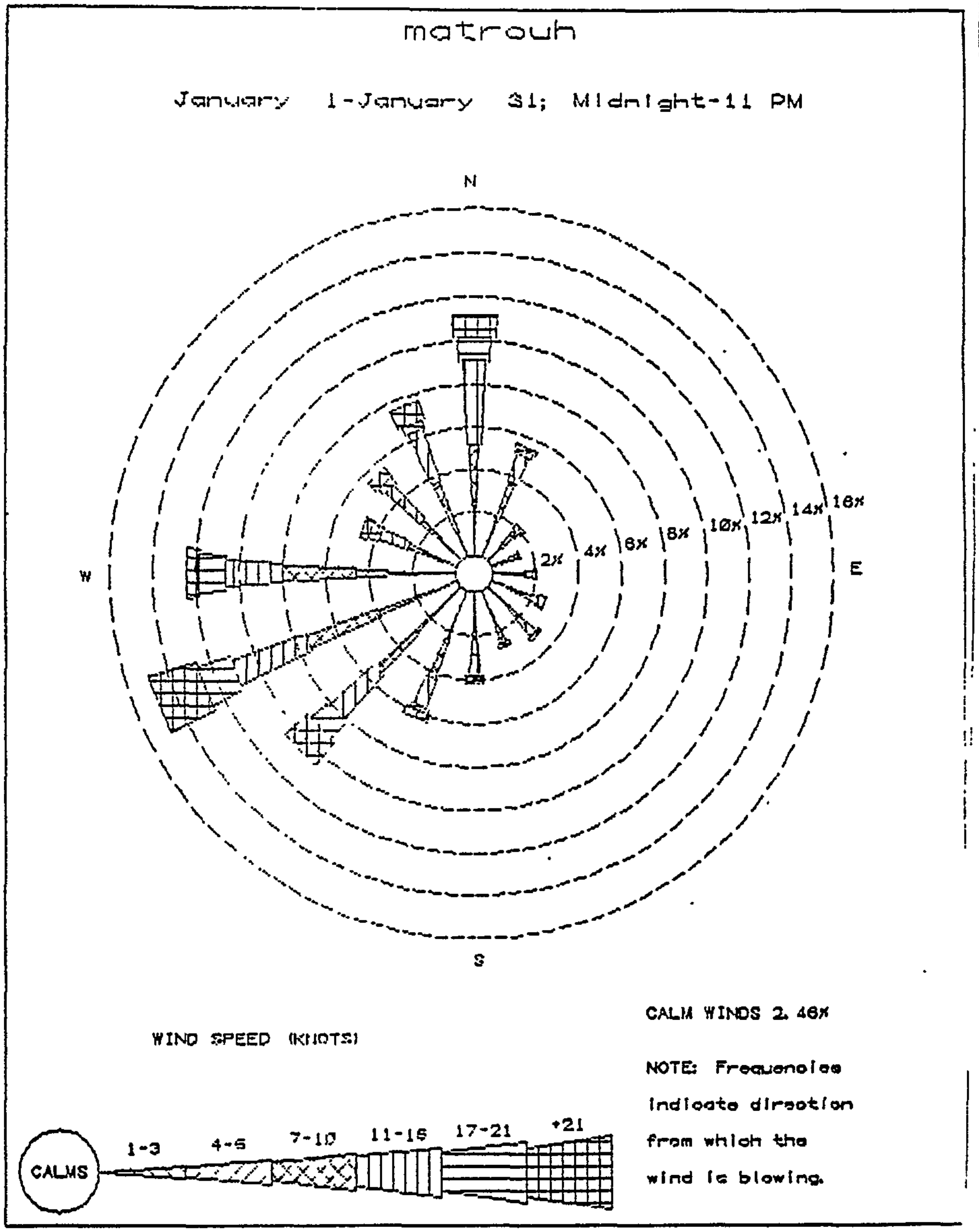


Fig. 9B January wind rose

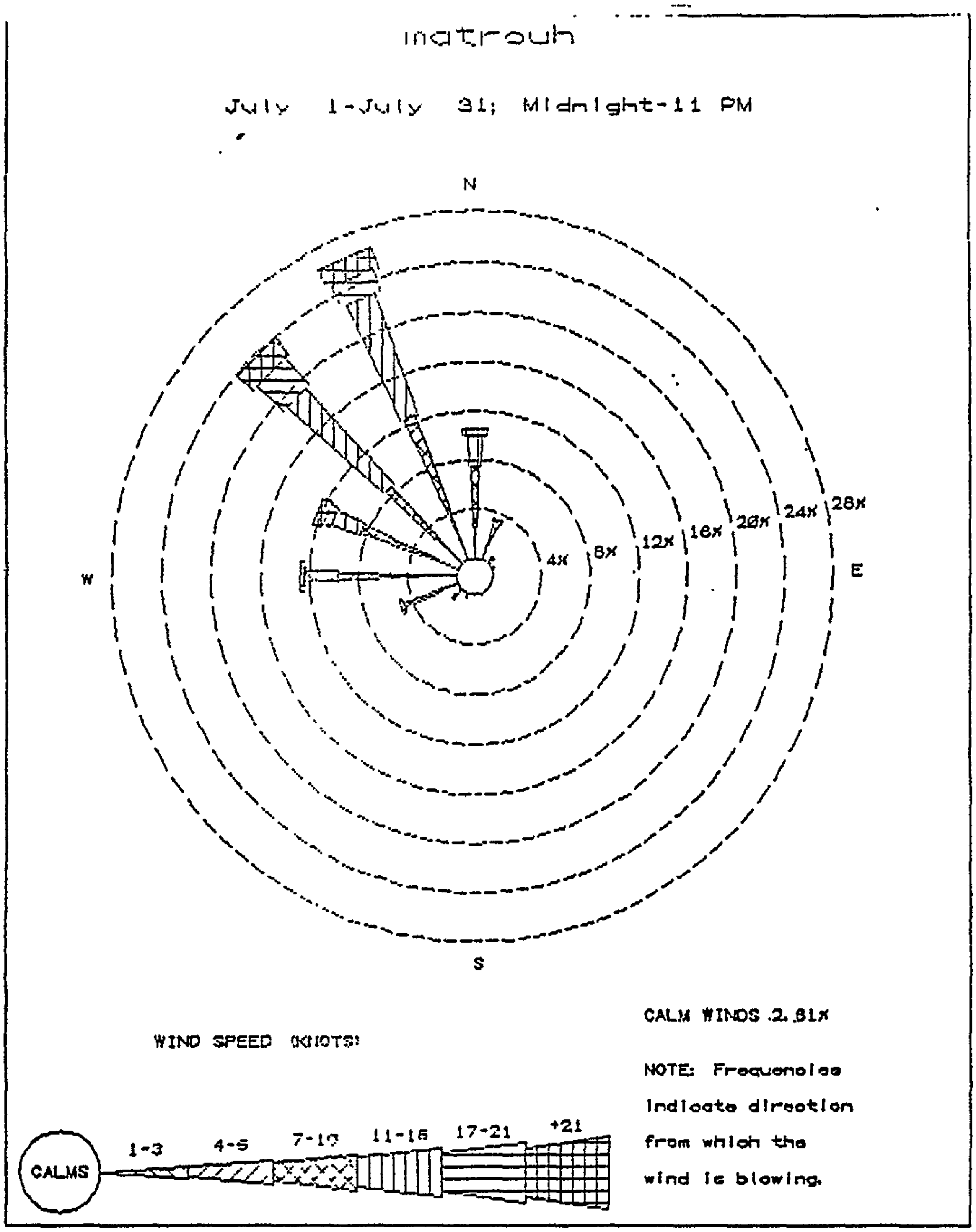


Fig. 9C July wind rose

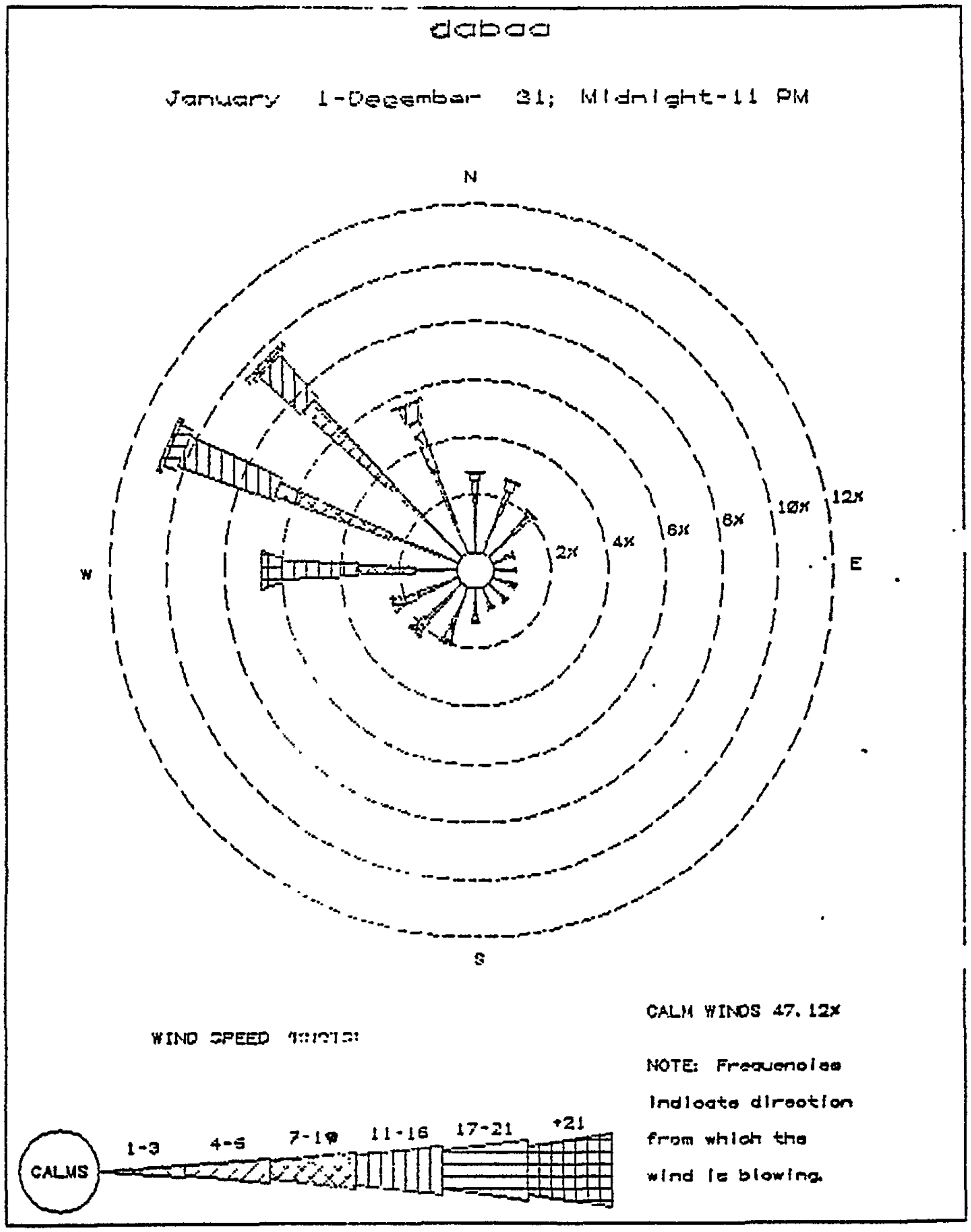


Fig. 9D Annual wind rose

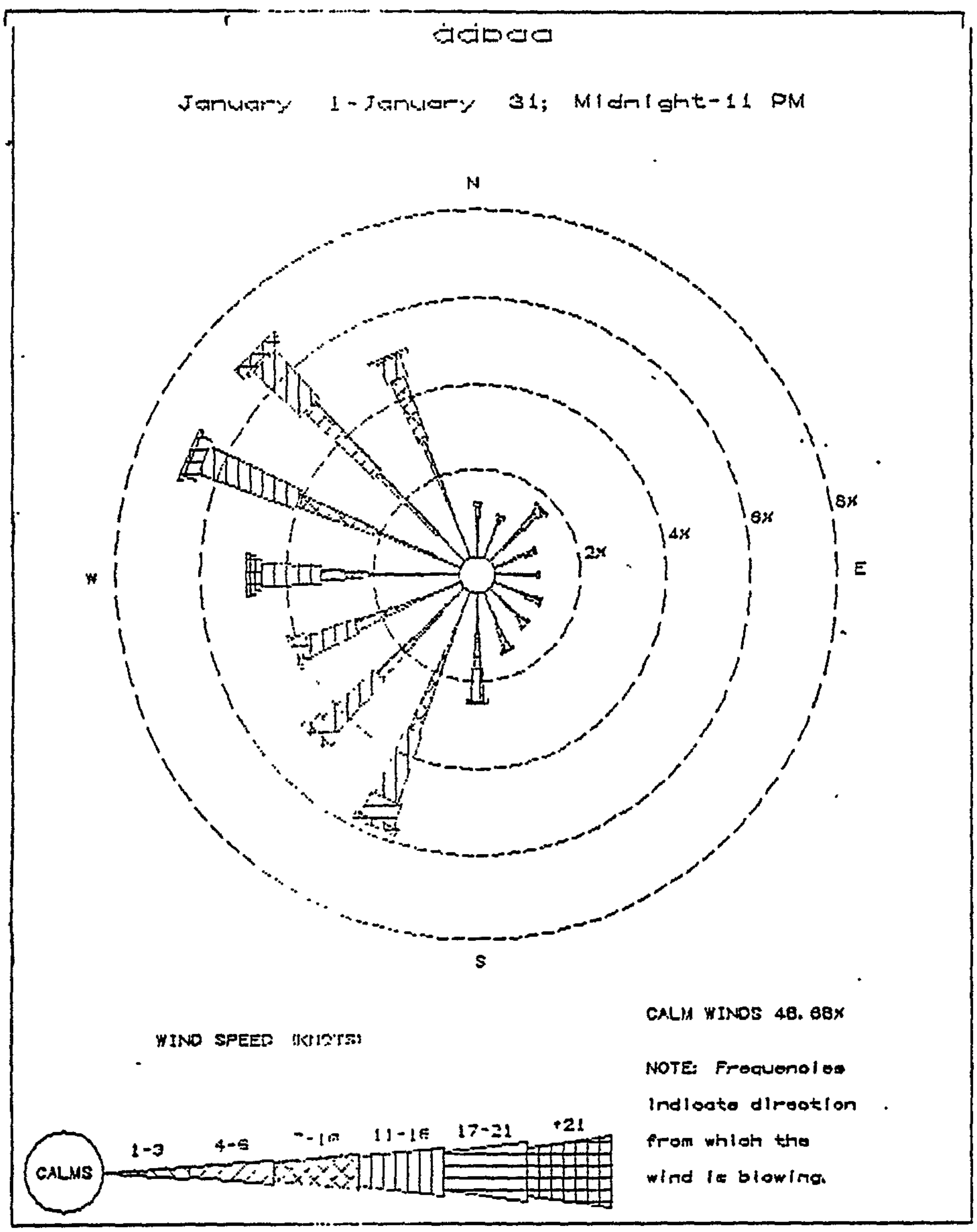


Fig. 9E January wind rose

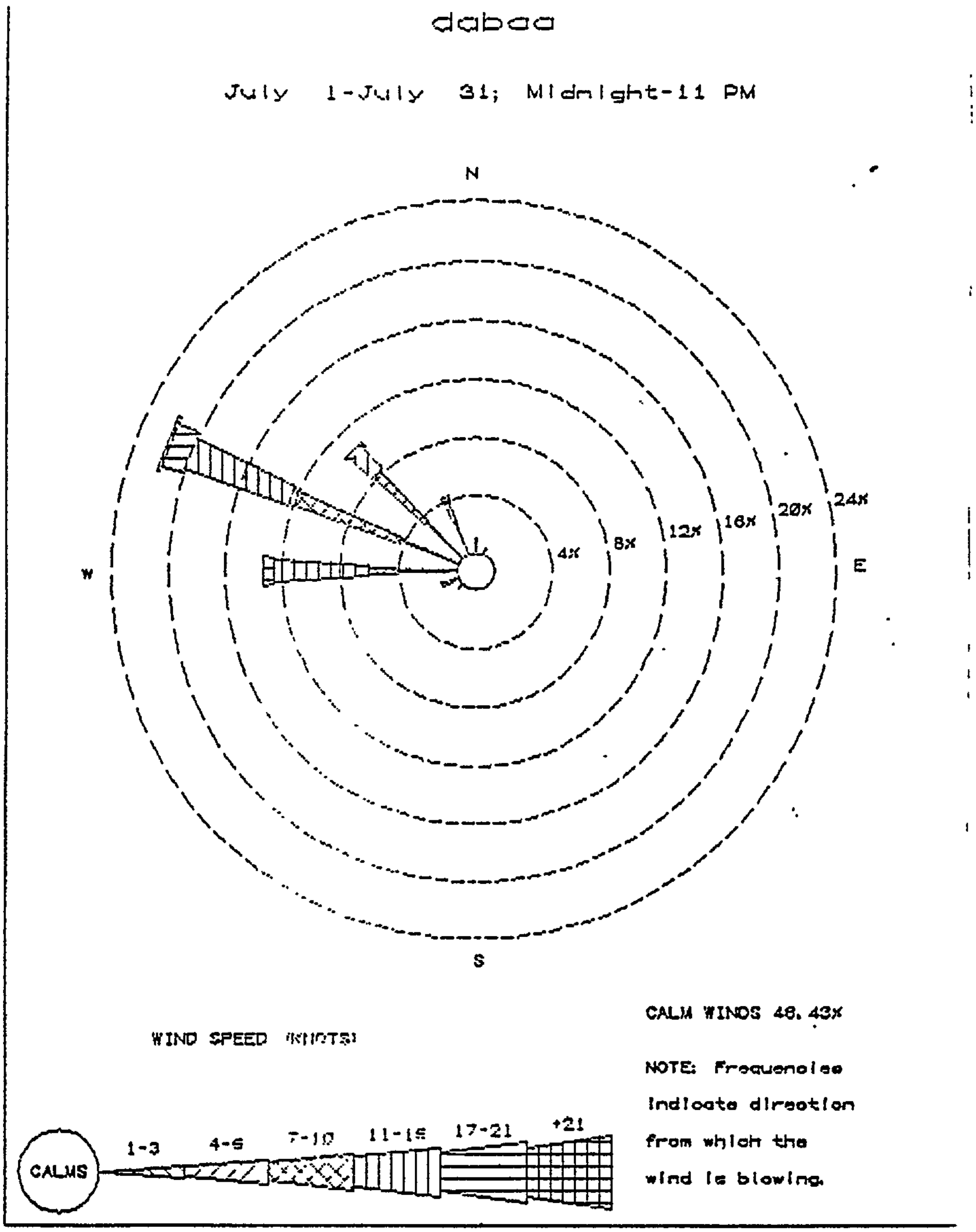


Fig. 9F July wind rose

Sham (1977) demonstrates the difficulty in defining a range of effective temperature, with which the majority of individuals from hot countries will be content and able to work at maximum efficiency as follows:

Comfort Range	Effective Temperature
above acceptable	above 24.5°C
upper acceptable	22.8-24.5°C
optimum	20 6-22.8°C
lower acceptable	18.9-20.6°C
below acceptable	below 18.9°C

Table 6

Mean Monthly Values of the Cooling Power and the Effective Temperature of the Air in Mersa-Matrouh

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct.	Nov	Dec	
a.	CP	968	951	878	781	629	510	440	404	448	542	690	892	in Kcal. $hr^{-1}m^{-2}$
b.	ET	14 0	14 0	15 5	17 2	19.5	22.0	23 5	23.7	22.7	20 5	17 8	15.0	in °C

According to the effective temperature, the indoor environment is lying in the upper acceptable range during July and August, during June and September in the optimum range, during May and October in the lower acceptable range, and from November to April in the range of below acceptable range (see Table 6b).

The residents have introduced their own moderating methods to reduce discomfort by either having light clothing together with considerable use of fans to produce comfortable conditions during July and August, or by having heavy clothing and warming means in winter. Fig. 10A gives thermal comfort classes and Fig. 10B gives effective temperature classes for Mersa-Matrouh.

2.1.1.7 Extreme Events and Other Meteorological Phenomena

Table 7 gives detailed data concerning the frequency of extreme events. It is worthy to mention that frost and snow are extremely rare phenomena in the region.

2.1.2 Atmosphere Interaction

2.1.2.1 Global Climate and the Greenhouse Effect

Global climate patterns are produced by a complex interaction between the Sun and the Earth's atmosphere, oceans, ice and land surface. Changes in any of these can upset the established equilibrium, and may affect global climate.

The Earth's climate is influenced by average global temperature and is sensitive to changes in temperature. The Earth has a natural temperature control system that keeps the planet warm enough to sustain life, yet prevents it from overheating. Certain atmospheric gases, the greenhouse gases, are critical to this temperature control system.

Greenhouse gases warm the Earth and its atmosphere just as glass, in effect, warms the air inside a greenhouse. Glass allows most wavelengths of the Sun's radiation to pass through it into the greenhouse, where it warms the soil and plants. The contents of the greenhouse, like all bodies, then

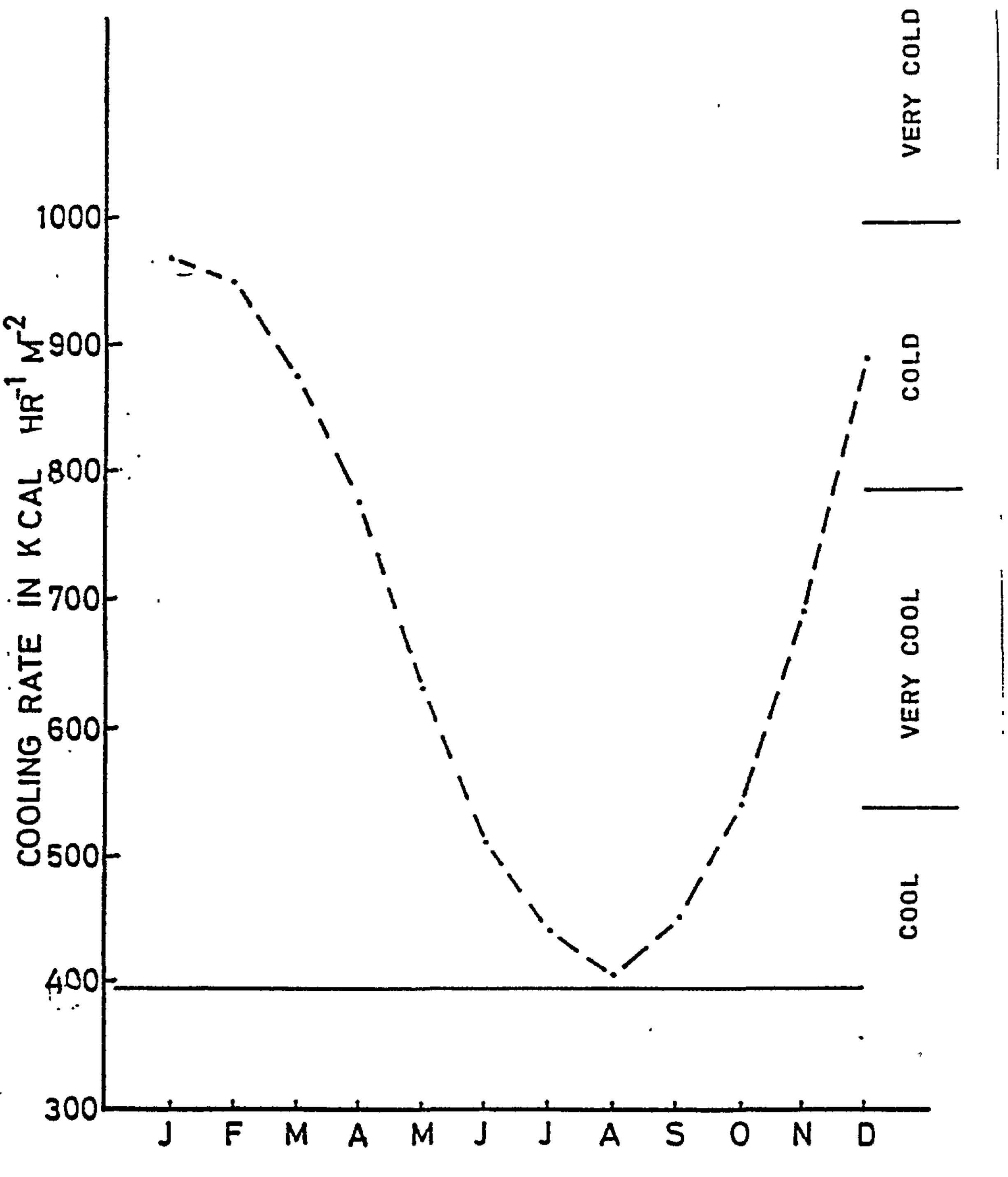


Fig. 10A Thermal Comfort Classes Mersa-Matrouh

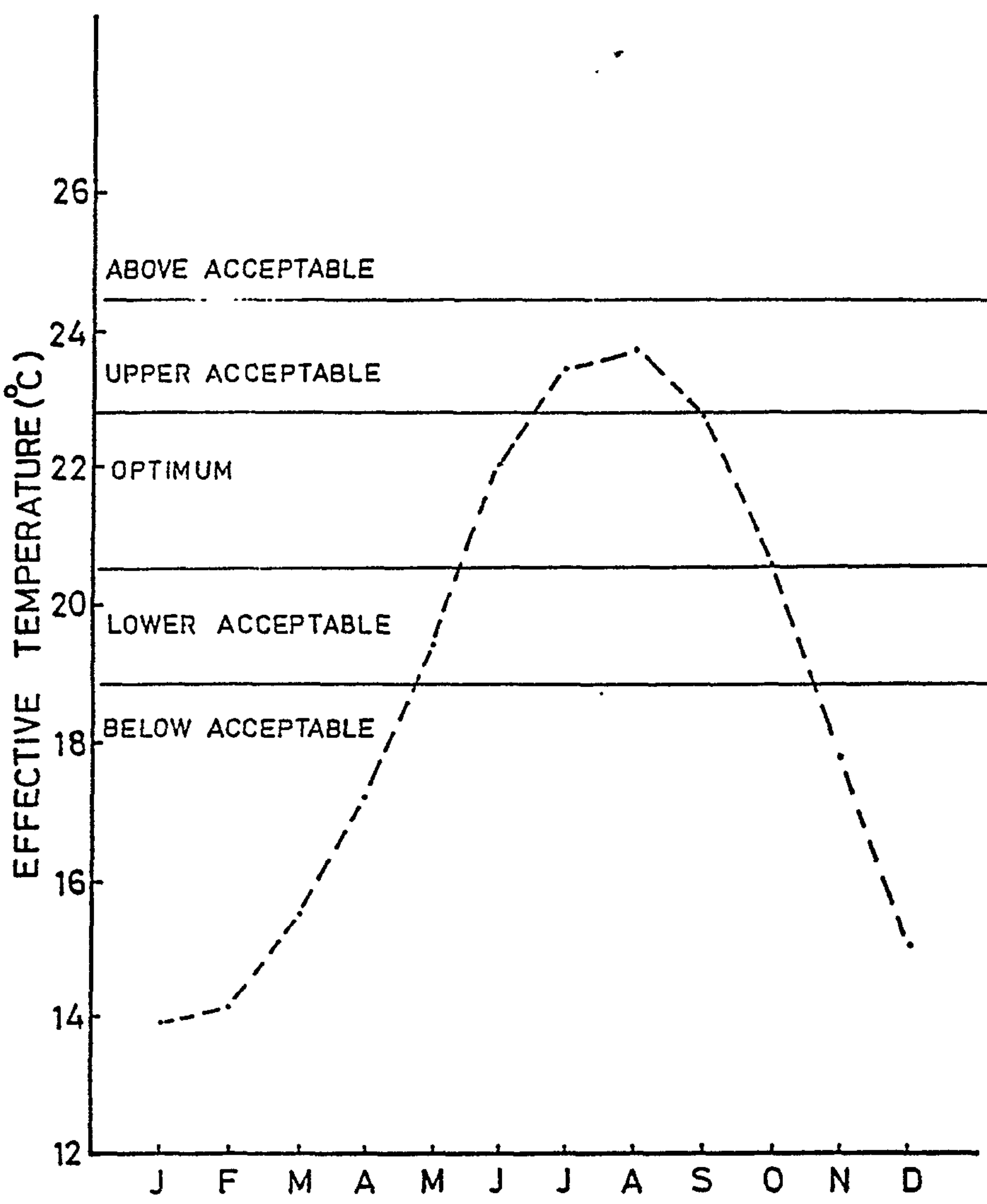


Fig. 10B Effective Temperature Classes Mersa-Matrouh radiate infrared energy back into the atmosphere. However, the glass in the greenhouse allows only about 10 percent of the radiation at these wavelengths to pass through it and escape into the atmosphere; the remainder, about 90 percent of the infrared radiation, is trapped in the greenhouse. The temperature of the greenhouse therefore stabilises at a higher level than that of the outside air.

A similar, but more complex interaction occurs between solar energy, the Earth and the greenhouse gases that surround the Earth. The Earth's temperature remains fairly constant because the levels of radiation from the Sun that enter the atmosphere are similar to those radiated back into space by the Earth and its atmosphere. However, temperatures on Earth are 33°C higher than those in space because greenhouse gases absorb and trap some of the radiation emitted by the Earth. This trapped radiation warms the Earth's atmosphere and, by creating a warm blanket of air around the Earth, also warms the planet's surface. This is known as the greenhouse effect.

Table 7

Extreme Events and Other Meteorological Phenomena

Station/ Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Absolute maximum temperature (°C)												
Matrouh	30.0	31 8	37.5	34 4	45 2	45.4	37 3	44 2	40 4	39.3	34 4	28.8
R.E.Hekma	26 2	32 3	37.0	40 4	37.0	43 0	38 8	38.4	38 8	35 2	31 3	26.7
Dabbaa	28.6	30 9	38 2	43.2	47 1	46 8	39 0	41.8	40 0	37 7	32.6	28.3
Absolute minimum temperature (°C)												
Matrouh	1.4	4.8	5 0	6.3	7 9	12.0	16.2	16 0	14 5	11 0	7.9	4.5
R E Hekma	2.3	5.0	4 8	6 5	9.5	14.0	16.2	16 5	13 9	11 6	6 5	5.4
Dabbaa	0 9	2 8	3 1	5.6	8 4	11.6	14.5	15.6	13 7	11.4	7 4	1.8
Absolute maximum rainfall in 24 hours (in mm)												
Matrouh	35.1	26 2	12.2	8 0	20.1	47 2	0.0	15 0	9.0	55 5	75.5	53.5
R E.Hekma	52.9	31.2	21 7	19.0	3 9	1.2	0 0	0.0	19.8	45 4	52 5	72.4
Dabbaa	49 0	34 7	32.0	7 6	23 3	0.3	0.0	0 0	26 2	36 3	41.0	30 2
Number of days of occurrence of thunderstorms												
Matrouh	0.6	0.4	0.4	0 3	0.3	0 0	0.0	0 0	0.1	0 5	0.8	0.7
Number of days of occurrence of gales												
Matrouh	1.1	1.8	0 9	1 0	0.3	0.0	0 0	0.0	0 0	0 1	0.4	1.0

2.1.2.2 Human Influence on Climate

Over the past few hundred years, human activity has significantly altered both the surface of the Earth and the composition of its atmosphere. These changes may be causing or contributing to the rise in global temperature observed over the past 150 years.

Greenhouse gases such as water vapour, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) exist naturally in the atmosphere but are also released into the atmosphere in great quantities when fossil fuels are burned and as a result of industrial and agricultural activities. The increasing concentrations of these gases in the atmosphere are likely to intensify the greenhouse effect and raise global temperature.

Concentrations of atmospheric gases were not significantly altered by human activity until the industrial revolution. Since about 1750, however, atmospheric levels of greenhouse gases have increased significantly.

Atmospheric CO_2 concentrations have increased by 26% since pre-industrial times. The main cause is the widespread and large-scale combustion of fossil fuels (coal, oil and gas) during which CO_2 is released into the atmosphere.

Deforestation, which alters the reflectivity of the Earth's surface and reduces the amount of CO_2 absorbed and conserved naturally by trees, is a secondary cause.

Methane concentrations have more than doubled over the same period because of increase rice production, cattle rearing and biomass burning - all of which produce methane. Nitrous oxide concentrations have increased by about 8% since 1750, and agriculture is likely to have been a contributor.

Some greenhouse gases, such as chlorofluorocarbons (CFCs), result only from human activity They result from industrial processes, and have been building up in the atmosphere since first used commercially in the 1930s. Most countries are reducing CFC production and consumption to comply with the Montreal Protocol, which came into force in 1989.

Carbon dioxide, CFCs and nitrous oxide remain in the atmosphere for many years. Even if emissions were reduced, it would be decades or even centuries before atmospheric concentrations of these gases reflected these lower emission levels. If all the emissions of CO_2 that result from human actions had stopped in 1990, about half the atmospheric burden of CO_2 caused by human activity would still be present in 2100 In the short-term, at least, increasing levels of atmospheric greenhouse gases are therefore unavoidable, irrespective of any future reduction in emissions.

2 1.3 Summary

The climate of the region could be considered as the Mediterranean type, being strongly influenced by the presence of the sea

The region has a winter rainfall (Mediterranean region), the rainy season extends from November to April, though mainly concentrated in December and January with average rainfall of 120-140 mms. The lowest amounts of annual rainfall recorded was 37 mms, while the highest amount was 277 mms

The lowest temperatures are observed in January and February; the mean monthly minimum stays around 9°C. The highest values of mean maximum temperature occur in July or August, the extreme maximum temperature exceeds 40°C. The average temperature between November and April is 15.2°C and that between May and October is 23 4°C and that between May and October is 23.4°C. The coldest period is January and February, while the hottest one is that from July to September.

Average daily relative humidity for winter is 69% while that for summer is 72%
Average daily cloud cover (in oktas) for winter is 3.4 while that for summer is 1.8
Average daily wind speed (m/sec) for winter is 5.0, while that for summer is 4.2
Average daily sunshine hours for winter are 7.5, while that for summer are 10.7

2.2 LITHOSPHERE

2.2.1 Geology

2.2 1 1 Introduction

Geologically, the northern coast of Egypt may be subdivided into two different units. The first unit extends eastward from Alexandria towards Sinai. This unit mainly consists of quartoze-sand-beach-dune belt which forms the seaward edge of the deltaic coastal plain. It has developed by the redistribution of the sediments of the River Nile. The coastal strip is bordered by the Nile flood plain.

The other unit extends westwards. This north-western coastal plain of the Mediterranean Sea is located between Alexandria and the frontier of Libya over a distance of about 500 km. The coastal zone has a minimum width in the west where the sea attacks the Miocene limestone which forms a wave-cut cliff, to several tens of kilometres in the east where a wide coastal plain and a narrower piedmont plain can be differentiated The coastal plain is mainly composed of oolitic and biogenic calcareous sand forming the coastal beach/dune ridges and encloses a coastal sabkha. Parallel to the coastal ridges and lying further inland, there are series of older indurated calcareous beach/dune ridges separated by depressions filled with lagoonal-sabkha deposits.

Prior to 1960, the northwestern coastal region was relatively isolated from the main stream of development activities in Egypt. The reason may be related to rainfall, topography, soil and climatic conditions which permit dry farming agriculture. Since then, the government has steadily increased its development efforts with particular emphasis on tourism, agriculture and industry. The evaluation of coastal land is an essential tool in land-use planning. It is assigned the indispensable task of translating the data on land resources into categories which can be used in land improvement. Coastal zone management plan of the N.W coast has to take into consideration the climatic changes and sea level rise in coming decades and their implications on coastal geomorphology.

The Fuka-Matrouh area is one of the representative areas of N.W. coastal regions (Fig. 1). Its extensions along the Mediterranean coast and its width southward to the limits of the Western Desert reflect different physiographic features. The objectives of the present study are to.

a. Characterise the geological situation and sediment resources.
b. Assess landscape variability.
c. Estimate the sediment drift rate at coastal environments.
d. Evaluate the impacts of sea level rise on coastal regions.

2.2.1.2 Quaternary Coastal Plain

The Quaternary coastal plain occupies the area between the tableland to the south and the present shoreline of the Mediterranean Sea to the north. It has a variable width being only a few hundred metres or less to the west, where the edge of the homoclinal plateau reaches the sea; whilst to the east, where the plateau lies further inland, it varies in width between 10-40 km.

The Quaternary coastal plain is bordered to the south and to the west by the outcropping Middle Miocene Marmarican limestone which forms a tableland. The latter is topographically higher than the former and occupies the northern end of the great homoclinal plateau that extends southwards to the Qattara depression (Fig. 15). The boundary between the sediments of the Quaternary coastal plain and Miocene sediments that succeed them to landwards in the west and the Quaternary deltaic plain sediments to the east lies over a fault system (Hassouba, 1980). This system trends N.50 - 60W. to S.50 -60E and is downthrown to the east. Hence, the Pleistocene gravels of the Nile Delta are in juxtaposition with the calcareous Miocene-Quaternary sediments to the west (El-Shazly *et al.*, 1975).

The tableland of the Marmarican limestone forms the northern edge of the homoclinal plateau. To the north of this, the Quaternary coastal plain is situated. The tableland is the northern part of the great homoclinal plateau. The latter is, in its highest part, a hundred metres or more above present sea level. It slopes gently northwards towards the Mediterranean Sea and eastward to the Nile Delta. The northern edge of the homoclinal plateau of Marmarican limestone reaches the Mediterranean coast in the northwest of Egypt to form a low cliff. Hence, the Quaternary coastal plain becomes narrower in a northwesterly direction.

The exposed rocks of the coastal area - Qattara depression are exclusively of sedimentary origin and date back to the Miocene-Holocene with maximum thickness of about 200 m. The stratigraphic sequence may be outline as follows:

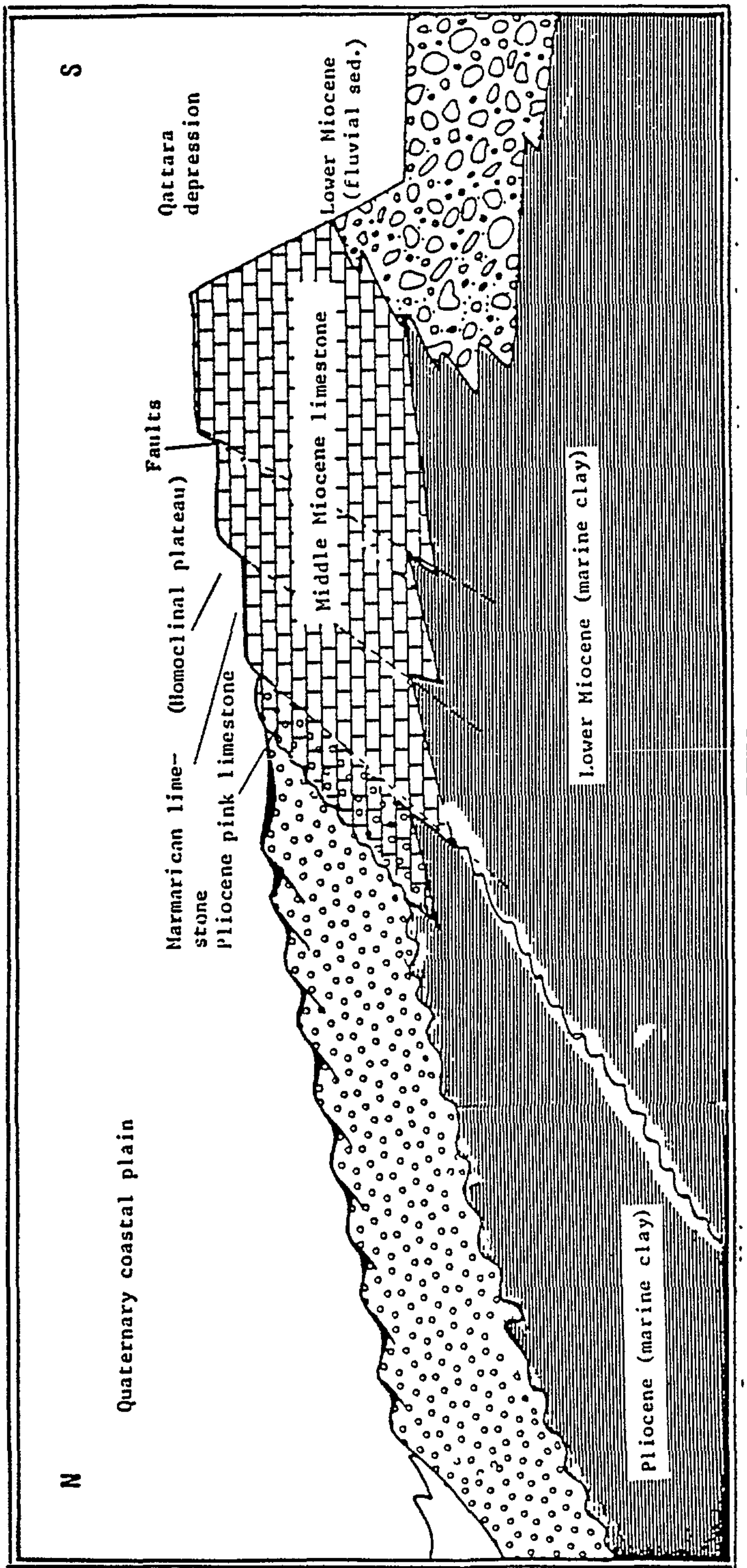


Fig. 15 Schematic N.S. cross section to show the Quaternary coastal plain

A. Quaternary age:

1. Holocene:
   - oolitic calcareous sand
   - *wadi filling*
   - loamy deposits
2. Pleistocene:
   - oolitic limestone of consolidated ridges
   - cardium limestone
   - pink limestone

B. Tertiary age:

1. Pliocene:
   - creamy limestone, upper series
   - brown limestone, lower series
2. Miocene:
   - *alternation of limestone and marl of upper horizon of middle Miocene*
   - fossiliferous limestone and marl of lower horizon of lower Miocene

Fig. 16 shows a log at Matrouh well (after Said, 1962)

2.2.1.3 Geological Evolution and Origin of the Quaternary Coastal Plain

The Quaternary coastal plain of the northwestern region with its beach ridges enclosing depressions filled with lagoonal-sabkha deposits is geologically similar to those coasts of the southern and eastern Mediterranean and other coasts around the world. The evolution of this coast can be related to the eustatic changes of sea level during Quaternary and formation of barrier islands. Fairbridge (1961) has summarised the hypotheses which have been suggested in order to consider the reason for such phenomena, these are:

1. <u>Tectono-eustacy hypothesis</u>

   This deals with the changes in sea level either positive or negative due to tectonic events which have taken place in the oceanic basins.

2. <u>Volcano-sedimento-eustacy hypothesis</u>

   This deals with the rise in sea level due to the deposition of sediments or volcanic *products in an ocean and a subsequent reduction in its capacity.*

3. <u>Geodetic hypothesis</u>

   The acceleration of the angular velocity of the earth would cause a rise of sea level in the equatorial belt and lowering at poles.

4. <u>Glacio-eustacy hypothesis</u>

   This is considered the most important factor which affects the changes in sea level. Glacio-eustacy is related to the change in volume of ice sheets which accompanied the climatic fluctuation that have taken place in the Quaternary period. The successive glacial and interglacial periods which accompanied ice sheets and the melting of the ice resulted in four or five major glacial phases (Fig. 17).

The eustatic curve helps to understand the stratigraphy of the Quaternary period on the northwestern coast and shows the past fluctuations in sea level and its drop from higher altitude *e.g.*

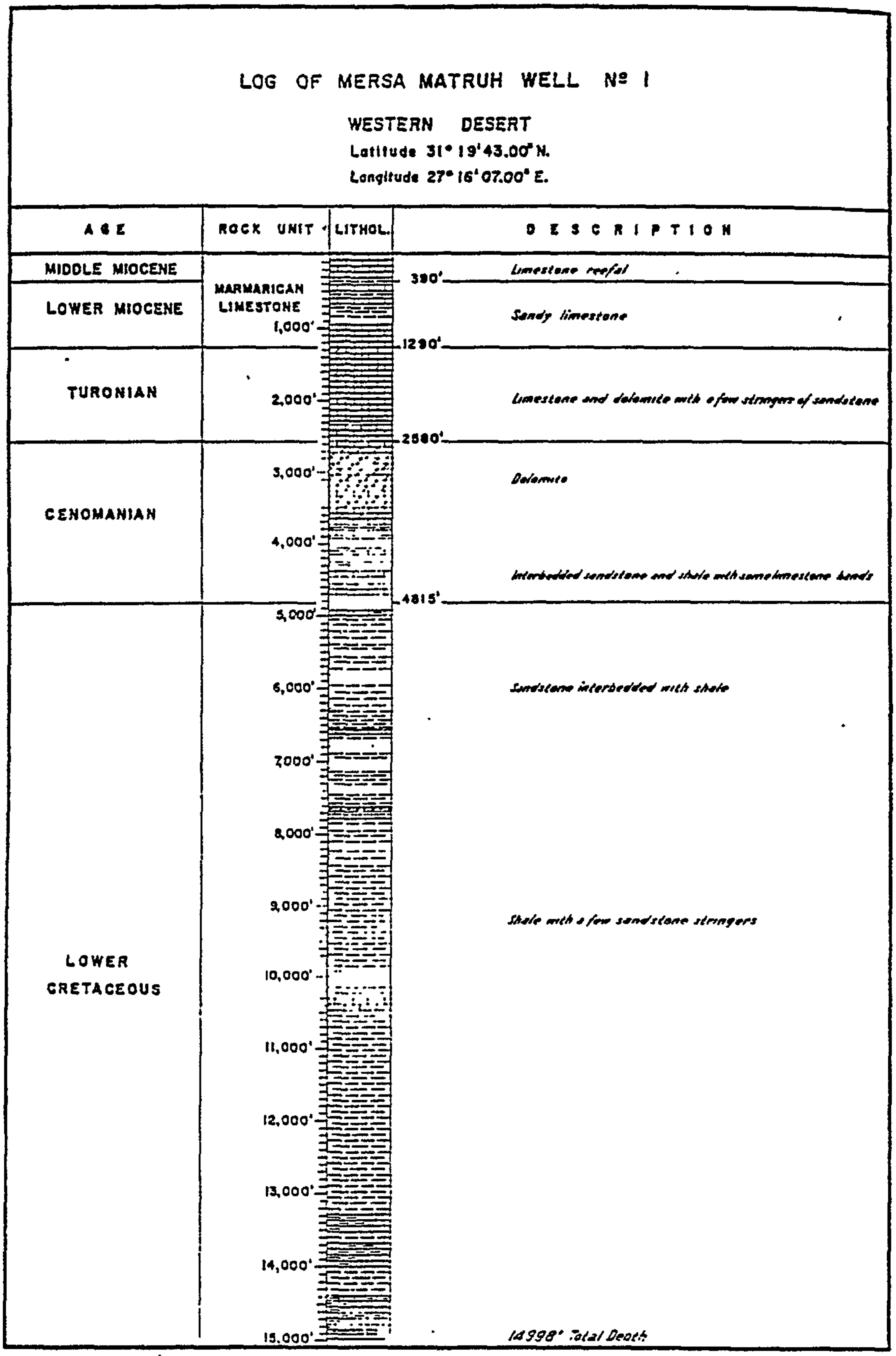


Fig. 16 Log of Matrouh well (after Said, 1962)

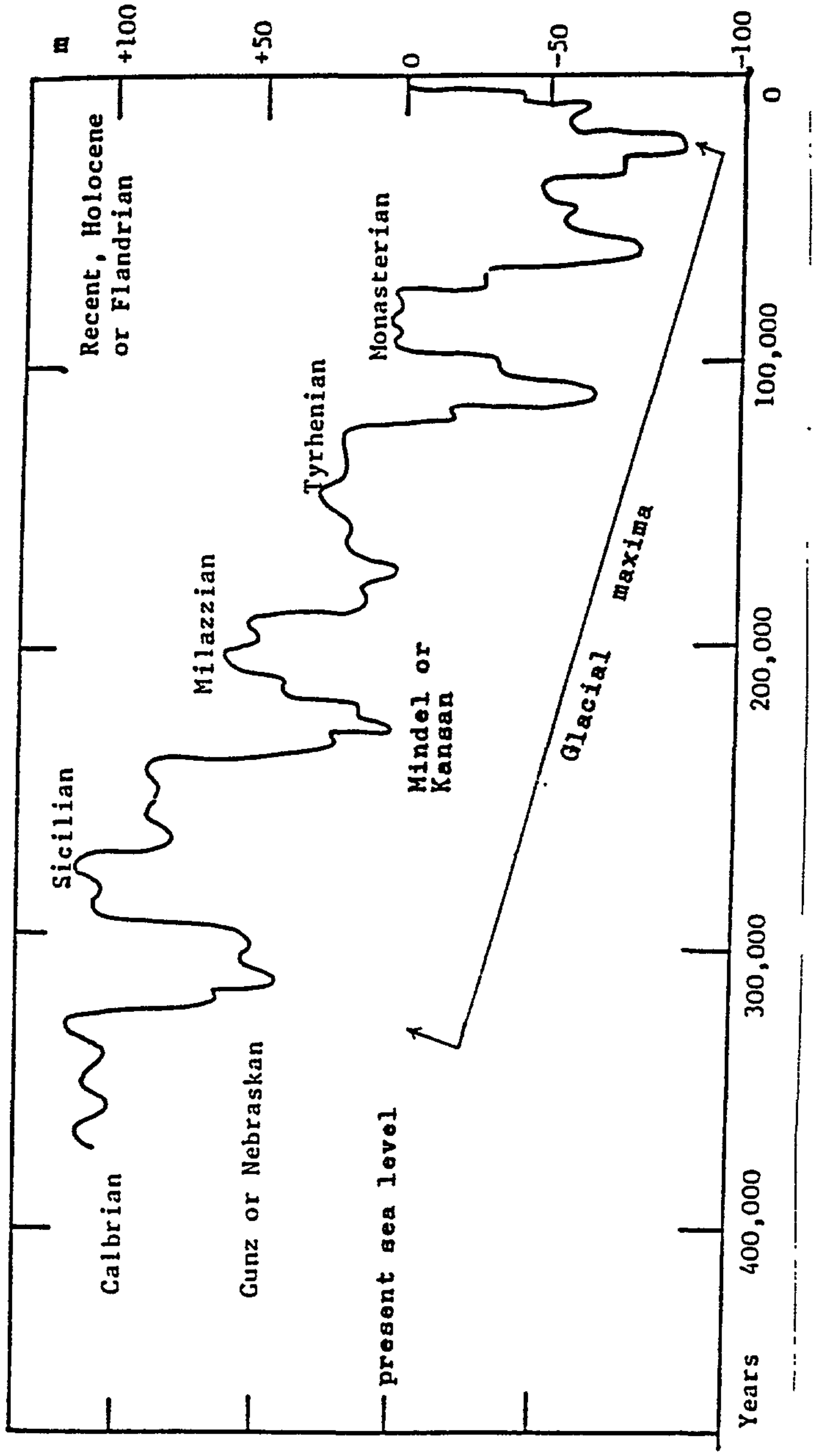


Fig. 17 Eustatic changes in sea level (after Fairbridge, 1961)

100 m in the early Pleistocene to its nearly present altitude in the Holocene. It indicates also the exposure of continental shelves several times during the glacial periods and then submergence during the following interglacial periods.

In fact, it appears that the coastal ridges of the western region have a complex origin. The investigators related their origin to:

a. successive sea level rise and fall during glacial and interglacial periods;
b. offshore or marine origin;
c. aeolian origin; and
d. successive earth movement.

2.2.1.4 Geomorphology and Microfacies of the Ridges

The coastal plain of the northwestern region is characterised by a series of nine elongated beach/dune ridges (Fig. 18). The most inland of the ridges is the highest and has an altitude of about +110 m, while the coastal ridge which borders the present coast is only about +10 m in height. These ridges are mainly composed of oolitic and bioclastic sand and have formed as a series of coastal beach/dune ridges which developed along the receding Quaternary shorelines (Shukri *et al.*, 1955). Seaward and to the north of the coastal ridge is a ridge which is, for the most of its length, submerged, but parts of which are exposed to form a series of isolated islands.

The following are the names which have been given to the ridges, described geomorphology and microfacies starting from the youngest most seaward ridge to the oldest most landward ridge:

Ridge 1 The coastal ridge (Late Monasterian), +10 m. This ridge is composed of friable limestone mainly consisting of oolitic grains together with organic components, *e.g.* calcareous algae, pelecypods, gastropods and a few foraminifera.

Ridge 2 Abu Sir ridge (Main Monasterian), +25 m. There is a similarity between ridges 1 and 2. Caliche layer is a product of recrystallisation due to the effect of rain water or the high humidity of the region. The ooliths in this layer have gradually lost their shape and have become smaller until they are obliterated.

Ridge 3 Gebel Maryut ridge (Tyrrhenian) +35 m. In this ridge, the appearance of quartz and heavy minerals and increase in amount of calcareous algae is noted. The faunal content of this ridge is mainly of Mediterranean type (different from the more seaward ridges).

Ridge 4 Khashm El-Eish ridge (Milazzian) +60 m. An abundance of Indo-Pacific species of foraminifera is observed in this ridge which suggests a connection between the Red Sea and the Mediterranean Sea at the time of its development. These species show evidence of a warmer climate which accompanied the higher sea levels in the interglacial period.

Ridge 5 Alam El-Khadem ridge (Sicilian) +60 m.

Ridge 6 Mikherta ridge (Sicilian) +80 m.

Ridge 7 Raqabat El-Halif ridge (Sicilian) +90 m.

Ridge 8 Alam Shaltut ridge (Sicilian) +110 m. Ridges from 5 to 8 are the most inland of the ridges and are similar in composition and micro-organic content. The conglomeratic appearance of the top layers of these ridges may be due to deeper recrystallisation and increase in quartz content. The organic remains consist of calcareous algae, foraminifera, pelecypods, gastropods and echinoid spins.

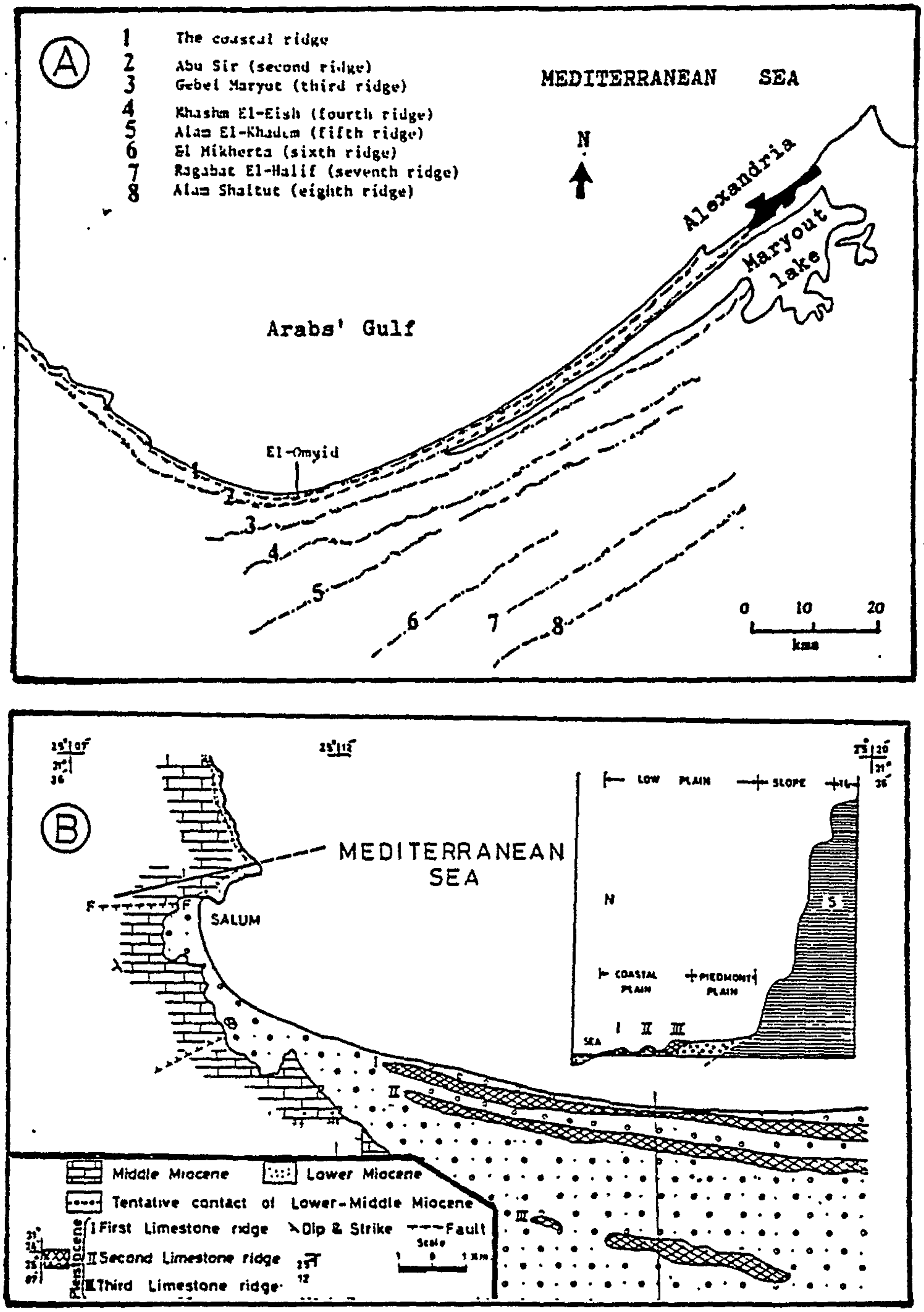


Fig. 18 Coastal and inland ridges along the northwestern coast between Alexandria (A) and Salum (B)

The cemented carbonate ridges (ridges 2-8) are capped by caliche deposits which form a distinctive surficial, indurated, brownish to pinkish carbonate crust. The thickness of this crust varies between 1-50 cm and appears to become thicker landwards as the ridges become older and higher. These crusts are sometimes laminated and superficially resemble algal-stromatolites. When fractured and brecciated, they show a conglomeratic appearance. Similar crusts may be found buried under the loessic sediment of the carbonate ridges.

At Dabbaa area, four well formed beach ridges are correlated with the beach ridges to the west of Alexandria. Well developed coastal ridge is recorded along Fuka coast and to the west of Ras El-Hikma. Matrouh area is formed by a series of ridges which range in age from Late Monasterian (the most seaward ridge), which is equivalent to the coastal ridge west of Alexandria, to the Milazzian, the most inland ridge. In fact, the coastal plain of Matrouh is covered by Quaternary deposits represented by only three elongated ridges separated from one another by three longitudinal depressions. The three successive ridges are:

a. The foreshore ridge (+10 m)
b. Matrouh ridge (+25 m)
c. South Matrouh ridge (+45 m)

Furthermore, there is a fourth ridge which runs parallel to the escarpment which forms the northern boundary of the homoclinal plateau.

To the west of Matrouh, the calcareous ridges with two intervening lagoonal depressions that run parallel to the sea are representing the Quaternary deposits at Salum district (Selim, 1974). Some ridges are present to the west around the entire coast of the Gulf of Sirte (Libya) and extend for a distance of about 5 km inland.

Therefore, the northwestern beach ridges seem to continue; but however may absent at some areas, from Alexandria to Dabbaa, Fuka, Matrouh, Salum and up towards Libya. They form a continuous and well marked chain. On the other hand, the outermost chains of ridges lying further inland are less regularly arranged.

2.2.1.5 Tectonic Movement and Subsidence

From the tectonic viewpoint (Said, 1962), no major true structural displacement (faulting or folding) are recognised along the northwestern regions (Fig. 19). Nevertheless, a few exceptions are found, representing by fracturing and jointing, genetically of epeirogenic movement and/or mild Post Miocene tensional forces (Abdallah, 1966). It is, however, reasonable to assume that only the eastern parts of the ridges, those close to the Nile Delta, have suffered some displacement as a result of subsidence of the deltaic body, whereas to the west the ridges may have been only slightly affected.

Evidences for continued subsidence during the last 2,000 years could be seen in Alexandria and the western part of the Nile Delta coast where Ptolemaic and Roman settlements are now found at depths below sea level. Subsidence rate along the delta coast shows wide variations. The eastern coast indicated a subsidence rate of 0.5 mm/year over the last 20,000 and a rate of 0.05 mm/year only during the last 2,000 years. Recently, Stanley (1988) estimated a rate of subsidence of 0.5-5.0 mm/year and gradually decreases from the western part of the delta coast to the east.

It is important to mention that the elevations of the ridges decreases eastward. The reason may be related to two reasons: the bending of the ridges under the load and subsiding of the delta sediments, and the addition of wind-borne material on their tops, this feature is more pronounced to the west.

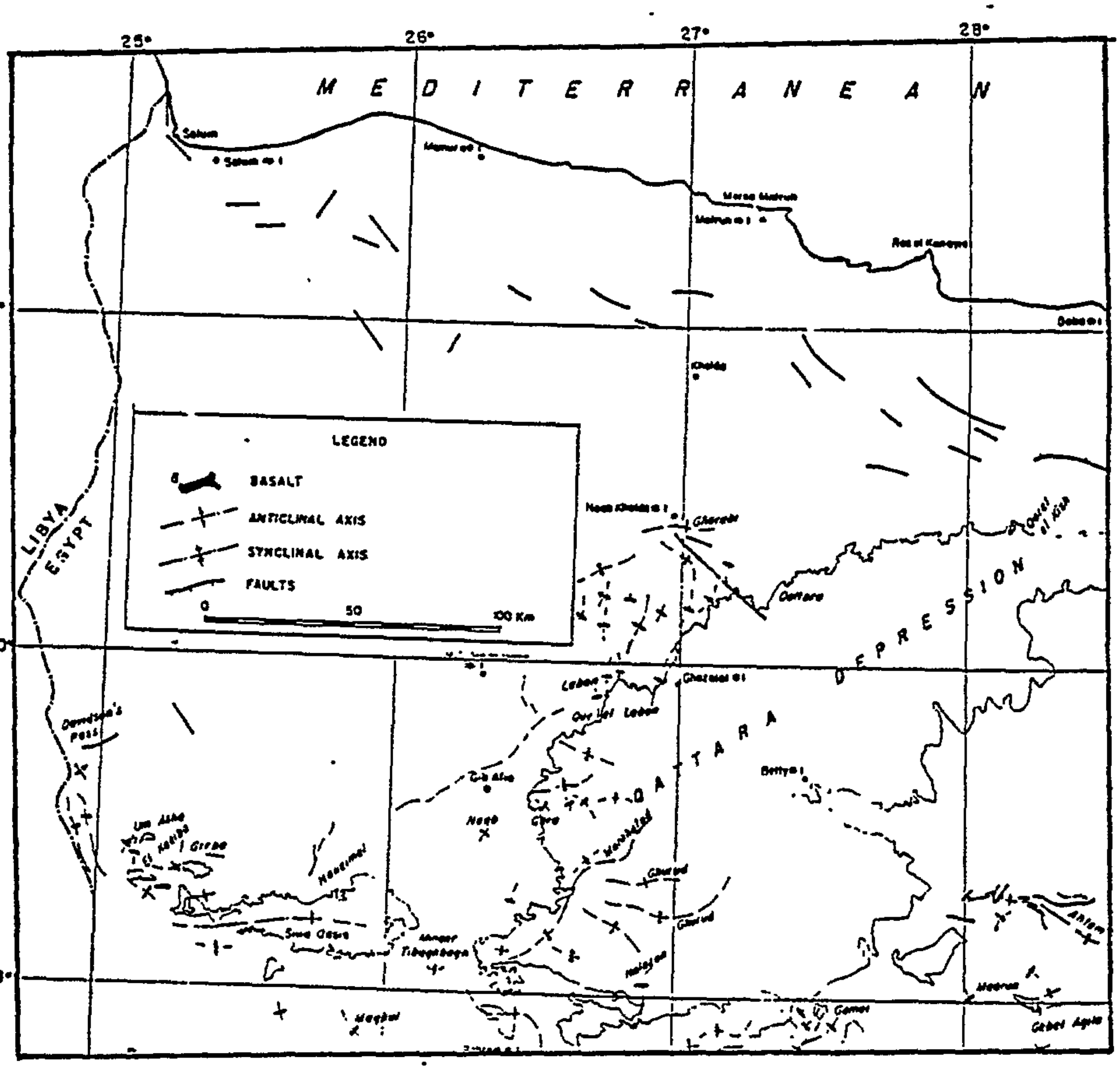


Fig. 19 Map showing surface structures at the northwestern coast (after Said, 1962)

2.2.1.6 Topography and Physiographic Zones

The studied area is characterised by a certain topography and physiographical features. The sediments are derived from highly calcareous parent material. The study of the physiographical zones of the area was based on the examination of its aerial photographs, topographic maps, slope maps and the field examinations.

The topography between Fuka and Matrouh shows that the intervals of the elevation occur in strips run parallel to each other (Fig. 20). These strips are narrow near the coast and become wider southwards. Detailed elevations could be seen at Ras El-Hikma and are shown in Fig. 21. The majority of the Fuka-Matrouh area has a slope class of < 4%, the escarpment have a slope class of > 8% (Fig. 22).

The area can be subdivided into three main zones and the following is a detailed description for each zone:

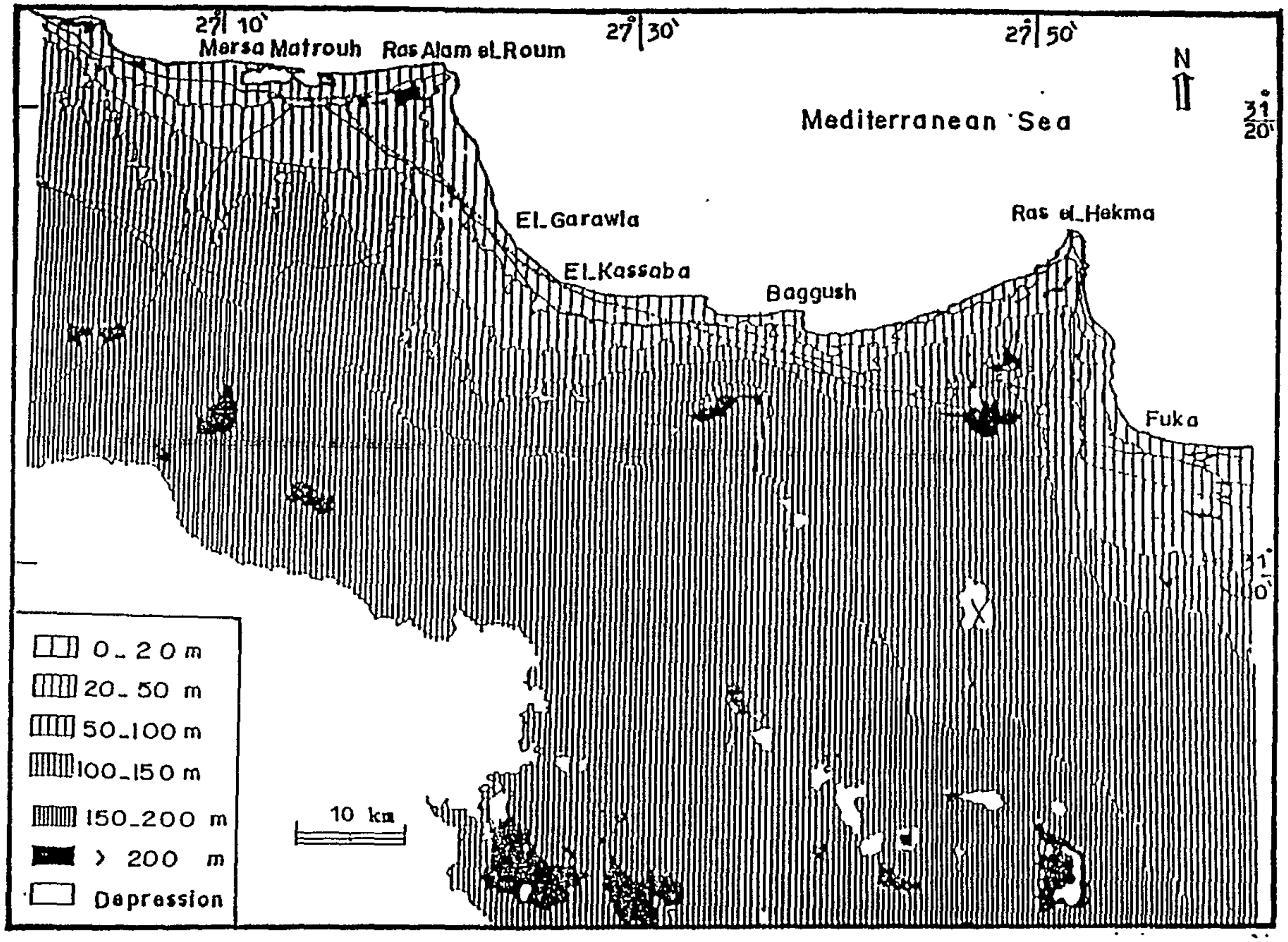


Fig. 20 Topographic map showing the elevations between Fuka and Matrouh

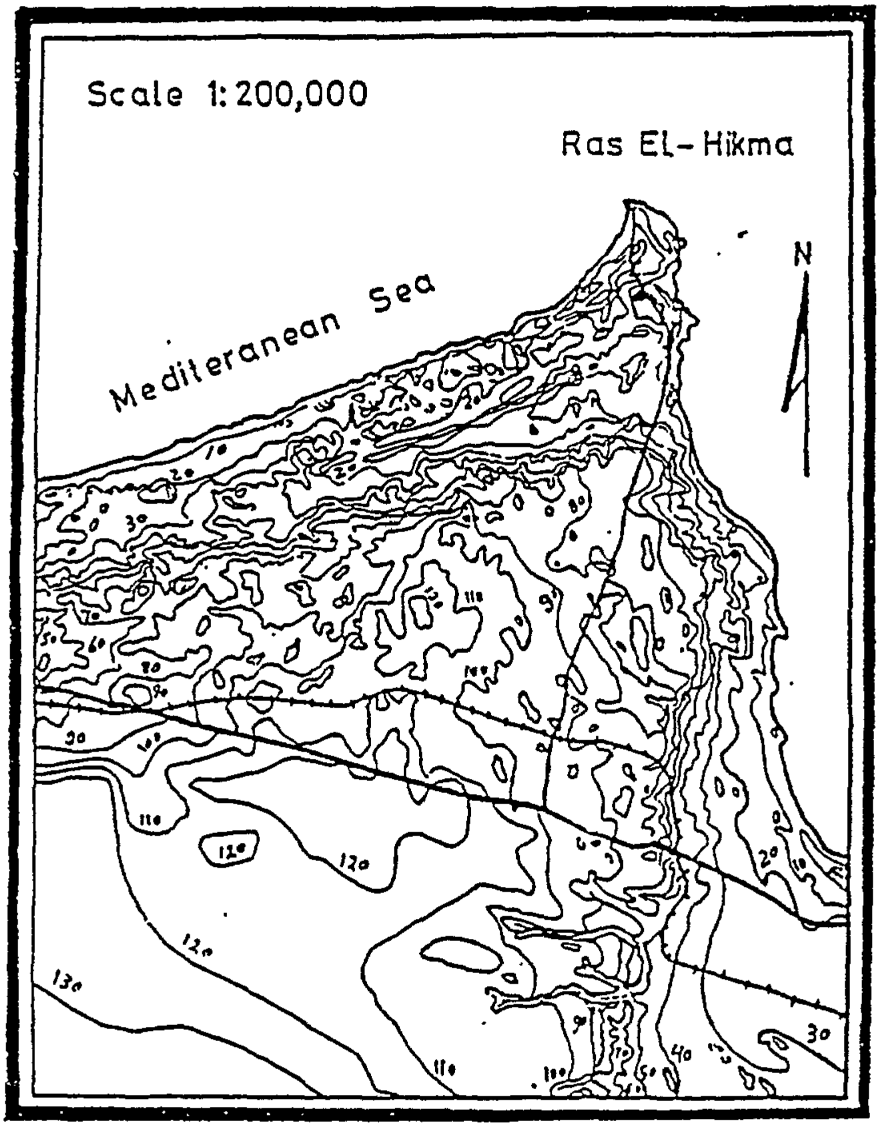


Fig. 21 Contour map of Ras El-Hikma

2.2.1.6.1 Recent coastal zone

It includes coastal plains which consist of different strips ranging between 1-6 km wide and up to 60 m high above sea level. The southern coastal zone consists of plains desiccated by 45 wadis. According to the height, the following strips are recognised:

- beach and drifting sediments;
- cemented oolitic sand dunes up to +20 m high;
- high rocky dunes at the peak of the area, +40 to +60 m;
- complex area of different texture, it is composed of rock (+10 to +20 m high) and deep soil of loamy sand (+10 m high);
- rocky ridge with some dnfted areas, +20 to +30 m; and
- depression with deep soils of different textures ranging between sandy loam and clay loam, +10 to +20 m.

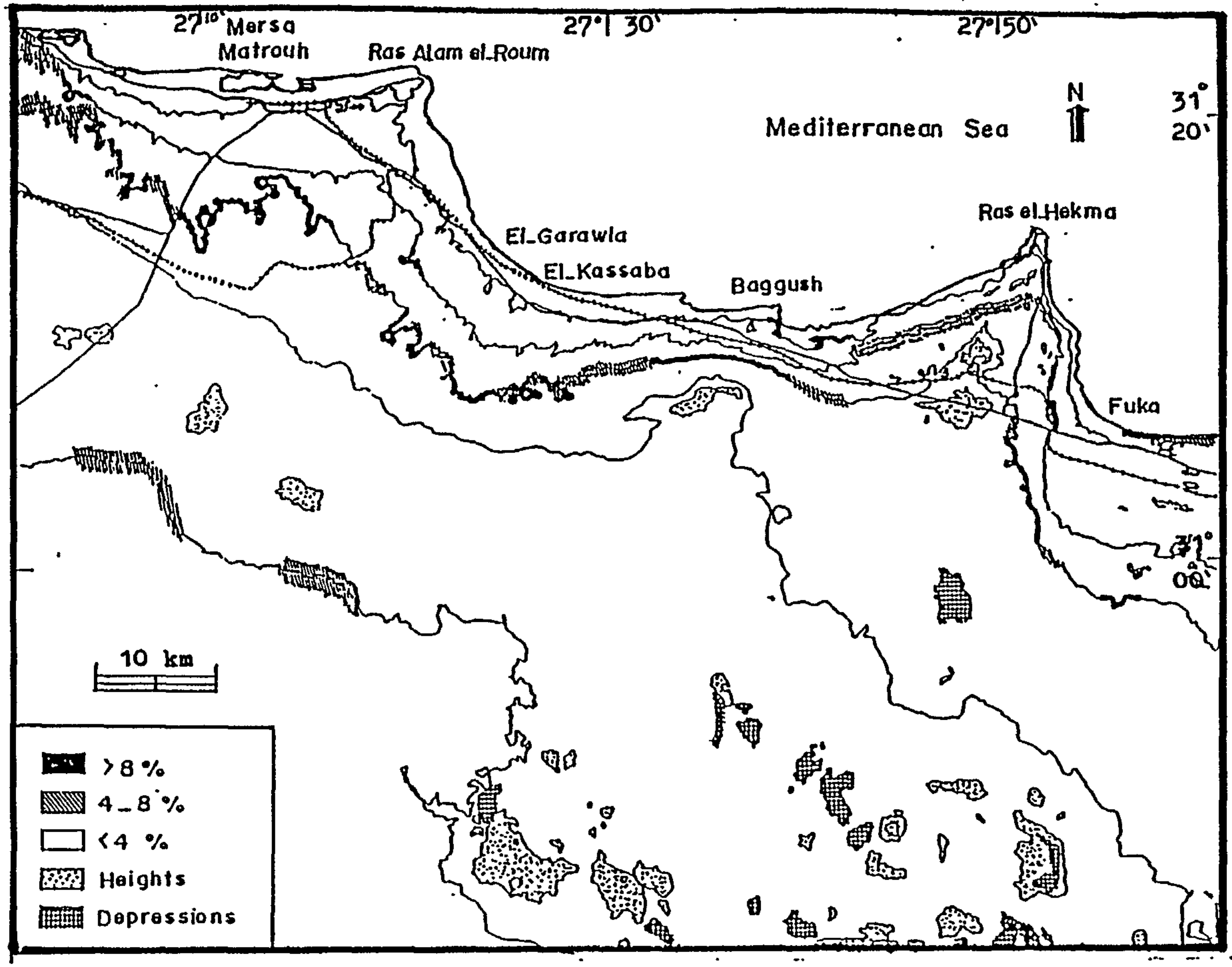


Fig. 22 Slope classes at coastal and inland areas of Fuka-Matrouh stretch

2.2.1.6.2 Northern plateau

The northern plateau is gently sloped with shallow wadis and alluvial sediments. It is a strip of 10-13 km wide and 30-80 m in height. This zone is characterised by sloping and dissected slope system of the old third ridge. Different textures can be recognised:

- gullied;
- without gullies; and
- alluvial fans at the foot slopes of soils limited in depth by caliche or rock.

2.2.1.6.3 Southern plateau

The southern plateau extends to 60 km southward with elevations between 80-120 m. It is characterised by complex areas and depressions. This zone consists of:

- complex areas of rock and soils of different depth and texture (loam, sandy loam and sand). It is limited by caliche and rock or slab;
- isolated areas of outwash plains of deep soils different in texture (sandy loam, sandy clay loam and loam); and
- denuded rockland with gentle relief.

Figure 23 shows the main zones at Ras El. Hikma

2.2.1.7 Sediment Resources

Regarding the origin of carbonate sediments of the northwestern coastal region, it can be mentioned that the precipitation of carbonate is the first step for the origin of all limestones. Usually, the presence of calcium carbonate in sediments can be divided into two types: primary or secondary. The primary calcium carbonate almost occurs as calcareous parent sediments and shows influence as a sediment forming factor. But the secondary calcium carbonate is a product of diagenesis which depends upon environmental conditions. On the other hand, chemical precipitation of calcium carbonates *in situ* has been proposed during evaporation of calcium bicarbonate-charged solutions. In fact, the limiting factors in the depth of carbonate accumulations are the parent sediments, permeability, texture, structure and climatic conditions.

Lime accumulation displays different forms such as concretions, threads, indurated nodules, patches, pebbles and boulders of different shape and size. Lime may also exist as coating on sediment grains or binding them together as a cementing material.

In addition, wind-blown dust and sand from the surrounding desert may also have settled in the coastal regions and contributed to such deposits.

The shallow depressions which separate the ridges from one another show a successive lowering in surface elevation towards the Mediterranean Sea. These depressions are filled with lagoonal-sabkha deposits consisting of alternating layers of gypsum and fossiliferous, gypseous marl and are covered with loessic sediment. Gypsum is being extracted from some old lagoonal-sabkha depressions. Much of the area of the depression between the second and third ridge is occupied by Lake Maryout (west of Alexandria). The outer sabkha forms an almost wet flat area that has an elevation of about 1 m above present mean sea level. The surface sediments of the sabkha consist of loessic sediment rich in calcium carbonate particularly near the carbonate ridges from which it receives a supply of wind-blown carbonate grains.

2.2.1.8 Loessic Sediments

Loessic sediment is defined as silt of very special character. It is unconsolidated, porous and commonly buff in colour (locally yellow to brown). The most characteristic feature is the lack of

Fig. 23 Physiographic zones of Ras El-Hikma
A - recent coastal zone
B - northern plateau
C - southern plateau

stratifications and remarkable ability to stand in a vertical slope. It is generally highly calcareous. The loess is found to be thick in the depressions between older ridges and also near the flanks of the ridges. It is also found on the top of the ridges and interfingers with the carbonate sediment of the ridges. Loessic sediment is also found to separate the various units of the cemented aeolian limestone.

It appears that the loess has been deposited from dust storms which blew from the adjacent deserts to the south. The source of the sediment may be composite (Hassouba, 1980), it is probably mainly derived from the alluvial plain of the Nile Delta to the southwest. Intermixed with this material is surface wash from the carbonate ridges and also the remains of pulverized terrestrial snails which live on the surface of the ridges and depressions. The sediment beneath the loess is very rich in gypsum which appears to have been deposited by the evaporation of water from the adjacent sea.

2.2.1.9 Wadis Sediments

The northern plateau represents one of the major topographic features of the region. The northern edge of the plateau or tableland of Miocene limestone forms an escarpment running mainly east to west and rising 50-75 m above the piedmont plain (Pleistocene and recent sediments). The plateau is dissected by consequent streams that flow northwards to the sea. These streams are mostly dry at the present time. About 45 wadis are located within a strip of about 4-6 km from the shoreline.

Wadis sediments south and southeast of Matrouh are investigated (Table 8). Nagamish, Garawla, Kasaba and Hashim wadis represent alluvial fans at the foot of the plateau. Their sediments are friable and mainly composed of clay, silt, limestone and shales. At some wadis, boulders occur to alternate with clay strata. The mean grain size of wadis sediment ranges between 0.11-0.17 mm. These sediments are fine, very fine and poorly sorted. The calcium carbonate content is somewhat uniform and ranges between 10-24%. A decreasing trend for the oolites content from the coastal ridge to the inland ones has been recorded and may be attributed to leaching, recrystallisation and diagenetic processes.

2.2.1.10 Offshore and Coastal Environments

The coastal plain extends from the shoreline southwards as far as the piedmont plain, or as the plateau, when the former is missing. Its width is narrow to the west and wide to the east. The coast includes a number of open bays; Kanayis Gulf (El-Hikma Gulf) along the eastern side of Ras El-Hikma and Abu Hashaifa Bay at the eastern side of Matrouh, with numerous bays separated by points in-between (Figs. 24 and 25). The headlands and bays seem to be related to some regional structural pattern. The bays are underlain by synclinical areas resulting in a wide coastal plain and the headlands by monoclines where the plain is narrow.

Matrouh inlet is completely sheltered by reefs. A fishing harbour is situated at the east end of the inlet. East of Matrouh, the coast is rocky and fronted by reefs which form closed chains of salt lagoons. Between Ras Alam El-Rum and Ras El-Hikma, the coast is indented by several sandy bays bounded inland by sand dunes.

The coastal plain could be subdivided into five environments according to the geomorphology and nature of sediments (Fig. 26 and 27, Table 8). Generally, all the coastal environments are normally sharply distinguished and extend in a strip up and down the length of the coast, with change in width. In fact, missing of some environments at some regions would disturb such system. Bagush region represents an ideal example where all coastal environments are well developed. Figs. 28-29 show the nature of coastal environments along the coasts of Ras El. Hikma and Bagush.

2.2.1.10.1 Coastal dunes

The recent coastal dunes (white dunes) are located at the far end of the backshore flat and surrounding the beach. Most of these dunes are of barchan type with elevations up to 5m above their base level. The distance between these dunes and the shoreline may exceed 100m. They are observed to develop well, without vegetation, at Bagush coast within a strip of about 1 km width. The coastal dune sediments are friable and mainly composed of oolitic limestone grains (96% carbonate content). These sediments are characterised by a mean grain size of 0.31 mm and are well sorted grains (Table 8). The sediments at the top of the coastal dunes are finer and better sorted than those at the foot of the dunes.

Table 8

Mean grain size and carbonate content of some samples, Fuka-Matrouh plain

Sample no.	Location	Mean Size Ø	mm	Carbonate %	Sorting Ø
1	Wadi Nagamish (a)	3.15	0.110	10	0.95
2	Wadi Nagamish (b)	8.00	0.004	-	1.80
3	Wadi Garawla	3.10	0.120	15	1.53
4	Wadi Kasaba	2.60	0.170	24	1.25
5	Wadi Hashim	3.05	0.120	21	1.31
6	Beach, Bagush	1.60	0.330	95	1.14
7	Backshore, Bagush	1.85	0.280	95	0.52
8	Dune, Bagush	1.70	0.310	96	0.50
9	Beach, Matrouh	1.95	0.260	77	0.51
10	Beach, Ageba	1.70	0.310	98	0.50
11	Dune, Fuka	1.32	0.400	96	0.60
12	Dune, east Fuka	1.55	0.340	98	0.54
13	Dune, south Fuka	2.70	0.155	97	0.43

Landward, the old coastal aeolian sediments are cemented oolitic-skeletal grainstone with rounded and well sorted grains. They occur as horizons which are lensoid in shape and are separated from one another by 2 m thick layers of loesses which increase in thickness towards the flanks of the dunes. Sedimentary structures of these cemented deposits range between gently dipping, cross bedding and planar stratifications which support their aeolian origin.

2.2.1.10.2 Backshore

The back of the beach is a strip of 50-60 m wide of flat area, referred to as the backshore. It may be absent at some regions. This zone is being influenced by wind action. On it, there are occasional patches of low foredunes with heights less than 1 m. Low parts of the backshore are flooded during winter storms and therefore may have a tendency to slight subsidence. The sediments of the backshore are of medium size (0.28 mm) and well sorted due to sorting processes by wind action. Carbonate content constitutes the main part (95%) of the backshore sediments.

2.2.1.10.3 Beach

The beach is the zone of unconsolidated sediments which extends from the low water level to the place where there is a change in physiographic forms and grain size. It is normally exposed to the action of waves and littoral currents. The beach is flat and averages about 20-30 m wide at Bagush coast. Some beaches along the coast may be entirely submerged during high storms. At the western coasts, the beach is closely bordered by about 100 m high wave-cut cliff. Beach face slopes are greatly varied, showing values between few degrees and 15 degrees.

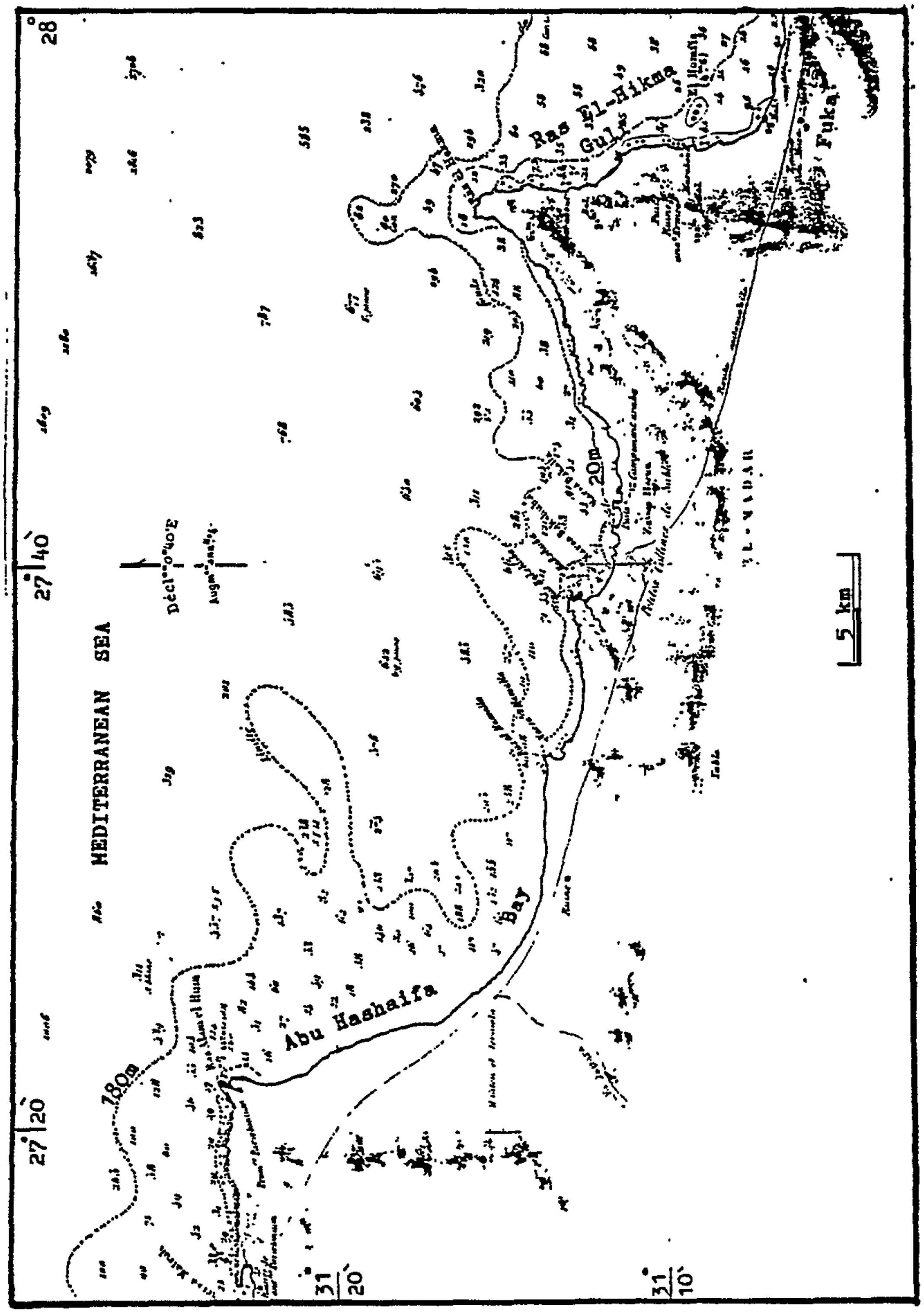


Fig. 24 Shoreline features and bathymetry of Fuka-Matrouh stretch, northwestern coast

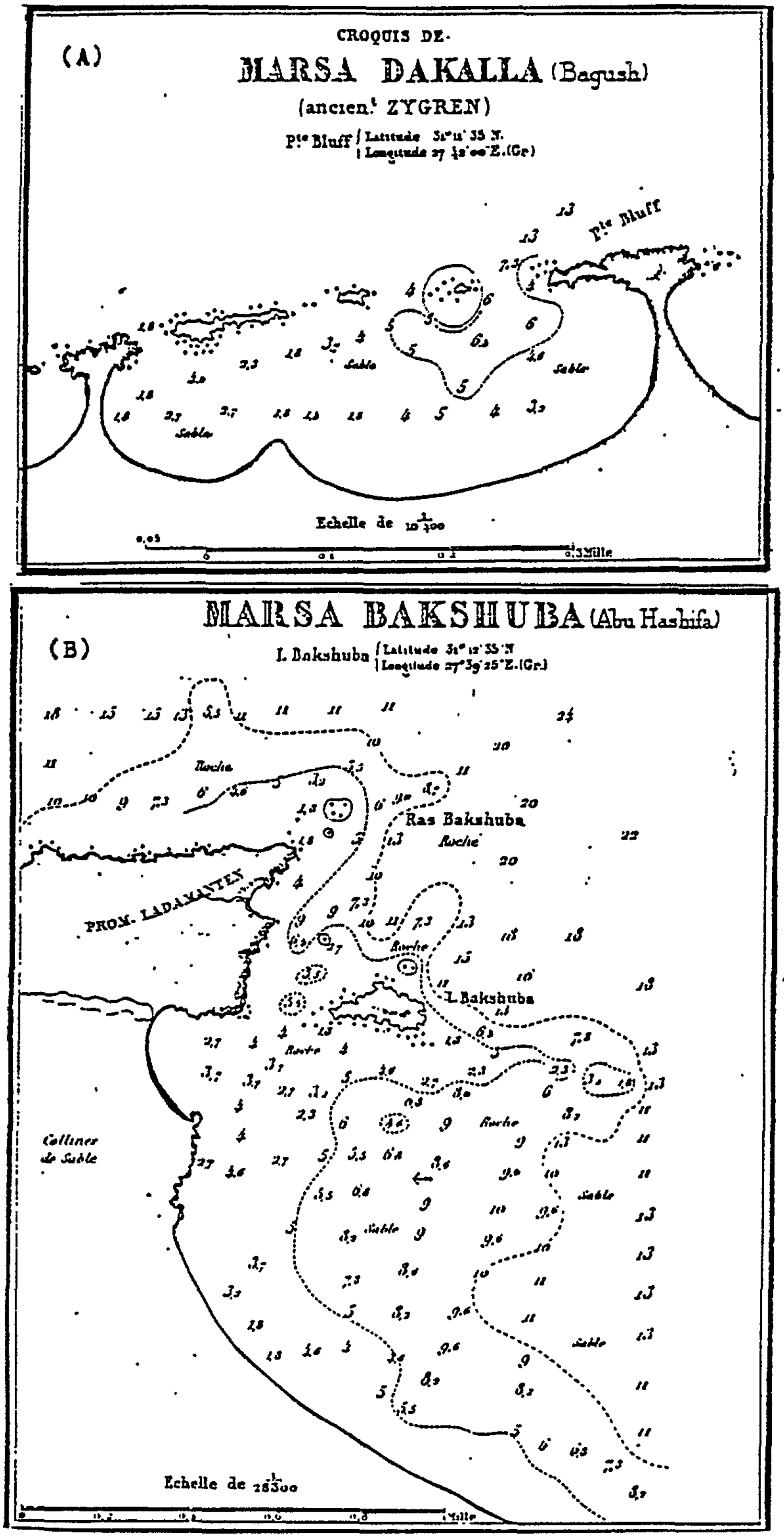


Fig. 25 Bagush beach (A) and Marsa Bakshuba (B)

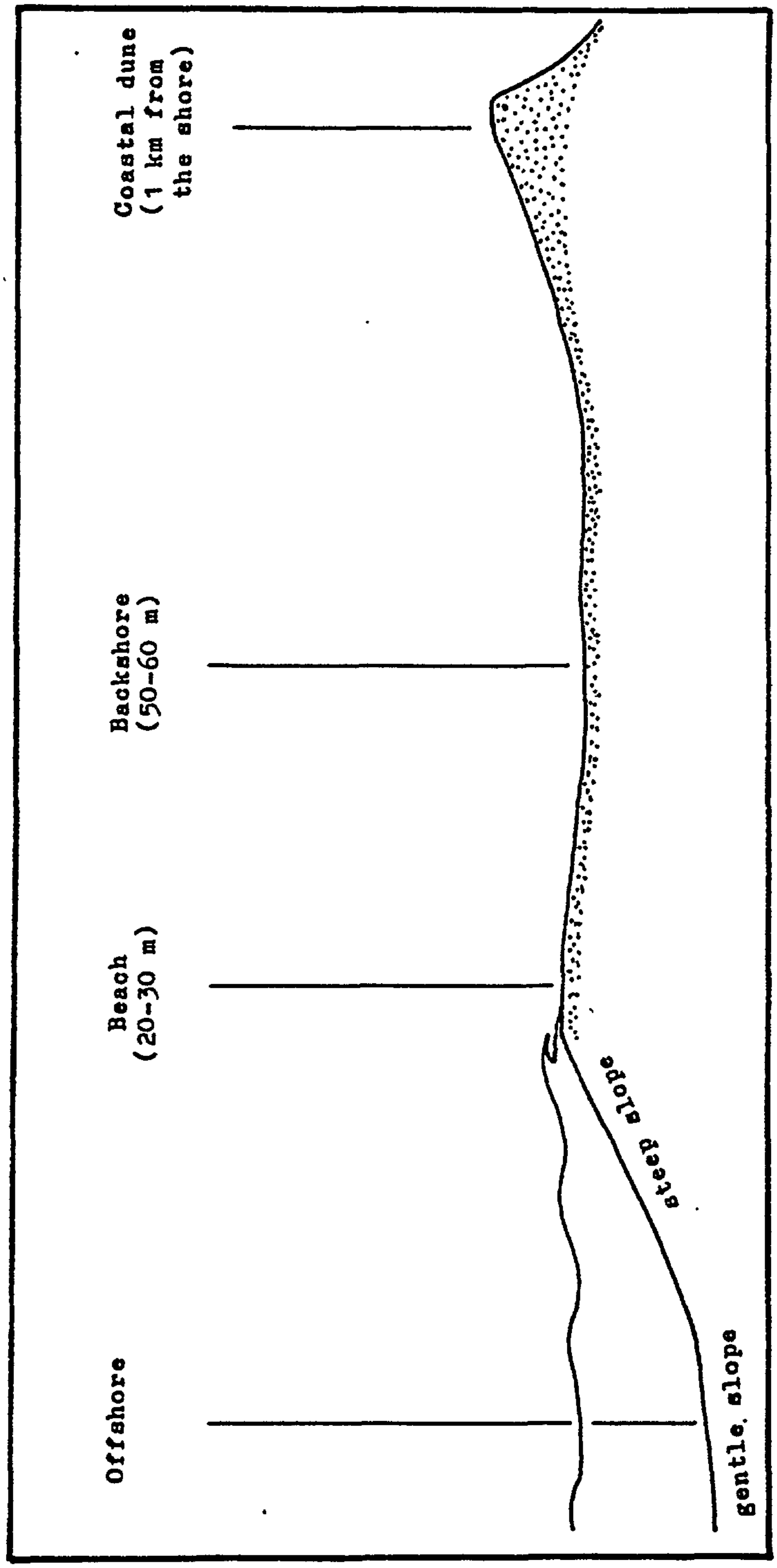


Fig. 28 Schematic diagram showing the coastal environments at Bagush area, northwestern coast

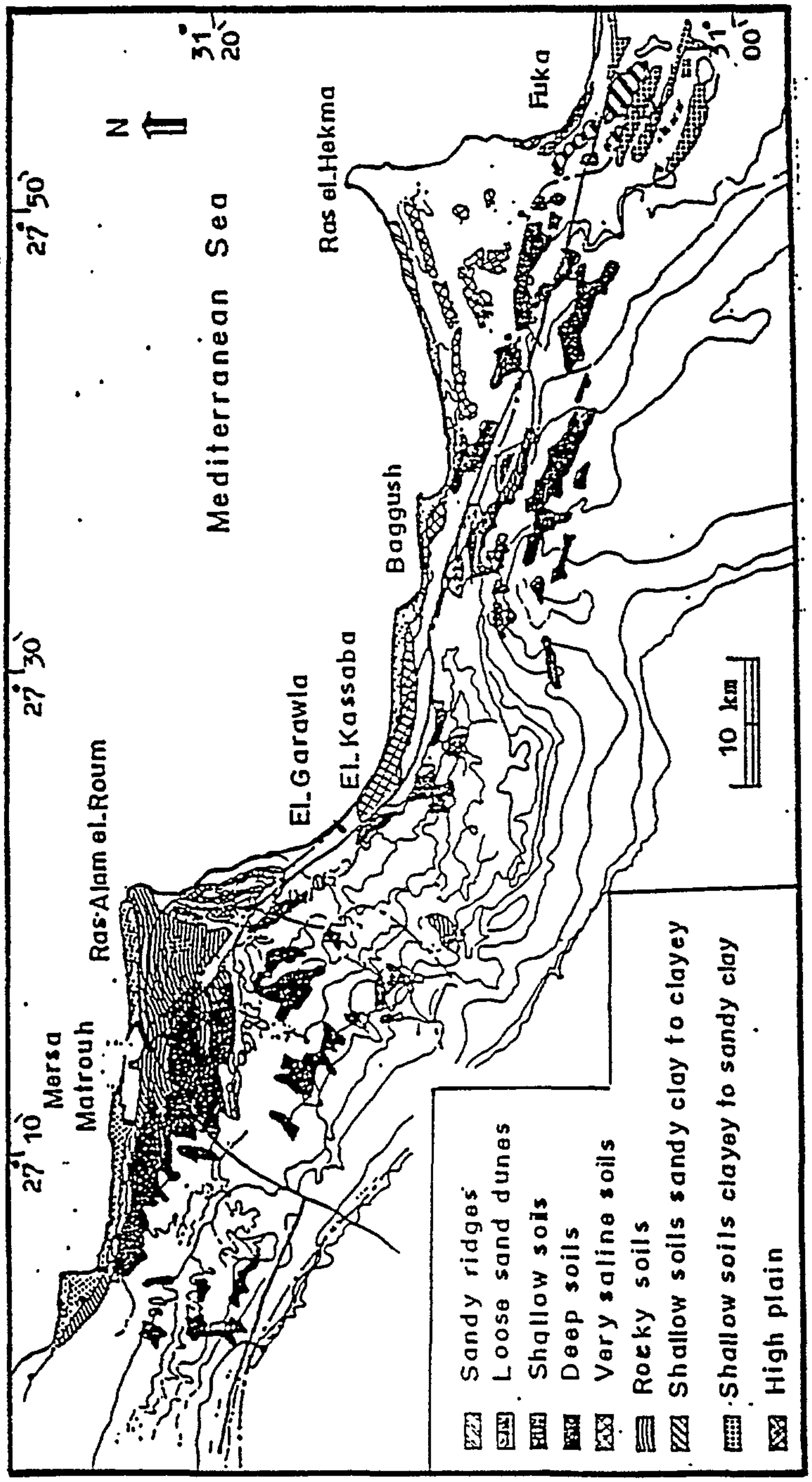


Fig. 27 Coastal and inland zones along Fuka-Matrouh stretch

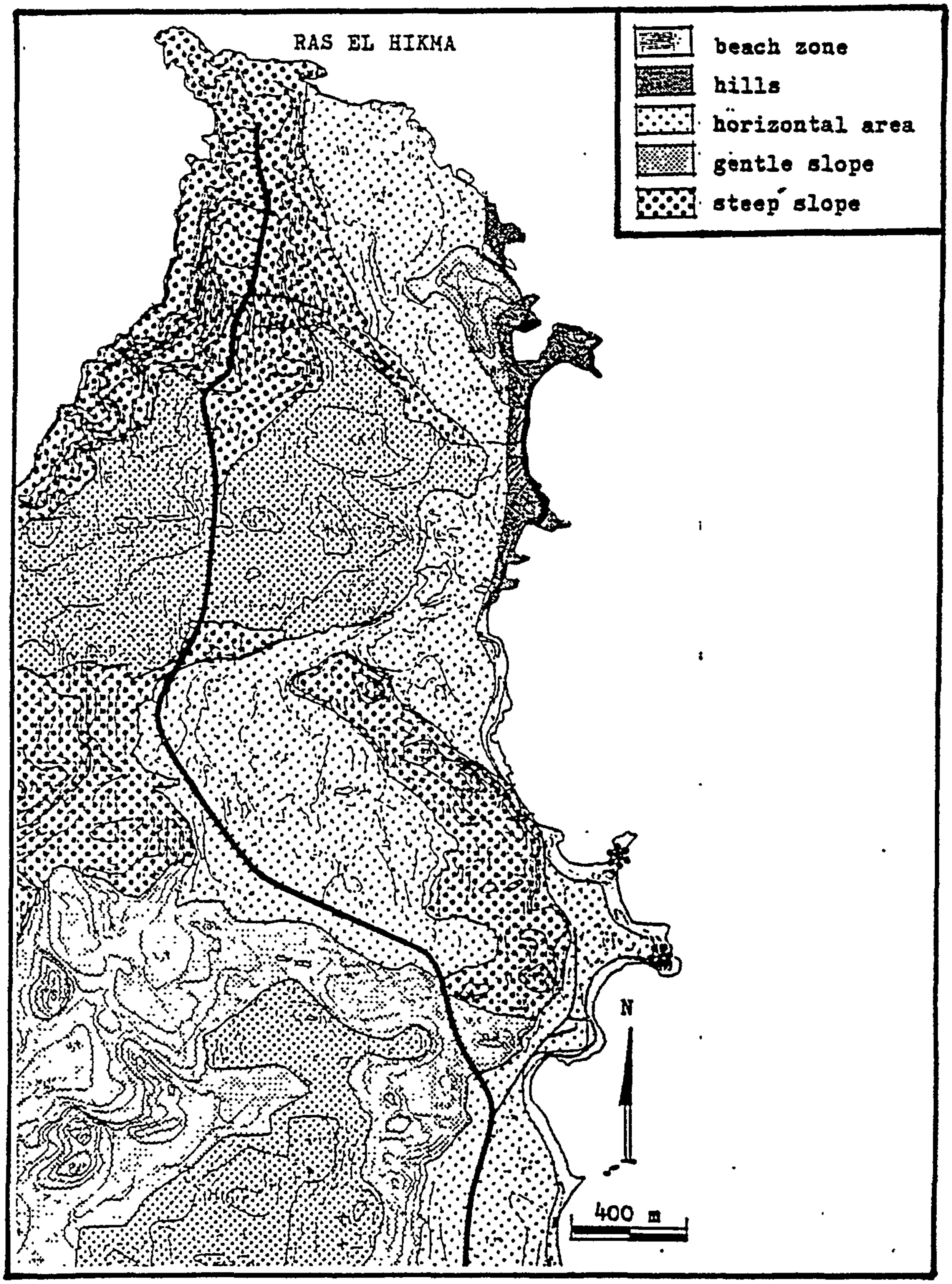


Fig. 28 Coastal environments at Ras El-Hikma area

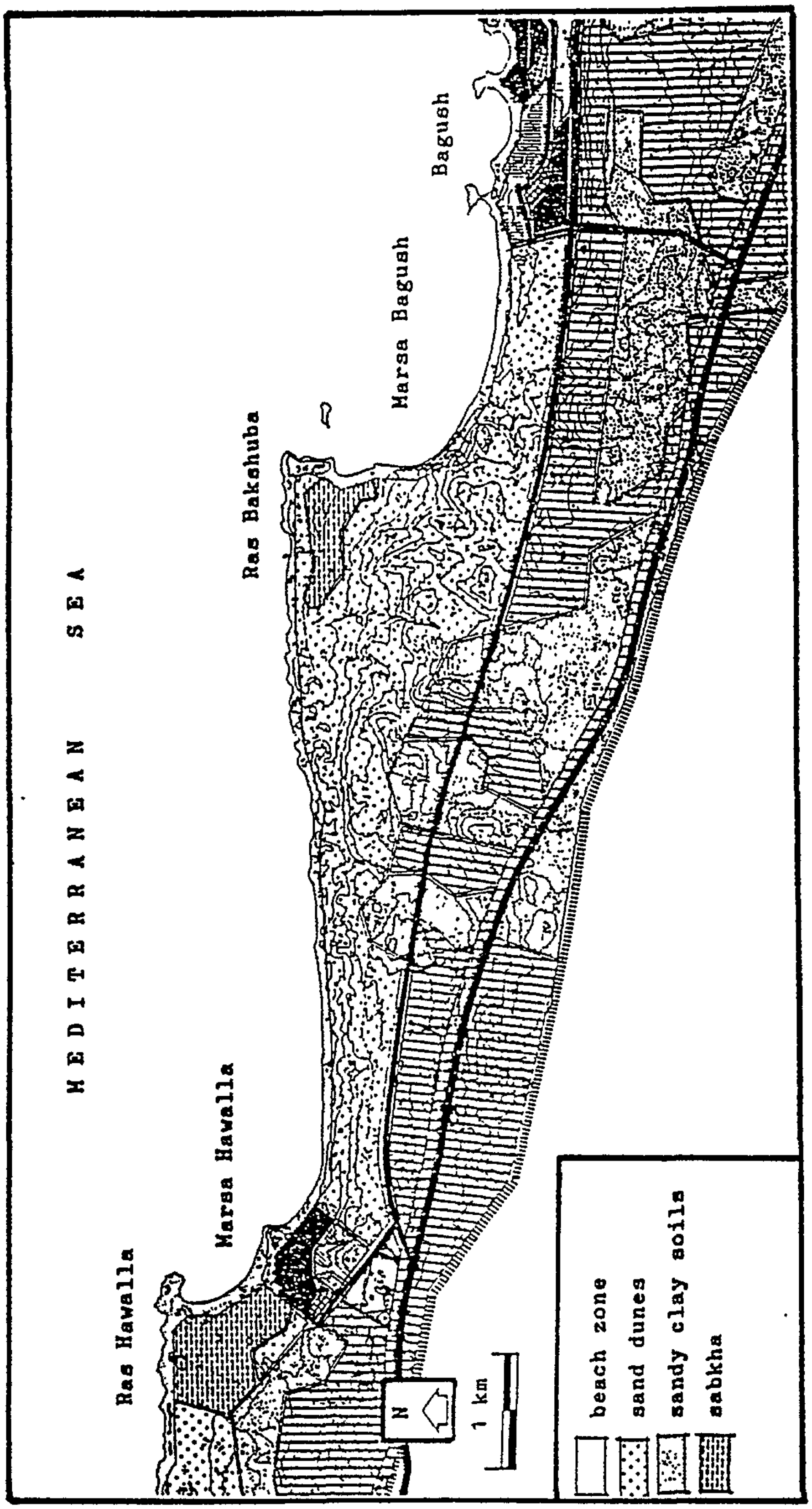


Fig. 29 Coastal plain at Ras Hawalla, Ras Bakshuba and Bagush

The shoreline indicates two types of beaches, they are:

a. Erosional beaches

Beaches subjected to erosion are mostly related to the headlands and points that trend nearly north to south. In these cases, the beach may be very narrow or missing and the beach zone is characterised by wave-cut platforms and cliffs. The steep slope of the beach face causes waves to break close to the beach which result in hazardous conditions. Therefore, the beach face slope of erosional beaches is relatively steep. Erosion at Beausite Hotel of Mersa-Matrouh and at Sidi Abdel-Rahman indicates one of the coastal problems which is mainly caused by man's interference in the coastal zone.

b. Accretional beaches

Beaches of accretion characterise the sheltered parts of the shoreline trending nearly east to west, *i.e.* away from the effect of the prevailing wind and wave action. The foreshore averages 5-15 m wide. Beach cusps, the wavy nature of the shoreline, are developed on the shore. The microcusps have an average length (crest to crest) of 10-100 m and amplitude (height of the crest above the trough) of 5-25 cm. Megacusps are observed to occur on the beach but they are fewer. Most cusps are usually asymmetrical with underwater bar extensions. These cusps tend to move laterally eastward with a mean longshore movement of about 15 cm/day. Matrouh beach may be considered as cuspate beach with an average length and amplitude of 10 m and 5 cm, respectively. Inside Mersa-Matrouh, the velocity of the littoral current affecting the coast is ranging between 16-20 cm/sec.

Alexandria coasts show minor erosion of 20 cm/year in long terms. As it can be compared, the northwestern coast is considered to be equilibrium where there is a balance between loss and gain of material and are generally defined as stable coast.

The beach sediments are made of white oolitic, pseudo-oolitic calcareous grains and biogenic debris without any contamination by mineral typical of recent Nile (Hilmy, 1951). They are derived mostly from the pleistocene oolitic inland ridges bordering the coast. Aragonite and to a less extent Mg-calcite are the constituent minerals of these carbonate grains. The carbonate content of beach sediments ranges between 77-98%. The selective addition of terrigenous materials such as wind-blown quartz grains from the western desert may play a role in the variations of carbonate content along the coast.

The mean grain size of beach sediments ranges between 0.26-0.33 mm (Table 8). Most of the beach grains vary in diameter between 0.063-1.00 mm. The beach sediments tend to be well sorted. Matrouh beach is relatively finer grains than the Bagush beach. The mean grain size of beach sediments at Matrouh coast was compared for two series of samples collected in 1951 and 1993. The time variation of mean size indicates a similar size of 0.26 mm for the two series. The carbonate content shows slight decrease.

Old storm beach deposits are found on the aeolinite unit on the northern side of the coastal ridges (Hassouba, 1980). These deposits consist of set of beach boulders with different heights (+13 to +15 m). Each boulder is in the form of a triaxial ellipsoid which has a long axis of 50-150 cm and a short axis of 10-30 cm. These boulders are composed of cemented, bored and oolitic-skeletal grainstone.

2.2.1.10.4 Barrier islands

Barrier islands occur on some coasts of Fuka, Ras El-Hikma and Matrouh. They are usually narrow strips of detrital sediments which form beach/dune complexes rising above sea level and extending for a considerable distance parallel to the coast. These barriers may be isolated or separated from the coast by a lagoon. Most of the Holocene barrier islands bordering the present coasts are thought to have been formed during the Flandarian transgression. The origin of such islands may be related to:

- Offshore origin: Barrier islands are formed as offshore bars. When the sea retreats, the submerged bars emerge and a lagoon develops behind them which is cut off from the sea behind them.

- Drowning of beach ridges: The topographic ridge is formed along the upper edge of the beach with either wind or wave action or by a combination of both. Successive ridges could have formed during regression of the sea to form series of beach ridges. In the succeeding stages of marine transgression, the area landward of the ridges would be flooded to form a lagoon behind the drowned ridges, which then became a barrier island.

2.2.1.10.5 Offshore

It is comparatively the flat portion of the beach profile which extends seaward. The offshore zone may extend for about 10 km from the shore and depends on its slope. The nearshore and beach face slope are relatively steep, but the slope becomes flatter in the offshore zone. At the western coast, the beach face and offshore slopes are found to be 1:3-1:10 and 1:20-1:90 respectively. The bathymetry of Fuka-Matrouh area (Fig. 24) indicates that the offshore slope in front of Ras El-Hekma is steeper than that around Ras Alam El-Rum. Comparison of the different surveys shows that erosion is starting to act in deep water and then approaching the shoreline. Such type of erosion may be due to temporary seasonal conditions.

Most of oolitic grains of the offshore sediments vary in diameter between 0.063-1.19 mm with a mean grain size of 0.30 mm. In general, values of mean size tend to decrease in a distant seawards. The coastal area is characterised by the absence of surf zone which can be confirmed from the disappearance of breaker zone (coarse-grained sand parallel to the shoreline). The offshore sediments west of Alexandria show a tendency to be slightly coarser where the mean grain size ranges between 0.14-0.71 mm with an average of 0.33 mm.

The distribution of offshore sediments in Arab's Bay, eastward of Fuka, is very complicated (Anwar *et al.*, 1984). The finest fractions on the beach lie in front of the coarser grains of the offshore sediments as observed at the eastern and western sides of the bay. On the other hand, the finest fractions of the central part of the bay are found in front of the coarsest fractions of the beach.

The adjacent beach sediments along Fuka-Matrouh are better sorted than the offshore ones. It can be attributed to the sorting processes of waves and currents affecting the beach. The winds, especially in winter season, may have also a role in sorting of beach sediments. Hence, the occurrence of a higher content of coarse sand grains and biogenic fractions in offshore sediments make them less sorted than the beach sediments.

The carbonate content in the offshore sediments is extremely high and ranges between 90-98%. Other non-carbonate components such as quartz are found in small amounts constituting 2-10%. The relatively higher content of true oolites recorded in the beach and offshore sediments than that occurred in the Pleistocene coastal ridges may indicate that the oolitic sediments of beach and offshore are not only reworked from the coastal ridges but also due to the occurrence of oolitic grains on the top of the continental shelf. These oolitic grains are younger in age, probably of early Holocene, and have had the opportunity to be more and better developed than those derived from the inland ridges.

2.2.1.11 Dynamic Forces Affecting the Coast

The dynamic forces which affect the processes that shape the coastal ridges and dunes of the N.W. coast are the winds, while those affecting the beach and offshore area are the waves and currents induced by them, and to a lesser extent those resulting from winds, tides, salinity and temperature. These primary agents cause transportation and deposition of the coastal sediments and therefore, change in the coastal processes. Tide changes and their seasonal variations are also essential in investigation of dynamic forces and coastal processes affecting the coast. These forces could be summarised as follows:

2.2.1.11.1 Waves

The height and direction of the waves are affected by refraction, dissipation of energy and breaking during their propagation into shallow water near the coast. The effect highly depends on the local bathymetry which may allow only a limited window of directions to reach a certain location. The directional distribution of the wave energy along the coast generally leads to a clockwise rotation of the local dominant wave direction. This causes a resultant eastward longshore direction of the wave energy along the coasts.

Available data at west of Alexandria (Fig. 30) recorded that the predominant waves are approaching from N.W. sector (Institute of Coastal Research, 1993). The following summarizes the wave characteristics:

- maximum wave height:250 cm
- average wave height:74 cm
- average wave period:6.8 sec

2.2.1.11.2 Littoral currents

Littoral current plays an effective role in sediment transport along the coast. The gradient current is dominating the surface circulation along the northwestern coast and not the drift current, as might be expected (Gerges, 1976). The computed velocity values of the total surface current in front of Fuka-Matrouh coast range between 11-15 cm/sec and feeding eastward. On the other hand, the bottom current values decrease noticeably down to 100 m depth to be 3-5 cm/sec and feeding westward. Rip current is usually occurred along many coasts of the western region. At Arab's Bay, there is a predominant eastward current which is disrupted by rip current (Wobber, 1967). West of Alexandria coast, both west and east currents were recorded with an average velocity of 27-31 cm/sec.

There are three main factors affecting the water movement in the Mediterranean Sea.

a. The force of horizontal gradient determined by the level difference of the Mediterranean Sea and the Atlantic Ocean, this fact accounts for the entrance of Atlantic waters into the Mediterranean in the upper layer resulting in a stable east current. The latter can be clearly traced along the northern shoreline of Africa, including the shores of Egypt.

b. The force of the horizontal pressure gradient caused by the water density difference in the said basins. This results in discharging the Mediterranean waters into the Atlantic Ocean in deep layers.

c. The force of tangential tension caused by the wind. The prevalence of north westerly winds over the Mediterranean Sea during the greater part of the year enhances the constant eastward water movement (Al-Kholy & El-Wakeel, 1975).

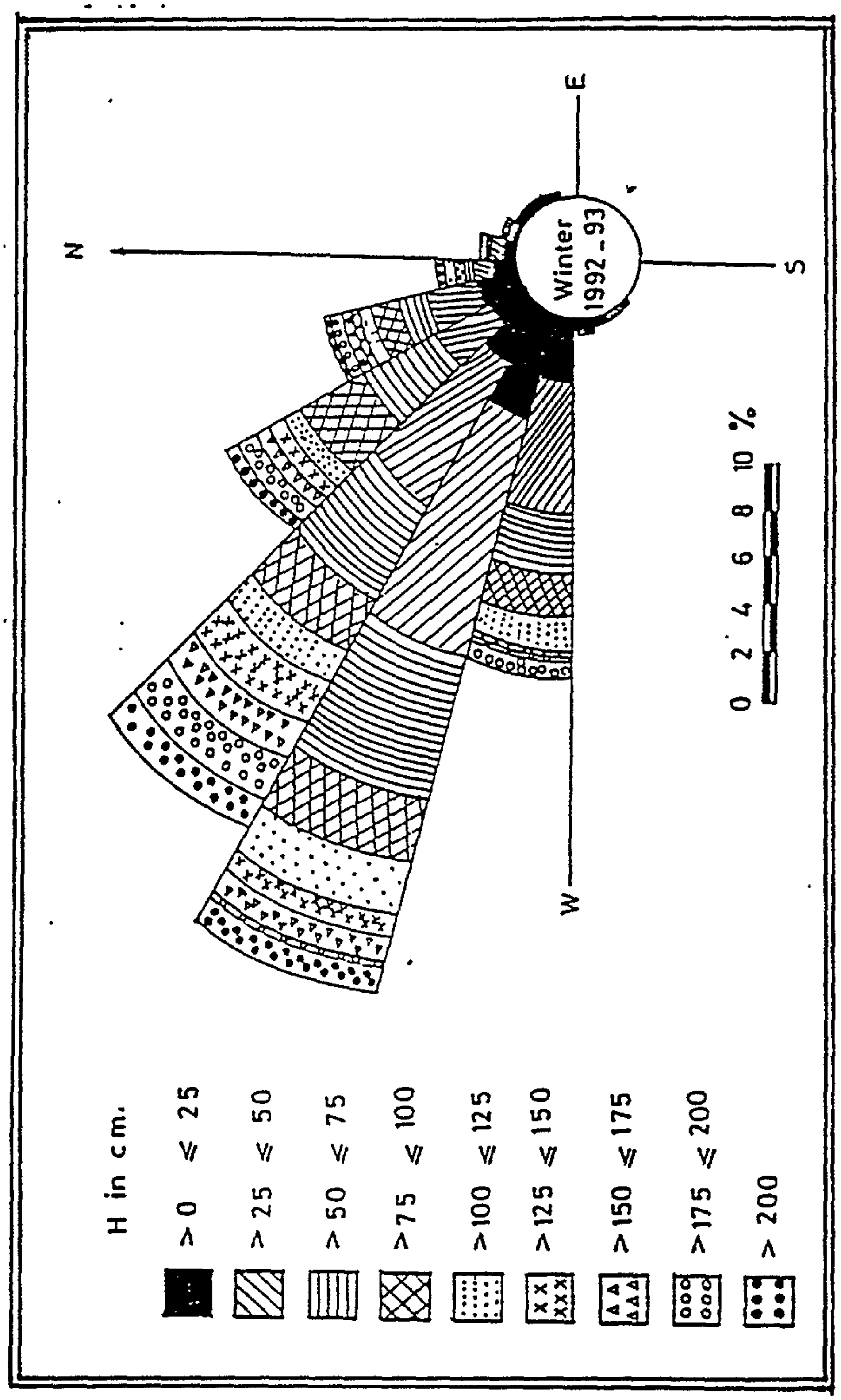


Fig. 30 Wave rose outside El-Dikheila Harbour, West of Alexandria (after Institute of Coastal Research, 1993)

The estimated surface current velocity in the area Fuka-Matrouh ranges from 9.26 to 13.5 cm/sec during summer, declines to 4.45 cm/sec during autumn, sharply increases due to the strong wind during winter to 23.14 cm/sec and declines again due to the calm weather during spring to 8.4 cm/sec (Anon, 1983).

The surface current in the Mediterranean Sea is a cyclonic due to the effect of the coriolis force (Al-Kholy & El-Wakeel, 1975). In Fuka and Matrouh, a coastward surface current of 9.26 cm/sec and 23.14 cm/sec prevails during summer and winter respectively (Anon. 1983).

There are a number of gyres in the Mediterranean Sea, one being located in the south-east part. During the warm season of the year, the water movement in the area of this gyre is cyclonic, the bearings of the central part being the meridians of 25-27°E long (i.e. adjacent to Matrouh). In Winter, the currents change their direction to the opposite direction and the speeds increase. The centre of the anticyclonic gyre is moved eastward to the area of 30°C long (i.e. east to Fuka, Ovchinnikov, 1965 & 1966, c.f. Al-Kholy & El-Wakeel, 1975). Between the shores and the said gyres there is an eastward water movement.

2.2.1.11.3 Tides

The effect of tide variations is pronounced in delineating the shoreline as well as wave characteristics, breaking point, determination of current and bar formation. Tide influences, to some limited extent, the sediment movement along the coast by shifting the level of attack of wave action and by governing the flaws in lagoons.

Tide gauge records were available at Alexandria for a long period. Analysis of the tide level records indicates that the tides are semi-diurnal in nature with two high and two low water levels in a tidal day with comparatively little diurnal inequality.

Long term analysis of tide variations indicates that the curves of the average mean sea level of the monthly date have two minima and two maxima. The major maximum occurs in August (60 cm), whereas the minor maximum occurs in December (54 cm). On the other hand, the major minimum occurs in April (37 cm) whereas the minor minimum occurs in October (46 cm) The tidal variations is considered to be small with a magnitude of 26 cm.

Storm surges during winter season and swell action during summer season (Manohar, 1976) may cause the increase of the water levels considerably and hence accelerate erosion along the coasts (El-Fishawi and Khapagy, 1991).

2.2.1.12 Measurement of Sediment Transport

In order to analyse the change in the beach geometry, to study the coastal processes accompanied to accretion and erosion, and to develop predictive models, precise measurement of the sediment transport rate is required. Fluorescent sand tracer, littoral current measurements and traps as methods of drift rate estimation are applied on some coasts of the western region.

Fluorescent tracers with desired characteristics, such as a particular grain size, was used in tracer experiments along the western coasts of Alexandria. The tracer techniques give an average total drift rate relative to a certain geographical area. Ingle (1966) technique depends upon at what rate the tracer grains left the respective sample grid. Thus, it is able to compute the sediment drift rate according to the equations from (1) to (4):

$t_{50} = \frac{1}{2}G/D_e$ ....(1)
$U_g = l/t_{50}$ ....(2)
$V = K.W.B$ ....(3)
$Q_l = V.U_g.1440$ ....(4)

where: t_{50} = time for one half the total tracer grains to leave the sample grid (min), G = total number of tracer grains released, D_e = average depletion rate (grain/min), U_g = average grain velocity (m/min), I = distance of tracer travel (m), V = unit volume (m^3), K = constant beach length of 1 m, W = width of the foreshore-inshore zone (m), B = thickness of the mobile bed layer (m), Q_l = sediment drift rate (m^3/day).

The results applying tracer sand experiments indicate that the sediment grain velocity ranges between 0.4-1.2 m/min with an average velocity of 0.90 m/min. Thus, the mean velocity of grains was approximately 1/22 the mean littoral current velocity (33 cm/sec) measured during the experiments. In fact, these velocities do not represent the range of absolute velocities of individual grains (may exceed 55 cm/sec). It is likely that the bulk of the sediment load travels along the western coast at a much slower rate. The relatively low grain velocities suggest that most grains are travelling in traction or within the mobile bed layer rather than in suspension. The thickness of this layer ranges between 1.0-2.1 cm. Along the western coast of Alexandria, the sediment drift rate is estimated to be 10,000-25,000 m^3/month. In Arab's Bay, the drift rate is found to be in the order of 4,200-8,300 m^3/month (Danish International Development Agency, 1991). The dispersion of sediments is directed eastward, westward and also offshore due to the affecting rip currents. As a comparison, the estimated drift rates along the western coast of Alexandria and Arab's Bay are relatively much lower rates if compared to those along the Nile Delta coast (50,000-300,000 m^3/month).

The littoral drift rates of sediments in front of Fuka-Matrouh coast were computed depending upon measured longshore current and waves (Fig. 31). In ordinary conditions, the current velocity ranges between 11-15 cm/sec with an average wave height of 30 cm. On the other hand, vigorous sea states reflect faster current velocities which may reach 50 cm/sec and wave height of 70 cm. Thus be applying the empirical equation of Komar (1990), the littoral drift rate is obtained from equation (5):

$$Q_s = 0.026\ (Hb)^2\ V \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

where: Q_s = littoral drift rate, Hb = wave heights and V = longshore current.

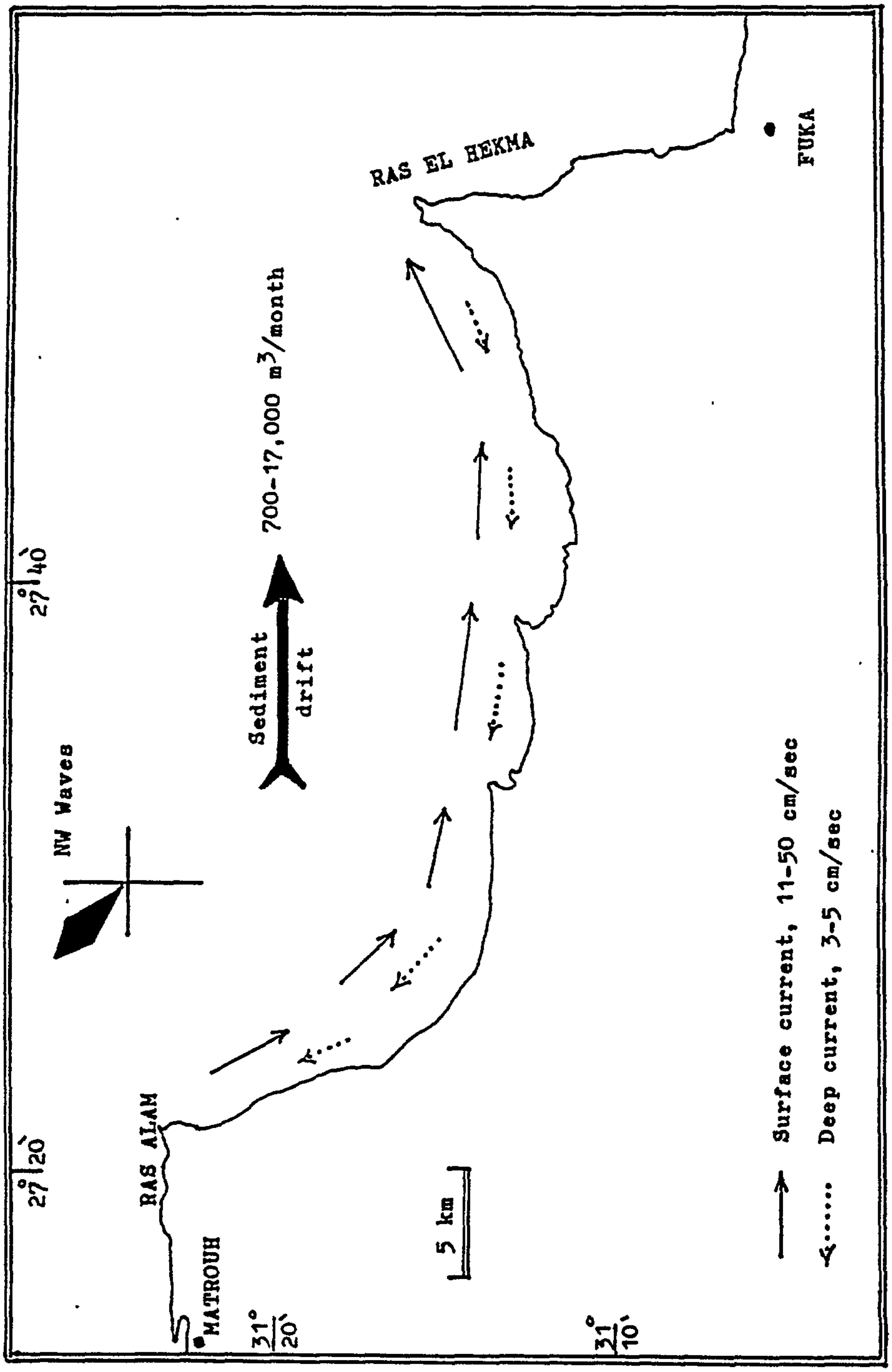
The resulted eastward littoral drift between Matrouh and Fuka is predicted to be in the order of 700-900 m^3/month in ordinary conditions and 17,000 m^3/month for vigorous conditions. These rates are still much lower than those found at the western coast of Alexandria. Therefore, the main conclusion is that the sediment drift rate slightly increases from Matrouh-Fuka coast to the western coast of Alexandria and attains its maximum value at the Nile Delta coast. Such phenomenon may reflect the relative stability of the northwestern coast.

Sediment transport by wind was determined by using sand traps on the backshore side of Marakia coast which extends westward of Alexandria (Institute of Coastal Research, 1993). The net accumulated volumes of sediments blown by wind is predicted to be 340 m^3/month. On the other hand, the wind is very effective at Fuka area. It usually causes movement and migration of sand dunes. Accumulations of wind blown sand are found to cover the railway and roads. Therefore, wind blown sand at the western coast is effective in disturbing the transport processes.

2.2.2 Soils

The soils in the area are almost alluvial soils (rock-land is here for convenience sake not considered to be soil). They are mainly sedimented by water action (alluvial material of the fans and out wash plains) but in some areas by wind (coastal dunes and inland dunes). Probably on the sub-surface layers of the limited deep alluvial fans on the Miocene plateau are formed *in situ* and therefore partly derived directly from the limestone bedrock. Water flows zones are illustrated in Fig. 32.

Striking in the whole area is the absence of gravel and sand layers in the alluvial deposits. Even the alluvial fans at the mouth of the big wadis do not contain considerable quantities of coarse material. Because of alluvial soil in the area are directly or indirectly derived from limestone, they are


RAS EL HEKMA
FUKA
700-17,000 m³/month
Sediment
drift
NW Waves
27° 40'
27° 20'
RAS ALAM
MATROUH
5 km
31° 20'
31° 10'
Surface current, 11-50 cm/sec
Deep current, 3-5 cm/sec

all rich in $CaCO_3$. Along the north-south direction of the area distinguished three conspicuous geomorphic units; the coastal plain, the piedmont-like plain and the structural plateau. These geomorphic units are usually associated with distinct soil types (Fig. 33) as follows:

1. Coastal plain: this includes soil of the lower and upper coastal plain ridges, inland dunes, rocky ridges and depression between plain and ridges.

2. Piedmont-like plain: it is the tableland plateau and transitional zone. This includes soils of wadis and fans and wash plains.

3. Structural plateau: this consists of the southern rocky tableland and its escarpment.

According to the supplement of the 7th Approximation of the American system of soil classification, the mapping units of reconnaissance maps (FAO, 1970, sheets III, IV) of the area can be classified on sub-group level as follows:

<u>Do coastal dunes:</u>
Do1 Typic Torripsamment
Do2 Typic Torripsamment
Do4 Typic Torripsamment

<u>DS inland dunes:</u>
DS1 Typic Torripsamment
DS4 Calsy Torripsamment
DS5 Calsy Torripsamment
DS6 Typic Torripsamment

<u>B soils in the former beach plain and dune depressions:</u>
B1 Typic Torriorthent
B3 Typic Calci/paleorthid
B4 Typic Calci/paleorthid
Bp Typic Salorthid

<u>F soils of the alluvial fans and out wash plains:</u>
F1 Typic Torriorthent
F3 Typic Torriorthent
F4 Typic Calci/paleorthid

<u>W soils of the wadis:</u>
Wb Typic Torriorthent
Ww Typic Torriorthent

<u>Main Characteristics of Distinguished Mapping Units Existing in the Studied Area and Their Suitability</u>

Table 9 represents the summary of main characteristics of mapping units which are present in the area and its potentiality for agriculture. The distribution of potentiality classes for different mapping units is illustrated in Table 10. Fig. 34 shows soil suitability map. The suitability for agriculture and distribution of different potential classes is presented in Table 11. Some physical and chemical properties of soils distinguished in the studied area are presented in Table 12.

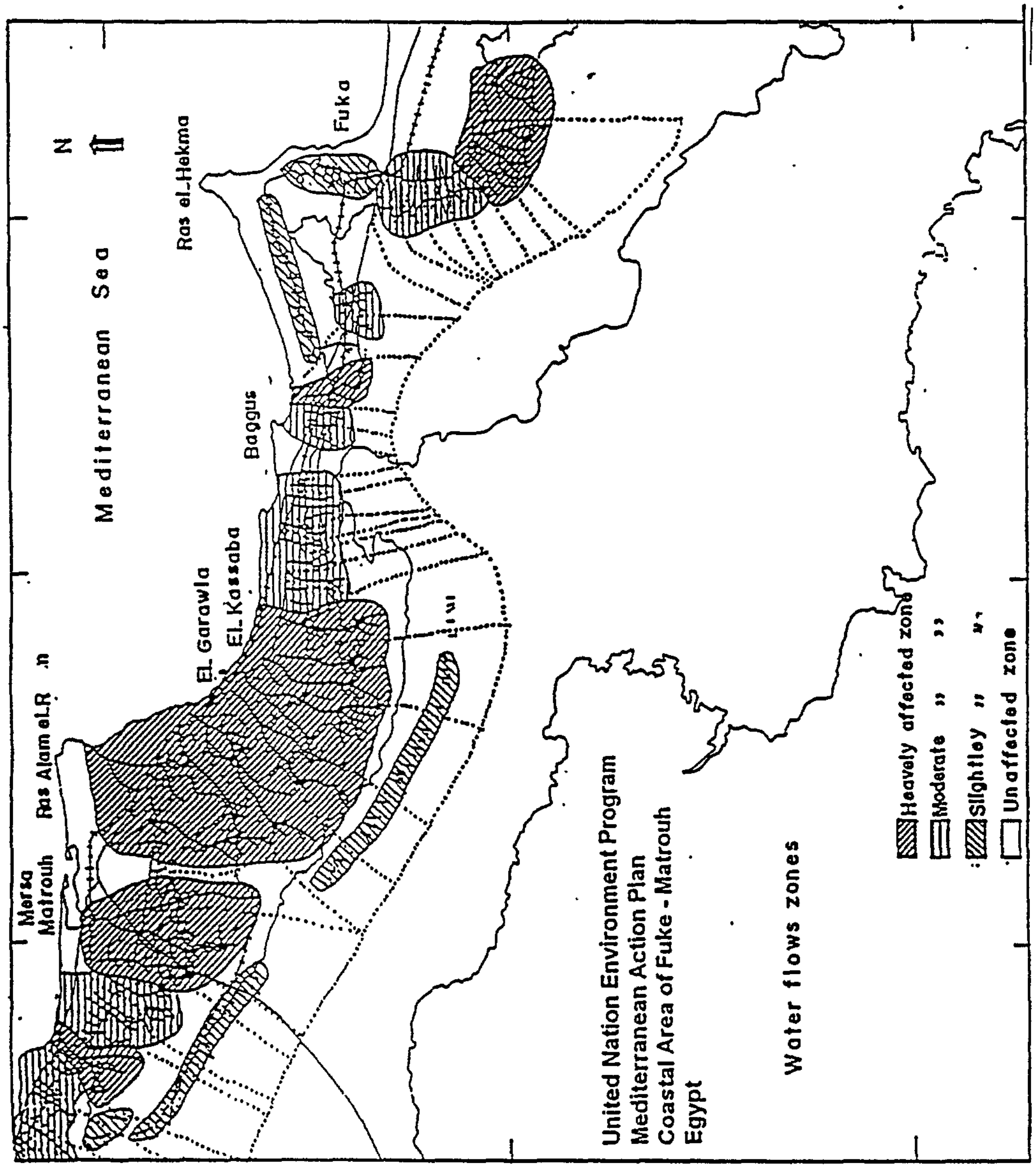


Fig. 32 Water flows zones, Fuka-Matrouh area

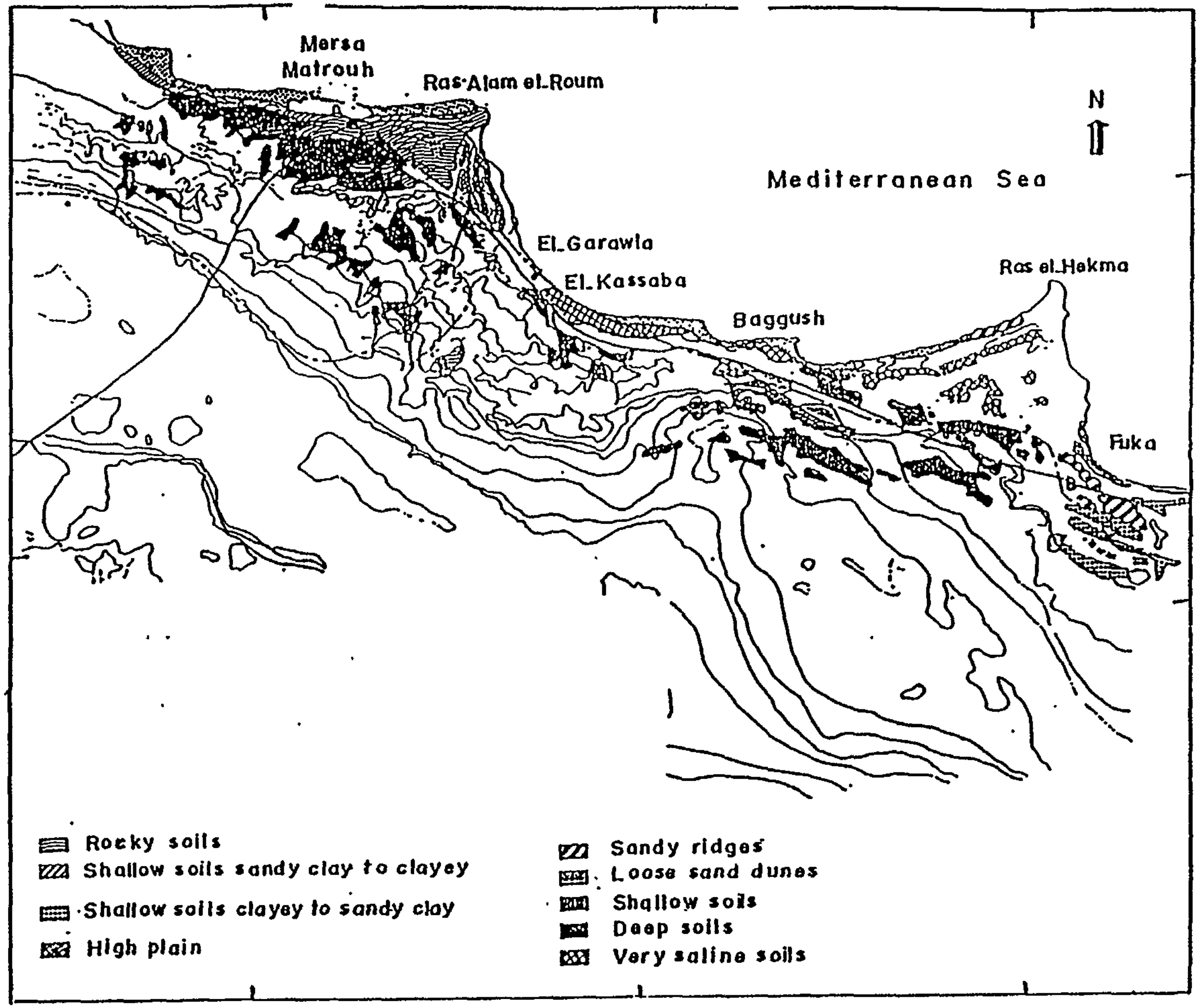


Fig. 33 Soil units, Fuka-Matrouh area

Table 9

Summary of Main Characteristics of Distinguished Mapping Units of the Reconnaissance Survey

Mapping unit	Depth of soil in cm.	Main texture	Permeability	Topography	Potentiality for Agriculture	Remarks
Do_1	-	Colitic sand	Moderately rapid to rapid	Irregular	Locally suitable for figs only	Shifting dunes
Do_2	-	Cemented and colitic sand	Slow	Irregular	Not suitable	Cemented dunes
Do_4	> 50	ls to l in depressions	Moderate in the soils	Irregular	Not suitable and moderately suitable	Cemented dunes with depressions
Ds_1	-	s to ls	Moderately rapid to moderate	Irregular	Not suitable	Low dunes
Ds_4	-	s to sl	Moderately rapid to moderately slow	Rather level	Not suitable	Shallow over rock
Ds_5	ca 60	ls to sl	Moderate to moderately slow	Level	Suitable for vegetables, field crops and moderately deep rooted crops	
Ds_8	-	s	Rapid to moderately rapid	Rather level	Not suitable	Shallow over rock
B_1	> 90	sl to l or cl	Moderate to moderately slow	Level	Suitable for all crops	Locally in depressions surrounded by rockland
B_3	30-90	sl to l or cl	Moderate to moderately slow	Level to nearly level	Suitable for moderately deep rooted crops, locally for shallow rooted crops only	
B_4	30-90	ls to slightly ls	Moderate to moderately rapid	Sloping and gullied	Suitable for moderately deep rooted crops, locally for shallow rooted crops only	
F_1	30-60	sl to l	Moderate	Nearly level to slightly sloping	Suitable for vegetables, field crops and other shallow rooted crops	Locally with gravels
F_4	30-90	sl to l	Moderate	Slightly sloping to gently sloping	Predominantly not suitable	Most soils are saline, locally gravels
Wb	> 90	sl to l	Moderate	Slightly sloping	Suitable for all crops	Terracing is needed; risk of damage by runoff water
Ww	> 90	sl to l	Moderate	Nearly level to slightly sloping	Suitable for all crops	

N.B. All mapping units of the miscellaneous landtypes consist of rockland with less than 30 cm soil. They are not suitable for agriculture but have value as range land

Table 10

Summary of the Potentiality Classes of the Reconnaissance Maps and the Mapping Units Occurring in Each Class

Potentiality Class		Mapping Units	
Code	Short description	Sheet III	Sheet IV
I	Suitable for all crops	B_1, F_3, Wb, Ww	B_1, B_2, P_1, F_3, Wb
IIa	Suitable for moderately deep rooted crops		F_2
IIb	Like Iia, but locally only suitable for shallow rooted crops	B_3, F_4	
III	Suitable for shallow rooted crops only	Ds_5, F_1	F_1, F_4
IVa	Locally suitable for figs only	Do_1	Do_1
IVb	Locally suitable for shallow rooted crops only		Fie
Va	Not suitable - rocky	Do_2, Ds_4, Rp, Rh, Rr, Rs, Rf, Rd, Rdg, Rde, Rt	Do_2, Do_3, Rp, Rh, Rr, Rs, Rg, Rf, Rd
Vb	Not suitable - very saline	Bp	Bp, Pp
Vc	Not suitable - inland dunes	Ds_1	Ds_1
Va/I	Complex of class Va and class I	C_2	C_2
Va/IIa	Complex of Va/IIa		Do_4
Va/IIb	Complex of class Va and class IIb	C_1	
Va/Vc	Complex of class Va and class Vc		C_3

Table 11

Summary of the Potentiality Classes of the Reconnaissance Maps, Their Areas and a Rough Estimation of the Saline Soils in Each Class

Potentiality class		Sheet III		Sheet IV	
Code	Short description	Feddan	%	Feddan	%
I	Suitable for all crops	67.600	13.07	11.675	1.82
IIa	Suitable for moderately deep rooted crops			2.200	0.34
IIb	Like IIa, but locally only suitable for shallow rooted crops	6.425	1.24		
III	Suitable for shallow rooted crops only	15.350	2.97	67.125	10.45
IVa	Locally suitable for figs only	1.425	0.28	2.850	0.44
IVb	Locally suitable for shallow rooted crops only			6.025	0.94
Va	Not suitable - rocky	400.675	77.47	529.850	82.47
Vb	Not suitable - very saline	1.200	0.23	6.475	1.01
Vc	Not suitable - inland dunes	2.975	0.58	600	0.09
Va/I	Complex of class Va and class I	11.775	2.28	5.450	0.93
Va/IIb	Complex of class Va and class IIb	9.750	1.89		
Va/III/IIa	Complex of class Va, class III and class IIa			9.225	1.44
Va/Vc	Complex of class Va and Vc			475	0.07
	TOTAL*	517.175	100.01	641.950	100.00

* water excluded

Table 12

Physical and Chemical Properties of Soils Distinguished on the Reconnaissance Soil Map

No.	Area	Mapping unit	Depth cm	Physical properties		Mechanical composition			Texture	EC mm Hos/ cm	$CaCO_3$ %	pH	Chemical Analysis						
													Cations				Anions		
				% cm/hour	field capacity	clay	silt	sand					Ca^{++}	Ng^{++}	Na^{+}	K^{+}	Cl^{1}	HCO^{1}_{3}	SO^{1}_{4}
1	Mersa-Matrouh	Do_1	0-30							1.0	86.9								
			30-60							1.7	98.8								
			60-120							1.9	97.9								
2	Mersa-Matrouh	Do_2	surface	5.7	19.5	0.5	0.5	99.0	s.	2.7	80.4		4.8	5.7	15.0	0.7	12.6	0.3	5.6
13	Fuka	B_1	0-25	5.7	12	9	21	70	s.l.	2.7	11.2		7.7	6.2	12	0.8	22	4.0	1.9
			25-60	6.6	12.5	16	18	66	s.l.	1 4	23.1		7.9	10.2	3	1.1	7.5	2.7	2.8
			60-90	3.2	13.5	28	28	44	l.	2.4	21		10.7	10.7	9	1.0	19	2.2	10.0
			90-120	1.2	14	34	24	42	c.l.	0.7	21.4		3.0	3.4	24	0.4	6	2.1	1.7
?	Fuka	Bp	0-40	-	17.0	21	30	49	l.	60	32.3		215.0	244	492	1.5	946.2	3.5	1.2
			40-80	-	19.5	29	36	35	cl.l	64	27.9		198.3	293.3	360	1.2	1031.0	2.7	-
			80-120	-	19.5	32	34	34	cl.l	69	20.2		202.0	198.9	440	1.2	1075.8	2.7	-
20	?	F_2	0-20	1.6	13.5	11	24	65	s.l.	0.8	16		4.2	2.6	3.5	0.3	6.1	0.2	4.3
			20-60	2.9	14.5	14	33	63	s.l.	1.0	24		3.5	1.5	6.5	0.3	8.1	0.2	3.5
			60-??	0.9	18.0	24	45	31	l.	21	26		5.0	4.4	12.1	0.7	18.2	0.2	3.8
21	Baqqush	F_3	0-15	2.9	16	11	26	62	s.l.	11.25	24.9		9.8	11.8	29.7	4.5	140.7	0.3	13.1
			15-30	4.8	15.5	9	??	54	s.l.	21.5	26.2		14.9	10.5	72.5	6.5	179.7	0.3	24.3
			30-100	1.1	16	10	??	49	l.	0.9	42.2		3.8	0.3	4.4	0.5	6.7	0.3	1.9
			100-130	2.0	17.5	9	53	38	sil	11.0	40.1		25.8	16.9	57.5	1.1	86.6	0.2	14.5
22	Baqqush	Wb	0-20	7.4	13.2	6	15	79	l.s.	0.6	34		5.5	1.3	2.3	0.8	2.0	4.3	3 5
			20-60	3.4	12.5	8	13	79	l.s.	0.8	28		4.3	4.7	3.4	5.1	4.9	4.1	5.1
			60-120	2.8	13.5	23	26	51	s.cl	0.7	18		3.2	3.5	3.4	6.7	3.1	3.7	4.1
23	Fuka	Ww	0-30		13.5	20	41	39	l.	1.4	26.8		6.9	4.6	4.9	1.2	13.5	0.3	2.3
			30-60		17.5	21	43	36	s.l.	1.6	36.8		7.1	3.9	5.7	0.9	10.6	0.3	6.5

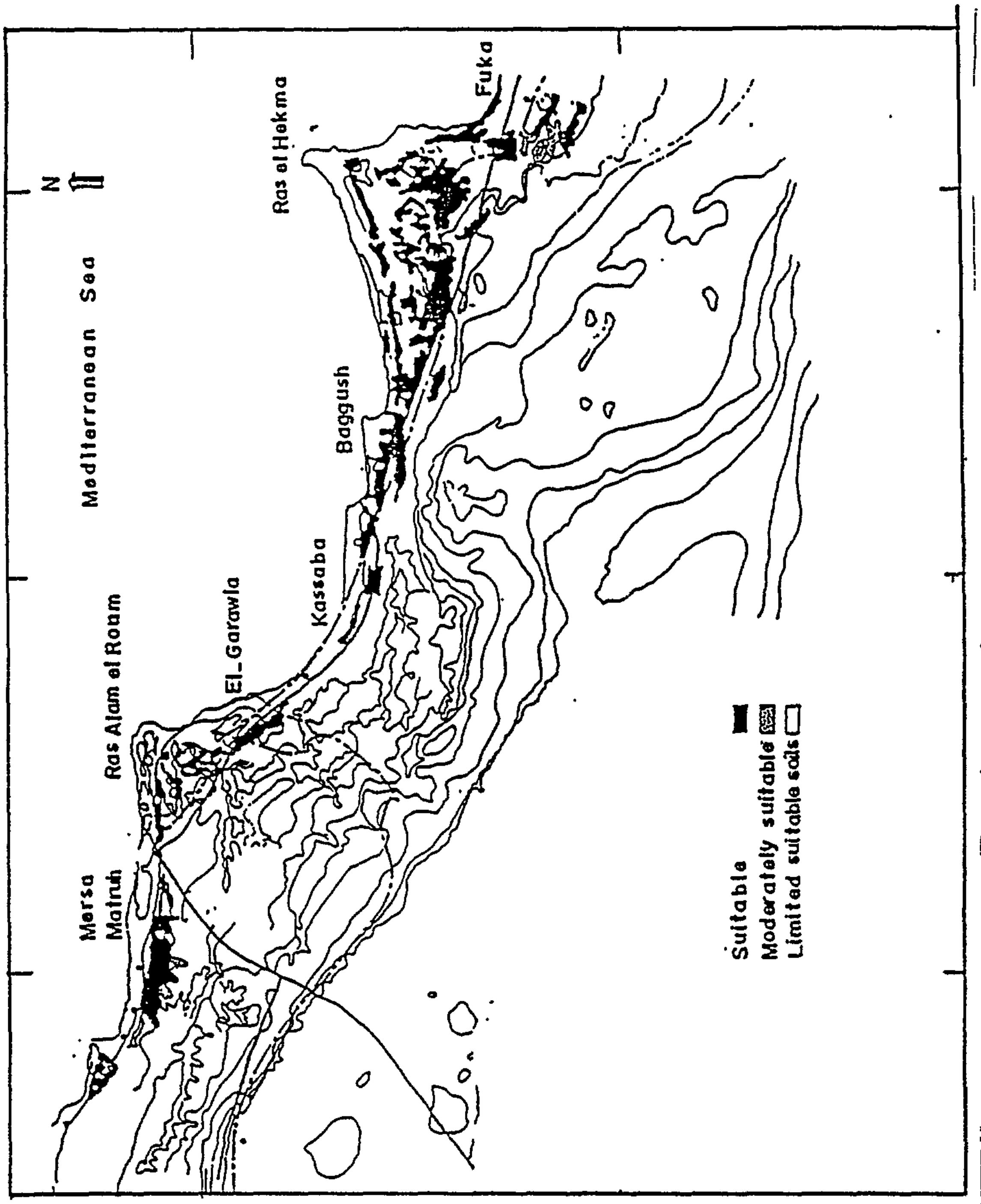


Fig. 34 Soil suitability, Fuka-Matrouh

2.3 HYDROSPHERE

2.3.1 Introduction

The hydrology of the studied area is determined by climatic conditions, geography and geology. Rain fall is the main water resource in the area. Normals of rainfall in the area are relatively higher than other areas in Egypt. The average monthly or annual rainfall as well as the maximum recorded amount in one storm are presented in Tables 13 and 14.

Table 13

Average Monthly and Annual Rainfall (mm)

STATION	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
Ras El-Hekma	42.9	9.8	11.6	5.7	0.9	0.1	-	-	3.3	14.8	20.8	37	147
Mersa-Matrouh	33.2	15.1	12	2.8	2.6	2.0	-	0.6	1.1	15 6	22.5	30.2	138

Table 14

Maximum recorded rainfall in one day

Station	Period of records	Maximum rainfall (mm/day)
Ras El-Hekma	1962-1975	72.4 (10/12/1964)
Mersa Matrouh	1947-1975	75.5 (22/11/1947)

Most of the rain falls during winter time (mid-October to mid-March) is decrease southward. The hydrography of the project area is characterised by a considerable number of wadis (35) in a hydrographic network (Fig. 35). Some of these wadis are important, also highly ramified, in this area (Wadi Nagamish, Wadi Zarga and Wadi Kassaba). As the annual rainfall is low, they carry less water than those west of Matrouh. The high cliff of Baggush, which rises sharply some 4-5 km inland has been cut into by a certain number of wadis, four of which reach the Baggush plain. Wadis of the area between Ras El-Hekma and Fuka are of medium size and run from west to east. Some of them are well ramified but carry very little water, since the area receives in general less rainfall. The zones which may be affected by over land flow in the project area are illustrated in Fig. 39. The main elements of water balance of the project area are rainfall as one input and evaporation, run off (sheet run off and wadi run off), recharge to ground water and change in soil moisture storage as outputs. Ground water is limited in the project area. Some is exploited in some locations like Fuka, Burbeta and Ras El-Hekma.

2.3.2 Surface Water

As mentioned in the pre-investment study of the north-western coast of ARE, FAO, 1970 and Land Master plan, 1986, that the result of hydrological survey indicated that 35 wadis of different sizes of catchment area are presented in the project area.

Wadi kilo 9 represents one of the wadis of the project are. Table 16 shows the result of hydrological investigation which was carried out by the pre-investment study of the ARE, FAO, 1970.

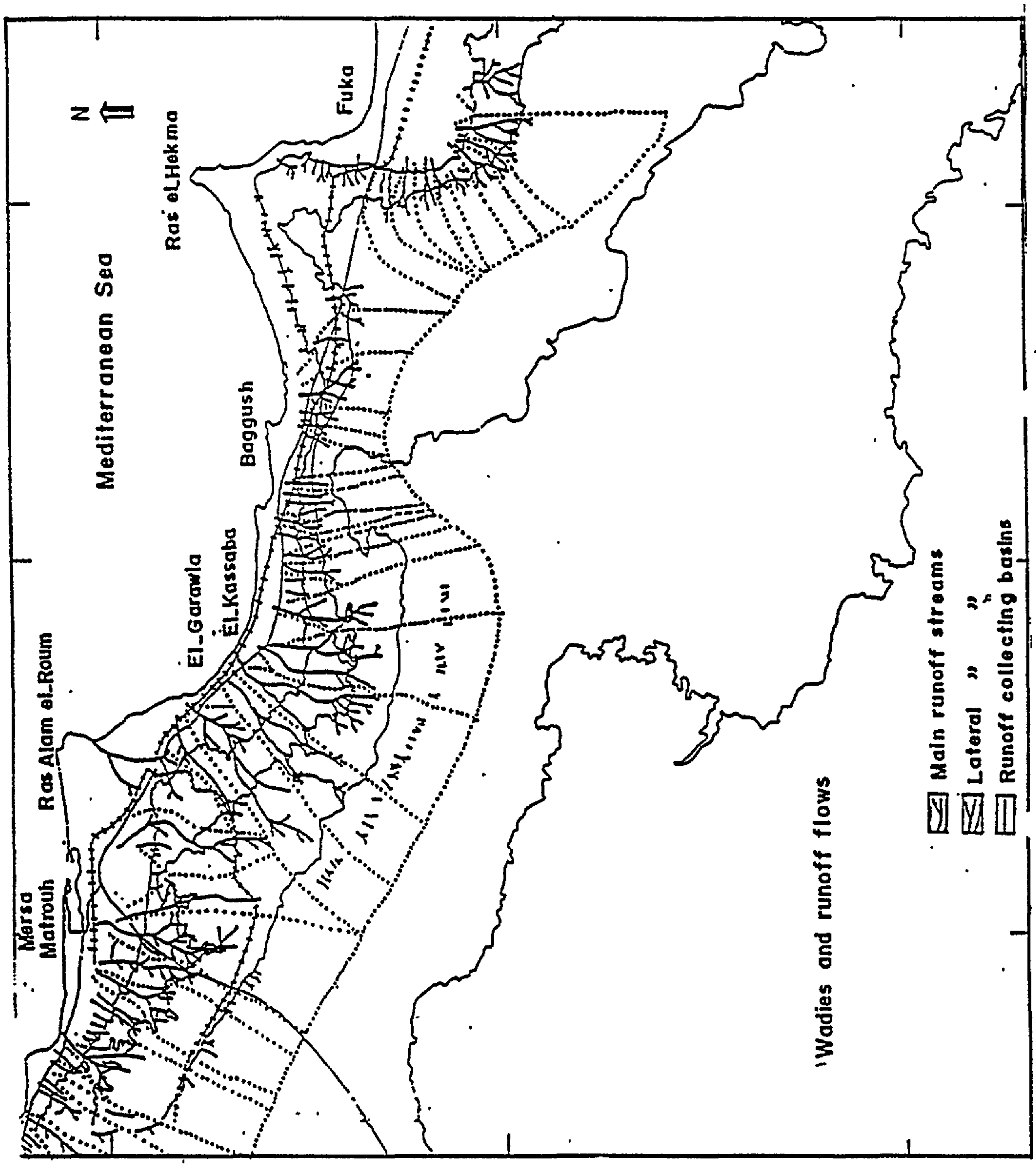


Fig. 35 Wadis and runoff flows, Fuka-Matrouh

Table 15 **(THIS TABLE IS NOT MENTIONED IN THE TEXT)**

Number of Wadis in the Project Area

Location	Size of Catchment Area (km_2)								
	5	5-10	10-20	20-30	30-40	40-50	50-100	100	no. of wadis
East of Matrouh/Ras El-Hekma	3	1	7	4	3	1	2	3	24
Ras El-Hekma/Fuka	2	-	2	4	1	-	-	2	11
Total	5	1	9	8	4	1	2	5	35

Table 16

Name of Wadi	kilo 9
Location	Ras El-Hekma
size of catchment area km^2	4.25
average slope	0.035
total length (km)	2.0
Total annual run off m^3	
(a) Freq. 0.5	15,000
(b) Freq. 0.6-0.7	10,000
Specific run off (m^3/km^2)	
(a) Freq. 0.5	3,500
(b) Freq. 0.6-0.7	2,300

The records estimated in Table 16 are based on rainfall-runoff correlations. Surface water as sheet runoff or wadi runoff are the main water resource in the area for irrigation and drinking water for animal and people. It is exploited by storage sheet runoff in underground indigenous reservoirs (cistern) either Roman cisterns or recently excavated. They are generally excavated in rock and are lined with cement, and water can flow into them from the surrounding area. In the project area there are 2,749 cisterns with the capacity of 778,382 m^3 to collect water runoff for domestic use and irrigation of 6,768 feddans. A set of earth, stone and cemented dykes are distributed in the project area to distribute and use water runoff of wadis. Thirty two million m^3/year could be used as sheet runoff and about 1.5 million m^3/year as wadis runoff and at present time 2.8 million m^3/year in intercepted and stored in the projected area. According to the records of the north-west coastal zone Authority for Developing and Rehabilitation, 432 cemented dykes of 53,448 m^3 to collect and distribute water for irrigation 1,188 feddans of orchards, 22 earth dykes of 321,184 m^3 to irrigate 2,361 feddans and 2,692 stone dykes of 218,807 m^3 to irrigate 4,862 feddans of orchards.

2.3.3 Ground Water

2.3.3.1 Introduction

Ground water in the project area occurs in the primary openings of the dunes deposits, alluvial material and older limestone and in secondary solution openings in the limestone and consolidated dune deposits. Ground water exists in the above-mentioned water-bearing formations under free water table and semi-confined conditions. Suitable ground water for agricultural and domestic uses occurs in relatively shallow non-artesian aquifers or in small shallow semi-confined aquifer with slight artesian pressure. Ground water in rocks belongs to age from Cretaceous to Miocene and is relatively in large quantities of non-usable quality from brackish to highly saline. The free ground water in the coastal plain occur in Miocene, Pliocene, Pleistocene and recent deposits which crop out at land surface and are recharged directly by rainfall and by the infiltration of surface runoff. These non-artesian ground waters in the coastal plain can be found as the main water table, the coastal dunes water table and the semi-confined water table in Fuka synclinal basin.

2.3.3.2 Main Water Table

The main water table aquifer is composed of alluvial silt and sand. The surface of water table is only about 1 m above sea level (12 km south of the coast). The relatively low water table gradient implies very slow movement of ground water towards the sea. Recharge to the main water tables through direct infiltration of rainfall and through infiltration of surface runoff and near the coast ground water is recharged through water ponds formed after heavy rains. The maximum thickness is about 10 m and therefore safe yields are low. The quality of water is however, generally good (TDS 1,000 ppm). The fresher water floats on more saline water and its thickness is related to the amount of recharge the aquifer and to the altitude of the water level above mean sea level. Near the coast, the fresh water layer is generally thicker because the water table is near the surface and receives substantial amounts of recharge. Yields of wells tapping the main water table are generally adequate to support a windmill if water quality is satisfactory. Excessive pumping causes rapid deterioration in the water quality. According to the last survey of dug wells in the area which was carried out in December 1993 by north-west coastal zone Authority for Developing and Rehabilitation the total number is 243 wells of maximum salinity 5,868 ppm and minimum 320 ppm.

2.3.3.3 Coastal Dune Ground Water

This free ground water aquifer is in beach sediments. In the project area the dunes are prominent and very well developed to about 40 km west of Matrouh. Recharge occurs through infiltration of rainfall, through lateral seepage of surface runoff behind the dunes, from seepage of ponded surface water (often salt marshes) and through sub-surface drainage. Where the dunes are well developed and receive substantial recharge, the water quality is very good (1,000 ppm). The position of the water table in the dunes is related to the balance between recharge and discharge, to topography and to the hydraulic properties of the dunes. The ground water is a floated fresh water lens above sea saline water. In the areas where there is less recharge or more discharge, the water level may be only a few centimetres above sea level. Discharge of water from the dunes occurs through collection galleries and wells.

Extensive gallery systems were developed during World War II in the Baggush-Burberta area. These galleries were reported to have produced 290 m_3 per day without over pumping. Unfortunately, these gallery systems have been allowed to deteriorate.

As mentioned in the general summary was prepared by the North West Coastal Zone Authority for Developing and Rehabilitation the length of galleries exist in the project area is 1,960 metres. The ground water is discharging to irrigate 196 feddans.

2.3.3.4 Semi-confined Synclinal Basin Ground Water

In Fuka, the Middle Miocene interbedded limestone and clay have been folded into gently synclinal basin. The penetrated succession consists of the following beds:

- an upper clay bed	16-18 m thick
- an upper limestone bed	12-20 m thick
- a lower clay bed	8-5 m thick
- a lower limestone bed	6 m thick (base not reached)

The ground water exists in the upper limestone bed. The lower clay bed separates water from the underlying main water table at sea level. The base of the upper limestone bed contacts the top of the underlying clay bed at a level between -1.8 m and +3 m on average sea level. The water is less saline (2,000 ppm) and water table is between 13 and 14 metres below ground surface. Ilaco

(1976) suggested that 2,000 m^3/day could be continuously withdrawn without seriously depleting the aquifer storage. Six pumping wells are in operation in the area (Fuka) using for domestic and agricultural purposes.

2.3.4 Other Water Resources

2.3.4.1 Introduction

The other water resources are mainly for domestic use (Fig. 36). These resources are the pipe lines carrying fresh drinking water to Mersa-Matrouh and to different villages (the Bedouin and touristic) along the coastal zone, desalination stations and the treated sewage water.

2.3.4.2 Pipe Lines

Two pipe lines are carrying fresh drinking water from Alexandria to Mersa-Matrouh. The old pipe line of 300 mm diameter was the old fresh water supply of 5,000 m_3/day capacity and now due to number of distributive branches along the northern coast the amount of water reached Mersa-Matrouh is estimated as 500 m_3/day only. The other pipe line of 700 mm diameter is the main source of drinking water. The water is pumping through 12 booster pumping stations. The capacity of this line is 50,000 m_3/day. The pipe line branches at El-Hammam city and at El-Dabbaa city. It is planning to extend it to Sallum.

2.3.4.3 Desalinisation Stations

There are four plants one of which is located within the project area at Mersa-Matrouh. The station desalinises sea water of 36,000 ppm salinity. The capacity of the station is 500 m_3/day.

2.3.4.4 Sewage Water Purification Treated Plant

Under construction now a sewage water purification plant located at eight kilometres east of Matrouh city is designed to produce 47,000 m_3/day treated water as a first stage for irrigation of 1,000 feddans.

2.4 NATURAL ECOSYSTEMS

2.4.1 Terrestrial Ecosystem

Sand Dunes

The coastal limestone formation with overlying sand dunes are a unique feature in the Mediterranean. This formation extends from Alexandria to some kilometres before El-Sallum, *i.e.* over almost the whole study area. Many parts of the sand dunes are still unspoiled (Kasparek, 1993).

Coastal Lagoons

There is a small lagoon at the tip of Ras Hawala and a large lagoon at Matrouh.

2.4.1.1 Natural Flora

The north coast of Egypt has one of the highest rainfalls of any desert area in the country. This rainfall and moisture nurtures the rich natural vegetation of the north coast which is floralistically the richest of all phytogeographical regions of Egypt (Ayyad, 1992). Of the total number of species recorded in the country nearly 50% (about 1,000 species) occur in the western Mediterranean region (Ayyad, 1992). The areas that exhibit the greatest diversity of plant species are the coastal dunes, rocky ridges and inland plateau (Ayyad, 1992).

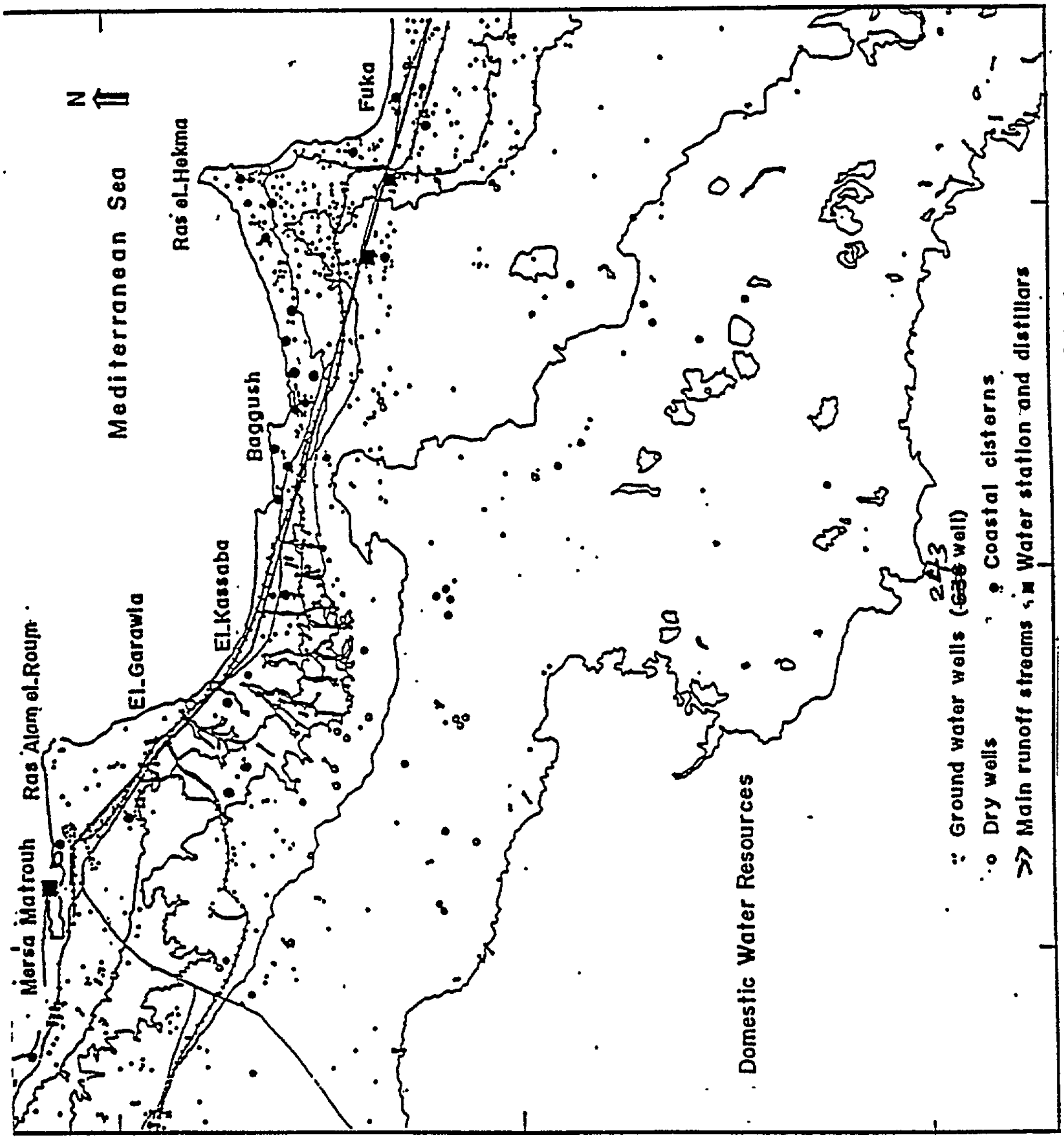


Fig. 36 Domestic Water Resources, Fuka-Matrouh

The plants of the sand dunes can be classified into nine life forms: annuals, perennial grasses, perennial herbs, evergreen succulent perennial sub-shrubs, evergreen non-succulent perennial sub-shrubs, partially deciduous perennial sub-shrubs, evergreen succulent perennial shrubs, evergreen non-succulent perennial shrubs and deciduous perennial shrubs. Annuals form the highest percentage of the total flora, followed by evergreen non-succulent perennial sub-shrubs and the perennial herbs (Kasparek, 1993).

In addition to the inland flora, Bartles (undated) has defined five phytogeographical zones for the coastal basin of El Qasr area (the area adjacent to Matrouh). The species dominant in each zone are listed in Table 17.

2.4.1.2 Fauna

2.4.1.2.1 Mammals

There is a relatively high number of mammals which occur in the coastal belt between Alexandria and El-Sallum. Osborn & Helmy (1980) listed records of 27 species (Table 18, c.f. Kasparek, 1993).

The Dorcus Gazelle *Gazelle dorcus*, listed by the "1990 IUCN Red Data Book" as "vulnerable", was formally known from various locations close to the coast in the western desert and north Sinai, but is presumed to have become locally extinct during the past two decades.

2.4.1.2.2 Birds

The ornithological knowledge of the coast between Alexandria and El-Sallum is very poor. The area between Alexandria and Mersa Matrouh has hardly been visited by bird watchers and the area between Mersa Matrouh and El-Sallum may never have been visited by birdwatchers (Goodman & Meininger, 1989).

Reviewing Goodman & Meininger (1989) and Kasparek (1993), it can be concluded that the ornithological list of the area Fuka-Matrouh contains 43 species (Table 19). Kasparek (1993) notes that the most surprising results of his survey is the regular presence of Greater Sand Plovers *Charadrius leschenaultii* on those beaches with flat beach rocks. There is no positive documentation of breeding of the Greater Sand Plover in Egypt, but there is a record that it had bred at Mersa Matrouh in the 1940d (Goodman & Meininger, 1989). The flat salt lakes between the coastal ridge and Abu Sir Ridge (in the area between Alexandria and Matrouh) provide an excellent habitat for the Greater Sand Plover. There is no reason to doubt that it actually breeds there and comes to the sea shore after breeding is finished (Kasparek, 1993). This would represent the western-most breeding area of the Greater Sand Plover and the only one in Africa (Kasparek, 1993).

The Houbara *Chlamydotis undulata*, listed by the "1990 IUCN Red Data Book" as "vulnerable" was a formally common breeding resident of the Mediterranean coastal desert between Sallum and Alexandria (Goodman & Meininger, 1989). The area between Matrouh and Sallum was thought to be one of the last remaining strongholds for the Houbara in Egypt; however, the present status of this species is unknown.

2.4.1.2.3 Reptiles

Thirty-seven reptile species (Table 20) were recorded by Marx (1968) from north-western Egypt (c.f. Kasparek, 1993). In his survey, Kasparek (1993) found five of these species in the area Fuka-Matrouh.

Table 17

Dominant Natural Vegetation Species in the Different Phytogeographical Zones in El Qasr Area (the Area Adjacent to Western Matrouh)

A. COASTAL BASIN:	B. INLAND:
1. Active coastal dunes: *Ammophila arenaria* *Euphorbia paralias* *Lotus polyphyllos* *Lygos raetam* 2. Interdunal plain: *Chrysanthemum coronarium* *Achillea santolina* *Convolvulus arvensis* *Enarthocapus strangulatus* *Avena fatua* 3. Older dune ridges: *Karduus sp.* *Thymelea hirsuta* 4. Interdunal depression: *Halocnemon strobilaceum* *Arthrocmenum glaucum* *Salicornia fruticosa* *Aeluropus massarensis* 5. Alluvial plain: *Suaeda pruinosa* *Salsola tet* *Frankania revoluta* *Polygonium equicetiforme* *Atriplex halimus* *Limoniastrum micro*	*Achillea santolina* *Anabasis articulata* *Asphodelus microcarpus* *Atriplex halimus* *Avena fatua* *Chrysanthemum coromarium* *Convolvulus arvensis* *Enarthrocarpus strangulatus* *Hamada scopparia* *Lycium arabicum* *Saliva lanigera* *Salsola tetragonum* *Salsola tetrandra* *Salsola vermiculata* *Suaeda pruinosa* *Thymelaea hirsuta*

The Egyptian Tortoise is classified by the "1990 IUCN Red Data Book" as "vulnerable" and is protected under international conventions. The world distribution of the Egyptian Tortoise is restricted to arid and semi-arid lands fringing the Mediterranean coasts of Libya, Egypt, the Gaza Strip and Israel. There is little recent information about the status of the population of the Egyptian Tortoise in Egypt. The local population is thought to have been extirpated due to collection of the species for the pet trade and habitat degradation, although a small population could still exist on the north coast and in north Sinai (Baha El-Din, undated).

Table 18

Mammals Recorded by Osborn & Helmy (1980) in the Coastal Belt Between Alexandria and El-Sallum

Hemichinus auritus libycus (Ehrenberg, 1833)

Paraechinus deserti deserti (Loche, 1858)

*Croidura suaveolens matruhensis** Setzer, 1960

This subspecies is endemic to the west Egyptian coast. Mersa Matrouh is so far the only locality where it has been found. It bears the name of Mersa Matrouh (Kasparek, 1993)

Lepus capensis rothschildi (De Winton, 1902)

*Gerbillus perpallidus** Setzer, 1958

This species is endemic to Egypt's north-western desert (Baha El-din, undated)

Gerbillus andersoni inflatus (Ranck, 1968)

Gerbillus gerbillus gerbillus (Olivier, 1801)

Dipodillus campestris wassifi (Setzer, 1958)

Dipodillus simoni kaiseri (Setzer, 1958)

Dipodillus amoenus amoenus De Winton, 1902

Dipodillus henleyi henleyi De Winton, 1903

Meriones shawi isis (Thomas, 1919)

Pachyuromys duparsi natronensis De Winton, 1903

Psammomys obesus obesus Cretzschmar, 1828

Spalax ehrenbergi aegyptiacus (Nehring, 1898)

Rattus rattus (Linnaeus, 1758)

Mus musculus praetextus (Brants, 1827)

Eliomys quercinus cyrenaicus (Festa, 1921)

Allacata tetradactylus (Lichtenstein, 1823)

Jaculus orientalis orientalis Erxleben, 1777

Jaculus jaculus Setzer, 1955

Canis aureus lupaster (Hemprich and Ehrenberg, 1833)

*Vulpes vulpes aegyptiaca** (Sonnini, 1816)

Foxes were recorded in the sand dunes and limestone ridges several times and also fox tracks were seen at a number of localities (Kasparek, 1993)

Poecilictis libyca libyca (Hemprich and Ehrenberg, 1833)

Herpestes ichneumon ichneumon (Linnaeus, 1758)

Felis chaus nilotica De Winton, 1898

*Acinonyx jubatus** (Schreber, 1776)

The most recent record is from 1964 (Kasparek, 1993)

Table 19

Birds Recorded in the Area Between Fuka and Matrouh and Their Status Within Egypt

Abbreviations:

CB casual breeder
MB migrant breeder
RB resident breeder
AC accidental visitor or vagrant (up to and including five documented records for the country)
PV passage visitor
WV winter visitor
( ) abbreviation in parenthesis is used to indicate that the status is variable or irregular, *e.g.* (PV) means "irregular passage visitor"
? status uncertain, *e.g.* RB? means "doubtful resident breeder"
O possible breeding in the area Fuka-Matrouh
* probable breeding in the area Fuka-Matrouh
\+ definite breeding in the area Fuka-Matrouh

(extracted from Goodman & Meininger, 1989)

Falco tinnunculus	*RB*	*PV*	*WV*	+
Falco biarmicus	*RB*	*WV*	*	
Alectoris barbara	*RB*	*		
Chlamydotis undulata	*RB*	*WV*	*	
Burbinus oedicnemus	*RB*	*PV*	*WV*	*
Cursorius cursor	*RB*	*PV*	*WV*	+
Charadrius alexandrinus	*RB*	*PV*	*WV*	+
Charadrius leschenaultii	*PV*	*WV*	*CB?*	
Charadrius morinellus	*WV*			
Calidris alba	*PV*	*WV*		
Limosa lapponica	*PV*	*WV*		
Numenius tenuirostris	*(PV)*	*(WV)*		
Numenius arquata	*PV*	*WV*		
Tringa totanus	*PV*	*WV*		
Tringa ochropus	*PV*	*WV*		
Tringa glareola	*PV*	*WV*		
Actitis hypoleucos	*PV*	*WV*		
Arenoria interpres	*PV*	*WV*		
Stercorarius pomarinus	*PV*	*WV*		
Stercorarius parasiticus	*PV*	*WV*		
Larus fuscus	*PV*	*WV*		
Larus cachinnans	*RB*	*WV*		
Sterna caspia	*RB*	*PV*	*WV*	
Sterna hirundo	*PV*			
Sterna albifrons	*MB*	*PV*		
Pterocles coronatus	*RB*			
Columba livia livia	*RB*	*		
Tyto alba	*RB*			
Athene moctus	*RB*	+	*	
Asio flammeus	*PV*	*WV*		
Apus pallidus	*RB*	*MB*	*PV*	*
Alcedo atthis	*CB?*	*WV*		

Table 19 (cont.)

Coracias garrulus	*PV*			
Ammommanes cincturus	*RB*	*		
Alaemon alaudipes	*RB*			
Chersophilus duponti	*RB*			
Melamocorypha calandra	*WV*			
Calandrella rufescens	*RB*	*WV*	O	
Galerida cristata	*RB*	+	*	
Lullula arborea	*WV*			
Eremophila bilopha	*RB*			
Anthus campestris	*PV*	*WV*		
Motacilla flava pygnaea	*RB*	*WV*	O	
Prunella modularis	*WV*			
Cercotrichas galactotes	*MB*	*PV*	*(WV)*	*
Erithacus rubecula	*WV*			
Luscinia svecica	*PV*	*WV*		
Phoenicurus ochruros	*PV*	*WV*		
Phoenicurus phoenicurus	*PV*	*(WV)*		
Saxicola torquata	*PV*	*WV*		
Oenanthe isabellina	*PV*	*WV*		
Oenanthe oenanthe	*PV*	*(WV)*		
Oenanthe lispanica	*PV*	*(WV)*	*MB?*	
Oenanthe deserti	*RB*	*PV*	*WV*	
Oenanthe moesta	*RB*			
Oenanthe lugens	*RB*	*(WV)*	O	
Oenanthe monacha	*RB*			
Turdus philomelos	*WV*			
Sylvia nisoria	*PV*			
Sylvia communis	*PV*			
Phylloscopus sibilatrix	*PV*			
Phylloscopus collybita	*PV*	*WV*		
Muscicapa striata	*PV*	*(WV)*		
Ficedula parva	*PV*	*(WV)*		
Lanius collurio	*PV*	*(WV)*		
Lanius excubitor	*RB*	*WV*	*	
Corvus corax	*RB*	+		
Sturnus vulgaris	*WV*			
Passer domesticus	*RB*	+		
Fringilla coelebs	*WV*			
Serinus serinus	*RB?*	*WV*		
Carduelis chloris	*RB*	*WV*		
Carduelis carduelis	*RB*	*WV*		

2.4.1.2.4 Amphibians

Two amphibian species were recorded in the area (Kasparek, 1993):

Bufo regularis	Reuss, 1834
Bufo viridis	Laurenti, 1768

Table 20

Reptiles recorded by Marx (1968) in north western Egypt (+: species occurring in north western Egypt, but have not yet been recorded in the coastal area; *: species recorded by Kasparek (1993) in the coastal region of Fuka-Matrouh

Hemidactylus turcicus (Linnaeus, 1758)
Ptychodactylus hasselquisti (Donndorff, 1798) +
Stenodactylus petrii Anderson, 1896 +
Stenodactylus stenodactylus (Lichtenstein, 1823)
Tarentola annularis (Geoffroy, 1823) +
Tarentola mauritanica (Linnaeus, 1758)
Agama agama spinose Gray, 1931
Agama mutabilis (Merren, 1820) *
Laudakia stellio (Linnaeus, 1758)
Acanthodactylus boskianus (Daudin, 1802) *
Acanthodactylus pardalis (Lichtenstein, 1823)
Acanthodactylus scutellatus (Audouin, 1829)
Mesalina guttulata (Lichtenstein, 1823)
Eremias rubropunctataus (Lichtenstein, 1823)
Ophisops elegans (Menetries, 1832)
Varanus griseus (Daudin, 1803)
Chalcides ocellatus (Forskal, 1775)
Chalcides sepsoides (Audouin, 1827)
Eumeces schneideri (Daudin, 1802) *
Mabuya quinquetaeniata (Lichtenstein, 1823)
Scincus scincus (Linnaeus, 1758)
Chamaeleo chamaeleon Linnaeus, 1758 *
Eryx colubrinus (Linnaeus, 1758)
Eryx jaculus (Linnaeus, 1758)
Coluber florulentus Geoffroy, 1827 +
Coluber rogersi (Anderson, 1893)
Lytorhynchus diadema (Dumeril and Bibron, 1854)
Macroprotodon cucullatus (Geoffroy, 1827)
Malpolon moilensis Reuss, 1834
Malpolon monspessulanus (Geoffroy, 1827)
Psammophis schokari (Forskal, 1775)
Psammophis sibilans (Linnaeus, 1758) +
Spalerosophis diadema (Schlegel, 1837)
Naja haje (Linnaeus, 1758)
Cerastes cerastes (Linnaeus, 1758) +
Cerastes vipera (Linnaeus, 1758)
Testudo kleinmanni (Lortet, 1883) *

2.4.1.2.5 Soil Fauna

Together with the problems of excessive heat and drought that desert soil fauna have to cope with, there is the problem of availability and quality of plant litter provided by the sparse vegetation, the basis of their food resources. This litter varies as a function of plant phenology and wind action which tends to accumulate this litter in depression or, more often under shrubs. Plant phenology is linked directly or indirectly to seasonality and rainfall thresholds for growth of perennials or ephemerals (Ayyad, 1978 c.f. Ghabbour *et al.*, 1984). The summer population of soil mesofauna associated with major shrubs in the littoral sand dunes of the north western coast are listed in Ghabbour *et al.*, (1977) (Table 21).

Table 21

Systematic List of Soil Mesofauna Associated with Major Shrubs in the Littora Sand Dunes (after Ghabbour *et al.*, 1977)

Isopoda, Oniscoidea:	*Agabiformes lentus* (B.L.) *Procellio albinus* (B.L.)
Dictyoptera, Blattoidea, Polyphagidae:	*Heterogamia syriaca* Saus.
Rhynchota, Heteroptera, Cydnidae:	*Sehirus melanopterus* H.S. *Macroscytus brunneus* F.
Myodochidae (Lygaeidae):	*Emblethis verbasci* F.
Neuroptera, Myrmeleonidae (Nymphs):	*Cueta* sp.
Coleoptera, Carabidae:	*Bradycellus lusitanicus* Dej.? *Cymindis suturalis* Dej. var
Scarabaeidae.	*Psammobius porcicollis* Ill.
Melolonthini (larvae)	
Cetonini (larvae)	
Tenebrionidae:	*Crypticus murinus* All. *Dendarus piceus* Ol. *Machlopsis crenatocostata* Pioch. *Pimelia* sp. (larvae) *Psammoica lucida* Sol. *Stenosis torre-tassoi* Koch.
Helopini (larvae)	
Antichidae.	*Hylophilus*?
Curculionidae:	*Otiorhynchus* sp.
Hymenoptera, Formicidae:	*Camponotus maculatus* F. *Messor barbarus* F. *Messor barbarus* var. aegyptiacus *Messor semirufus*
Diptera, Ceratopogonidae (larvae)	
Therevidae (larvae)	
Bibionidae (larvae)	
Arachnoidea, Opiliones:	*Phalangium savignyi*
Araneae, Agelenidae	
Dysderidae	
Gnaphosidae, Laronieae	
Salticidae	
Acari, Prostigmata, Trombidiidae	
Pseudoscorpiones:	*Olpium kochi* Simon
Myriapoda, Chilopoda, Geophilomorpha	*Geophilius* sp.

2.4.2 Freshwater Ecosystems

Rainfall water is the main source of fresh water in the area. The annual average rainfall is around 140 mm, most of which falls during winter time (mid-October to mid March) and it decreases southward. This water is harvested through cisterns and dykes to be used for agricultural and animal and human use purposes (see 2.3). Natural flora and its associated soil fauna as well as amphibians depend to a great extent on this rain fall (see 2.4.1.1, 2.4.1.2.4 and 2.4.1.2.5). Some limited underground water is exploited in some locations like Fuka, Burbeta and Ras El-Hekma.

2.4.3 Marine Ecosystems

See 2.2.1.11 for waves, currents and tides.

2.4.3.1 Temperature, Salinity and Density

During a four-seasons survey performed in 1977, the hydrographic variables of the seawater in Fuka and Matrouh at different depths from the surface and down to 100 metres deep (stations 24, 25 and 26 in front of Fuka and stations 27, 28 and 29 in front of Matrouh, Figs. 37-45)) were measured. The distribution of temperatures and salinities are indicated in Figs. 37-42. Based on these figures, the following seasonal hydrographic features in Fuka and Matrouh were concluded (Anon, 1983).

A. Fuka

In winter: both the temperature and salinity distributions indicate the intrusion of a water mass of temperature range from 18.00 to 18.10°C and salinity range from 38.90-39.00‰. This water appears as a tongue of relatively lower salinity moving towards the coast at a level between 10-30 m below the surface, with a corresponding density of 28.40 sigma-t units. Meantime, there exists a flow of water of higher temperature and higher salinity moving seaward over the shelf. However, this latter flow does not move very far down the slope as it is met by the intrusion of the 18.0°C-39.0‰ water mass moving up the slope as described above.

In spring: a weak stratification in both temperature and salinity distribution is observed, with corresponding density stratification. There is a tendency of temperature and salinity decrease with depth, but the vertical gradients are rather small, apparently due to some vertical mixing occurring in earlier months.

In both summer and autumn seasons: although a distinct seasonal thermocline is clearly observed, the halocline practically disappears. However, the temperature stratification reveals a reasonable degree of density stratification. This density stratification may develop in the shelf area in summer, but can hardly be permanent because of its shallow depth (about 75 m), and the relatively strong winds which are frequently encountered in the coastal area during the succeeding seasons, *i.e.* during late autumn/early winter seasons.

B. Matrouh

In winter: the water is relatively homothermal except at the most outer station where a thermocline is observed between 50-75 m with a corresponding halocline. The intrusion of the relatively colder and less saline water mass with corresponding density 28.6 sigma-t units is also observed but at level deeper than that observed in the earlier section "Fuka".

In spring: the coastal water is still more or less homogenous. However, at the most outer station a thermocline and halocline are developed in the upper layer of the water between the surface and 20m below the surface.

In summer and autumn: a distinct seasonal thermocline is observed between 50-80 m below the surface but without corresponding halocline. The sharpest gradients of temperature along the bottom occur over the slope, where the change in depth in this particular section is rather rapid. This is generally a characteristic feature of the western part of the Egyptian continental shelf. There is still an indication of an intrusion of open seawater toward the coast. An interesting feature is also observed from the density distribution. That is the existence of an intermediate layer of density less

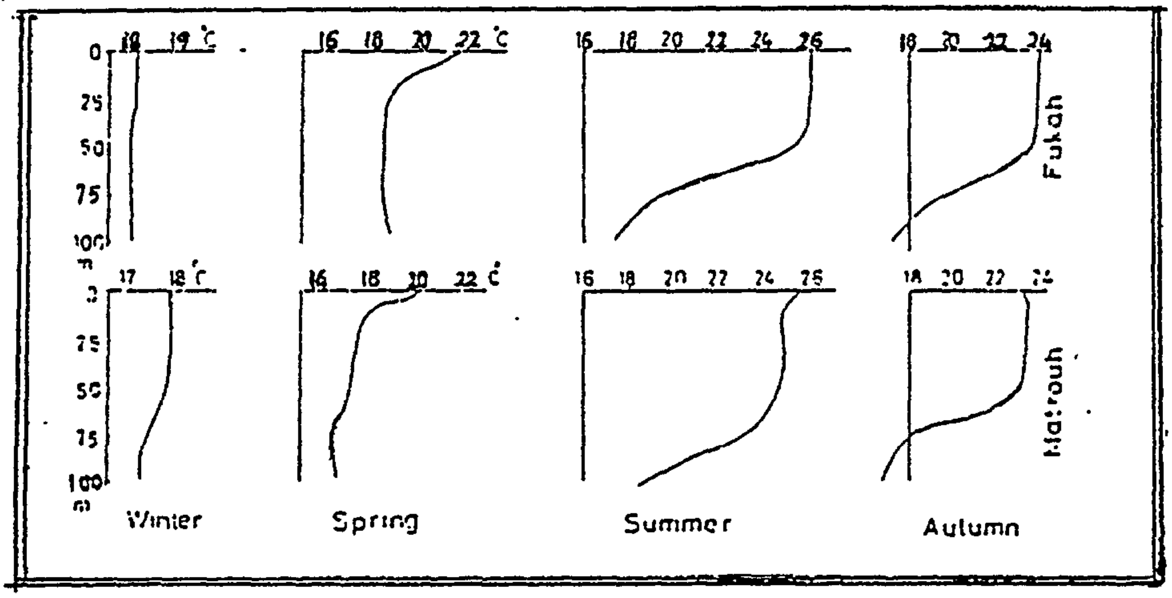


Fig. 37 Vertical profiles of seawater temperature in Fuka and Matrouh (after Anon, 1979)

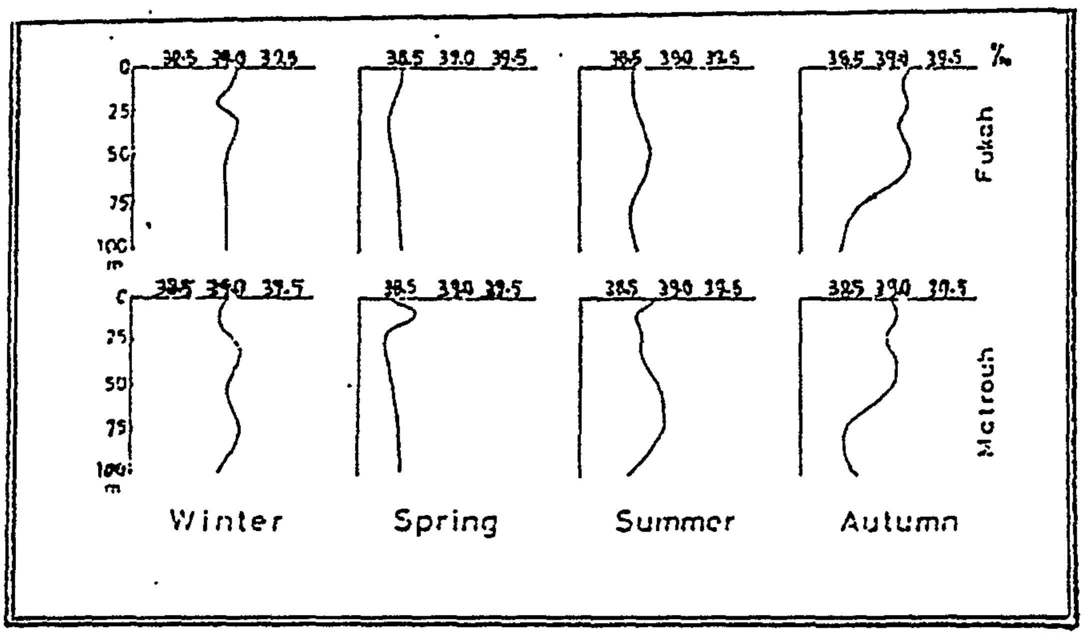


Fig. 38 Vertical profiles of salinity in Fuka and Matrouh (after Anon, 1979)

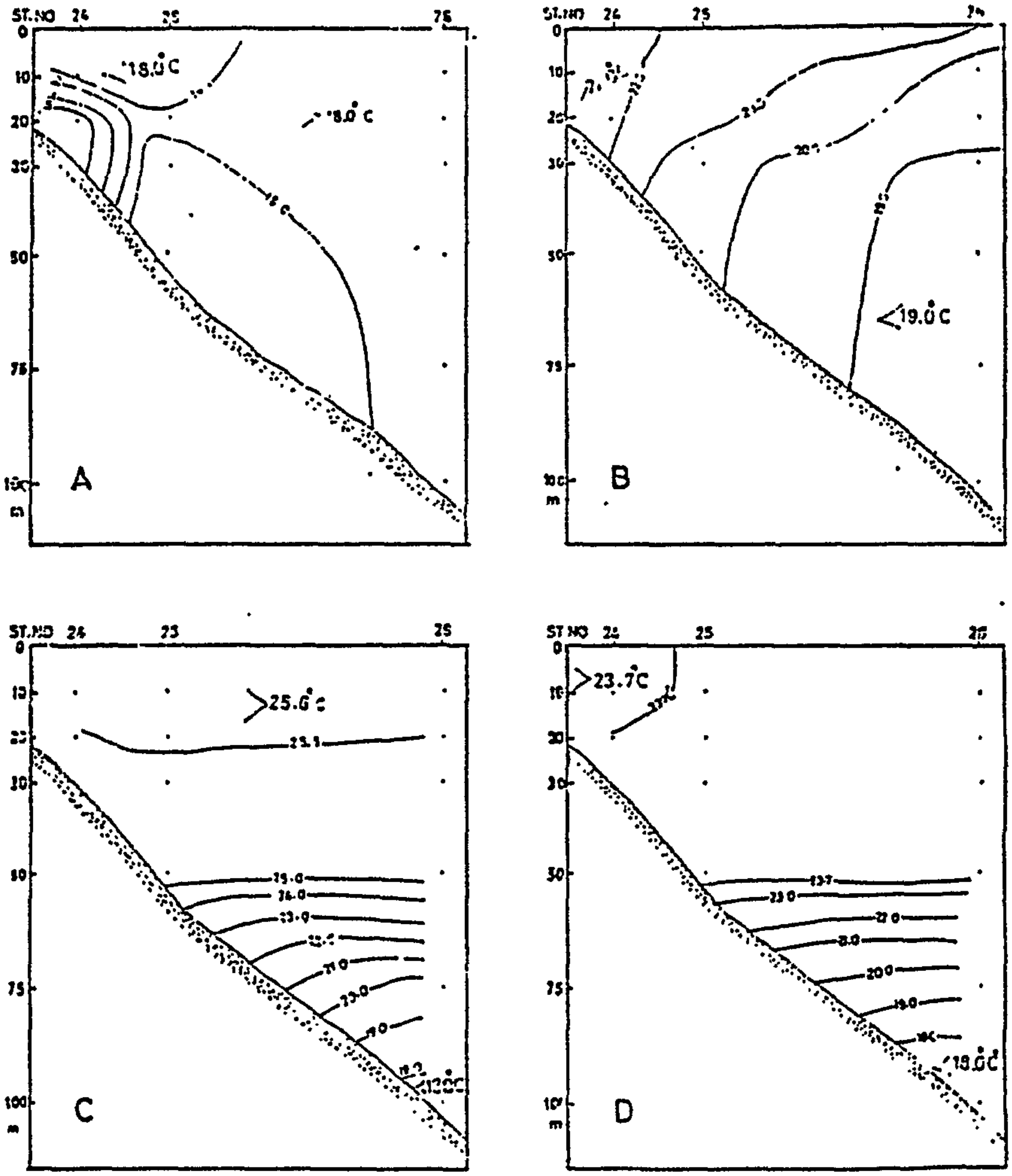


Fig. 39 Vertical distribution of seawater temperature for Fuka during: (A) winter, (B) spring, (C) summer and (D) autumn seasons (after Anon, 1979)

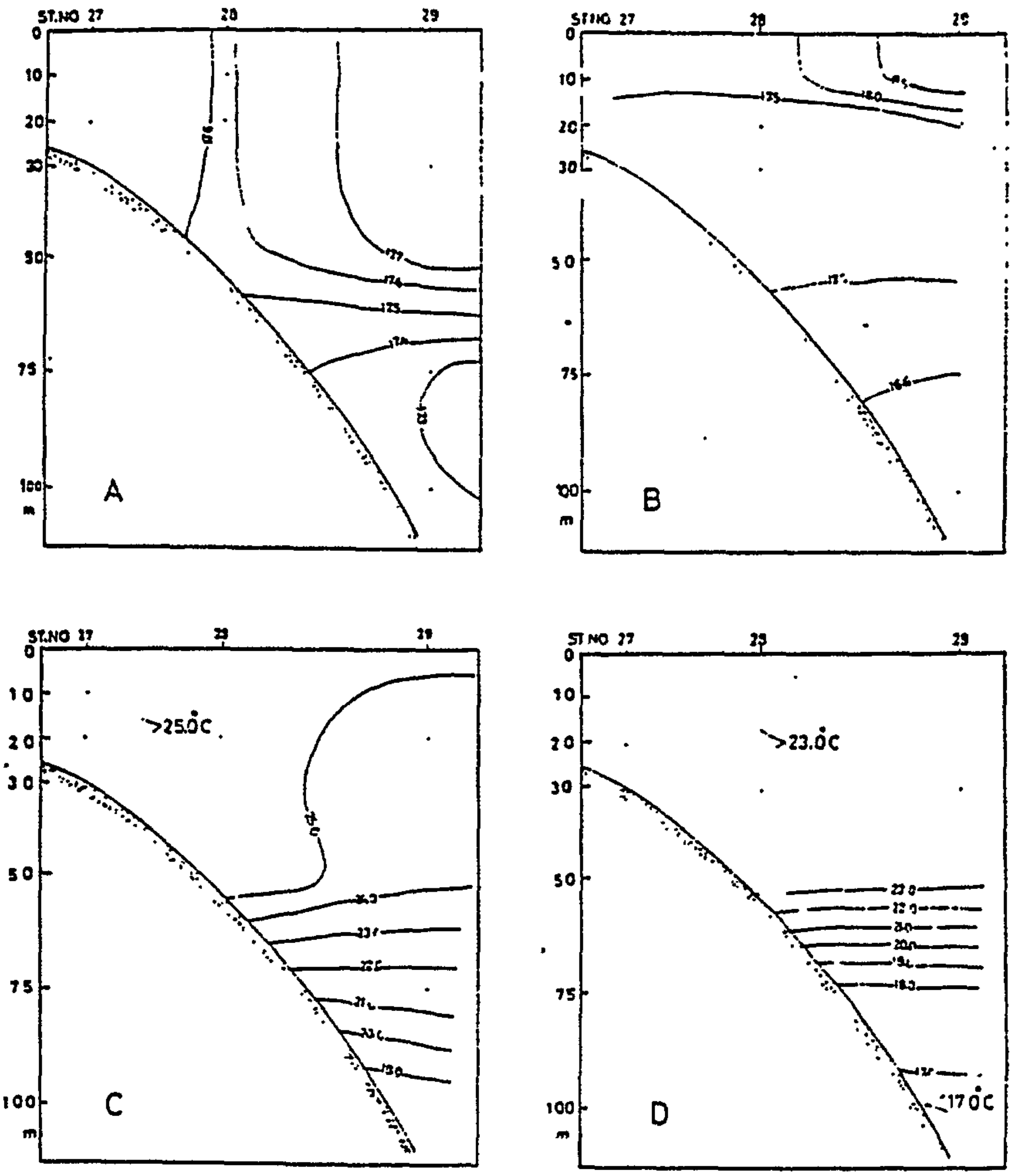


Fig. 40 Vertical distribution of temperature for Matrouh during (A) winter, (B) spring, (C) summer and (D) autumn seasons (after Anon, 1979)

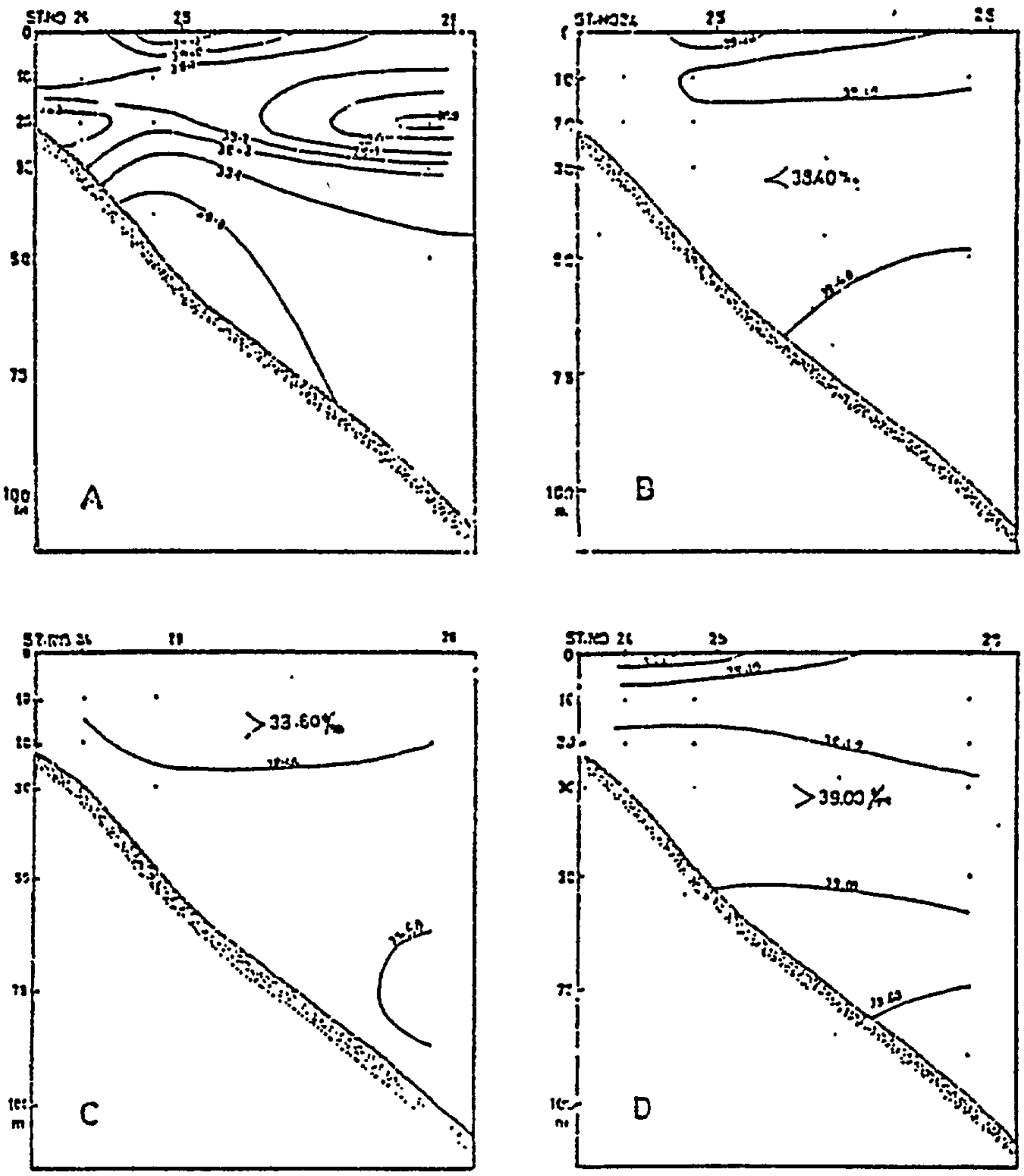


Fig. 41 Vertical distribution of salinity for Fuka during (A) winter, (B) spring, (C) summer and (D) autumn seasons (after Anon, 1979)

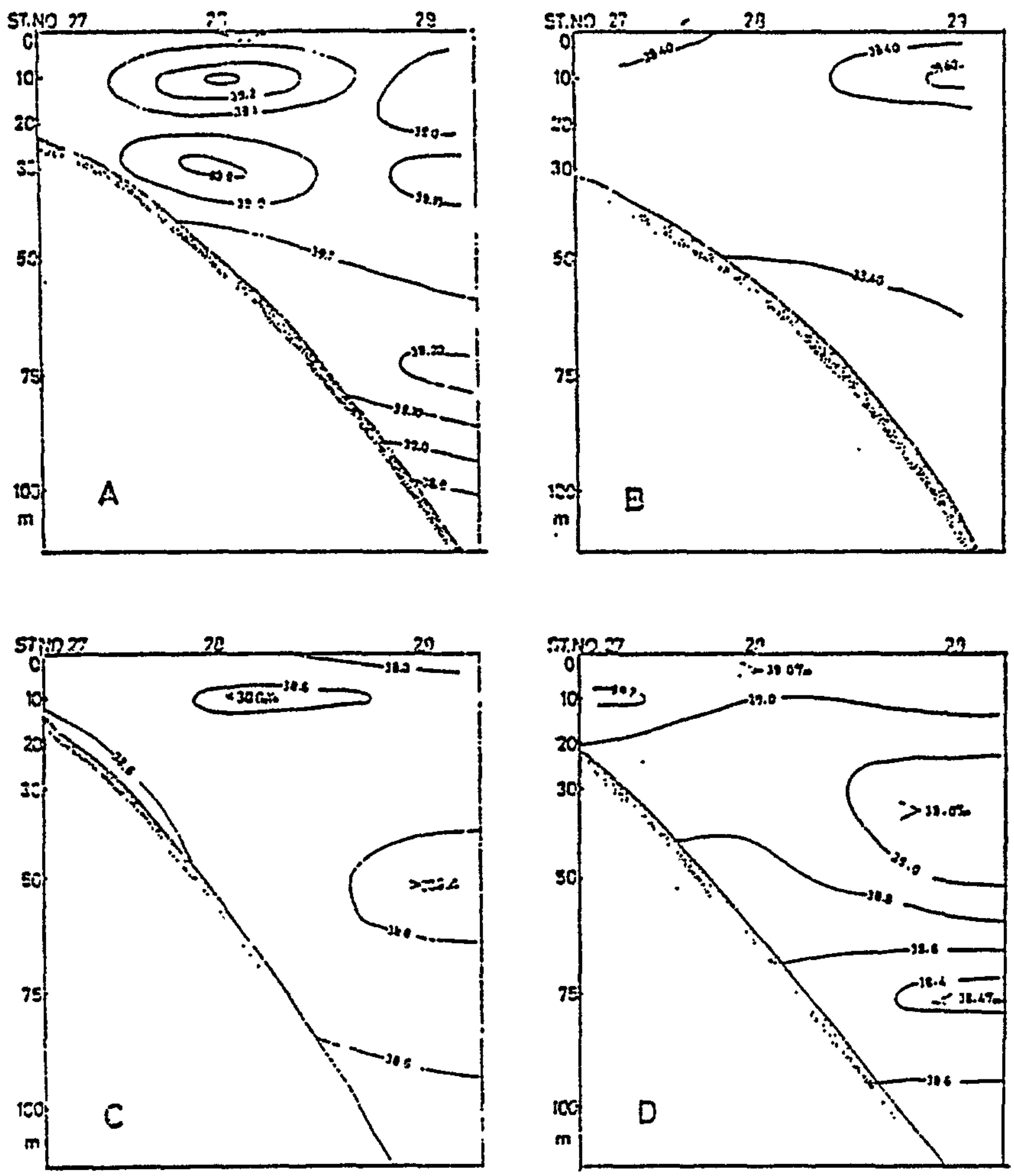


Fig. 42 Vertical distribution of salinity for Matrouh during (A) winter, (B) spring, (C) summer and (D) autumn seasons (after Anon, 1979)

than 27.0 sigma-t units included between water of larger densities above and below it. This reduction in density of a particular layer may occur at any time of the year near shore due to either an increase of local runoff or an intrusion of low-salinity water from the open sea. The last is, of course, the reason in our case. This is confirmed by the existence of a tongue of water of low salinity (less than 38.40%) as revealed from the salinity vertical distribution in the autumn seasons.

2.4.3.2 Oxygen

According to Anon (1983) the oxygen content of the surface seawater in Matrouh showed a high value during winter (6.0 ml/l) and there is a slight decrease towards the offshore. During spring and summer, the oxygen content was slightly lower than during winter. During autumn the oxygen content was around 4.5 ml/l. This value was less than that observed during summer.

Vertical Distribution of Oxygen

During winter (January, 1977) the effect of water convection and mixing of water masses appeared where values of 3.5-4 ml/l isolines extended from the surface of water and down to 100 metres deep without remarkable variation from the surface to downward (Fig. 43). During February, a remarkable increase in oxygen content appeared where more than 6 ml/l was recorded in the inshore of 10 metres deep (Fig. 44). That may be due to the lower temperature and higher agitation occurring during this month.

Compared with January 1977, a remarkable increase in oxygen content at 20-50 m deep occurred during spring (April, 1977). The same phenomenon of subsurface high oxygen content previously recorded during 1966 (Emara, 1969 and Emara *et al.*, 1973) and during 1975 (Al-Kholy & El-Wakeel, 1975).

During summer and autumn, this subsurface highly oxygenated layer disappeared and the distribution showed a water body of low oxygen content comes from the offshore area during autumn and mixes with the inshore water of Fuka (Fig. 45).

Contrary to the observation of 1966 and 1971 (Emara *et al.*, 1973), the seasonal variations in oxygen content during 1977 were not well defined (Anon, 1983).

2.4.3.3 Nutrient Salts

In general, the eastern Mediterranean is considered of the oligotrophic areas poor in nutrient salts which are necessary for phytoplankton's growth and flourishment. The area Fuka-Matrouh is one of the most oligotrophic areas in the eastern Mediterranean.

In 1977, the nutrient salts of the Mediterranean waters of Egypt from Rosetta to Matrouh were defined. The following are the results of that survey for the area Fuka-Matrouh.

A. Inorganic Phosphate

In winter, the distribution of phosphate at the surface layer of the area Matrouh-Rosetta is uniform and very low (0.30-0.60 μg/L during January and 0.30-0.90 μg/L during February) and the vertical distribution indicates a vertical mixing characterising a winter convention (Anon, 1983).

During spring, the surface phosphate in the area Matrouh-Rosetta was around 0.30-5.58 μg/L and as winter, the vertical distribution shows no stratification (Anon, 1983).

During summer, higher phosphate values (1.24-1.86 μg/L) were observed at Matrouh. Little variation with depth was observed (Anon, 1983).

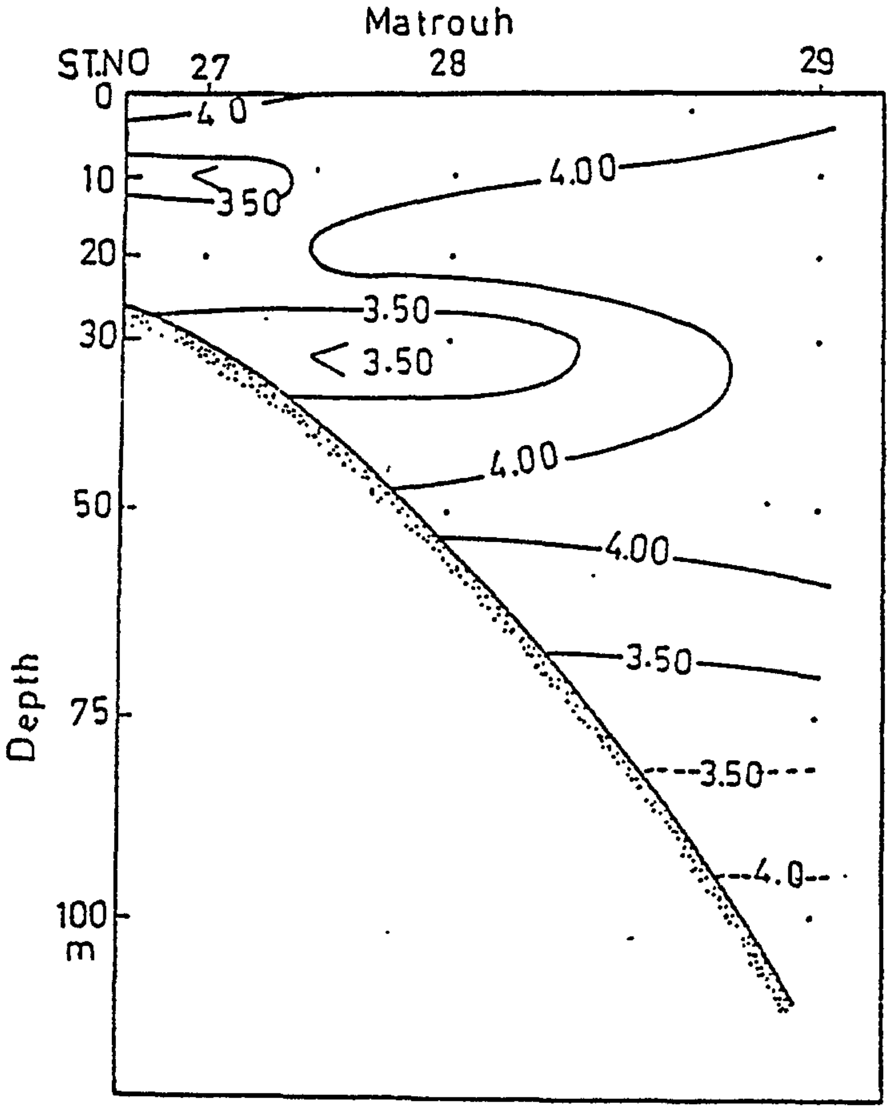


Fig. 43 Vertical distribution of oxygen (ml/l) at Matrouh in January 1977 (after Anon, 1983)

During autumn, the phosphate concentration for the area Matrouh-Rosetta did not exceed 1.15 μg/L. *At Fuka and Matrouh, inorganic phosphates were completely depleted from the vertical* column.

B. Nitrite and Nitrate

As indicated in figures 36 and 37 in Al-Kholy and El-Wakeel (1975) the nitrite in the surface water of Fuka-Matrouh did not exceed 0.7 μg/L and the area was depleted of nitrate.

C. Reactive Silicate

During winter the silicate was depleted both at the surface and down to 100 m deep (Anon, 1983).

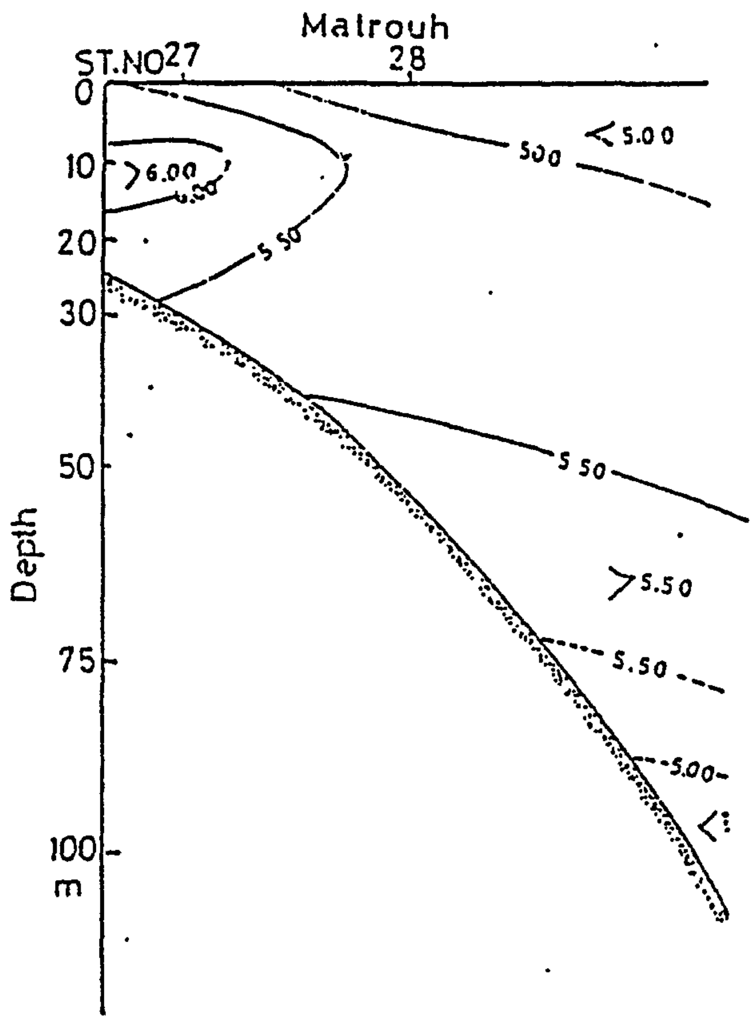


Fig. 44 Vertical distribution of oxygen (ml/l) at Matrouh in February, 1977 (after Anon, 1983)

During spring, the silicate in the surface water of Matrouh ranged between 308 µg/L in the offshore and 364 µg/L in the inshore (Anon, 1983).

During summer, 224 µg/L was the concentration of silicate in the inshore surface water of Matrouh. This concentration increases seaward and downward (Anon, 1983).

During autumn, the concentration of silicate in the surface water at Fuka was around 84 µg/L (Anon, 1983).

Table 22 summarises the chemical properties of the surface Egyptian Mediterranean seawater and this water at 100 m deep.

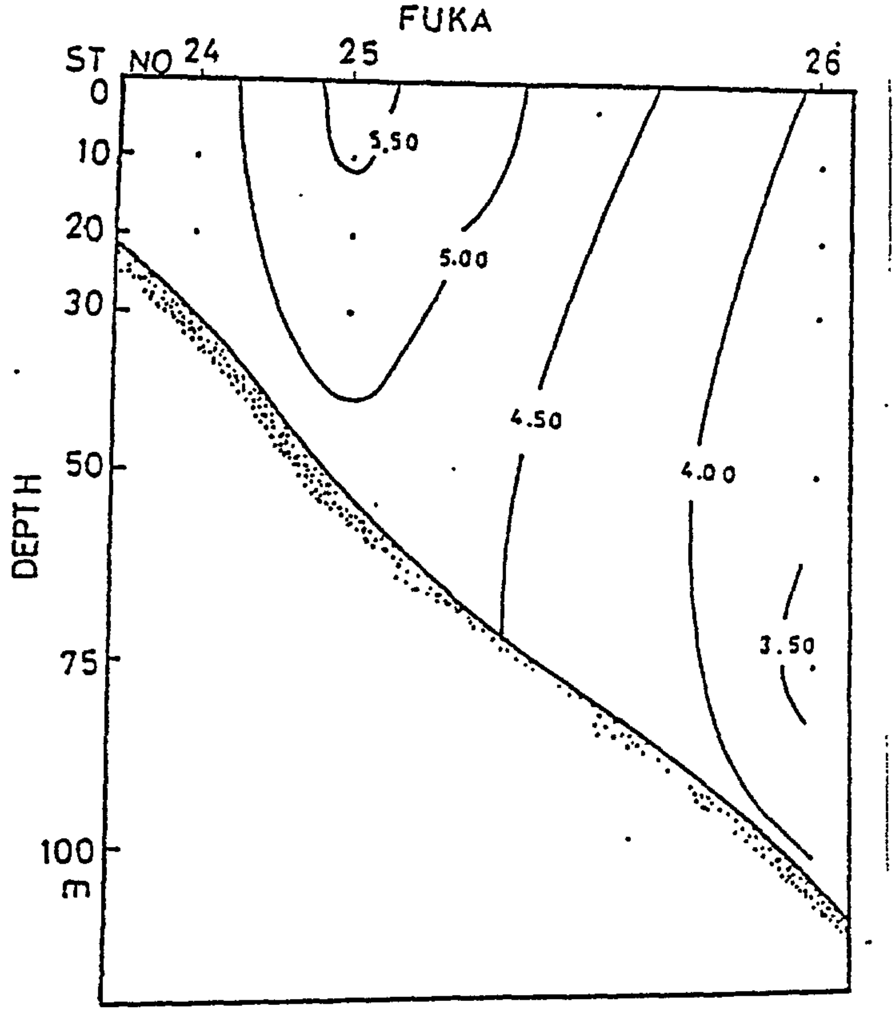


Fig. 45 Vertical distribution of oxygen (ml/l) at Fuka in October 1977 (after Anon, 1983)

2.4.3.4 Phytoplankton

The phytoplankton of the area was investigated during the four seasons of 1977. The results were published in Anon (1979a, 1983a) and Abdalla *et al.* (1992). As shown in Table 23, the phytoplankton production of Matrouh (1,792 cell/l/year) was slightly higher than that of Fuka. It is obvious that the area is oligotrophic. The production increased towards offshore of Matrouh and vice-versa occurred in Fuka (Table 23).

The characteristics of phytoplankton in the area during the different seasons can be summarised as follows:

<u>Fuka</u>

In both the inshore and offshore winter was the flourishing season, followed by a decline in production during spring and drastic decreases during summer and autumn (Table 23).

Table 22

Concentration of Dissolved Oxygen and Nutrient Salts at the Surface and 100 Metres Deep During 1966, 1971 and 1976 (after Anon, 1983)

Parameters	Depth in metres	Units used	Concentration of 1966	Concentration of 1971	Concentration of 1976
Oxygen	0	ml/l	4.42-5.96	4.45-6.35	2.20-6.29
	100	ml/l	5.12-6.37	around 5.50	3.28-5.92
Phosphate	0	μg/L	0.6-6.8	0.00-6.8	0.3-5.5
	100	μg/L	0.6-8.3	0.00-5.2	0.3-3.0
Nitrite	0	μg/L	-	0.00-2.5	0.00-0.84
	100	μg/L	-	0.00-1.12	0.00-0.84
Nitrate	0	μg/L	-	0.00-4.3	0.00-23.2
	100	μg/L	-	0.00-7.28	0.00-5.6
Silicate	0	μg/L	-	0.00-445.2	0.00-504
	100	μg/L	-	5.6-501.2	0.00-364

Table 23

Phytoplankton production (cell/l) during the seasons of 1977 in the inshore and offshore zones of Fuka and Matrouh (Adapted from Abdalla *et al.*, 1992)

	Inshore					Offshore					Total Av.
	Winter	Spring	Summer	Autumn	Av.	Winter	Spring	Summer	Autumn	Av.	
Fuka	4226	2761	238	240	1866	4568	1242	200	280	1572	1719
Matrouh	4725	599	301	332	1489	6732	1070	400	175	2094	1792

The dominant species were *Cyclotella kutzingiana* during winter, *C. kutzingiana, Melosira crucipunctata* and *Leptocylindrus danicus* during spring, *L. danicus* and *M. crucipunctata* during summer and *Rhizosolenia calcaroavi, L. danicus* and *Chaetoceros affinis* during autumn.

Matrouh

As in Fuka, the winter was the flourishing season and the standing crop sharply declined during the other seasons of 1977.

The phytoplankton community was dominated by *Cyclotella kutzingiana* during winter and spring, *Melosira crusipunctata* and *C. kutzingiana* during summer and *Bacteriastrum elongatum, C. afinis* and *L. danicus* during autumn.

2.4.3.5 Zooplankton

The only available literature on the zooplankton of Fuka-Matrouh are Anon (1979a) and Anon (1983a) which report on a survey performed through the four seasons of 1977. The seasonal distribution of the zooplankton in the inshore and offshore zones of the area is indicated in Table 24, illustrated by Fig. 46 and can be summarised as follows:

Table 24

Distribution of the total zooplankton (org/m^3/year) during the different seasons at both inshore and offshore zones in Fuka and Matrouh (adapted from Anon. 1983a)

	Inshore					Offshore					Total Av.
	Winter	Spring	Summer	Autumn	Av.	Winter	Spring	Summer	Autumn	Av.	
Fuka	1262	1583	1176	1962	1496	883	947	1121	2931	1470	1483
Matrouh	863	1801	3042	2721	2107	642	1165	1603	1399	1202	1654

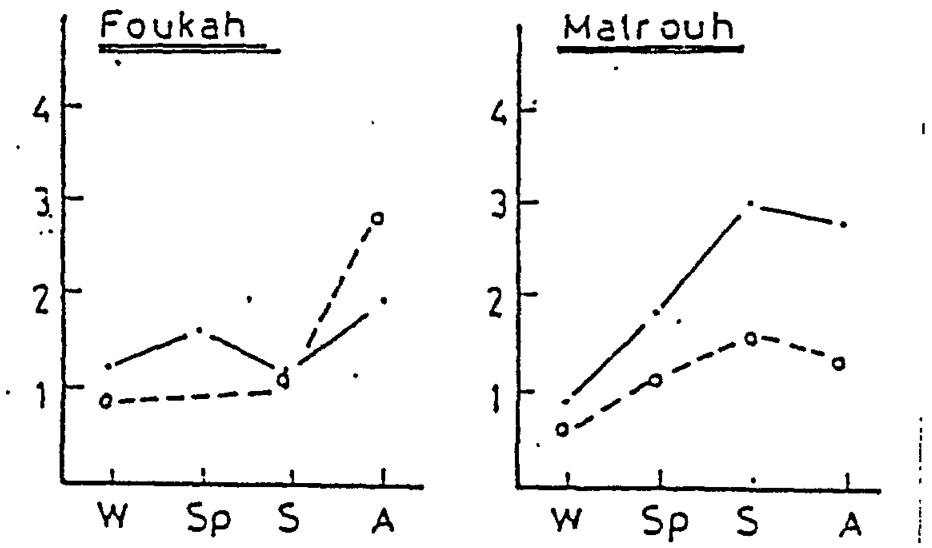


Fig. 46 Seasonal variations of the total zooplankton (organisms/m^3) recorded at both the inshore (._______.) and offshore (o——o) of Fuka and Matrouh (after Anon, 1983a)

Fuka

The average population density (PD) of zooplankton in Fuka during winter amounted to 1,072 m^3. The copepods *Paracalanus* and *Oithona* were the dominant plankters and the crustacean eggs, *tintinnides*, *Sagitta* and Pteropods were frequent.

During spring the PD slightly increased to 1,265 org/m^3. The copepods, particularly *Paracalanus* and *Oithona* remained as the dominant plankters. Other groups including tintinnides, *Oikopleura*, gastropod veligers and *Sagitta* were frequent.

During summer, the standing crop was slightly less than that of spring. The copepods *Paracalanus* and *Oithona* dominated the zooplankton community.

Autumn was the most productive season (PD = 2,446 org/m^3). Unlike the other seasons of the year, the zooplankton production increased seaward. Like in summer, the dominant plankters were *Oithona* sp., *Paracalanus* sp. and nauplius larvae.

Matrouh

The zooplankton population in Matrouh (752 org/m^3) was the lowest during winter. Its production decreased towards offshore. The dominant plankters were *Paracalanus, Oithona* and *Clausocalanus* and the frequent plankters were the crustacean eggs, *Oikopleura* and tintinnides.

During spring, the production (1,483 org/m^3) was about double the winter production and it decreased offshore-ward, *Paracalanus* and *Oithona* were the most dominant plankters. The tintinnides, echinoderm larvae, gastropod veligers, Fritillaria and Oikopleura were frequent. Fish larvae were recorded at the inshore.

During summer, the average PD increased to 2,322 org/m^3. The highest population existed at the inshore due to the excessive number of copepod nauplii and gastropod veligers. *Paracalanus, Oithona* and *Centropages* were the dominant plankters. Gastropod veligers, polychaeta larvae, tintinnides and lamellibranch veligers were frequent.

During autumn, the zooplankton production slightly decreased to 2,060 org/m^3. The highest population existed at the inshore zone and in the surface water. *Oithona* and *Paracalanus* spp. were the dominants. Tintinnides, polychaete larvae, forminefera and lamellibranch veligers were frequent.

2.4 3.6 Biota of Sea Bottom

Nature of Sea Bottom

The sea bottom in the area Fuka-Matrouh is rocky with fine and coarse sand and mud in the inshore zone (down to 50 m deep), silty sand with pebbles and rocks in the offshore of Fuka and silty with gravels and rocks in the offshore of Matrouh (50-100 m deep).

Bottom Flora

The inshore area is inhabited by green algae such as *Caulerpa prolifera* Lam., *Codium bursa* Ag., *Halemida tuna* (Ell & Sol.) Lam. and *Udotea petiolata* (Turra). Strands of brown algae mainly represented by *Sargassum* spp. are commonly found and a belt of the sea grasses *Posidonia* sp. and *Zostera* sp. spreads in the area (personal observation, 1977 and Farag, 1981).

The offshore zone is characterised by high vegetation of red calcareous algae such as *Lithothamnium* spp. and *Lithophyllum* spp. (personal observation, 1977 and Farag, 1981).

Spring and summer were the algae flourishing seasons.

Bottom Fauna

Other than the works of Paget (1922), El-Beshbeeshy (1983), Kheirallah *et al.* (1989) and Ramadan *et al.* (1989) which were concerned with sponge, no investigations on the benthos of the area Fuka-Matrouh were available except that survey performed during 1977 and published in Anon (1979a, 1983a) and Farag (1981).

The sponges in the area were represented by 11 species, five of which were commercial and six were non-commercial (Ramadan *et al.*, 1989). For the sponge fisheries see 2.5.2.

The other macrobenthic invertebrates were mainly represented by species of polychaeta, Sipunculidae, Crustacea, Mollusca, Brachiopoda, Echinodermata and Ascidia. The number of species representing each group in the inshores and offshores of Fuka and Matrouh are indicated in Table 25. The macrobenthic invertebrates production (as population density and biomass) compared with phytoplankton and zooplankton productions in inshores and offshores of Fuka and Matrouh are indicated in Table 26.

Table 25

Number of Macrobenthic Species in Each Group Procured in the Area Fuka-Matrouh during 1977 (adapted from Farag, 1981)

	Inshore		Offshore	
	Fuka	Matrouh	Fuka	Matrouh
Polychaeta	9	12	7	8
Sipunculidae	-	-	1	1
Crustacea	5	7	5	4
Mollusca	12	8	3	9
Brachipoda	-	-	1	1
Echinodermata	4	1	3	4
Ascidia	1	1	1	1
Total	**32**	**29**	**21**	**28**

Table 26

Average Population Density (PD) of Bottom Macro Invertebrates (org/80m^2/year) and their Biomass (B) as (gm/80 m^2/year) Compared with Phytoplankton Production (cell/l) and Zooplankton Production (organism/m^3) in the Inshore and Offshore of Fuka and Matrouh During 1977 (adapted from Farag, 1981)

	Fuka				Matrouh			
	PD	B	cell/l	org/m^3	PD	B	cell/l	org/m^3
Inshore	9	32.33	1945	1496	11	9.30	2022	2107
Offshore	31	15.10	1268	1470	41	14.73	1900	1202

According to Anon (1983a), the seasonal variation in the production of macrobenthic invertebrates is as the following:

Fuka

The winter population at the inshore of Fuka reached 5 org/haul (haul = 80 m^2) and comprised molluscs, echinoderms and polychaetes. This value increased during both the spring and the summer to 11 org/haul when polychaetes were more dominant in the spring and molluscs in the summer.

In the autumn, the standing crop was reduced to 6 org/haul (Fig. 47A).

The offshore stations were very rich and they sustained an average of 31 org/haul/year. The counts of benthos amounted to 34 and 33 org/haul during the spring and summer respectively and consisted mostly of polychaetes and brachipods. This value dropped to 17 org/haul in the autumn where polychaetes remained as the main components.

Unlike the numerical abundance of benthos the average biomasses were much higher at the inshore (33.3 gm fresh wt/haul) as compared with the offshore (14.1 gm fresh wt/haul). This is particularly due to the higher biomasses of molluscs and echinoderms in the former stations (Fig. 47B).

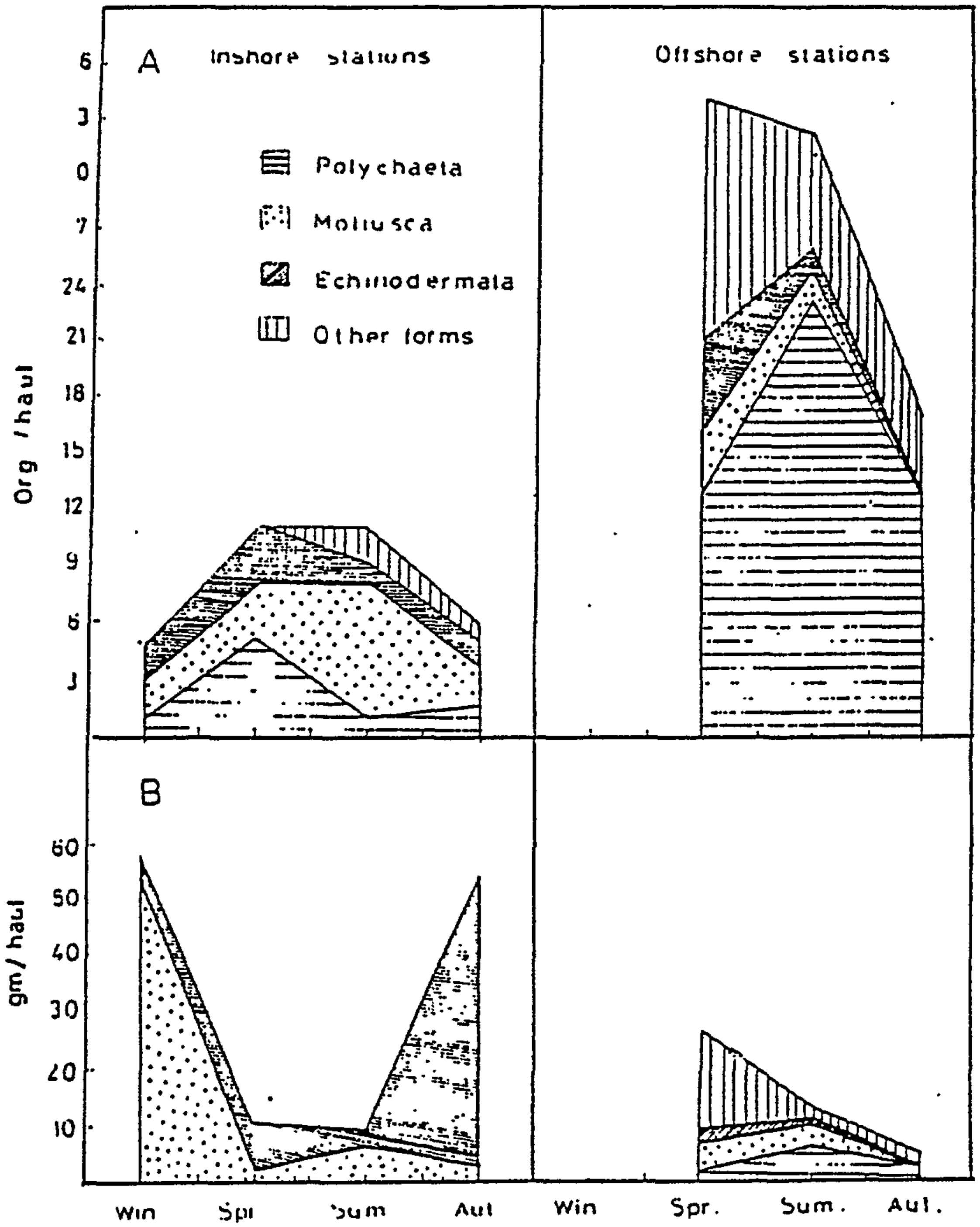


Fig. 47 Seasonal variations of the total fauna along Fuka section at both the inshore and offshore stations.
A - organism per haul (80 m^2)
B - gramme fresh weight per haul (80 m^2)
(after Anon, 1983a)

Matrouh

The average numbers of benthos recorded at the inshore reached 14 org/haul during the winter. Polychaetes were more dominant than other groups. The total fauna decreased to 8 org/haul in the spring and this was accompanied by a reduction in polychaetes. The benthic fauna increased again to 12 org/haul with the appearance of crustaceans. This was followed by a sharp drop to 3 org/haul in the autumn and was only represented by polychaetes (Fig. 48A).

The offshore stations were numerically more productive during the different seasons. Thus their density attained 52 org/haul in the winter and was dominated by polychaetes, while echinoderms and ascidians appeared as frequent forms. The number of benthos showed a further increase to 65 org/haul in the spring and this was accompanied by a pronounced increase of echinoderms. The community dropped again to 12 org/haul in the summer and this was followed by an increase to 39 org/haul in the autumn.

The average annual biomass of benthos reached 9.3 and 14.73 gm/haul for the inshore and offshore respectively. The peaks were observed at the inshore during the winter and at the offshore in the spring where echinoderms formed the main bulk of benthos (Fig. 48B).

2.4.3.7 Sea Turtles

Information available on the marine turtles of the Egyptian Mediterranean Sea is very scarce. Nonetheless, there are three species of marine turtles known from the area. The commonest being the Loggerhead Turtle, *Caretta caretta*, second in rank is the Green Turtle, *Chelonia mydas*. The Leather-backed Turtle, *Dermochelys coriacea*, is the rarest and is only known from a handful of records (Marx, 1968; Frazier and Salas, 1984, c.f. Delft Hydraulics, 1992).

Through a survey of the north-western coast of Egypt, Kasparek (1993) found marine turtle tracks on the beaches of Arab's Bay, west to Matrouh and Sallum Bay. All tracks of emerging nesting turtles were identified as tracks of the Loggerhead Turtle, *Caretta caretta*. As well, the dead turtles which were found washed ashore and those found in fish markets and elsewhere were identified as Loggerhead Turtles, *Caretta caretta*.

In spite of the fact that all the marine turtles are listed as endangered throughout their range, the Egyptian official statistics (CAPMAS) show that the turtles landing increased from 100 tons in 1989 to 418 tons in 1990.

2.4.3.8 Sea Mammals

The study area does not provide suitable habitats for the Monk Seal (*Monachus monachus*). Rocks are rather flat at most locations and no coastal caves are present (Kasparek, 1993).

2.4.3.9 Summary

The coastal limestone formation with overlying sand dunes extends over almost the whole study area which includes two lagoons.

The coastal dunes, rocky ridges and inland plateau exhibit the greatest diversity of plant species. The plants of sand dunes can be classified into nine life forms. Of which, the annals form the highest percentage of the total flora.

Between Alexandria and El-Sallum, 27 mammalian species were recorded. Of which, *Croidura suareolens matruhensis* and *Gerbillus perpallidus* are endemic to west Egyptian coast. The *Dorcus Gazelle* is presumed to have become locally extinct.

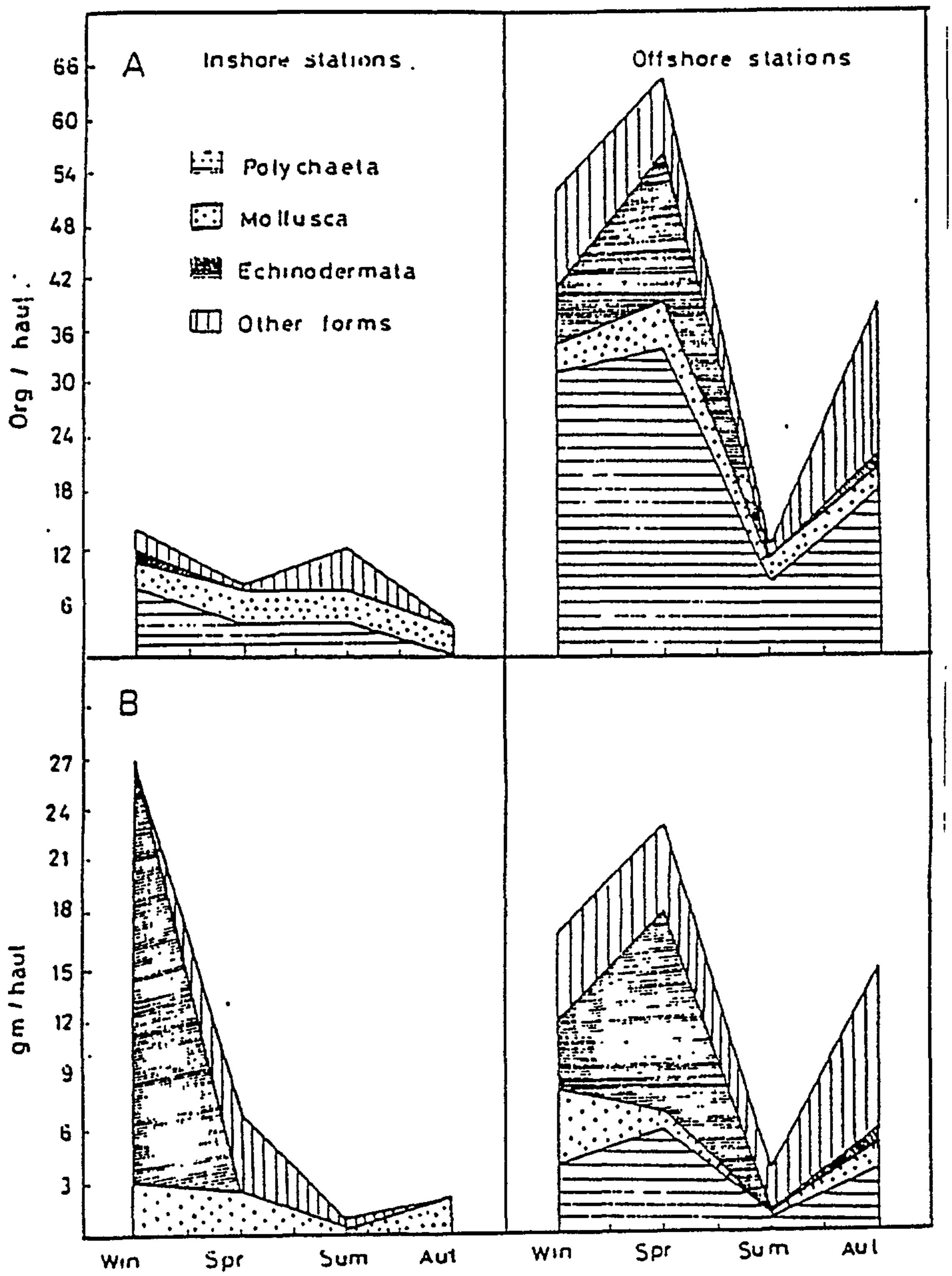


Fig. 48 Seasonal variations of the total fauna along Matrouh at both the inshore and offshore stations.
A - organism per haul (80 m^2)
B - gramme fresh weight per haul (80 m^2)
(after Anon, 1983a)

The ornithological list of the area contains 43 species. The supposed breeding of the Greater Sand Plovers in the flat salt lakes between the coastal ridge and Abu Sir ridge would represent the wester most breeding area of this bird and the only one in Africa. The present status of the Boubara *Chlamydatis undulata* (listed as vulnerable species) is unknown in Egypt.

Thirty seven reptile species were recorded from north-western Egypt. The presence of five of which was recently confirmed in the area Fuka-Matrouh.

The Egyptian tortoise is classified as vulnerable. There is little recent information about the status of its population in Egypt. Its local population is thought to have been extirpated due to the pet trade and habitat degradation. Although a small population could still exist on the north coast and north Sinai.

The amphibians are represented by two species. The soil fauna in the area have to cope with the problems of excessive heat and drought, as well as the problem of availability and quality off plant litter provided by the sparse vegetation.

The natural flora and its associated fauna, as well as amphibians depend to a great extent on the rainfall.

The results of the most recent (available) oceanographic survey to the area during 1977 show that:

During winter, at both Fuka and Matrouh, the intrusion of a water mass with relatively lower salinity (39%) and temperature (18°C) moving coastward was observed. This water mass was balanced by a flow of water of higher salinity and temperature moving seaward.

During spring, while a weak stratification in both temperature and salinity was observed in Fuka, the coastal water in Matrouh was still relatively homothermal.

In both summer and autumn seasons, a distinct seasonal thermocline was observed in both Fuka and Matrouh.

The oxygen content of the surface seawater in Matrouh showed a high value during winter and decreased during spring and summer through autumn.

In general, the eastern Mediterranean is considered of the oligotrophic areas poor in nutrient salts which are necessary for phytoplankton's growth and flourishment.

The area Fuka-Matrouh is one of the most oligotrophic areas on the eastern Mediterranean.

The phytoplankton standing crop in Matrouh was slightly higher than in Fuka. The population increased towards offshore of Matrouh and vice-versa occurred in Fuka.

While the least population density of zooplankton was recorded during winter season in both Fuka and Matrouh, autumn and summer were the flourishing season in Fuka and Matrouh, respectively.

Spring and summer were the flourishing seasons of benthic flora.

The sponges were represented in the area by eleven species, five of which are commercial.

The highest population densities of the bottom fauna were recorded during spring and summer in both the inshore and offshore of Fuka, during winter and summer in the inshore of Matrouh and during spring in the offshore of Matrouh.

Nonetheless, there are three species of marine turtles known from the Egyptian Mediterranean Sea, all tracks of emerging nesting turtles around the area Fuka-Matrouh were identified as tracks of the Loggerhead Turtle, *Caretta caretta*.

Although all the marine turtles are listed as endangered throughout their range, the official statistics show the increase of the Egyptian turtle landing to 418 in 1990.

The study area does not provide suitable habitats for the Monk Seal.

2.5 MANAGED ECOSYSTEMS

2.5.1 Agriculture

As shown in Fig. 34 and Table 27, the area of suitable soils for agriculture at the project area are about 88,000 feddan. The deep soils represent 16% of this area. The shallow soils suitable for shallow root crops represent 80% of these suitable soils. The rest of the area is the sand dune soils which is distributed at Ras El-Hekma.

Table 27

Distribution of Soils Suitable for Agriculture in the Project Area

Soil Type	Area (thousand ha.)	%
Deep soils	14.1	16.02
Shallow soils	70.9	80.57
Sand dunes	3.0	3.41
Total	88.0	100.00

In the project area, the main source is rainfall (100-150 mm/year). This water is stored as soil moisture storage, surface water intercepted by different dykes or stored in roman cisterns and new cisterns. Thirty-two million m^3/year could be used as sheet runoff and about 1.5 million m^3/year as wadi runoff and at present time 2.8 million m^3/year is intercepted and stored in the project area. The other source is ground water.

Agricultural activities in the project area are crop production, range and animal production and fisheries. The limiting factors of agricultural production are the ecological parameters such as soils available for agriculture and available water resources. According to the ecological conditions, the project area is classified into different zones as shown in Fig. 49. These zones are the agricultural zone, intensive range zone, mixed agricultural and range, uncultivated zone and low range capacity zone. Within these zones more detailed classification is carried out.

As shown in Fig. 50, the project area is classified into intensive cultivation, moderate cultivation, low cultivation, no cultivation, intensive range, moderate range, no range, marginal range with high intensity, marginal range with moderate intensity, marginal range with low intensity.

The total soils available for agriculture in the Matrouh Governorate is about 156,250 hectares, 36,000 hectares of which are located in the project area. These areas represent 23% of the total area. The actual utilised area for agriculture is about 52,500 hectares in the whole area while in the project area only 8,333 hectares is utilised which represents only 16%.

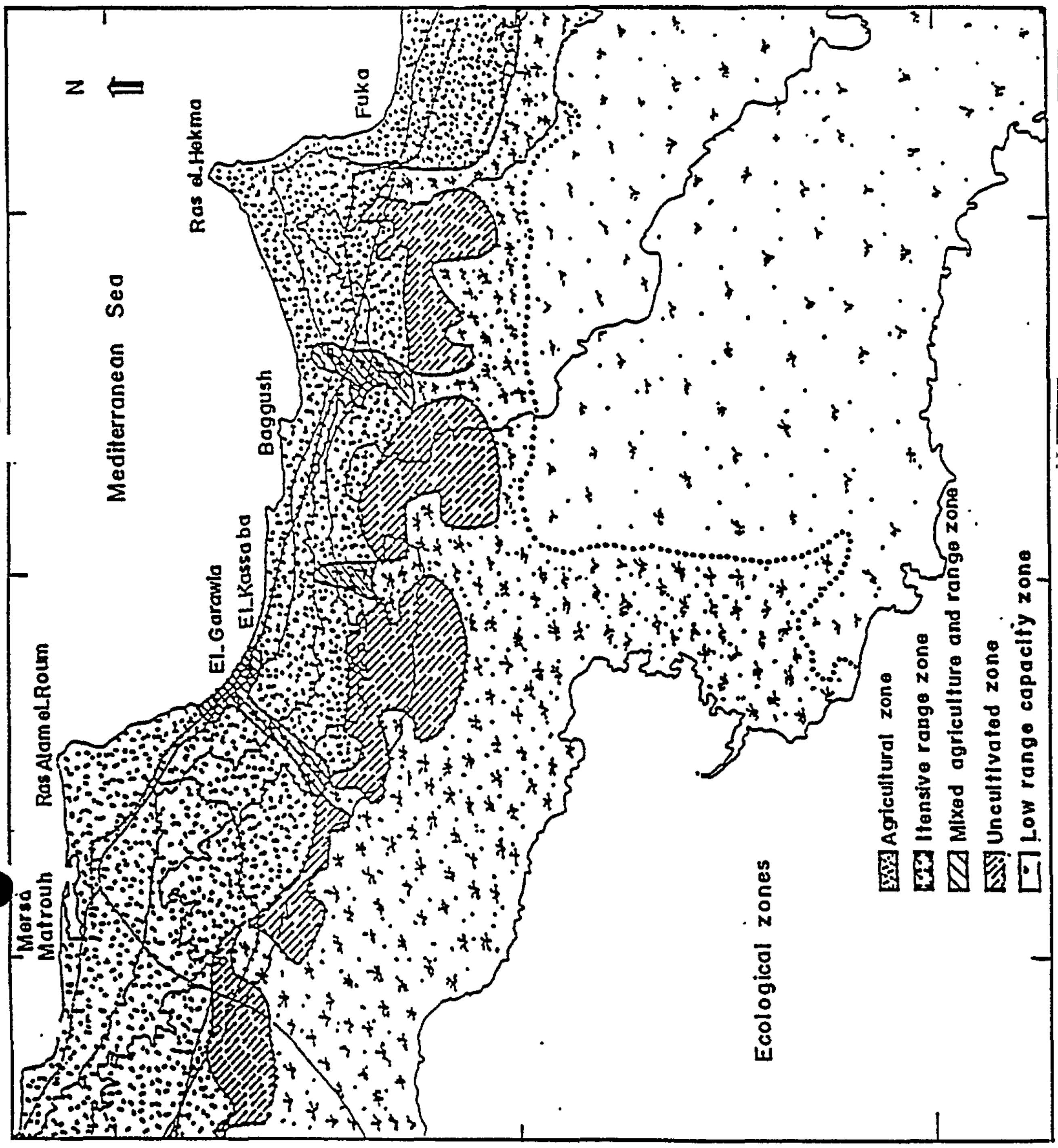


Fig. 49 Ecological Zones, Fuka-Matrouh area

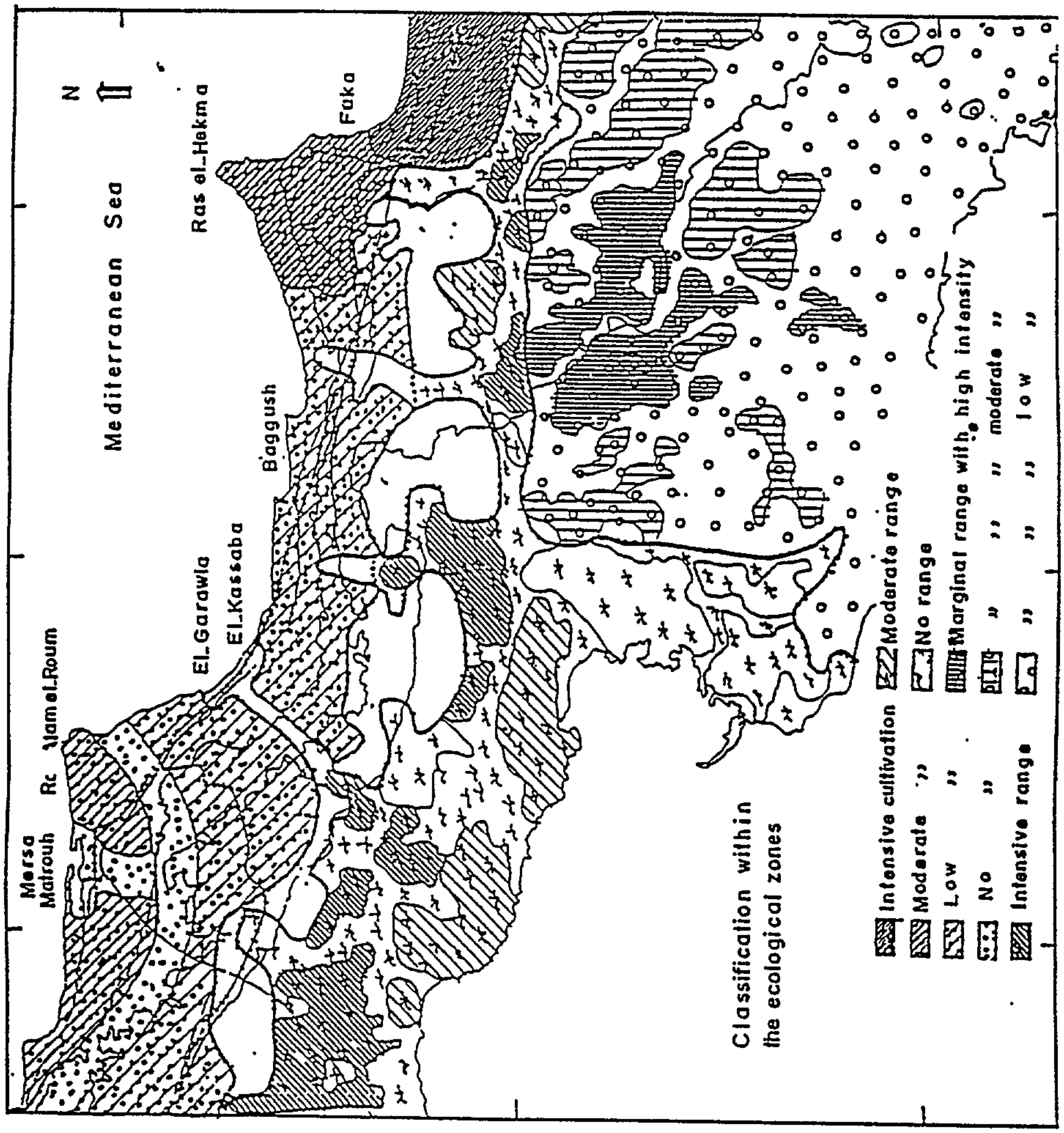


Fig. 50 Classification within the ecological zones, Fuka-Matrouh area

Table 28

Cropped Area in the Project Area and in Matrouh Governorate

Crop	Governorate	%	Project Area	%
1. Annuals: Grains (Wheat and Barley)	41.6	80	0.29	34
2. Perennial: Orchards (Fig and Olive)	10.6	20	5.50	66
Total	52.2	100	5.79	100

These data indicated that the agricultural activity in this project area is not the limiting factor for economic activity and not the effective factor for the economic development. The agricultural activity represents only 22% of the economic activities in the project area. Data in Table 28 showed the crop area in the whole governorate and in the projected area.

The distribution of the cropped area is presented in Fig. 51. As shown in Table 28, the area cropped by barley and wheat in the project area represents only 34% while the fruit production is the main agricultural product in the area and generally represents 66%. Concerning range and animal production activity has the same importance as crop production. According to 1989 survey, the number of sheep heads in the whole governorate is 451,500 while in the project area is 152,700. Fig. 52 shows the range carrying capacity in the studied area. A sensivel deterioration is observed in range land and range capacity which requires a programme of range improvement to stop this deterioration and develop the range lands in the project area. Fisheries will be covered under the next heading.

2.5.2 Fisheries - Fishing Potentials of the Western Egyptian Mediterranean Waters

Past Trend and Present Situation

The Egyptian Mediterranean waters are the largest fishing area in national fishery. However, the available statistical data of the commercial catch show that its annual catch is too low reaching about 32,435 tons/year during 1988-90, which represent about 11% of the total fish catch and aquaculture of the country.

It has to be mentioned that the Egyptian Mediterranean coast is about 1000 km long, extending from El-Sallum in the west to El-Arish in the east. The fishing grounds along this coast can be divided into two distinct zones:

1. The western zone, extending from Alexandria to El-Sallum, with a coast length of about 550 km.
2. The eastern zone, extending from Alexandria to El-Arish, with a coast length of about 450 km.

Also, it has to be said that the fishing activities have been concentrated totally along the coast of the eastern zone, where the continental shelf (to 200 m depth) is very wide and flat, reaching a maximum width of about 70 km in front of the Nile Delta, while the western zone is nearly not utilised in the fishery for many reasons.

Factors Affecting the Exploitation of the Western Egyptian Mediterranean Waters

Matrouh Governorate has special peculiarities that makes it different from other provinces of the country. As the fishery sector is concerned, there are some features that seriously affect the fishing activity in Matrouh Governorate.

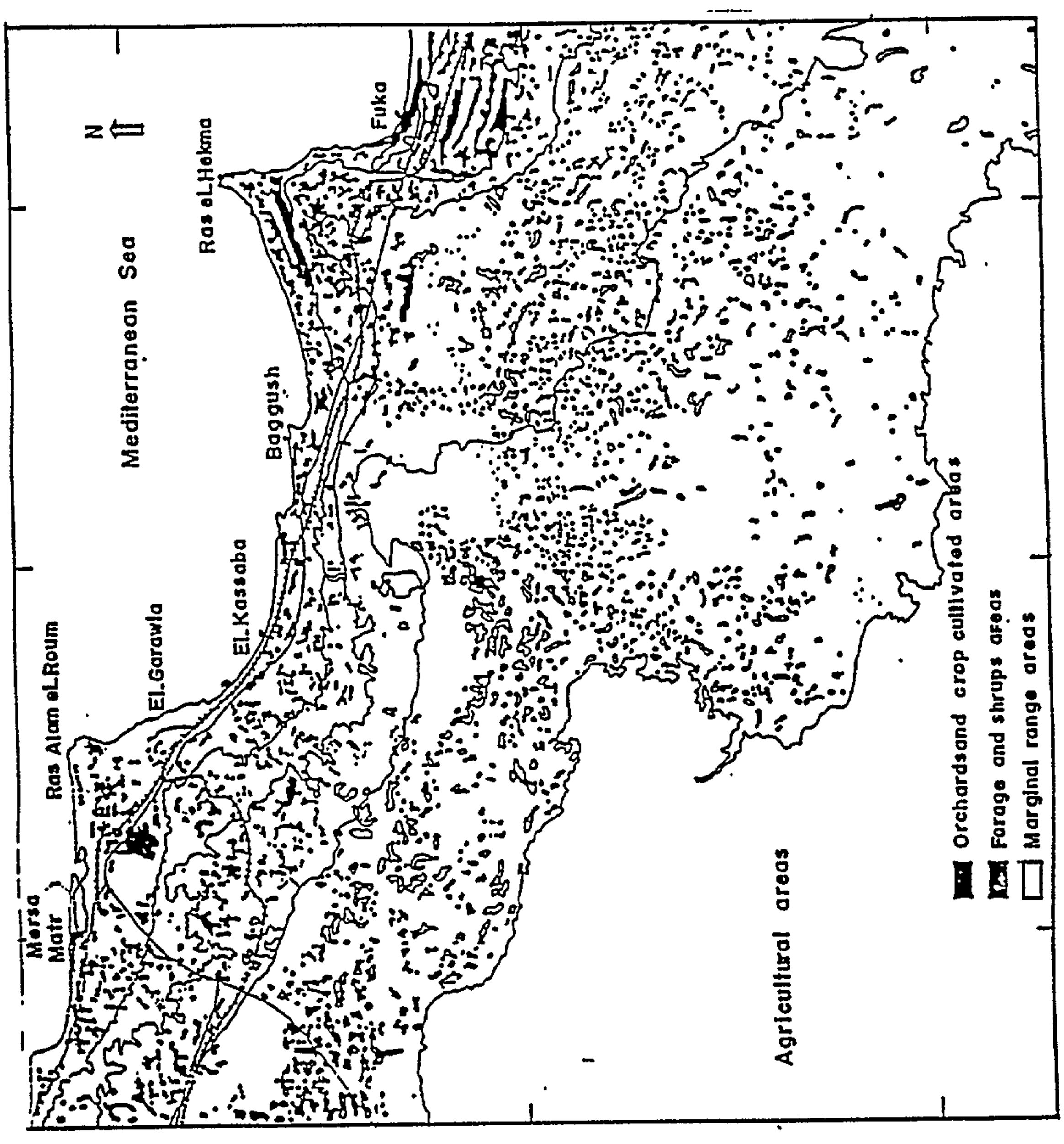


Fig. 51 Agricultural areas, Fuka-Matrouh area

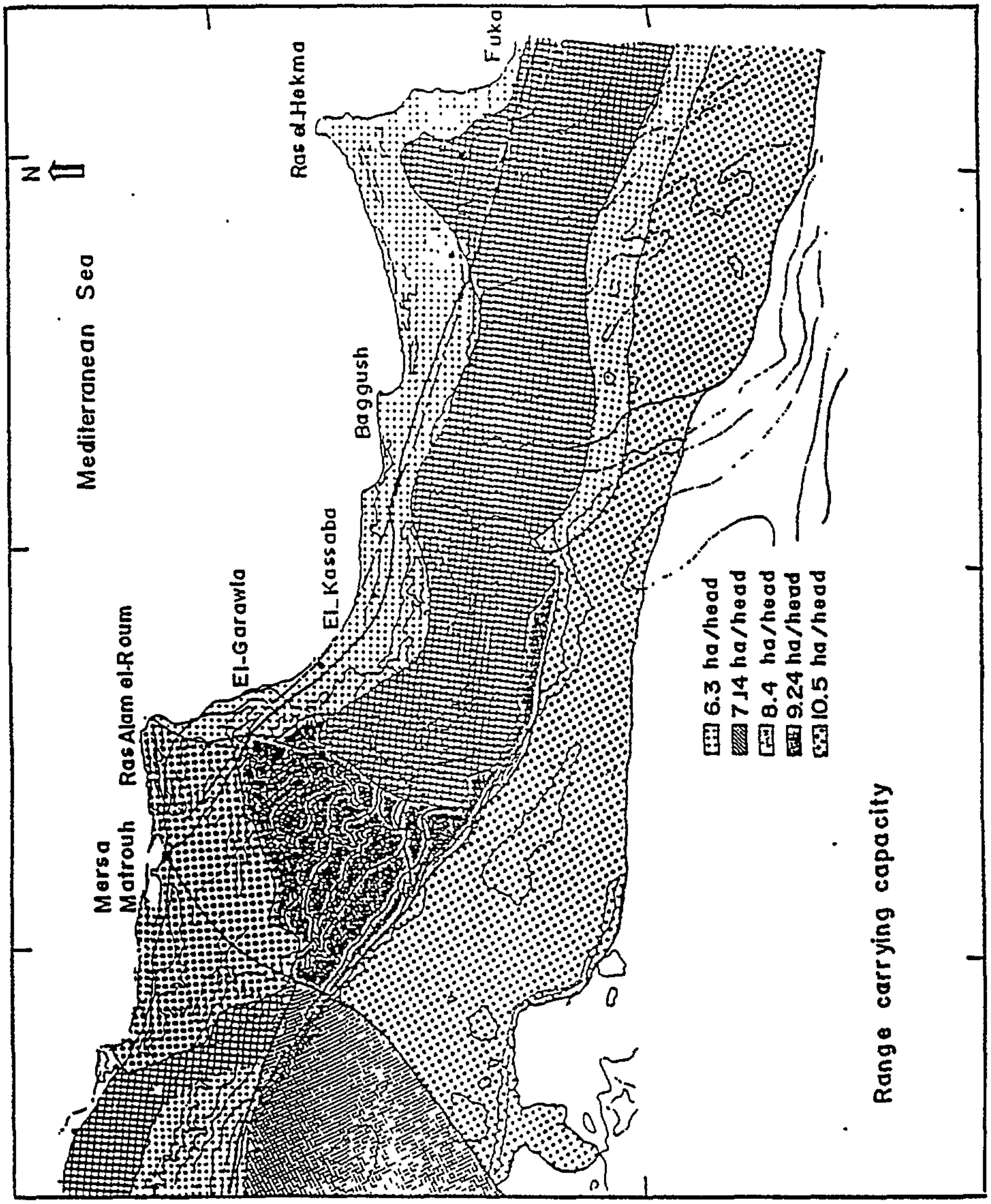


Fig. 52 Range carrying capacity, Fuka-Matrouh area

1. *The nature of the sea bottom in Matrouh Governorate is rocky and the continental shelf* is very narrow (Bathymetric chart, Fig. 53). Sailing to the east of Matrouh towards Ras El-Hekma, the bottom falls steady into the deep and the depth varies much and at short intervals Only one nautical mile from the coast, the depth reaches 150 fathoms and in many places the depth was greater than the echo-sounder's range of 275 fathoms. However, in very few separate areas, the bottom seems to be flat (Yugoslavian Expedition 1958-59).

   A thorough sonic sounding survey of El-Hekma Bay was carried out by the Russian Research vessel "Ichthaalog" (1970-71). The hydroacoustic survey showed that the El-Kanayes Bay is not suitable for trawling because of the rough bottom and reef formation. Also the area between Fuka and Mersa-Matrouh offers no favourable possibilities for trawling. Either the bottom falls so steeply into great depths near the shore, or it is so rocky and uneven that it is absolutely impossible to use trawl nets (The Soviet Exp. 1970/71).

2. The western coast is exposed to a more or less permanent north and northwest winds. Storms are frequent during the autumn and winter months. From the beginning of October to the end of March, there are about 16 "nawas" with strong stormy weather, that cover about 60-70 days during that period (*i.e.* 60-70 days out of 180 days). At the same time, over the distance from Fuka to Matrouh, there are no sheltering places for boats in case of stormy weather except Matrouh harbour and to some extent, the bays of Abu-Hashaifa and Ras El-Hekma.

3. Social behaviour of the natives, most the inhabitants of Matrouh Governorate are Bedouins, with their special social characters. They are not willing to work at sea or even to eat fish. Thus no resident fishermen communities are found along the Matrouh coast. Also, the great distance to fish consumption centres (Cairo and Alexandria), and the seasonal variation in local fish consumption in Matrouh (maximum fish consumption in summer and near to nothing in winter) badly affects the development of coastal fisheries in Mersa-Matrouh.

All these factors together with some others greatly affect the fishery exploitation of the area.

Quantitative Estimation of Fish Catch at Matrouh

In the past, there were no official statistical data of fish in Matrouh. Also in literature estimates of fish stocks in the Matrouh area are missing. Furthermore, the biological data necessary for the assessment of stocks for the commercially important fish are also incomplete. This is because little scientific work has been done in this area.

However, for the time being, and with such conditions of the under-exploited resources of the western Egyptian coast, together with the absence of official statistical data of both fish landing and fishing effort, we are obliged to use the available information just to give a primitive picture for the situation of the fishing activity in Matrouh during the summer resort and the other times of the year (Hashem, 1970).

In 1982, the Matrouh Governorate started a fishing enterprise. It bought two fishing boats (12m long and 45 hp engine), then built another two similar fishing boats. In 1983, the Governorate built four smaller fishing boats (9 m long and 30 hp engine). Many difficulties had faced the enterprise among which the experience and capability of the working staff were not adequate enough to reach the enterprise target. There was a contribution profit covering the running costs of the enterprise, but the contribution was not enough to cover the fixed costs of the boats. In 1986, the Matrouh Governorate was obliged to stop the enterprise and sold the boats.

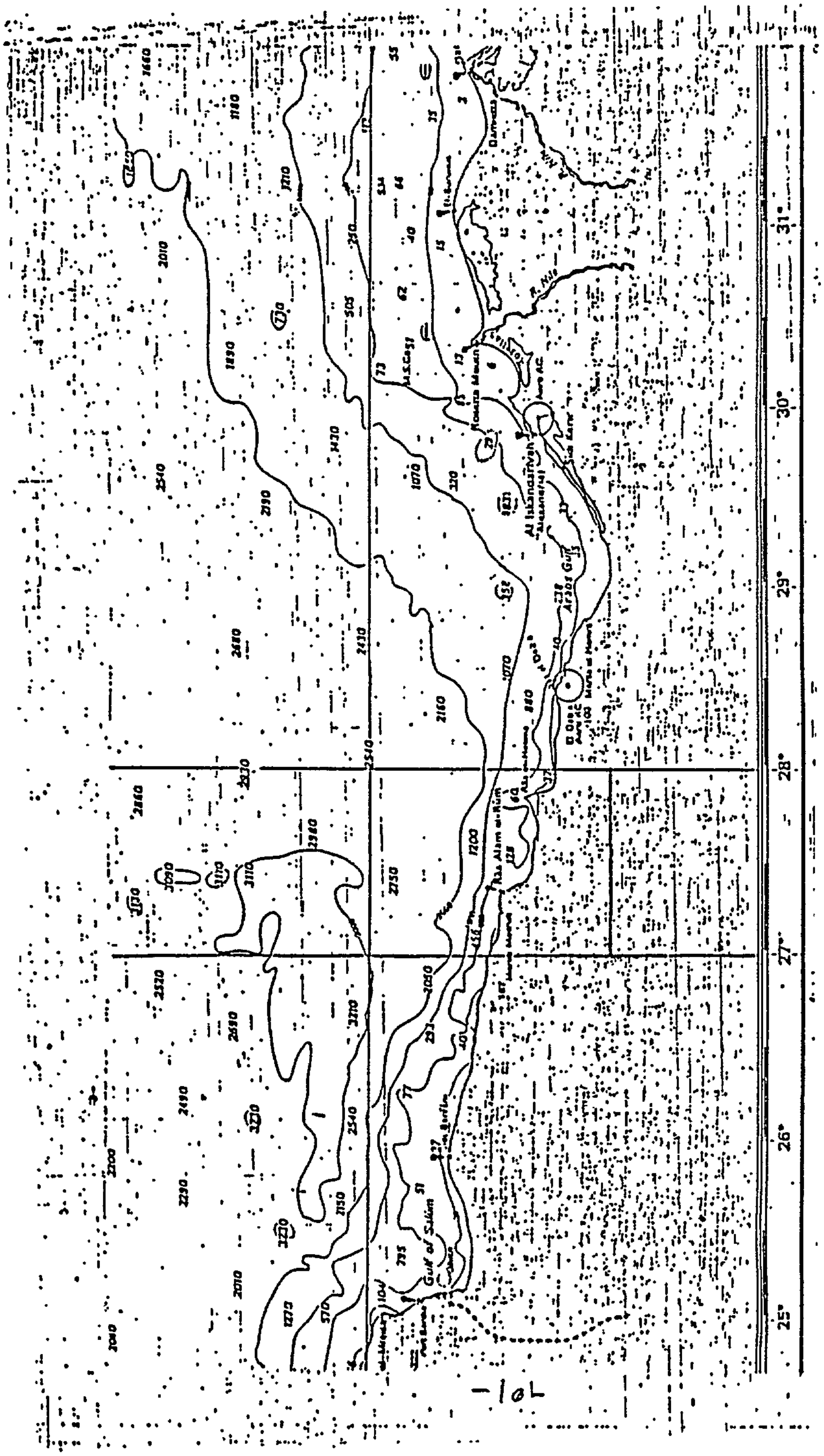


Fig. 53 Bathymetric chart of Matrouh territorial waters

It has to be mentioned that although the data of the fishing enterprise were mostly concerned with the economical parameters rather than the biological ones, however it was possible to estimate 60 kg/boat/day as an average catch/effort for the Matrouh area (Table 29).

At the eastern side of Matrouh harbour, there has been a coastguard office that records the movement of all sailing units. The coastguard office at the harbour records the number of fishing boats working in the area, their names and the number of fishing trips performed per day and month. From this information and on the basis of the assumed catch/effort for the Matrouh Fishing Enterprise during 1984-85 (60 kg/boat/day) (Table 30), the boat can land 150 km per (2-3 days) trip on average during warm months (May-October) and 90 kg per (1-2 days) trip during the other months (November-April). Then the amount of fish landed each month can be calculated. The monthly landed fish was estimated by about 20 tons per month during June-September (the summer season). Table 30 also shows that during the months of May or October, the amount of fish landed was about 13.5 tons, and during the other months (November-April), the amount of fish landed was about 5 tons per month. Hence the annual yield during the period from May 1985 to April 1986 would be about 140 tons of fish during that year (Table 30).

Table 29

Fish Catch and Sales Income of One Boat (Ras El-Hekma, 45 hp) during 1984-85. Matrouh Fishing Enterprise

Month and date	No. of fishing days	Fish landed in kg						Sales Income (LE)
		Large	Medium	Small	Others	Total	Av/Day	
1984								
April 11-29	9	61	317	233	40	651	72.3	1071
May 8-29	10	101	652	223	27	1003	100.3	1774
June 4-18	12	109	176	184	-	469	39.1	808
July 3-18	8	222	79	148	-	449	56.1	1248
Aug 2-28	10	176	182	390	-	748	74.8	1588
Sept 11-23	10	252	126	250	-	628	62.8	1446
Oct 2-23	6	293	49	28	40	410	68.3	1318
Total	65	1214	1581	1456	107	4358	67.0	9253
1985								
4/5-18/6	18	945	-	200	100	1245	69.1	3047
26/6-4/7	8	146	24	84	5	259	32.4	682
15/7-23/7	6	139	35	111	5	290	48.2	658
7/8-19/8	9	107	81	71	4	263	29.1	646
2/10-31/10	10	-	190	35	-	225	22.5	455
1/11-4/11	3	12	69	29	-	110	36.5	183
Total	54	1349	399	530	114	2392	44.3	5671

Note: Average catch per effort = about 60 kg/boat/day

The data obtained from the fishing activity of the boats previously working in the fishing enterprise of Matrouh Governorate during 1982-86, together with some data of near-shore experimental fishing with sinnar and kanar at Fuka-Matrouh during the work of Mr. S.F. Youssef when collecting data for his Ph.D. degree (unpublished data) in 1980/85. These two sources of information can be taken as a simple measure for the near-shore fishery potentials of Fuka-Matrouh area as the most promising fishing area in Matrouh Governorate as follows (see Table 30 of the fishing enterprise):

Table 30

Approximate Estimation of Fish Landed at Matrouh During One Year (May 1985 - April 1986)

Month and year	No. of fishing boats			No. of fishing trips	Assumed	
	Governmental	Private	Total		Catch/Trip	Landed catch
May 1985	6	7	13	92	150 kg	13800
June	6	8	14	138	per (2-3)	20700
July	6	10	16	152	fishing	22800
August	5	14	19	115	trip	17250
September	4	13	17	114		21600
October	5	8	13	88		13200
November	3	3	6	52	90 kg per	4680
December	2	3	5	42	(1-2 days)	3780
January 1986	1	3	4	43	fishing	3870
February	2	6	8	49	trip	4410
March	2	8	10	85		7650
April	2	7	9	60		5400
Total	44	90	134	1060		139140

Note: *Average catch per effort = 60 kg/boat/day (see Table 29)*

- For *sinnar* (hooks) the catch per boat per day generally varied from 20 to 200 kg, with an average of about 70 kg/boat/day

- For *kanar* (trammel nets) the catch per boat per day also varied between 20 and 200 kg, with an average of about 50 kg/boat/day.

- For *kaddameya* (gill nets) the catch per boat per day varied from 10 to 120 kg, with an average of about 30 kg/boat day.

- Here, we have to say that the previously stated catch per unit effort can be increased by carrying out fishing with more effective fishing techniques.

- Also, some data were previously obtained from the fishing survey of sardine and other pelagic fish carried out along the Mediterranean coast from Rashid to El-Sallum during (1974-79). This survey revealed that for *purce seine* (Shanshoulla), the catch per unit effort varied in the Matrouh area from 200-800 kg, with an average of about 400 kg/boat/night during the summer months.

- Also, it has to be mentioned that an illegal and dangerous fishing method with dynamite is frequently carried out by the Bedouins and some members of the military forces along Fuka-Matrouh sea coast.

- The western lagoon of Matrouh has an area of 2 x 5 = 10 km^2 and is connected to Matrouh harbour with an opening (inlet) of about 200 m wide. The lagoon is relatively deep (more than 10 m) and there is well established quay of more than one km in length for the Navy.

In this western lagoon there are some fishing activities with small rowing and sailing boats. There are more than 10 boats working mostly with kanar and sometimes with sinnar. The fishing catch is composed of small fishes, *Lithognathus mormyrus* and *Diplodus annulari* (10-15 cm in length) and *Serranus scriba* (10-20 cm in length) together with crabs.

The average catch of a rowing boat in the lagoon cannot exceed 5 kg/day. The semi-closed nature of the lagoon, in addition to the use of dynamite may be responsible for the small catch per effort in the lagoon (Hashem, 1990).

Official Statistical Fish Yield at Matrouh

During the past time there was no official statistical data of fish catch in Matrouh, as there was no permanent daily landing at Matrouh harbour. There has been only occasional fish landing at that site and so there was no recording for fish landing.

After the political statement of President Moubarak at the First Meeting of People's Assembly and the Shure Council (1984) that the national fish production should be increased within 18 months, so that the country becomes self-sufficient. Consequently, the General Authority of Aquatic Resource Development (GAARD) and the Central Agency for Public Mobilisation and Statistics (CAPMAS) started to record any fish landing at Matrouh fishing harbour since 1985. Table 31 shows the official statistical data of fish yield, either from sea fishing or from aquaculture performed at Matrouh, during the last ten years (1983-1992).

Table 31

Official Statistical Data of Fish Yield at Matrouh Governorate During the Last Few Years
(- = no data)

Year	Total Fish yield (ton)	Aquaculture (ton)	Sea fishing (ton)
1983	-	-	-
1984	-	-	-
1985	304	304	-
1986	355	355	-
1987	304	304	-
1988	626	304	322
1989	211	75	136
1990	758	287	471
1991	497	238	260
1992	335	-	335

The clearest proof of the stage of fishing activity in Matrouh is the number of fishing boats licensed at Mersa-Matrouh.

In 1990, the number of fishing boats registered in Matrouh was 5 boats (12 m long and 45 hp) and 2 small boats of 10-20 hp, together with some fishing boats licensed in Alexandria and came to work in Matrouh area, that varied from 3 to 14 boats monthly (Table 29).

During the years 1991-92, there were 12 small motorized sinnar fishing boats licensed at Mersa-Matrouh. However, the majority of these fishing units were not working and if it works it happened occasionally

Qualitative Description of the Catch

With regard to the sea currents existing and the unsuitable relief and bottom topography of the continental shelf of the western coast, it is assorted that the pelagic fish in Matrouh area do not thrive in great quantities, and if they do, it is only occasionally since there are no geographical and geological factors which should enable a quick and prolific development of plankton, which is the basic food for thriving of pelagic fish (Yugoslavian Survey, 1958-59).

However, the mostly caught pelagic fish of the Fuka-Matrouh area are the following:

Sardinella sp.	sardine
Trachurus sp.	horse mackerel
Seriola dumerili	amberjack
Sphyraena sp.	sea pike

On the other hand, the rocky bottom in Matrouh area is a suitable living place for a relatively rich fauna of demersal fish. This provides a good possibility for a profitable coastal fishery. The most important demersal fish are the following:

Bony fish

Epinephulus sps.	groupers
Serranus sp.	sea bass
Pagrus sp.	common sea bream
Pagellus sp.	red sea bream
Lithognathus sp.	striped sea bream
Diplodus sp.	two banded bream
Chrysophrus auratus	gilt-head bream
Dentex dentex	dentex
Maena smaris	picarel
Synodus sp.	lizard fish
Mullus sp.	goat fish
Merlucius sp.	hake
Umberina sirosa	croaker

Cartilagenous fish

Myliobatus sp.	eagle ray
Raia sp. ray	

Mollusca

Sepia sp.	cuttlefish
Octopus sp.	octopus

It has to be mentioned that the rocky coast is usually a suitable living place for relatively rich fauna of coastal fish. The presence of these fish presents an excellent possibility for small coastal fisheries but there is no chance for developing industrial fisheries.

Also, it has to be said that the majority of demersal fish caught by sinnar (hooks) and kanar (trammel net) in Fuka-Matrouh area are of good quality and are sold at high prices. The small coastal fishery, although it does not present a basis for intensive industrial fishery, is needed for satisfying the demands of the consumers for a very high quality of fish.

One of the highly valued fish that represent a majority in the catch of sinnar, is the *Epinephelus* species Rafail *et al.* (1969), Mikhail (1980), Ezzat *et al.* (1981) and Wadie *et al.* (1981) studied the age and growth of the three different species present in Matrouh area and found the following:

1. *Epinephelus alexandrinus*: locally known as Soudaya, length range 18-55cm, average size 25cm.

Age group	1	2	3	4	5	Year
Cal. length	17	25	32	38	42	cm
Cal. weight	66	198	396	644	924	gm

2. *Epinephelus gigas*: locally known as Orfosa, length range 18-50cm, average size 30cm

Age group	1	2	3	4	5	6	7	Year
Cal. length	17	24	28	35	40	44	48	cm
Cal. weight	77	217	438	730	1086	1489	1925	gm

3. *Epinephelus aeneus*: locally known as waker, length range 20-100cm, average size 50cm

Age group	1	2	3	4	5	6	7	8	Year
Cal. length	18	33	48	61	72	82	95	95	cm
Cal. weight	68	42	1299	2571	4262	6089	9722	9722	gm

Species Composition of the Shanshoulla Catch

Experimental fishing with shanshoulla in the area from El-Allamein to Mersa-Matrouh, during April and May 1977 (El-Sallum project) showed the following:

- During April 1977, the catch of boat per night was 105 kg in the east of El-Dabbaa, while the catch of lighting hour reached 49 kg/hr. *Trachurus mediterraneus* dominated the catch (63.3%) followed by *Sardinella aurita* (18.1%), *Boops boops* (9.5%) and *Sardina pilchardus* (9.1%).

- During May 1977, the catch of boat per night varied between 216 kg in Sidi-Abdel-Rahman and 563 kg in Ras El-Hekma, while the catch per lighting hour was found to be 11 kg/hr in Sidi-Abdel-Rahman and 32 kg/hr in Ras El-Hekma. The average catch per lighting hour is estimated to be 231 kg/hr for the two places. *S. aurita* dominated the catch (61.5%) followed by *T. mediterraneus* (23.3%), *B. boops* (13.3%) and *S. pilchardus* (1.9%).

- During the two months, the body lengths of *S. aurita* ranged between 11 and 25 cm (length = 15.9 cm and weight = 38.7 gm), for *B. boops* between 14 and 24 cm (length = 18.3 cm and weight = 61.6 gm), and for *T. mediterraneus* between 9 and 26 cm length = 20.6 cm and weight = 77.6 gm).

Analysis of the few bottom trawl catches during 1985-86 (Faltas, 1993) showed that the majority of the catch in the Matrouh region was composed of *Boops boops* (37%), *Pagrus* and *Pagellus* species (14%), skates and rays (10%), lizard fish (9%) - only *Synodus saurus*, whereas the *Saurida undosquamis*, a Lessepsian migrant, was absent from Matrouh catch - *Mullus* sp. (8%) and *Trigala* sp. (8%).

2.5.3 Sponge Fisheries

Past Trend and Present Situation

In Egypt, studies on sponges have so far received little attention. Of the earliest reports dealing with sponges in the Egyptian Mediterranean waters, the work of Paget (1921, 1922 & 1923) is of great interest.` Paget (1921) investigated sponge beds west of Matrouh to the Libyan border. Paget (1922) made a survey on sponge beds along the Egyptian Mediterranean coast from El-Agami to El-Sallum. He established the three commercial sponges, namely Turkey cup, Honey comb and Zimocca. He also made a comparative study on the different methods of sponge fishing (Scophander, Fernez and naked diving boats). Paget (1923) investigated the sponge beds in Port Said and on the western coast from El-Agami to El-Sallum.

From 1936 up until 1983, no studies were made on the Egyptian commercial sponges, except the statistical yearly data of the catch. In 1983 El-Beshbeeshy has obtain M.Sc. degree on the sponges west of Alexandria (Kheirallahy *et al.*, 1989).

In this work, four regions (El-Hammam, El-Allamein, Fuka and Matrouh) were chosen for sampling sponges within the continental shelf. The last two sites lie about 2-5 km from the sea shore (Fig. 54).

The Egyptian sponges are considered the best all over the world, because of the suitable environmental factors along the west coast of Alexandria through Matrouh to El-Sallum. This area is characterised by suitable temperature and the abundance of solid substrate which favour the growth of sponges.

Two main types of solid substances are necessary for sponge settling. These are rocky substratum and consolidated substratum. The consolidated substratum is constructed by the action of the living organisms. Each substratum is covered with the sea grasses *Zostera* sp. or *Posidonia* sp., in addition to the green algae *Caulerpa prolifera, Lamouraux*, characteristic for commercial sponge beds all over the western Egyptian coast.

The Egyptian commercial sponges are the following:

Scientific name:	English Name:	Local Name:
Spongia officinalis *Spongia agarcinia*	Turkey Cup	Banati
Hippospongia communis	Honeycomb	Kapadika
Spongi zimocca	Zimocca	Zimocca

The Egyptian commercial sponges are characterised by their smooth texture, high ability of absorbing liquids and tendency to high compression. For these good characteristics, the Egyptian commercial sponges have invaded all the foreign markets (*i.e.* all the catch goes into international trade).

The study of the abundance of the commercial sponges (El-Beshbeeshy, 1983) revealed that the total of the mean numbers of the three sponge types in the region of El-Hammam was 99.469 individuals/km^2, in the region of El-Alamain was 35.632 individuals/km^2, in the region of Fuka was 52.421 individuals/km^2, and in the region of Matrouh was 64.49 individuals/km^2 (Table 32 and Fig. 55).

The mean number of each commercial sponge types in each region were as follows:

a. Turkey Cup: 55.705 individuals/km^2, in region A, 20.07 individuals/km^2 in region B, 21.878 individuals/km^2 in region C and 15.57 individuals/km^2 in region D.
b. Honeycomb: 26.47 individuals/km^2, in region A, 10.142 individuals/km^2 in region B, 18.15 individuals/km^2 in region C and 34.21 individuals/km^2 in region D.
c. Zimocca: 17.294 individuals/km^2, in region A, 5.42 individuals/km^2 in region B, 12.393 individuals/km^2 in region C and 14.71 individuals/km^2 in region D.

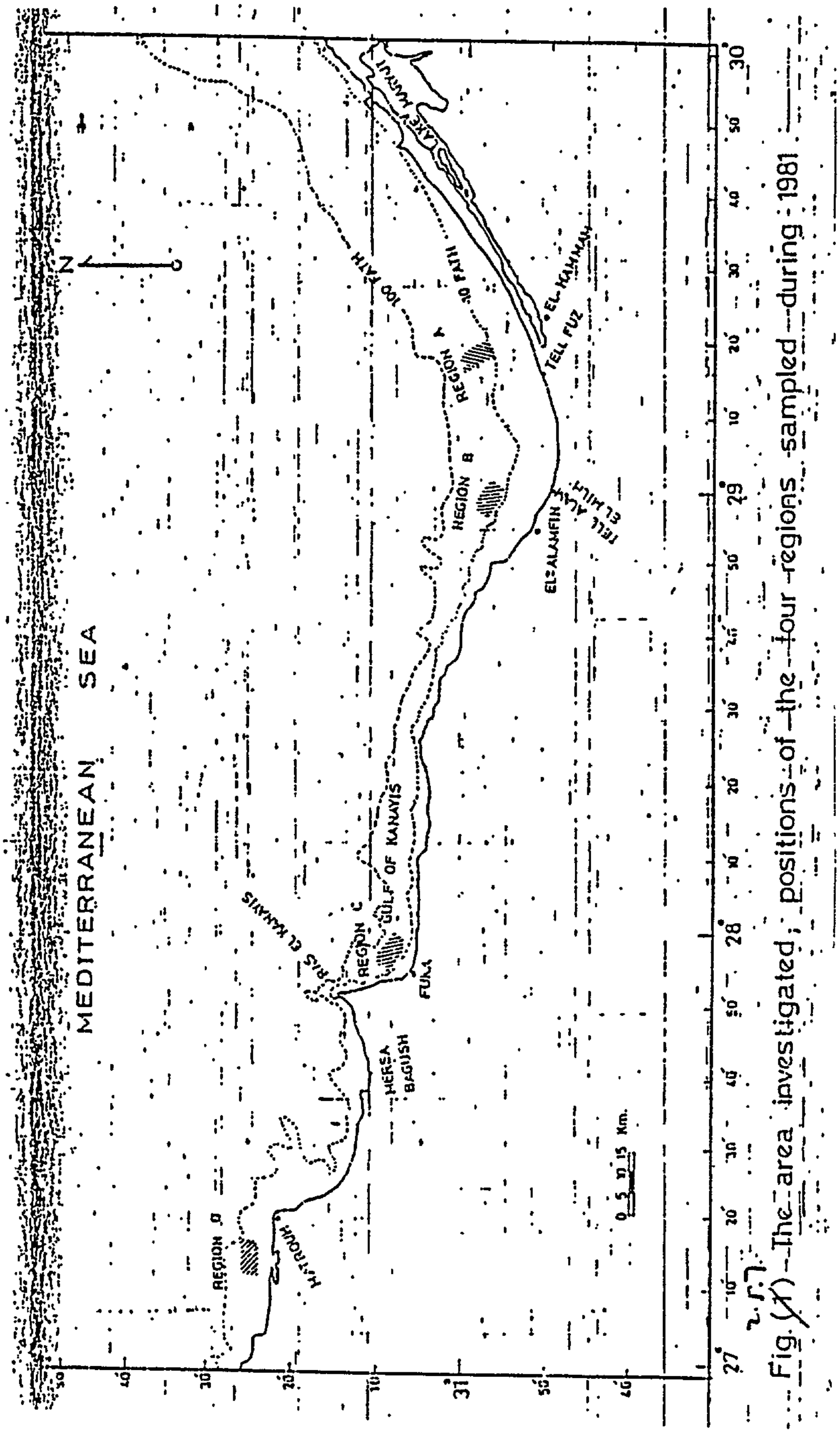


Fig. 54 The area investigated, position of the four regions sampled during 1981

Table 32

Population density of the three commercial sponge types in each region (km^2) with standard errors. Sample size in round brackets. The lower figures indicate range of water depth

Region	Date of Sample	Mean Population Density per km^2 (± S.E.)		
		Turkey Cup	Honeycomb	Zimocca
El-Hammam (A)	18/6/81-21/6/81	55.705 ± 3.544 (17) 30 - 56	26.47 ± 4.432 (17) 11 - 54	17.294 ± 3.394 (17) 9 - 23
El- Alamain (B)	8/8/91-11/8/81	20.07 ± 2.141 (14) 8 - 30	10.142 ± 0.891 (14) 5 - 16	5.42 ± 0.803 (14) 1 - 8
Fuka (C)	18/9/81-21/9/81	21.878 ± 1.146 (33) 10 - 32	18.15 ± 1.011 (33) 9 - 35	12.393 ± 1.78 (33) 5 - 30
Matrouh (D)	20/10/81-24/10/81	15.57 ± 1.36 (14) 9 - 27	31.21 ± 2.33 (14) 16 - 41	14.71 ± 2.04 (14) 6 - 25

The Egyptian Company for Fishing and Fish Gears has been the responsible authority for fishing and marketing the sponges. Personal communications with the responsible people of the company revealed that a well trained diver, with Fernez apparatus, in Matrouh area can collect 150-200 kg of sponges per season, and a sponge fishing boat with six divers can produce one ton per season, which usually begins in May and continues until October. This amount is usually sold by about 100,000 LE. in foreign currency.

Trained divers usually collect the sponges from different depths, ranging from 10 down to 50 m, and the renewal of sponge beds usually takes 3-4 years to reach the commercial size.

The statistical yearly data of the Egyptian sponge catch and the annual export during the last few years (1980-1991) is given in Table 33 (CAPMAS, 1980-91).

It is quite clear that a sharp decrease in the annual catch of our sponge fisheries was recognised in 1987. A total of about 5,663 kg was obtained in 1986, dropped suddenly to about 1,087 kg in 1987 and reached only 200 kg in 1992.

During the last few years the status of our commercial sponge beds from Alexandria to El-Sallum is very bad. The observations of the divers all over the area and the symptoms they have observed emphasise the infection of our sponges with fungus diseases. The shape, size and amount of all the commercial sponge types are greatly affected with fungus infections (water mould).

2.5.4 Aquaculture

Past Trend and Present Situation

Previous experiments conducted in many parts of the world had shown that many marine fishes are able to grow at high densities on artificial feeds. Further studies revealed higher growth rate and food conversion efficiency for many fish.

Pens and cage culture have been recently started in Egypt. This type of fish farming succeeded in fresh water, but in the sea it is still in the experimental stage.

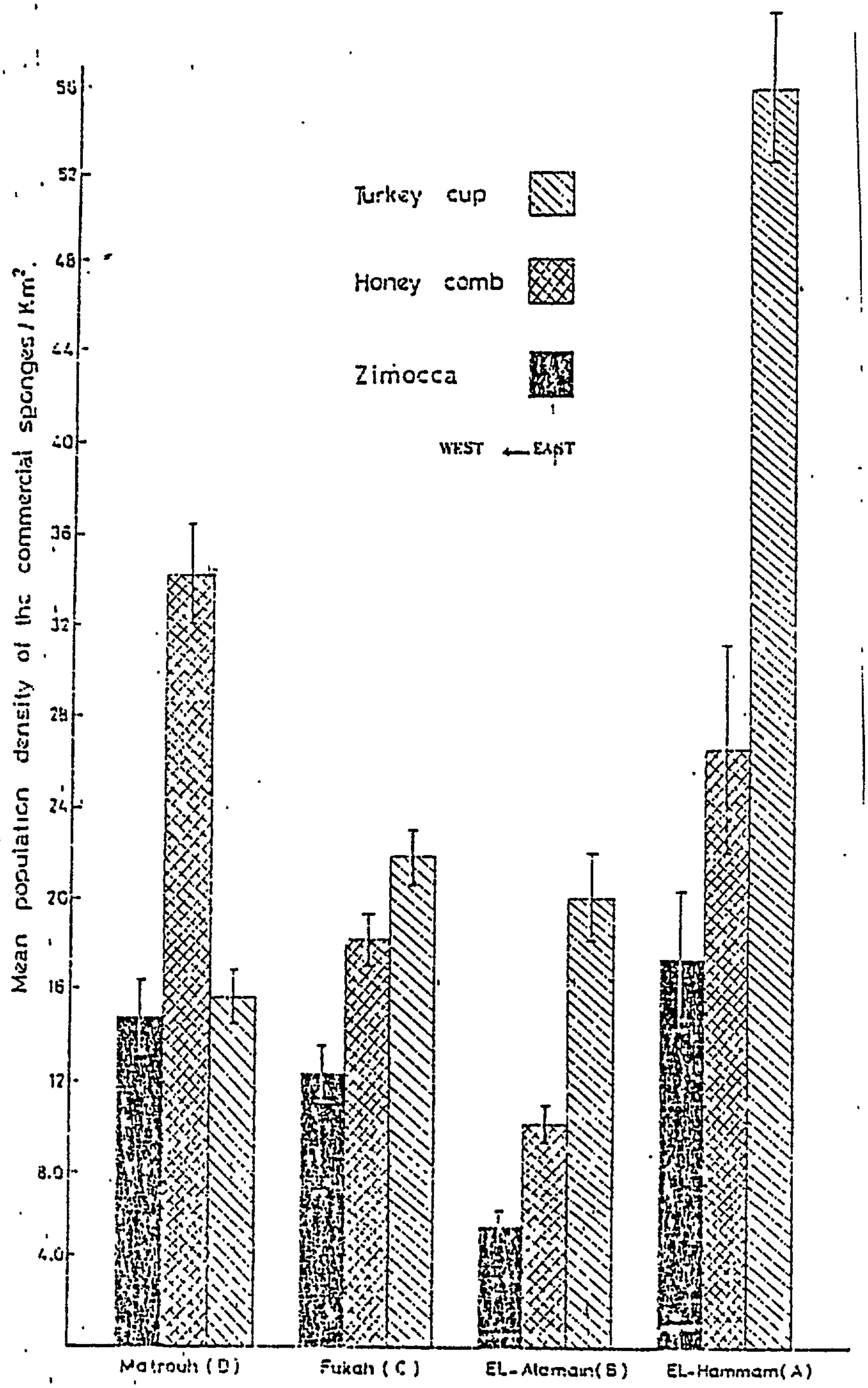


Fig. 55 The mean population density of the three commercial sponge types per km^2 in each region. Vertical lines indicate the standard errors of the mean

Table 33

The Egyptian Sponge Catch and the Annual Export During the Years 1980-1991

Year	Sponge Type (kg)			Total		No. of fishing boats	Av. catch per boat (kg)	Export	
	Turkey Cup	Honey Comb	Zimocca	Amount (kg)	Value (L.E.)			Amount (kg)	Value (L.E.)
1980	1277	2415	1371	5063	134863	7	723.3	6199	158170
1981	2492	1996	613	5101	198021	7	728.7	4846	200762
1982	1012	2469	686	4174	162035	8	521.8	4738	177202
1983	2633	2037	693	5363	288957	8	670.4	4638	198153
1984	1034	2189	823	4046	351710	7	578.0	7529	263524
1985	2017	2689	964	5670	75786	10	567.0	3616	145410
1986	2016	2678	969	5663	75787	9	629.2	5361	396152
1987	284	703	100	1087	14566	9	120.8	3007	302477
1988	222	387	122	731	21999	5	146.2	991	31392
1989	54	412	226	692	269430	5	38.4	666	258870
1990	291	257	574	1122	364738	6	187.0	400	155600
1991	35	450	302	787	318604	5	157.0	-	-
1992				200					

Source Central Agency for Public Mobilisation and Statistics, Statistical Year Book, Arab Republic of Egypt (CAPMAS)

The technology of rearing fish in pens or cages is simple and does not require much space or capital. For this type of fish farming, you should have the following:

a. The suitable site for laying out the pens or cages.
b. The quality and quantity of fingerlings to be farmed.
c. The suitable artificial feeding, which should be economically feasible.
d. Continuous guarding and meticulous inspection of the cages should be a daily activity.

All these requirements can be easily made for such new and beneficial activity to individual or cooperative fishermen in the Fuka-Matrouh sector as follows:

The western coast of Egypt is exposed to a more or less permanent north and northwest winds. On Fuka-Matrouh section, storms are frequent during the autumn and winter months. Over the distance from Fuka to Matrouh there are no sheltering places suitable for laying out fish pens or cages in case of stormy weather except the western lagoon of Matrouh and the bays of Ras El-Hekma and Abu-Hashaifa.

It is essential to secure the necessary fish seed in the amounts that will meet the requirements of cage farming. In Egypt, the most suitable fish to be cultured in the sea are *Chrysopherus auratus, Dicentrarchus labrax, D. punctatus* and grey mullet. There are about eight centres along the Mediterranean coast (from Alexandria to Port Said) for collecting the fry and fingerlings of the above-mentioned species.

The cage is made up of nylon knotless netting materials. It is installed in water and held in place by various types of anchors and floats. The life expectancy of the cage is about 4-5 years. The size of cage may vary according to one's choice, needs or capability. A fish farmer with small capital may start with cages measuring 6 x 6 x 6 m. For large scale production, the ideal size per cage is 150-200 m^2 with 6-8 m depth.

Stocking rates vary according to the size and species of fish to be farmed. It may reach 50-100 fish per m^3. The growing period may reach about 8-10 months. Artificial feeding is essential in mariculture. The daily amount of food supplied is about 3-5% of the fish weight, given twice or three times daily.

The main item to increase the economic viability of cage culture is to reduce feed costs because it accounts for the largest portion of costs. Local sources of feed are important to research. The possibility of using cheaper, lower protein quality feeds (20% protein) without sacrificing growth rates of fish is the aim.

The cage farm should have adequate security measures against poaching. A guardhouse should be located on the spot to allow for immediate detection of intruders. Meticulous inspection of the cages should be a daily activity. Nets could be slashed and, if undetected will result in the loss of stock.

Partial harvesting may be made before the scheduled harvest, if the market price allows good profit, even the fish have not reached the projected or expected size. Sometimes, the fish population is deliberately reduced by partial harvesting to induce better growth of the remaining fish.

Unsuccessful field trails of floating fish cages were carried out during 1990 by the Egyptian company of fishing and fish gears in the western lagoon of Matrouh to determine growth rates and food conversion efficiencies of sea bream and sea bass fed on a high protein commercial pelleted feed three times daily (personal communication).

2.5.5 Sylviculture

Forests do not exist in the studied area. Only some Accacia shrubs are cultivated to fix sand dunes or as forage crop.

2.6 ENERGY AND INDUSTRY

2.6.1 General

This section reviews the energy supply, consumption patterns, available power resources in the area and the supplies of the new energy needed for new developments. It also gives the common industries in the area and their future plans.

2.6.2 Energy

The current energy resources in the study area are:

2.6.2.1 Traditional Energy

Electricity is considered the primal resource of the energy upon which the development largely depends. From the previous studies (Pacer/Egypteam, 1986), it is clear that there is no high voltage line; from the main electric network of Egypt; reaching Fuka-Matrouh area. It is because these lines are ended at Burg El Arab city about 170 km to the east of Fuka.

So the study area depends generally for its needs of power on local thermo-electric station and diesel generators of limited outputs. The following Table 34 gives the different sources of energy in Fuka-Matrouh area.

Table 34

Sources of Electricity in the Study Area

Place Name	Source of Energy	No. of Units	Power
Mersa-Matrouh City	thermo-electric station thermo-electric station steam electric station	1 1 1	3 mega watt/hr 5 mega watt/hr 30 mega watt/hr
Sidi Henish	diesel generator unit	1	50 kilo watt/hr
Bagush	diesel generator unit diesel generator unit	1 1	50 kilo watt/hr 80 kilo watt/hr
Ras El-Hekma	diesel generator unit diesel generator unit	2 1	105 kilo watt/hr 240 kilo watt/hr

This is in addition to some private generators to provide electricity in some of the scattered villages and/or settlements. The produced energy is used for household, governmental offices and motor power in the local industries.

Fig. 56 gives the breakdown of electricity consumption by sector in Governorate of Matrouh in 1992. It is clear that household is consuming maximum electricity (72.2%) while the motor power is the minimum one (9.9%).

Kerosine is becoming an increasingly important and common source of fuel in the area (El-Miniawy *et al.*, 1992). It is used to provide light and fuel for cooking. While shrubs are still used for cooking and heating, they are gradually being replaced by kerosine. The shrubs and kerosine are usually used in the villages and settlements far away from the main roads. The furnaces producing bread are using Masut as an energy source. The benzine and also kerosine are used to run the cars, motorcycles and vehicles.

2.6.2.2 Wind Energy

It is well known that the wind on the northwest coast is the highest in the entire country. That is why the wind energy was used in the study area since early 1960s for pumping water and the inhabitants of Fuka-Matrouh area were encouraged to use it. This experiment did not work as successfully as anticipated for the lack of a continuous maintenance system needed for the fans, and the mechanical parts which are always spoiled by the frequent sand storms.

The use of this method seems to be very appropriate for water pumping, where the output of the wind pump is convenient for the well production of available water, and over-pumping - if applied by mechanical means - will exhaust the non-saline water and produce saline water, a matter which is harmful to the crops that do not tolerate high salinity. With the future proposed industrial development in the area and establishing the electro/mechanical maintenance centre will encourage the people to use and operate these wind pumps, to produce water for irrigation and cultivating the land. This energy is a clean and non-polluting one.

2.6.2.3 New Energy

There are many resources for the new energy on which the development project can depend. The following is a brief summary of these resources:

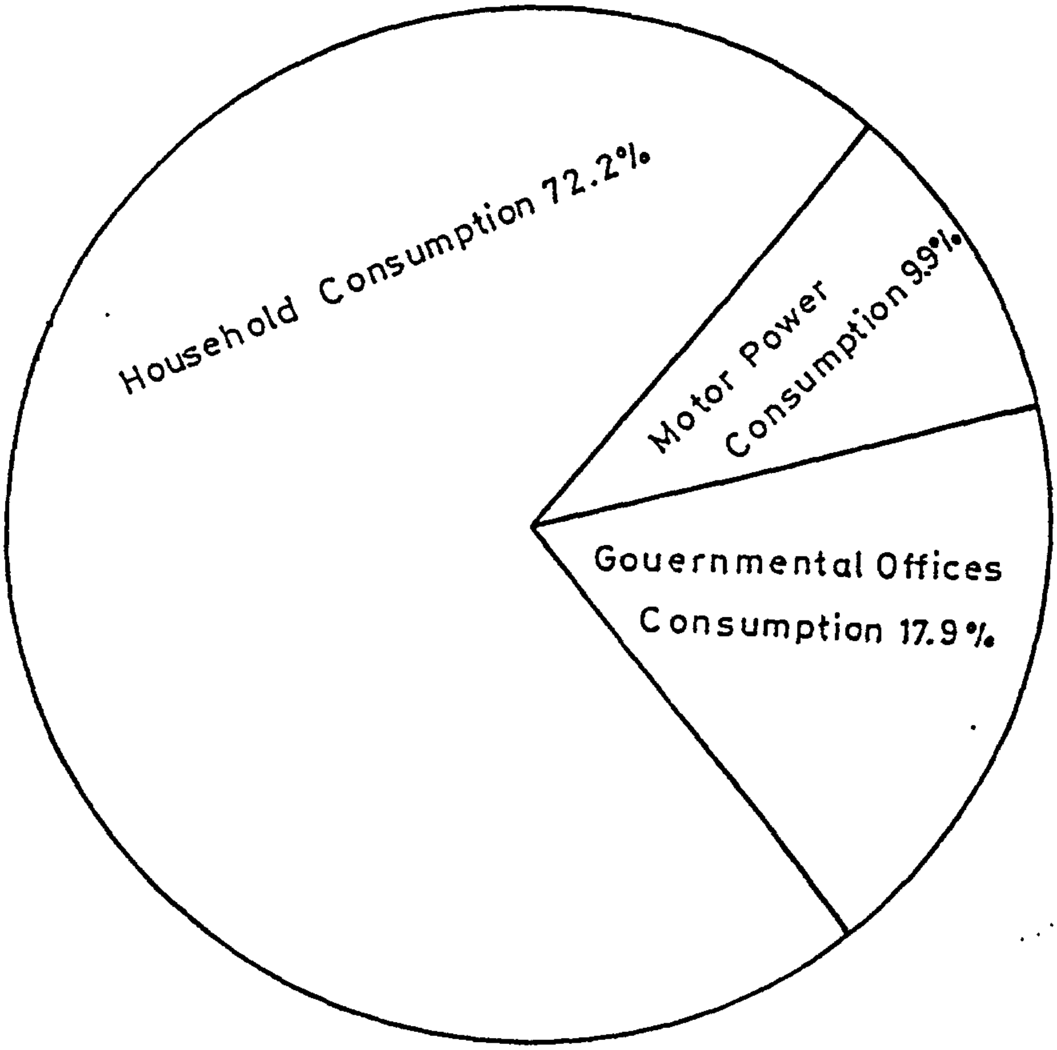


Fig. 56 Breakdown of Electricity Consumed by Different Sectors

a. <u>Dabbaa Nuclear Station</u>

Nuclear energy represents one of the inevitable solutions for the acquisition of the necessary energy for the development plans in the study area in an economical manner. This station was already scheduled to provide 2,000 mega watts by the end of the first stage and will reach 8,000 mega watts by the end of the year 2000.

This type of energy is underway after having been discussed in detail on the levels of technical and political committees.

b. Hydro Power (Quattara Project)

The Moghra-Quattara project for generating hydro power is still under consideration. The capacity of the proposed generator is 1,800 mega watts, which can provide 1,525 mega watts in the top consumption during the time of filling the lake for 8 hours daily. Electricity should be transmitted through a double high voltage lines of 500 kilo volts to the station at Haram (Pacer/Egypteam, 1986).

c Solar Energy

The study area is distinct for the long hours of sunrise throughout the year, reaching 3,500 hours on average The intensity of the sun reaches an average of 3,500-5,000 kilo calorie/m^2 and could be used in some applications such as:

- water heating in domestic and industrial requirements;
- drying of crops and agricultural products;
- deep freezing by use of solar freezers (used in the fish freezing); and
- generation of mechanical power by thermal units that are used in water pumping.

d. Wave Energy

An American scientist (Mr. Bill Eberle) has invented recently the MOTO (Motion of the Ocean) installation to get electricity and/or distilled water from the ocean wave power. The products can be utilised in the new coastal developments.

This method is a completely non-polluting one. To generate electricity, a toroid is engineered to produce and store over 172,000 cubic feet of compressed air at 400 psig (pound per square inch gauge). The compressed air is drawn off at 100 psig to run a current generating turbine. Compressed air output from a basic MOTO installation (3 toroids/3 pilasters) can generate as much as 3 mega watts of electricity which is enough to supply power to about 1,500 houses. Also this basic MOTO installation will produce enough power to convert sea water to fresh water at a rate of nearly 2 million gallons per day (Eberle, 1992).

2.6.3 Industry

Statistical analysis of the employment on the economic activities shows the relative importance of the following sectors in the study area (see Fig. 57).

- agriculture, grazing and fishing = 71.3%
- distribution sectors (trade, storage, transport and communities) = 17.6%
- construction and buildings = 5.2%
- services sectors (personnel and social services and others including non-classified activities) = 5.0%
- manufacturing, industries, mining and electricity = 0.9%

It is apparent that agriculture and grazing are of prime importance compared to the other economic sectors, while industry shows a minor role in absorbing labour in the area. This may be due to the insufficient supply of the energy and water in the area, and the traditional life of the Bedouins who migrate after water and pasture and have weak connections with permanent settlements.

All the industries in the region consist of agro-products such as: pickled olives; olive oil; dry figs; dry mint; jam production; dairy products such as fresh milk, butter and cheese; handicrafts such as blankets, carpet wool spinning, pillow covers, necklaces and tents; meat products such as traditional kadid, pemmican and pasterma; and leather products such as shoes and handbags, etc. Most of these products are for household use except leather products which are for sale.

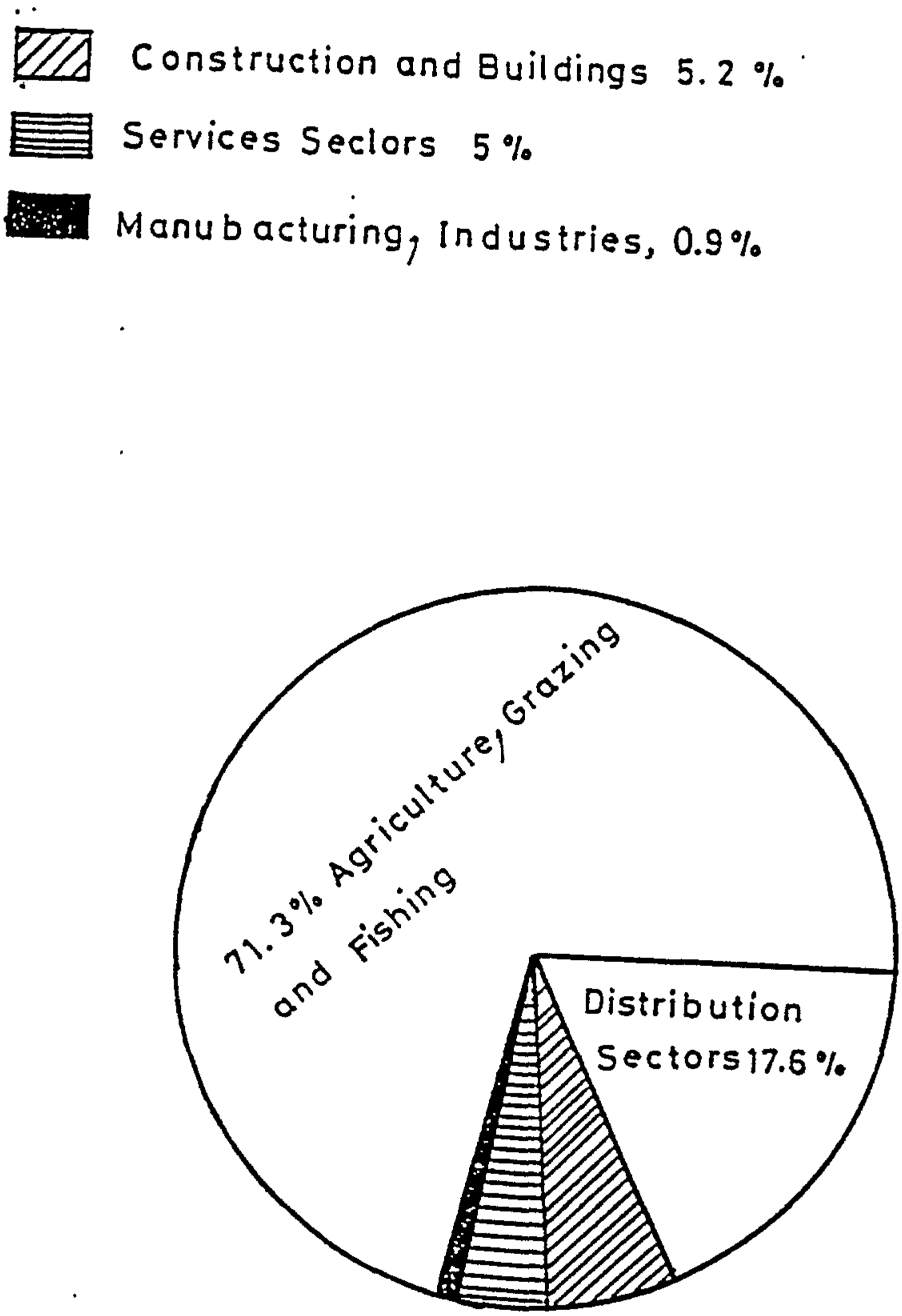


Fig. 57 Breakdown of Employment on the Economic Activity Sectors

This is in addition to some small private workshops for carpentry, vehicle maintenance, electro-mechanical ones for the repair of agricultural equipment, plumbing and blacksmith. The majority of these workshops could be found in the big cities like Matrouh.

Future Plans

The targets of the development plan include four industrial groups that will conform with the possibilities of the area and its future developments. They are represented in the following:

a. A Central Industrial Plant

It is recommended to be established on an area of 805 feddans south of the Matrouh/Alexandria international road between km 26 and 28.5 from Matrouh with a width of 1.5 km. This site is near the city of Garawla. The plant includes the following:

i. Workshops for:
   - heavy industries such as collecting and manufacturing of vehicles, agricultural machinery and equipment for new reclamation areas;
   - medium industries such as marble and building materials; and
   - light industries such as blacksmith, carpentry, repair and maintenance of vehicles workshop and windmills.

ii. exhibitions for investors and administration offices.

iii. services which include:
   - water station, electric stations, fuel stations and waste treatment plants;
   - bank, telephone and post office, integrated hospital, fire station and security;
   - residential area for the workers in the zone; and
   - green area reaches 40-45% of the industry zone.

b. Agro-Industrial Projects

These projects include the construction of olive presses. It is recommended to distribute them within the study area in the olive cultivation areas. It is expected that one ton of olives will yield 230 kg of oil. The programme also includes dairy products processing factory integrating with animal production projects with a capacity of 70 tons/day of milk.

c. Handicrafts and Household Industries

Within the scope of these projects, the programme recommends that construction of a training centre for the group of crafts that could be performed by one labourer so his income could sustain himself and his family. This will enable him to settle in the area. Also encouraging of crafts cooperating will assist the workers in this field to develop traditional schemes, modernisation of their crafts of carpets and kleems.

d. Fisheries Projects

The project invests the natural characteristics of the area to increase fish production for the expected future consumption of the population and tourists. The plan includes projects to cultivate fish in floating cages, mixtures of fish and shrimps in earth basins and fenced areas. The plan proposes the construction of these fish culture centres along the coast at Ras El Hekma, Fuka and Garawia.

2.6.4 Summary

Energy demands in the study area are satisfied mainly by electricity generated from local thermo electric stations and diesel generators. Kerosine is becoming important and common source of fuel in the villages and settlements for away from the main roads. Wind energy is used for pumping water for cultivation but it is suffering from the lack of maintenance. The study area could e supplied by new energy sources from Dabaa Nuclear stations and from Hydro-power (Quattara project) when they are operated. Solar energy is also recommended as well as wave energy for the coastal areas. These energies are clean ones, i.e. there is no pollution products from them.

Industry is limited to agriculture, grazing and fishing. New industry plans are under development such as heavy and light industries (vehicles, agriculture machinery, blacksmith, carpentry, repair and maintenance workshops); improving existing agro-industrial projects, handicrafts and household industries.

2.7 TOURISM

2.7.1 General

This section gives how the tourism industry is developing in Egypt, in Alexandria and the western coast. It shows the advantages of specific zones in Fuka-Matrouh area such as Matrouh city and its neighbourhood, Hawala/Bagoush reach and Ras El Hekam triangle. This part also illustrates the present and expected tourism industry in the area.

2.7.2 Introduction

Estimates have shown that the resident population in the Mediterranean of about 130 x 10^6 people doubles itself during the peak summer months (UNEP, 1992). By the end of the 1980s, over 120 x 106^6 tourists had visited the countries of the Mediterranean, which is about 36% of all tourists throughout the world. By the year 2025, if the present holiday patterns are maintained, there will be between 35 x 10^6 and 52 x 10^6 additional tourists who will visit the Mediterranean region over the three month summer tourist peak of June to August. By 2025, it is estimated that 400 x 10^6 will visit the Mediterranean annually

2.7.3 International Tourism in Egypt

In Egypt, as one of the Mediterranean countries, tourism development is related to the international development of the world tourism as shown in Table 35. This shows that the share of Egypt with respect to international tourism has been increased during the period from 1974-1984 from 0.34% to 0.60% respectively.

Statistical data shows that there is a continuous increase of the tourists visiting Egypt due to the new open investment policy that Egypt has adopted. Fig. 58A shows that the tourists visited Egypt in 1971 was 428 x 10^3 while they are increase to be 3207 x 10^3 in 1992 and 2508 x 10^3 in 1993. The total tourism nights they spent in Egypt were increased from 5990 x 10^3 in 1971 to 21836 x 10^3 in 1992 and to 15089 x 10^3 in 1993, Fig. 58B. In spite of the increase of the total tourism nights and the number of tourists arriving in Egypt, the average overnight stays was decreased from 14 nights in 1971 to 6.8 nights in 1992 as shown in Fig. 59B. This is because of the increase of the number of businessmen and the tourism groups who always stay for short periods (a matter of one or two days). Fig. 59A shows that the number of tourists arriving in Egypt by nationality which indicates that the Arab tourists have increased during this last period.

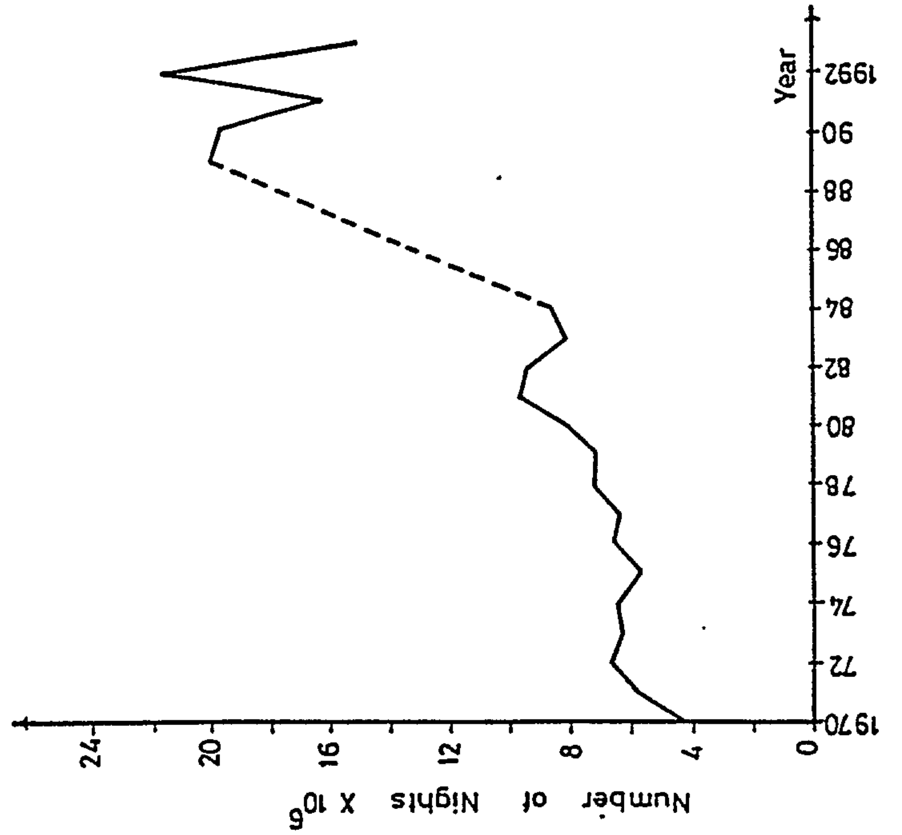


Fig. 58B Total Tourist Nights in Egypt

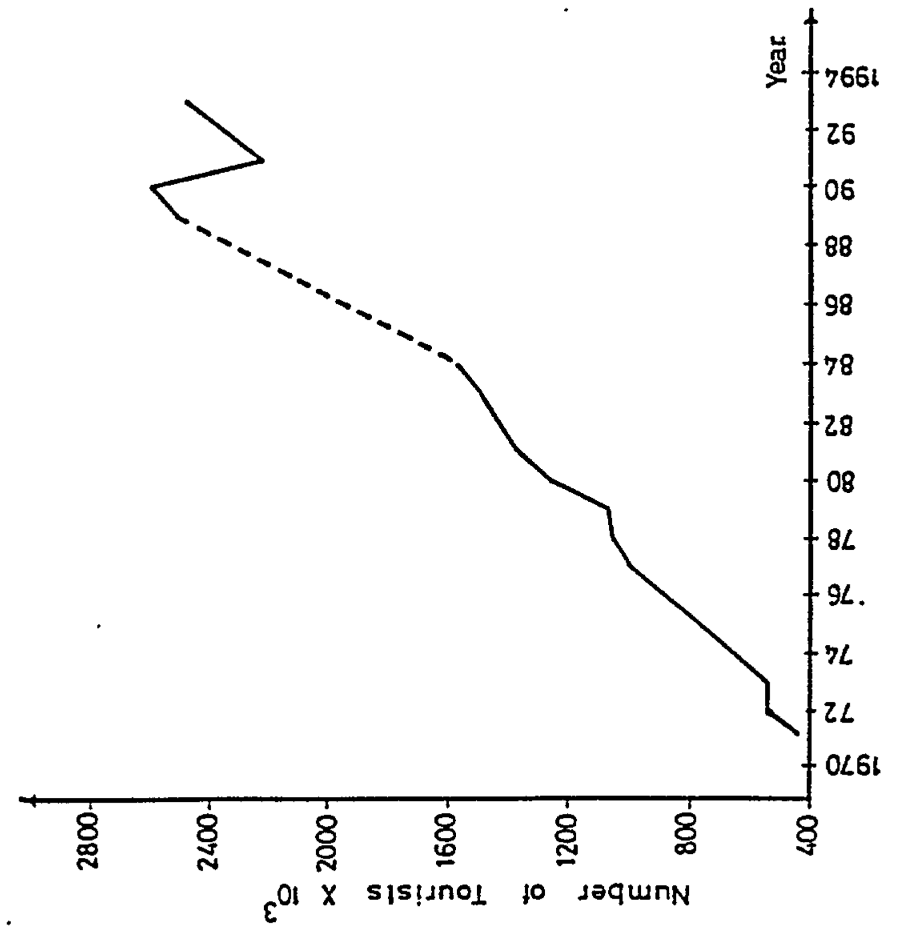


Fig. 58A Total Number of Tourist Arrivals in Egypt

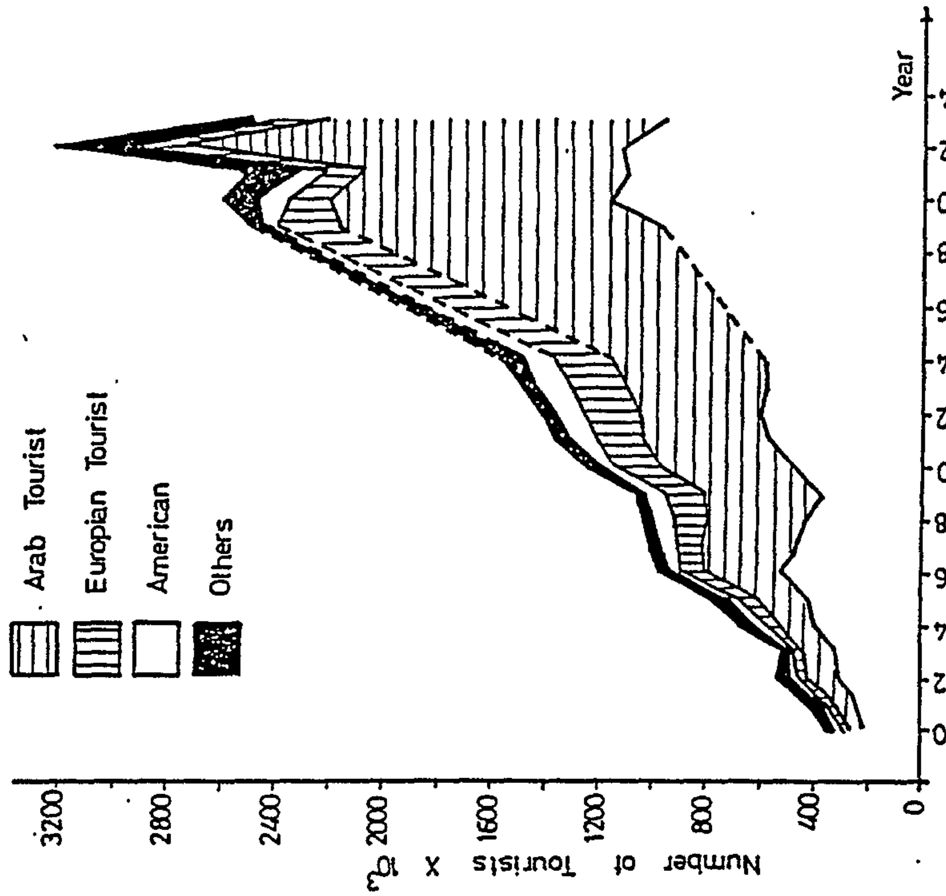


Fig. 59A Number of Tourists Arriving in Egypt by Nationality

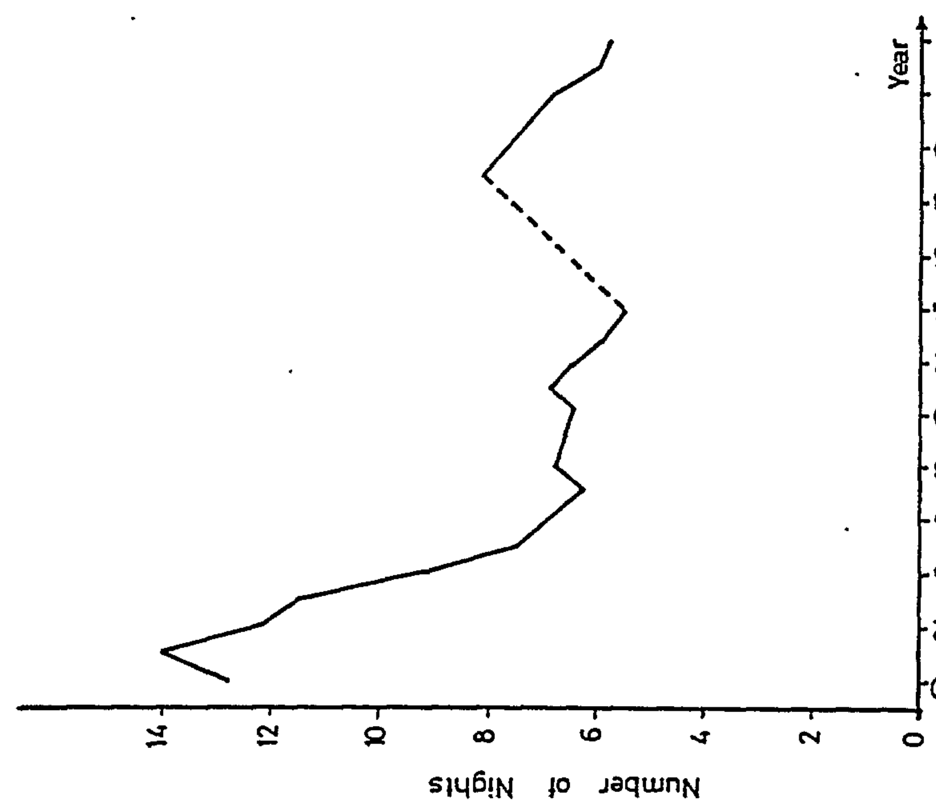


Fig. 59B Average Overnight Stays in Egypt

Table 35

Share of Egypt from the International Tourism

Year	Total number of tourism x 10[6]	Number of tourists who visited Egypt 10[3]	Percentage
1974	197	676	0.14
1975	207	792	0.38
1976	227	984	0.43
1977	244	1004	0.41
1978	260	1051	0.40
1979	270	1064	0.39
1980	285	1253	0.44
1981	288	1376	0.48
1982	285	1423	0.50
1983	287	1500	0.52
1984	293	1598	0.55

The International Authority for Tourism (Pacer/Egypteam, 1986) (C, Annex No. 3) showed the international tourism could be classified to:

a. Recreational tourism (50-75%)
b. Business and/or trade tourism (25%)
c. Recovery tourism (25%)

This shows that the recreational tourism has the highest percentage. Fig. 60 gives the distribution of the arrivals during each month of the years 1981, 1992, 1993 and 1994. It also shows the total arrivals during each of these years.

The available data shows that the largest number of the tourists is during the summer season Table 36 and especially in August, Fig. 60. Statistical analysis of 24 tourism companies showed that cultural and historical tourism, to visit Cairo, Luxor and Aswan, is 75% of the total tourism industry, 20% for other purposes and 5% for recreational tourism on beaches.

Table 36

Seasonal Arrival of Tourists

Year	Number of tourists x 10[3]				
	Winter	Spring	Summer	Autumn	Total
1981	304.2	355.1	436.9	279.8	1376 0
1992	709.1	776.5	975.2	746.1	3206.9
1993	592.0	605.8	743.6	566.4	2507.8

2.7.4 Internal or National Tourism

The above-mentioned section is connected to the foreign tourism in Egypt, but there is still the internal or national tourism which depends on the following sources:

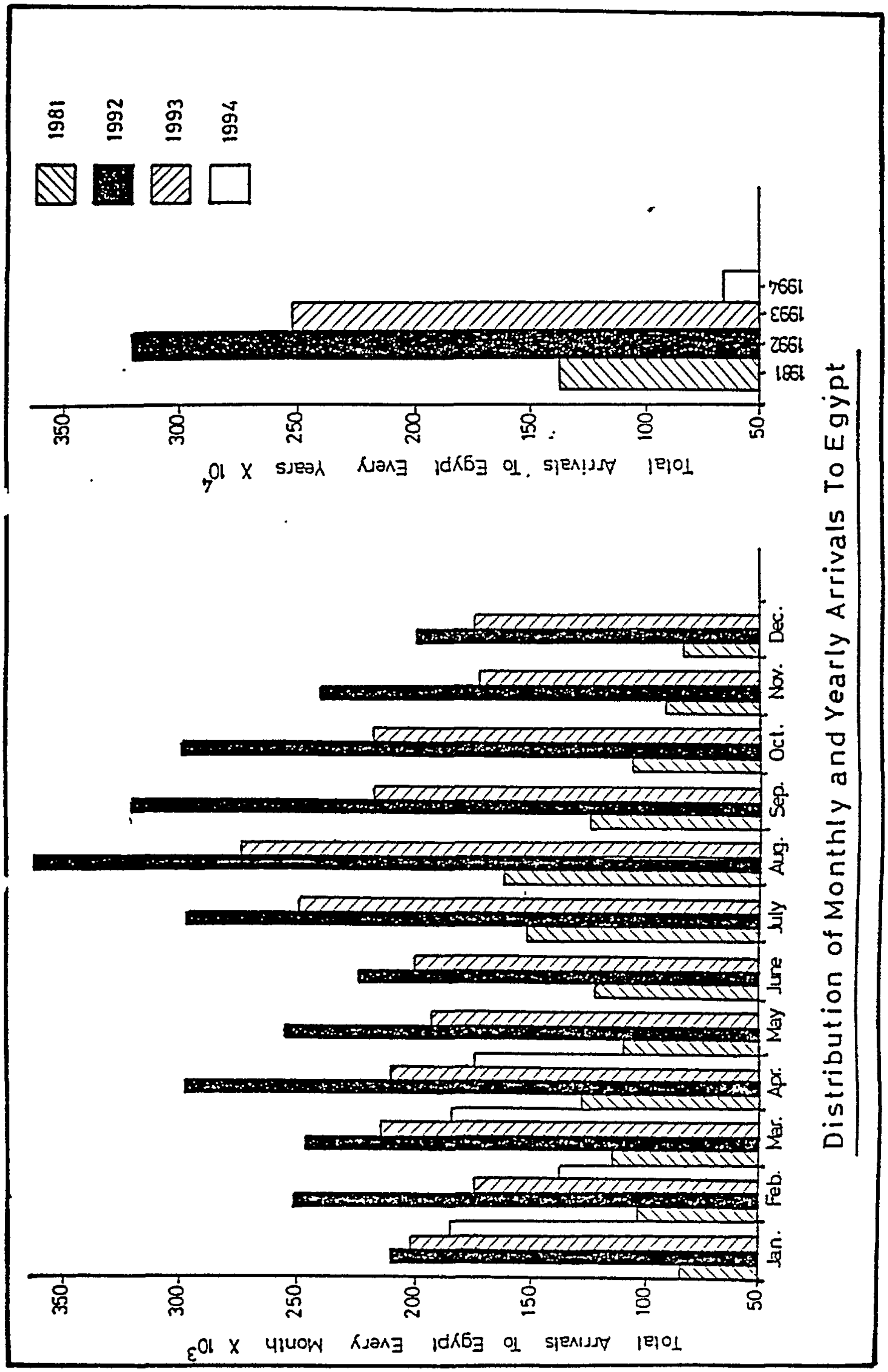


Fig. 60 Distribution of Monthly and Yearly Arrivals in Egypt

i. Egyptians staying in Egypt;
ii. Egyptians working outside; and
iii. *Foreigners staying in Egypt such as those who are working in embassies, petroleum* companies etc.

This type of tourism is directed mainly towards the seashores especially in the summer season.

Table 37 shows the estimated expected number of tourists, up to 2010, to spend their holidays on the Egyptian shores (Pacer/Egypteam, 1986 C). It shows that the internal tourism industry in about 90% of the total tourism. Also with the new developments on the beaches the number of the arrivals at the seaside will increase by 11% up to the year 2010.

Table 37

Estimated Expected Number of Tourists on the Egyptian Shores

Year	International tourism $x 10^3$				National tourism $x 10^3$		
	Arabs	Western	Others	Total	Egyptian	Foreign	Total
1985	80	30	15	125	1840	75	1915
1990	100	55	25	180	2240	83	2323
1995	150	105	30	285	2860	92	2952
2000	215	215	35	465	3830	100	3930
2005	340	390	40	770	5370	110	5480
2010	465	540	45	1050	7890	121	8011

2.7.5 Tourism on Alexandria Beaches and Western Coast

The statistical data of the Ministry of Tourism (Pacer/Egyteam, 1986 C) showed that 60% of the internal tourism and 90% of the Arab tourism in average are directed towards Alexandria and the western coast of Egypt as given in Table 38.

It is noted that Alexandria became a very busy city in both winter and summer. The beaches are not sufficient for the big number of people who want to spend the summer season there. Also the extension of its development became very difficult and may be impossible. That is why most of the people directed their sights towards the western coast where the land is still wide and virgin, and the improvement of the tourism services and developments are still available. Table 39 shows the expected estimates of the tourism demand on the west coast beaches up to the year 2010. It is clear from this table that the internal tourism is forming 85% of the total demand in 2010.

2.7.6 Tourism on the Study Area

The study area which extends from Fuka to Matrouh of 72 km length is attractive for national and international summer tourism This area is characterised generally by the following: its mild summer climate, white sand beaches, clear blue water, its calmness, its long distance from noisy and busy places such as Alexandria, distinctive coastal areas especially Obaid and Agiba and its unpolluted clear sea. Winter tourism including game hunting trips to oases outside the project area such as Siwa as well as historic sites (Cleopatra Baths, Rommel Museum in the eastern harbour of Matrouh, tradition museum in the main building of Matrouh Governorate) could be developed.

Table 38

Tourism Demand for Alexandria and Western Coast of Egypt

Year	Tourism demand x 10³ people for							
	International tourism				Internal tourism			Total
	Arab countries	Western countries	Other countries	Total (1)	Egyptian	Foreign resident in Egypt	Total (2)	1 + 2
**	90%	40%	80%		60%	40%		
1985	72	12	12	96	1104	30	1134	1230
1990	90	22	20	132	1344	33	1337	1509
1995	135	42	24	201	1716	37	1753	1954
2000	194	86	28	308	2298	40	2338	2646
2005	276	110	32	418	3222	44	3266	3684
2010	389	156	36	581	4434	48	4482	5063

** The figures on this line are the tourism demand for Alexandria and western coast of Egypt to the total demand on the Egyptian shores

Table 39

Tourism Demand on the West Coast of Egypt

Year	Tourism demand x 10³ person from							
	Arab countries		Other countries		International tourism		Total	
	No.*	%**	No.	%	No.	%	No.	%
1985	14	20	12	50	237	20	263	21
1990	23	25	23	55	344	25	390	26
1995	40	30	40	60	526	30	606	31
2000	78	40	80	70	818	35	976	37
2005	124	45	107	75	1306	40	1537	42
2010	195	50	154	85	2017	45	2366	47

* number in thousands
** percentage is the ratio of the number given to the total tourism demand given in Table 38

Note: These numbers did not include the daily trippers.

This area could be divided into the three touristic zones from west to east (see Fig. 61).

2.7.6.1 Zone No. 1

This consists of the city of Mersa-Matrouh and its neighbourhood. This zone includes the following touristic zones to attract the tourists:

- Rommel Museum in the eastern harbour of Matrouh;
- Tradition Museum in the main building of Matrouh Governorate;

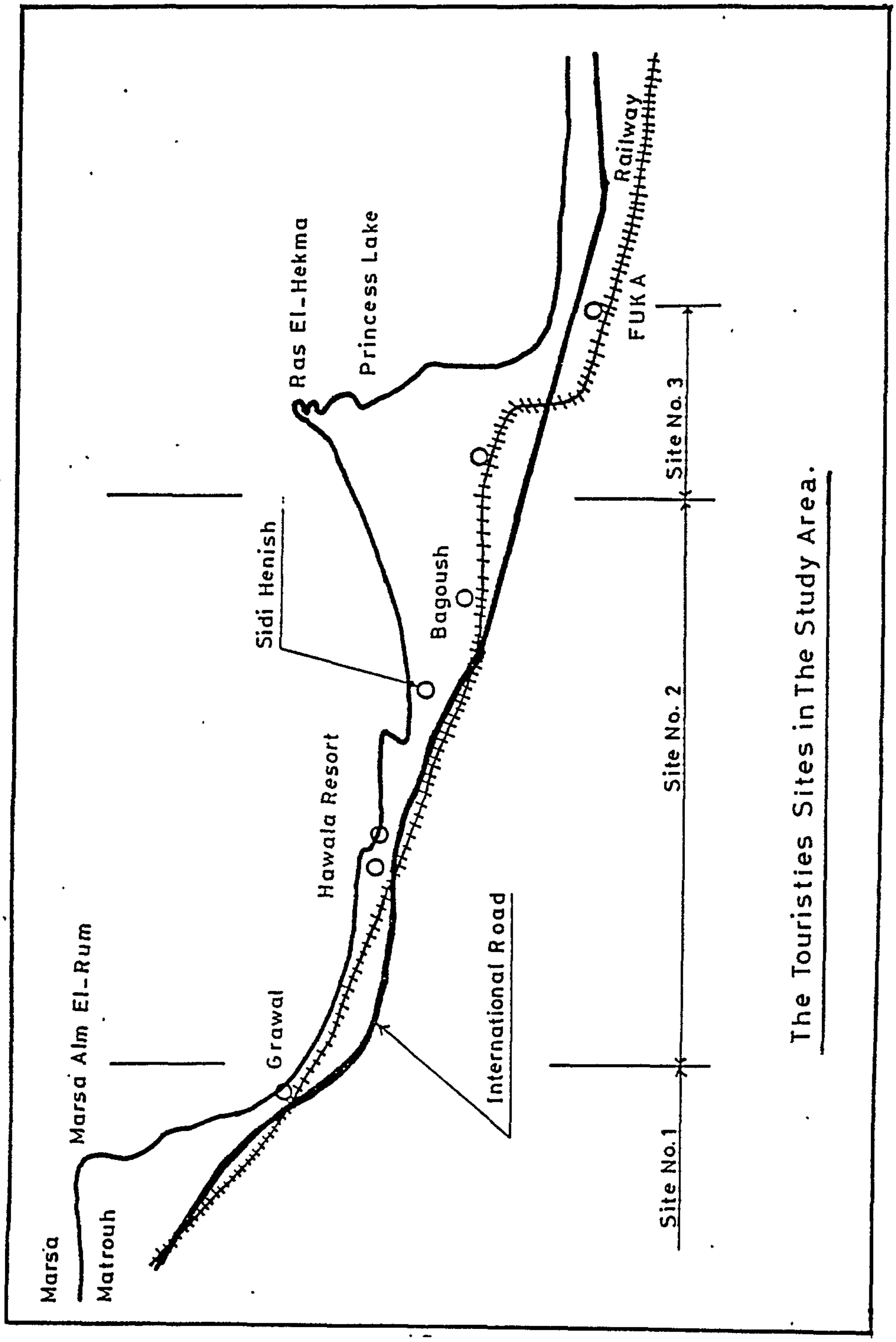


Fig. 61 Touristic Zones in the Study Area

- Beaches of Rommel, Lido, Gharam, Beausite, Maonbeach and TV beach;
- Cleopatra Baths which lie 12 km to the west of Mersa-Matrouh and can be reached by car;
- Obayyed beach which is located 20 km to the west of Mersa-Matrouh and can be reached by car;
- Ageeba beach which is located 35 km to the west of Mersa-Matrouh and can be reached by car and Ramses Temple at Ageeba;
- Ras Alam El-Rum which is located 10 km to the east of Mersa-Matrouh. The beach of this zone is naturally protected as shown in Fig. 61; and
- There are many recreational places, such as Matrouh Summer Cinema, Culture Directorate Cinema, open theatre at Cornish and Bedouin Tent, TV area and public gardens.

Mersa-Matrouh includes most of the hotels (Table 40) and touristic villages, camps and youth hostels (Table 41) (Tourist Department, Matrouh Government, 1992).

Table 40

Number of Hotels, Rooms and Beds

Type of Hotel	Number of		
	Hotels	Rooms	Beds
One Star	1	32	64
Two Stars	6	309	576
Three Stars	11	1196	2424
Four Stars	2	377	754
Five Stars	1	15	30
Unclassified	52	1226	2884
Total	73	3155	6732

Table 41

Number of Touristic Villages, Camps and Youth Hostels

Type	Number of		
	Each type	Rooms	Beds
Touristic Village	14	328	980
Camp and Youth Hostels	29	989	3840
Total	43	1317	4820

2.7.6.2 *Zone No. 2*

This zone 45 km to the east of Mersa-Matrouh and includes Hawala-Bagoush Reach (Fig. 62). This zone is considered the best of all the underdeveloped zones of the study area due to the following:

i. extended flat sand beach 16.5 km length and 40 m depth;
ii. mild climate;
iii. *white sand and clear water free from pollution;*
iv. distinct angles of vision and bays;

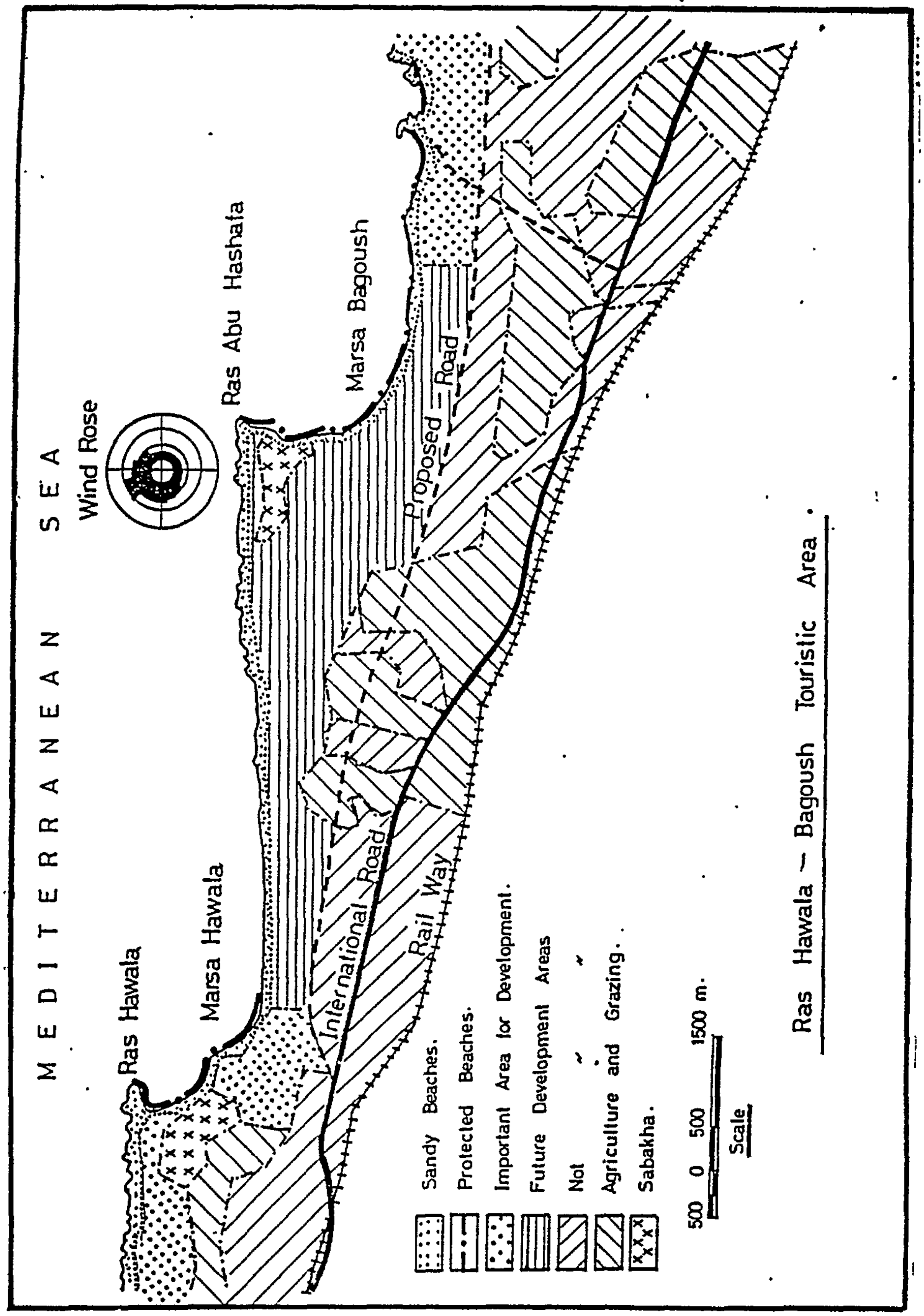


Fig. 62 Ras Hawala - Bagoush Touristic Area

v. good, wide and virgin land suitable for touristic purposes extending southwards about two kilometres in average,
vi. natural protected beaches; and
vii. its easiest connection to Mersa-Matrouh especially good chances to use its airport for transporting of the tourists.

Fig. 62 shows the analysis of the natural facilities of this zone. Eight touristic villages are under construction in this zone but there is not any more available information on it. Also it is worth to mention that this zone could be considered as a natural extension to the city of Mersa-Matrouh.

2.7.6.3 Zone No 3

This zone, Fig 63, which is still under development, lies at a distance of about 65 km to the east of Matrouh and a distance of about 20 km to the east of zone No. 2, and known by Ras El-Hekma triangle. Its northern end is situated at a distance of about 15 km from the international road between El-Sallum and Rafah. This zone is considered as one of the most important touristic zones in the study area due to the following:

i. distinct scope of vision because of the high sites near the shore;
ii. mild climate,
iii. protected bays and beaches for different kinds of sports; and
iv. flat areas for horse riding and golf sports.

This zone will include some elite features like swimming pools, golf courses, horse riding, sauna baths and diving. There are some camps and touristic villages in this zone but we cannot get more data about them.

The development in the number of tourists and tourism nights in the study area during the years 1990-1992 is given in Table 42. This table shows that the number of tourists has increased in 1991 and then decreased again in 1992, while the number of hotels is always increasing. Also the average overnight stay is also increasing especially from Mersa-Matrouh to the west of Ageeba and Obayyed beaches which are about 20 km distance. But these day trippers could be directed towards Hawala-Bagoush area 45 km from Mersa-Matrouh and may be to Ras El-Hekma. These day trippers which are 700 visitors/day by the year 1990 will increase with time until it reaches approximately 2,500 visitors/day by the year 2010.

Although tourism is still a weak activity it is likely that it will become important in the future. Tourism will attract capital investment.

The studies carried out by Dr. Abd El-Latif *(1992) showed that the accommodations capacity* (no. of beds) in the year 2010 will be as follows:

- for Mersa-Matrouh, Alam, El-rum, Obayyed = 52,000 beds;
- for Hawala-Bagoush area = 22,500 beds; and
- for Ras El-Hekma area = 5,000 beds.

It is worth noting here that in-between the mentioned zones there are superb locations that may allow for the construction of smaller resorts (between 500 to 1,000 beds each) such as Fuka village on the eastern borders of the study area.

This is in addition to a new touristic village under construction in Alam El-Rum area near Matrouh with a total cost of 10^6 Egyptian Pounds and will allow 8,000 new jobs for the natives of the area.

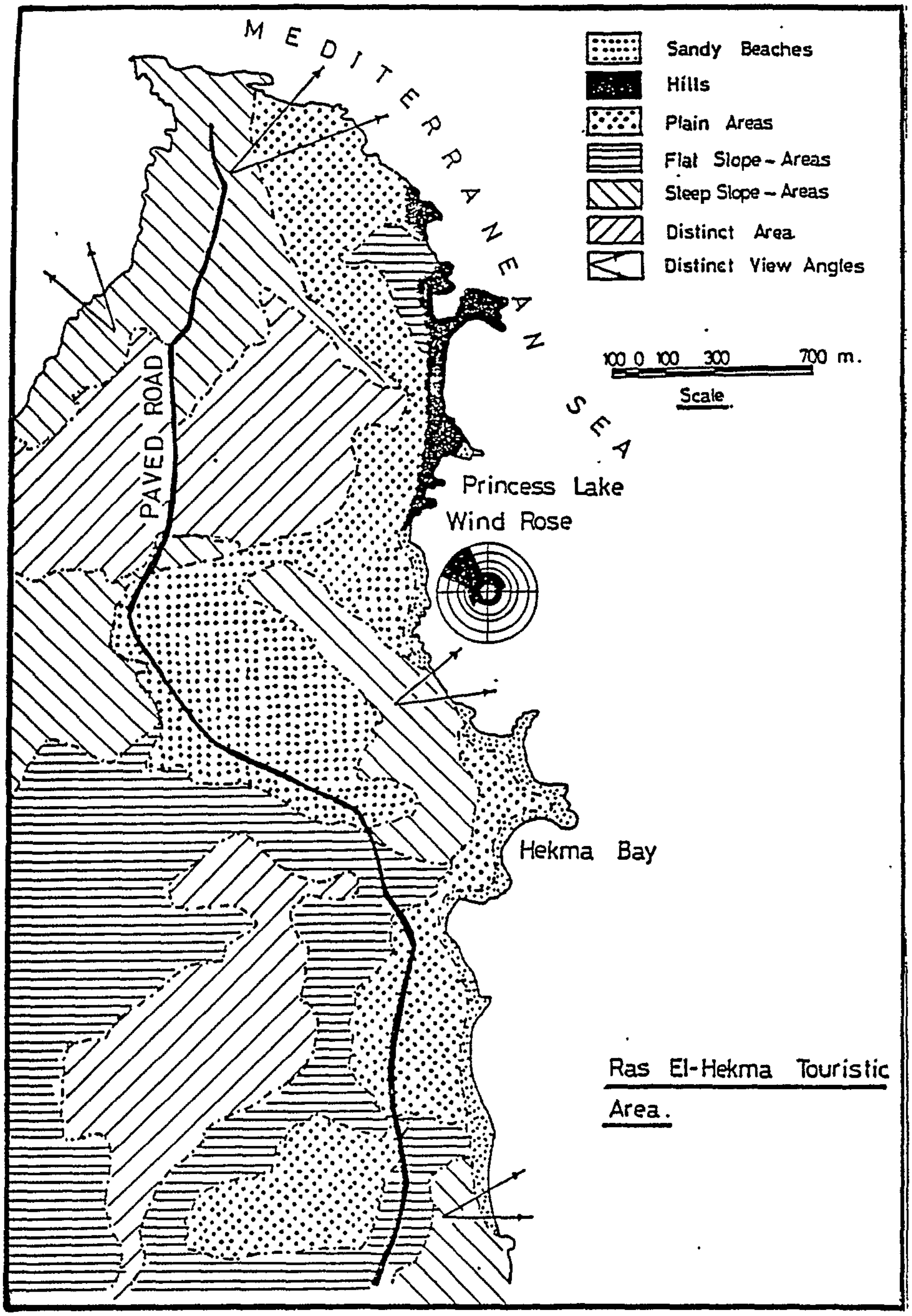


Fig. 63 Ras El-Hekma Tounstic Area

Table 42

Number of Tourists and Tourism Nights

Year	Number of arrivals				No. of tourism nights	No. of hotels	Average night stay
	Egyptian	Arabs	Other	Total			
1990	119506	20800	7937	148243	173307	54	1.17
1991	165890	49745	5030	220665	338818	56	1.54
1992	92727	18839	4772	116338	205916	72	1.77

2.7.7 Summary

The statistical data show that the number of tourists visited Egypt has been increased from 428000 in 1971 to 3,207,000 in 1992 due to the new open investment policy. In 1993 this number was decreased to 2,508,000 due to some political situations. The international tourism could be classified to: recreational tourism (50%), business and/or trade tourism (25%) and recovery tourism (25%).

It was found that Alexandria became a very busy city in both winter and summer and its beaches are not sufficient for people. The tourism demand in the west coast of Egypt was 390,000 in 1990 and expected to be 976,000 in the year 2000 and 2,366,000 in the year 2010.

The study area with its mild climate, white sand beaches and clear blue water has attracted the national and international tourists to it. This area could be divided into three zone: city of Marsa-Matrouh and its neighbourhood, Hawala-Bagoush beach (about 45 km to the east of Matrouh) and Ras El Hekam triangle about 65 km to the east of Matrouh. This is in addition to some locations that may allow for the construction of smaller resorts such as Fuka village.

2.8 TRANSPORT AND SERVICES

2.8.1 General

The area is served by a reasonable transportation network, such as: paved roads, local tracks, railway line, airport, harbour as well as by transportation means of conveyance such as buses, trains, aeroplanes, boats and ships

2.8.2 Transportation Network

The basic road and transportation network in the region links Alexandria and Sallum along the north coast. Links from Mersa-Matrouh to the western desert oases and from oases to Giza/Cairo complete the transportation grid tying Cairo and Alexandria to the western desert, Fig. 64. Also Mersa-Matrouh is joined to Quattara depression by a secondary road from station Maatin El-Garawla. The network is financed by the national authorities. The following gives more details:

2.8.2.1 Main Roads

The international coastal road from El-Sallum to Rafah extending for 1000 km and 22 m wide is an important development factor especially since its widening into a four-lane highway. It passes through the study area with a total length of 72 km from Fuka to Matrouh. It serves as a development corridor where tourism activities and settlements are concentrated. It also provides a marketing/transportation link from the study area (Fuka, Ras El-Hekma, Sidi Henish, Hawala and Garawla) to the delta and Nile valley via Alexandria. The western part of this road joining Matrouh to Sallum is some 200 km long is a 2 lane width. This road could be in the future serve as an axis for

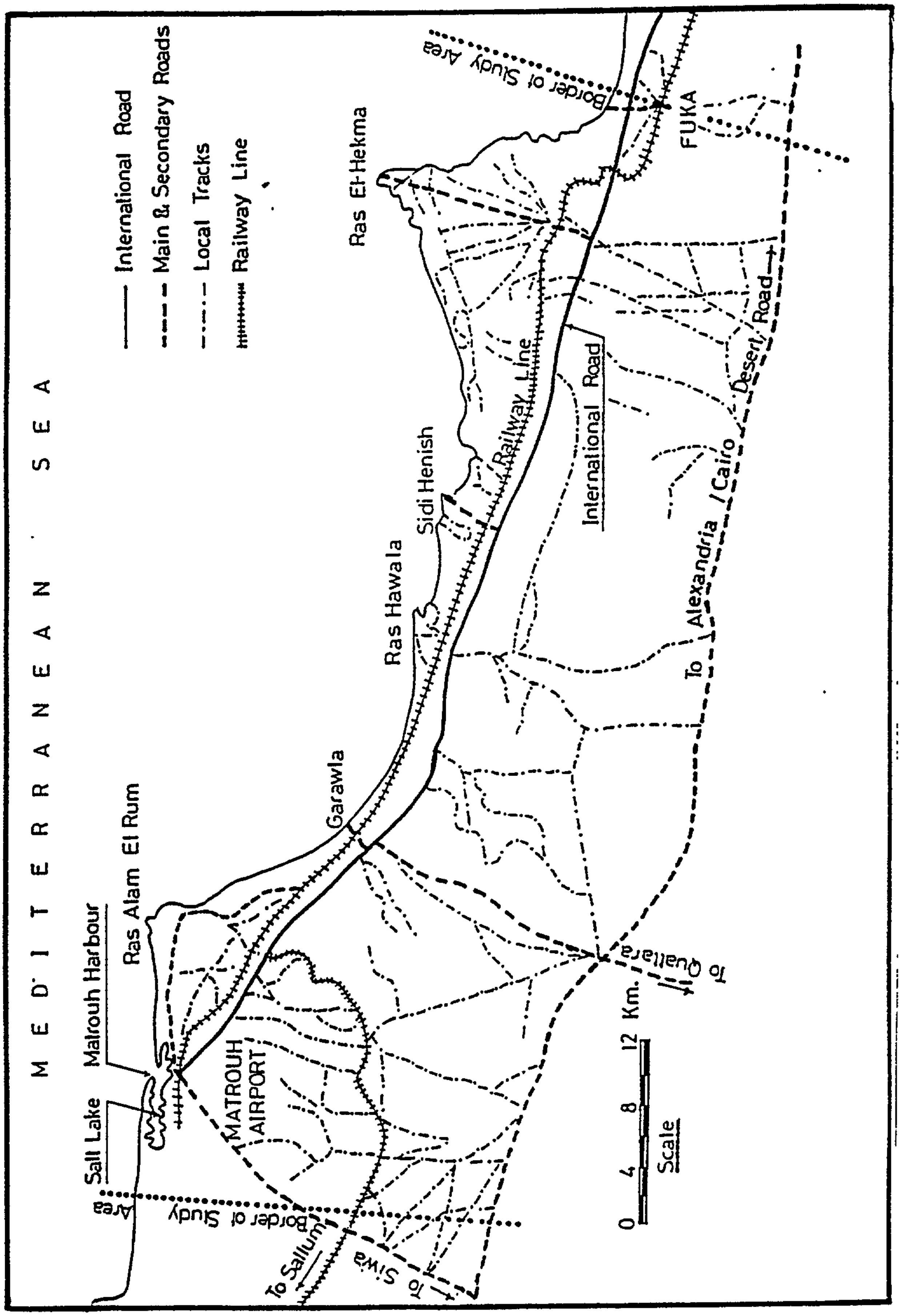


Fig. 64 Network of Transport Facilities

more intensive exchanges with Libya and transit trips from North Africa to Mecca through Egypt especially once it is widened to four lanes.

There is a second paved road parallel to the coast which passes through the southern plateau and is 6 m wide. While this is a military road, private and public transportation vehicles are permitted to travel on it. This road is an important transportation link between Cairo-Alexandria desert road and Sallum directly through the desert. It also serves the southern part of the study area.

The north-south axis perpendicular to the coastal and Sallum roads extends from Matrouh to Siwa for some 300 km. It has been recently paved and widened to 7.5 m with 3 m levelled shoulders on each side. It is often used by hydrocarbon prospection companies, travellers from Siwa to Matrouh and some international tourists going to or coming from Siwa via Matrouh.

2.8.2.2 Secondary Roads

There are some paved tracks that join the international coastal road to the shore at the following locations:

- at Fuka 3 km long and 6 m wide
- at Ras El-Hekma 15 km long and 6 m wide
- at Sidi Henish 3 km long and 6 m wide
- at Garawla 2 km long and 6 m wide
- a tourism road that joins Alam El-Rum to Mersa-Matrouh 17 km length and double track.

The track between the international and military roads to Sallum is levelled and has a base layer. It is about 13 km long and is wide enough for one car to pass.

2.8.2.3 Local Tracks

There are also large number of small tracks linking the roads extending through the desert. While most of them are just unpaved tracks, they serve in linking settlements and groups of houses throughout the southern zone of the study area. Furthermore, they will serve as a basis for developing the road network within Fuka-Matrouh area in the future.

2.8.2.4 Railway

The national railway line from Cairo to Alexandria, Matrouh and then Sallum passes through the study area and stops at stations: Fuka, Ras El-Hekma, Atrouh, Sidi Henish, Hawala, Garawla and Mersa-Matrouh. It is a single line. It is adjacent or near to the international road to Matrouh and could be utilised as an important development corridor in the study area. It also carries passengers in the summer. In winter, it is mostly used by the teachers. Nowadays Luxe trains with sleeping beds are used on this track to encourage the tourism industry.

2.8.2.5 Airports and Places for Flight

The airport serves as an important link for rapid transport to the rest of the nation. In the summer months it is an important tourist inlet. It is located in the southwestern part of Matrouh and 2 km from its centre. While this airport belongs to the military forces, the National Authority for Civil Aviation leases landing rights for civilian use from June to October. In addition to this airport, there is a place for landing and flying in Fuka. It is used in emergency cases.

2.8.2.6 Harbours

In the study area there is only one harbour at Mersa-Matrouh. It consists of a large water basin parallel to the shore and it is protected by two chains of rocks as breakwaters with an opening 100 m and water depth of 6 m. This harbour could serve as a significant element in this network especially for transport of tourists and goods. Also it encourages the car and yacht tourism.

2.8.3 Transportation Means of Conveyance

The following traffic density transportation per day takes place in the study areas:

Buses

- Super-jet bus, Matrouh-Cairo — 4 times
- Super-jet bus, Matrouh-Alexandria — 2 times
- Ordinary bus, Matrouh-Cairo — 4 times
- Ordinary bus, Matrouh-Alexandria — 11 times
- Ordinary bus, Matrouh-Sallum — 5 times
- Ordinary bus, Matrouh-Siwa — 3 times

Trains

- Trains, Matrouh-Cairo — 2 times
- Luxe trains with sleeping beds — 2 times

Aeroplanes

- Aeroplanes Matrouh-Cairo — 3 times

Taxi

- Taxi service Matrouh-Cairo and Matrouh-Alexandria is continuous at the taxi station which is beside the bus station

This is in addition to the famous means of transport in Mersa-Matrouh streets known by the KARETTA which is drawn by a donkey. The price is one pound per person.

The following Table 43 *shows the number of transport units and persons transported during* 1993.

Table 43

Transportation in the Study Area

Transport Means	Number of Units		Number of Passengers		Remarks
	Summer	Winter	Summer	Winter	
Trains	4	2	10000	15000	
Bus	15	13	6000	1000	
Private Cars	4000	2000	750000	200000	
Lorries	1000	800	-	-	To transport
Lorries with trailer	350	300	-	-	goods
Pickup	5000	3000	50000	25000	

2.8.4 Summary

Fuka/Matrouh area is connected internally and externally by a good net transport facilities. This area is connected to Alexandria, Cairo, El-Sallum, Siwa and Quattra depression by aeroplanes, railways, superjet buses, ordinary buses and taxis.

As soon as the midpart of the International road between Rosetta and Damietta will be completed, the study area will have an easy access to the Nile Delta, as well as to Saini. The traffic density will be increased tremendously due to the new developments in the area.

2.9 SANITATION AND HEALTH ASPECTS

2.9.1 General

Under this topic a brief description is given on the water supply for domestic purposes, liquid waste system, solid waste system and types of diseases which may widely spread in the area.

2.9.2 Sanitation

A brief description is given on water supply system, waste water system and solid waste system.

2.9.2.1 Domestic Water Supply System

Since Fuka-Matrouh region is an arid zone, there is a great shortage in water supply for domestic purposes. The following sources are the main ones:

i. Water from a group of shallow surface wells distributed along the northern coast and in Fuka plain. This water is not good for drinking but it is usually used for domestic purposes and agriculture.
ii. In addition to the old 200 mm water pipeline, a 700 mm diameter water pipeline exists between Alexandria and Mersa-Matrouh. Its capacity is 50,000 m^3/day. However, repeated legal and illegal tapping along the length of the line greatly diminishes the amount of water reaching the study area. A new pipeline is being constructed from Alexandria to Mersa-Matrouh. At present this line extends from Alexandria to El-Allamein.
iii. There are 4 desalination stations in Mersa-Matrouh area with a capacity of 500 m^3/day, each intended to serve the tourism zone. These units, however, are currently out of operation.

Water is also transported in water tanks carried by railways. A new water network for Matrouh is under construction which consists of main pipe network 236 km length and 3 high level storage tanks with 120 x 10^3 m^3 water capacity. The total cost of the new water supply system in Matrouh area is 75 x 10^6 L.E.

Another network is proposed to distribute water to touristic villages, settlements and other areas under sufficient pressure for domestic, touristic, industrial and commercial purpose. This network may be:

i. Tree system suitable for small communities.
ii. Circle system suitable for medium communities.
iii. Grid iron system suitable for crowded communities.

The water consumption in the area is expected to increase especially with the increase of the population and the temperature.

2.9.2.2 Water Sewerage System

The sources of the liquid wastes are as follows:

i. Domestic liquid wastes: these water wastes result from the residential communities, hotels, tourism villages, hospitals, schools, offices etc. Generally these wastes are originally fresh pure water which was polluted as a result of their use, together with the wastes of humans. They usually contain a small percentage of solids which may be in suspension and/or deposited on the bottom or dissolved.

ii. Industrial liquid waste: this is the output of different factories existing and/or planned suggested for the development of the study area. These wastes are usually more concentrated than those of the domestic ones and its concentration depends on the types of industry.

iii. Storm waste water: the maximum rate of rain is 75 mm/day which causes wastes to the sewers ranges from 3-6 times the wastes from domestic purposes. These water reaches the sewage network from the paved roads and the roofs of the residential settlements.

2.9.2.3 Types of Sewers

The study area is characterised by the low density of population which ranges between 70 and 110 person/hec (Pacer/Egypteam, 1986), except in Matrouh where the density becomes much bigger in summer. That is why the primitive methods to get rid of the wastes are used in the zone between Fuka and Matrouh. These methods are: septic privy, pit privy, septic tanks and manholes. This approach if not very carefully studied, could lead to the pollution of the water layer under the sand dunes which is the most reliable source of water in the coastal zone. Recently an integrated waste water network is under construction for the city of Matrouh and the adjacent tourism zones. This system is composed of the indoor sanitation connected to a network of PVC sloping pipes leading to 3 pumping stations which pump the wastes to the treatment plant of 100,000 m^3/day capacity. Two waste water mains are connecting the stations with the treatment plant which is currently under construction: one main is 8.5 km and the other is 3 km long. The total cost of this system is 90×10^6 L.E.

Currently large tourism projects on the coast depend on septic tanks for sewage disposal. Bedouin communities, however, have no waste water or solid waste disposal system up to date.

It is planned for the future and up to the year of 2100, that tourism resorts at Fuka, Ras El-Hekma, Bagoush, Sidi Henish, Hawala and Garawla, will be gradually have their own integrated waste water network. While no plans exist to integrate Bedouin communities before the year 2000.

2.9.2.4 Solid Wastes

The solid wastes in the study area are produced from the houses, hotels, touristic villages and from the industry especially the agro-products. It was found that the people get rid of these wastes by throwing them in any space, empty sites or beside the houses. The solids from the hospitals and clinics are burned causing pollution to the surrounding atmosphere.

With the increase in the population and the settlements and the new developments such as the industries, new communities, new touristic villages and hotels, etc., the quantity of the solid wastes will increase tremendously. They will consist of the following:

- organic and inorganic wastes from the houses, hotels, hospitals, etc., and include the remains of the food material, vegetables, fruits, papers, wood pieces, plastic bags and covers, etc;
- industrial wastes which vary according to the types of the developed industries;
- inorganic big solid wastes produced from the remains of the construction material, maintenance and repair operations; and
- wastes from the streets which mainly dust, papers, and branches of the trees.

The quantity of these wastes varies according to the environment, habits of the people and from one season to another. From the studies of similar areas (Pacer/Egypteam, 1986 B), it would found that the quantity of the solid wastes without industrial ones are about 0.8 kg/person/day and its density is ranging from 200-300 kg/m^3). The industrial wastes are estimated to be 50% (by weight) of the above values.

There are many methods to treat and/or get rid of these waste such as:

- Land fill: for each residential community the wastes are collected, buried and covered by dust at the end of each day to prevent the bad smells and the growth of flies and harmful insects. These wastes will be left for a period of time to be decomposed. These areas can be used afterwards as public gardens of playgrounds, etc. This method is considered an economic means to get rid of the wastes got from the houses, hotels, etc., when the low empty sites are sufficient and cheap in price.

- Decomposed method: the wastes are converted to organic fertiliser for the agriculture land by the biological methods. The cost of this method is relatively high.

- Burning the wastes: the collected solid wastes are burned in special furnaces. The resulted material after the burning process is very small but it causes pollution of the air.

2.9.3 Health

Egypt with its favourable climate, has been considered an ideal place for the convalescence of invalids. Because of the lack of data and information this section will give a very brief summary on the widely spread diseases in the coastal areas and the desert:

i. Diseases of the respiratory organs such as bronchial asthma.
ii. Eye diseases such as cataract, eye infections, terracoma.
iii. Epidemics of enteric disorders such as typhoid and para-typhoid fever.
iv. Skin diseases such as sun burn and skin cancer.

2.9.4 Summary

In the study area, there are different sources of water for domestic use such as the pipe-line from Alexandria, shallow surface wells and desalination stations. Also water is transported in water tanks carried by railways. A new water network for Matrouh and its neighbourhood of 120×10^3 m^3 water capacity is under execution. The consumption of water in the area is expected to increase due to increase of the population and the new developments.

According to the low density of the population in the study area and specifically for tourism projects, the primitive method such as septic tanks are used to get rid of wastes. Bedouin communities have no waste water or solid waste disposal system up to date. The solid wastes from the houses, industry, touristic villages are collected and thrown in any space site or beside the houses. The solids from the hospitals and clinics are burned causing pollution to the surrounding atmosphere.

Diseases that are widely spread in the area are: eye diseases, skin diseases, respiratory organ diseases and epidemics.

2.10 POPULATION AND SETTLEMENT PATTERNS

2.10.1 Past Trend and Present Situation

The study area is a semi-desert, sparsely populated area, which is part of the northwest Mediterranean coast of Egypt. The inhabitants of the region are Bedouin (nomads). Before 1960, the Bedouin used to travel about for grazing all over the desert. They are settled actually in the area at the beginning of the 1960s. Because of the lack of reliable figures on the population size before 1976 census[1], only the figures of 1976 and 1981 are considered to represent population growth (Table 44).

Table 44

Population Size and Growth Rate between 1976 and 1986

	1976	1986
Size of population	27608	40112
Percentage of (NWCZ)* population	24	25
Annual growth rate (%)	-	3.2
Average annual national population growth (%)	-	2.5

* north west coastal zone of Egypt
Source: Central Agency for Public Mobilisation and Statistics, Census 1976 and 1986

As shown in Table 44, the population on the study area represents about 25% of the population of Matrouh Governorate. During the period 1976-1986, the region's population grew from approximately 27,000 to 40,000 an average annual growth rate of 3.2%. This rate is higher than the average national population growth of Egypt (2.5%). The urban population is 76% of the total population where the rural is 24%. The rapid increase of the population can be attributed to several factors first, the stability of the Bedouin in settlements and cultivating land with permanent trees such as figs and olive. Second, the considerable increase of per capita income in the last two decades, and finally it is common by the Bedouin to marry more than one wife.

A formal questionnaire has been carried out in the study area to recognise the main demographic characteristics of the area.

Table 45 shows that the average number of people living in the household is 12. This average is higher than the average of the Governorate of Matrouh which is approximately 7 people according to the 1986 census. The age distribution declare, that about 60% of the population in the range of 6-65 years category, and about 47% are less than 15 years old. The table indicates also that 65% of the population over the age of 10 are illiterate. This is relatively high percentage compared to the illiteracy in Egypt which is 49% approximately.

Distribution of population

The bulk of the population of the region is concentrated in the coastal area, as a consequence of favourable natural conditions, existence of services and infrastructure, urbanisation and development policies of the government. The region can be divided into three zones. The coastal zone in the north in which about 72% of the population live. The median zone, in which about 25%

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1 The Matrouh Governorate information system estimates the area population as 16,000 in 1960, and as 25,000 in 1970.

live and the southern zone in which only 3% of the population live. The intensity of the three zones are 72 people/km^2, 12 people/km^2 and 2 people/km^2 respectively.

Table 45

Main Demographic Characteristics of the Population in the Study Area

Family Characteristics	unit	
Average household size	No.	12
male	%	50.5
female	%	49.5
more than one wife/man	%	53
Age Distribution		
1-5 years	%	27
6-14 years	%	25 2
15-65 years	%	45.1
65 and above	%	2.7
Educational Status (10 years and over)		
Illiterate	%	65.4
Only Reads and writes	%	20.3
Primary	%	7.2
Preparatory	%	4.5
Secondary	%	2.4
College	%	0.2

Settlement

The residential area of the region is estimated as 40 km^2. Public land is estimated as 10,000?. The technical infrastructure is about 2 km^2. Where the tourism area is about 20 km^2. There are two types of buildings. The first is the Bedouin settlements which consist of flat buildings normally far from the seashore. The second is the tourism villages which are normally close to the seashore. The buildings of such villages consist mostly of more than one floor.

2.10.2 An Outline of the Population Growth

The objective of this section is to provide a projection of the population of Fuka-Matrouh region by the year 2030. Because of the lack of historical data (annual data) on population on the study area, it is not possible to provide projection based on the time trend extrapolation. The method used here in projection depend upon three common formulas which are normally utilised in population projections. These formulas are the exponential, the geometric and the numeral respectively.

a. $P_t = P_0 e^{rt}$
b. $P_t = P_0 (1+r)^t$
c. $P_t = P_0 AI$

where: P_t is the population number in projected year
P_0 is the population number in base year
r is the rate of increase
t is the number of years between P_t and P_0
AI is the average absolute increase

In the first formula (exponential form) together with the second formula (geometric form), the yearly increase is not constant. In the third form the yearly increase is constant. Because the growth rate in region (3.2%) and the fertility rate (5 children per mother) are relatively high, the first and second formulas seems to be more convenient, as they add the variate yearly increase to the population number in base year. Table 46 shows the projection results of the population until the year 2003.

Table 46

Population Projection for the Year 2030

Population	1986	2001	2015	2025	2030
Exponential	40112	64889	108927	157698	189764
Geometric	40112	64327	106979	153826	184494
Numerical	40112	56362	73862	86362	92612

As shown in Table 46, the results of the exponential and geometric formula are far more reliable than the numerical one.

3. POTENTIAL IMPACTS OF EXPECTED CHANGES ON NATURAL SYSTEMS AND SOCIO-ECONOMIC ACTIVITIES

3.1 ATMOSPHERE

3.1.1 Predicting Future Climate Change

The evaluation of the earth climate in the next fifty to hundred years will result from ongoing natural variations combined with a warming trend forced by man-made modifications of the atmospheric concentrations of greenhouse gases. Natural variations on relatively short time periods of decades to a century will be caused by the internal dynamics of the earth's climate system. The warming trend, on the other hand, will be induced by the steady increase of the greenhouse effect in the atmosphere. Actual warming is being delayed by the thermal inertia of the world ocean, but it will also continue long after the composition of the atmosphere is stabilised. No matter how drastic the actions taken to control the emission of greenhouse gases into the atmosphere, the global warming to which we are already committed will be realised in the next fifty to a hundred years: global environmental change is inevitable.

Present Situation

Major Expected Changes and their Impacts

By comparing the means of atmospheric pressure, air temperature, relative humidity, cloud cover and the hours of bright sunshine for the period 1961-1975 by those for the period 1976-1990, we find:

- small increase in atmospheric pressure (from 14.8 HPa to 15.36 HPa);
- no change in air temperature (from 19.27°C to 19.28°C);
- small increase in relative humidity (70.3% to 70.7%);
- no change in cloud cover (oktas) (2.6 for both);
- small decrease in the hours of bright sunshine (9.17 hrs to 9.08 hours); and
- considerable decrease in wind speed (from 5.30 m/sec to 4.62 m/sec).

An increase in atmospheric pressure diminishes frontal activity, which necessarily implies less rainfall. Furthermore certain anticyclonic situations enhance subsidence thereby restricting convection and hence rainfall. Besides, an increase in atmospheric pressure implies an increase in anticyclonic situation, which in turn implies more low level inversions. These inversions trap the atmospheric pollutants which are not dispersed by the wind due to the slack pressure gradient associated with anticyclonic conditions. This would necessarily increase the incidence of haze (number of hazy days increases from 5.5 days/year to 5.9 days/year).

By studying the variation of annual global radiation (Fig. 65) recorded over Matrouh for the period 1982-1991, we noticed a considerable decrease trend for global radiation over Matrouh, which may imply increase of aerosols concentrations.

Besides, turbidity (Fig. 66) is measured in Sidi Barrani - 140 km to the west of Matrouh, but with the same climatic conditions as Matrouh - since 1980, from the curve of turbidity we can find a general increase in the turbidity, which in turn means an increase in aerosols.

According to studies in the western coast of Egypt by Mehanna (1990) based upon the assumption of an annual temperature increase of 1.5°C, evapotranspiration would increase by about 10%. This would lead to a decrease in run-off of 10%, even without a decrease of precipitation. With a decrease of precipitation of about 10%, a conservative estimate of run-off would go down even further. As potential evapotranspiration is calculated to increase by as much as 12%, water for irrigation in the area will diminish at the same time as demand increases.

We may conclude from the point of view of the microclimate and the water balance in the region, a reduction in the amount of winter rainfall and an increase of evapotranspiration are to be expected.

3.1.3 The Local Scenario of Climate Changes

For this report the best available regional scale climatic scenario for northern Egypt has been used. The Climatic Research Unit (CRU) of the University of East Anglia, UK, has specifically developed for UNEP a computer simulation of atmospheric general circulation for northern Egypt based on meteorological data from long-term (1951-1988) records for temperature and precipitation collected at local stations (Annex III).

The output provides a valuable information base concerning the spectrum of possible regional climatic changes for temperature, and with a lower degree of confidence, for precipitation.

According to this model, the temperature changes for the Egyptian coastline west of Alexandria are expected to be less than the global change i.e. in the range 0.7-0.8°C per °C global change. Broadly, the same pattern is seen in each season. Only in summer does the warming in the Fuka-Matrouh area approach the global level (with changes in the range 0.9-1.1°C per °C global change).

The scenarios of precipitation indicate drier conditions at the annual level, with a change in rainfall in the range of -4 to 0% per °C global warming. This relatively small change is accounted for by decreases in winter and autumn, whereas conditions in spring and summer are shown to be wetter as a result of global warming. In winter, the greatest change is seen in the west, towards the border with Libya, with a reduction in rainfall of over 10% per °C global warming. In autumn, the changes are between 0% and -14% per °C global warming. The increase in rainfall in spring is over 8% per °C global warming over the whole of the Egyptian coastline west of Alexandria. In summer, rainfall is non-existent.

The problem associated with the construction of regional scenarios of climate change due to the enhanced greenhouse effect are discussed at length by Palutikof *et al.* (1992), in their report to UNEP on the construction of climate change scenarios for the whole Mediterranean region. The

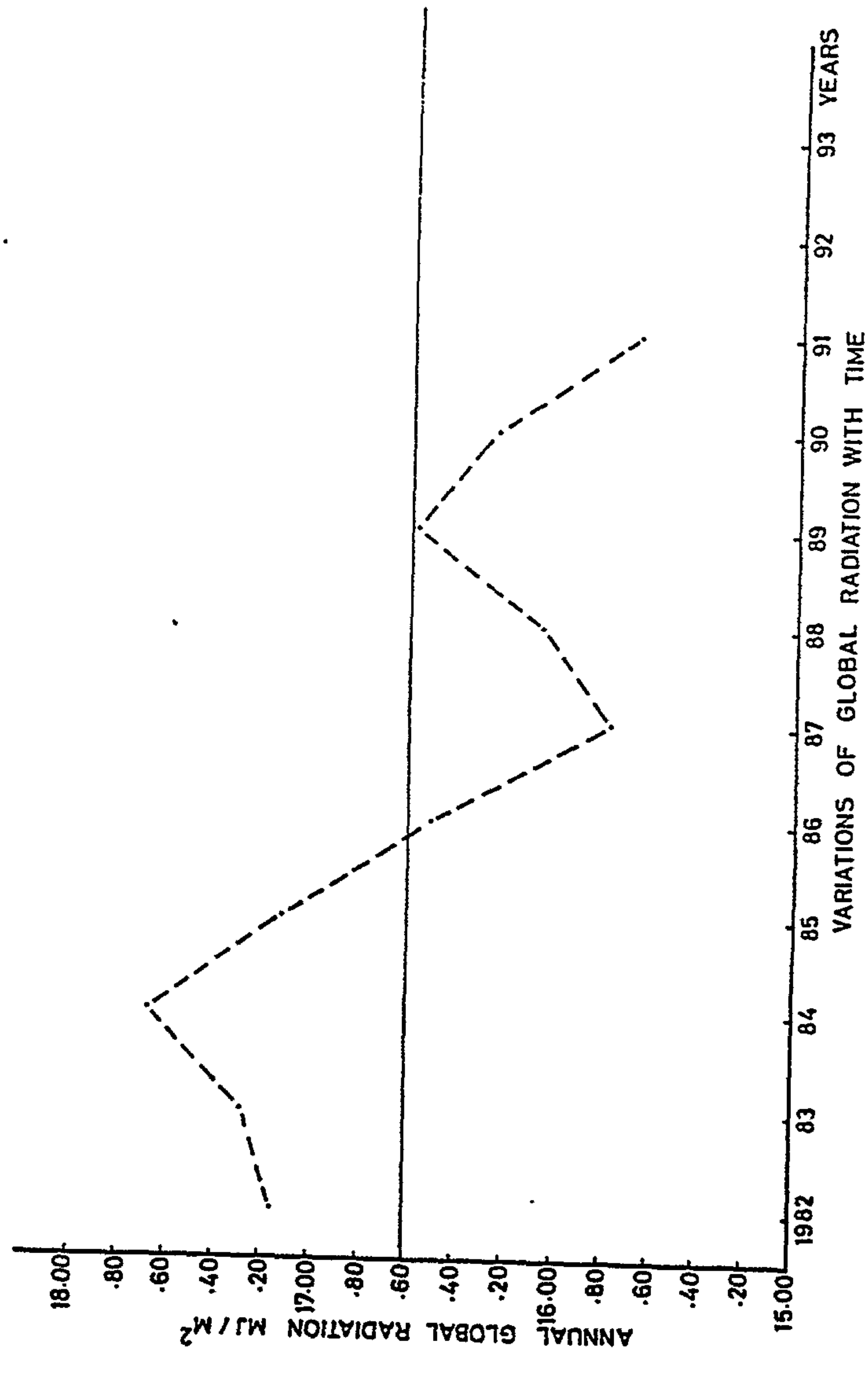

Fig. 65 Global Radiation

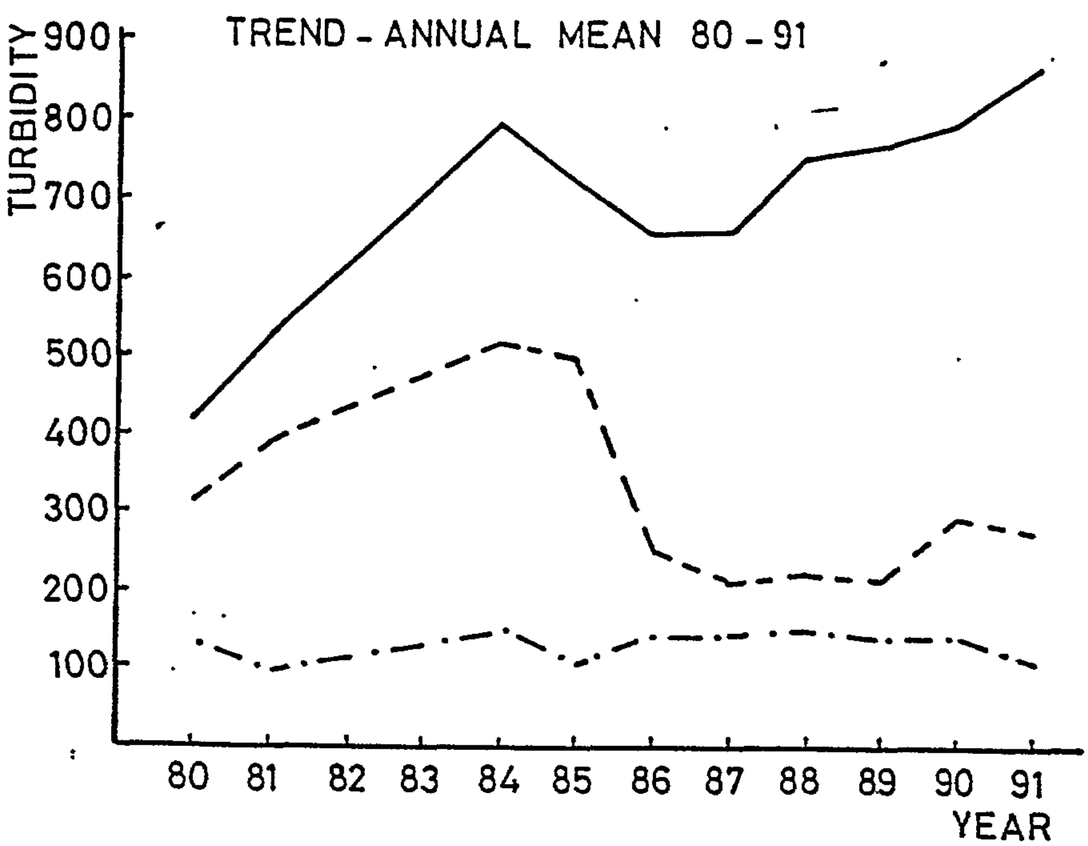

Fig. 66 Turbidity

confidence that we can place in sub-grid scale scenarios of precipitation is particularly low. These scenarios should be considered only as indicators of changes that might occur.

3.1.4 Impact of Climate Change

On the other hand, from the viewpoint of general atmospheric circulation, our area, as well as the area between 23°N and 30°N are all located more or less under the influence of the so called subtropical high pressure system, where the air almost permanently is in subsiding motion, thereby preventing rain mechanisms from operating. In areas marginal to the deserts, such mechanisms do occasionally operate and semi-arid conditions are hereby created. It is important, however, to separate the rain mechanisms operating on the high latitude margins of the arid regions from those which operate in low latitude marginal lands. The marginal lands on the high latitude side are bordering on Mediterranean climate with winter rainfall associated with the temperature latitude westerlies and varying with fluctuations in the temperature latitude winter circulation. In semi-arid lands marginal to the deserts on the low latitude side, rain mechanisms are connected instead with the wanderings of the intertropical convergence zone (ITCZ) or the monsoon circulation. Rainfall is therefore mostly a summer phenomenon in those regions.

It is obvious that agriculture in the semi-arid regions is already marginal and is extremely vulnerable to fluctuations in climate conditions. We must therefore expect global warming to be of particular significance in those areas. On the other hand, as these are already under extremely variable climatic conditions (particularly with respect to rainfall), it is also true that agriculture is often more adaptable to climate change than in many other areas.

As with Mediterranean climates, it is quite possible that these semi-arid areas might become drier, if the subtropical high pressure systems that cause deserts which they border move northwards in the winter season.

With respect to our region, the present data are insufficient to determine whether these changes are trends, or a reflection of longer-term variability.

The predicted decrease in rainfall is smaller than existing spatial and inter-annual variations, thus changes in this parameter are not expected to result in significant overall effects. Moreover, Hassan *et al.* (1991), on their study "On Computation of Climatological Power Spectra", show quite an increase of rainfall to at least the next decade.

If emissions follow a business-as-usual pattern under the IPCC Business as Usual (Scenario A), emissions of greenhouse gases, the average rate of increase of global mean temperature during the next century is estimated to be about 0.3°C per decade (with an uncertainty range of 0.2°C to 0.5°C). This will result in a likely increase in global mean of about 1.5°C above the present value by the year 2030, and 3-5°C above before the end of the next century.

As regards rainfall, the most important climate change would be the northward shift of winter cyclonic patterns affecting the western and central Mediterranean in winter. There might be a decleration of cyclonic activity and more erratic rainfall, drier summers, and higher evapotranspiration.

Climatic zones may shift northward thus increasing the length of summer at the expense of the other seasons. Increased variability and patchiness of rainfall might extend summer aridity.

Relatively small changes in the mean values of rainfall and temperature can have a marked effect on the frequency of extreme levels of available warmth and moisture. For example, the number of very hot days, which can cause damaging heat stress to temperate crops, could increase significantly as a result of 1°C or 2°C increase in the mean annual temperatures. Similarly, reductions in average levels of soil moisture as a result of higher rates of evapotranspiration could increase substantially the number of days with a minimum threshold of water availability for given crops. In addition, relatively small decreases in rainfall or increases in evapotranspiration could markedly increase both the risk and the intensity of drought in currently drought-prone regions.

An important additional effect of warming, is likely to be the reduction of winter chilling (vernalisation). Many temperate crops require a period of low temperatures in winter, to either initiate or accelerate the flowering process. Low vernalisation results in low flower bud initiation and, ultimately reduced yields. A 1°C warming would reduce effective winter chilling by between 10% and 30%, thus contributing to poleward shift of temperate crops.

Predicted rise in temperature is likely to increase personal discomfort of the people and effect refrigeration units which will necessitate the use of more energy to maintain levels of temperature within the buildings.

Expected average temperature rise of 1°C will shorten the season of indoor heating which will spare a defined energy quantity. Ordinary heating season of this area lasts from the beginning of December to mid of April. Also, temperature rise will, however, increase energy demand for air conditioning in summer.

It is worth mentioning the increase of air conditioning energy demand will be considerably lower than that of heat energy demand, which means that the total energy demand will be reduced.

3.2 LITHOSPHERE

3.2.1 General

The coastal zone of the northwestern region is sandy-rocky, with projections of rocks, fine sandy beaches and clear blue water, perpetually washed by the Gibraltar current, feeding from west to east, which makes it very convenient for tourism. It is a remarkable feature of the western regions to have successive bays into its shores. Abu Hashaifa Bay begins at Ras Alam El-Rum and extending eastward. This is succeeded by Ras El-Hekma bay from Ras El-Hekma headland to the east. These coastal capes are formed by rocky projections often a result of local diagonal breaks. It is noted that they decrease in dimensions eastwards.

Fuka-Matrouh coastal zone consists of several small sandy bays which are protected by rocky headlands and as such, constitutes separate littoral transport units. The maximum sediment transport feeding eastward is predicted to be in the order of 17,000 m^3/month.

No significant changes in the Fuka-Matrouh shoreline are currently taking place and only a seasonal shoreline migration has been noticed due to winter high waves. Sand dunes surrounding some beaches are stable and subjected only to wind action and movement.

3.2.2 Erosion and Man-Made Structures

Beach erosion is a natural part of beach behaviour and occurs if the supply of sediment to a coastal stretch is inadequate to meet the transport capacity of the littoral drift away from that stretch. Erosion becomes a problem only when it threatens property. The essence of the problem is not that beaches are eroded, but that a development has taken place within the zone of these natural beach movements.

Man-made erosion, on the other hand, is caused by the interference of man with the natural processes that occur in the coastal zone. The following are examples of such man-made erosion along the western coast:

a. Construction of a fishing harbour (Matrouh) that acts as a barrier to the littoral drift or change the gradient of the littoral drift.
b. Construction of groin (touristic villages, Matrouh) that acts as a barrier to the littoral drift.
c. Dredging of navigation channel (Matrouh) that changes the bathymetry.
d. Destruction of reefs which form natural protection of the shoreline against wave attack.

3.2.3 Sea Level Rise

Monitoring long-term changes of the sea level in the Mediterranean indicates that it is areally and temporally variables due to tidal, meteorological and geological factors. Tide gauge data have suggested a tendency to sea level rise varying between 0.3-5.0 mm/year (Pirazzoli, 1989). The relative sea level rise is being due to eustatic sea level rise, natural subsidence and to aquifer dewatering.

The tides along the Mediterranean coast of Egypt are semi-diurnal in nature with two high and two low water levels in a tidal day. Seasonal changes indicate that the major maxima occur in August whereas the major minima occur during April.

Studies combining all the tide gauge measurements along the Nile Delta coast reveal continuing rise in sea level with rates ranging between 1-3 mm/year. El-Fishawi (1993) indicates a rising sea level of 1.2 to 1.3 mm/yr (Fig. 67). Subsidence plays an effective part in increasing sea level. The rate of subsidence may reach 5 mm/year (Stanley, 1988).

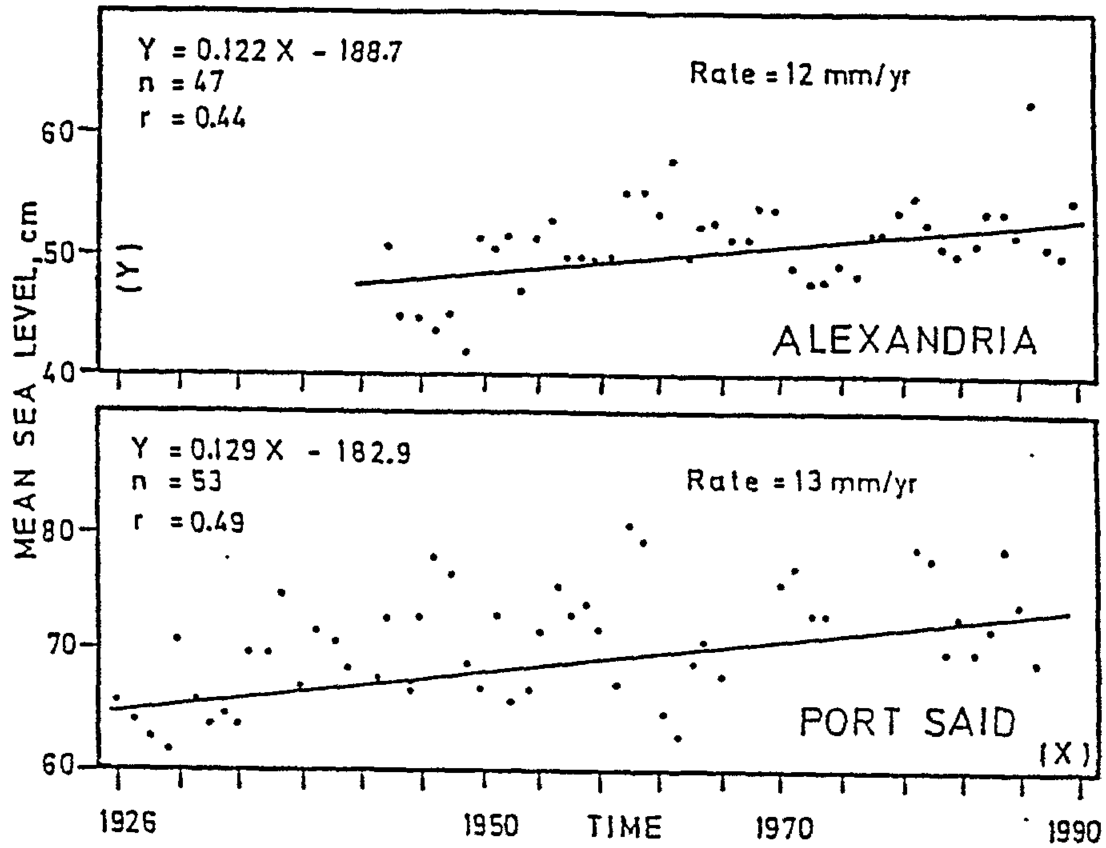

Fig. 67 Sea level rise at Alexandria and Port Said for the period 1926-1990 (after El-Fishawi, 1993)

The rise of the mean sea level in the coming century, due to global warming, would be a substantial acceleration over the local rise that has taken place at the Mediterranean coast of Egypt. Estimation of sea level rise by the year 2100 (El-Fishawi and Fanos, 1989) reveals a rising of 45 cm between 1944 to 2100 at Port Said (Fig. 68). Several scenarios have been suggested to estimate the rate of sea level rise in coming decades. The best-guess scenario, based on Wigley and Raper (1992) appear to be:

16 cm rise in mean sea level rise by 1990-2030
48 cm rise in mean sea level rise by 1990-2100

3.2.4 Impacts of Future Rise in Sea level

The present study reports the result of an ongoing investigation of the potential impacts of rising sea level. The aim is to estimate the impact which a rising sea level may have on coastal morphology, community development, investment in new and existing touristic villages and on the choice and implementation of protective measures.

The geomorphological impacts could be considered as a beginning estimate to the analysis of the effects of rising sea level. Further analysis as required to evaluate the importance of these physical impacts for the economy and society. In fact, an understanding of the potential economic and societal impacts of sea level rise may improve the private and public decisions to avoid losses caused by conditions resulting from sea level rise.

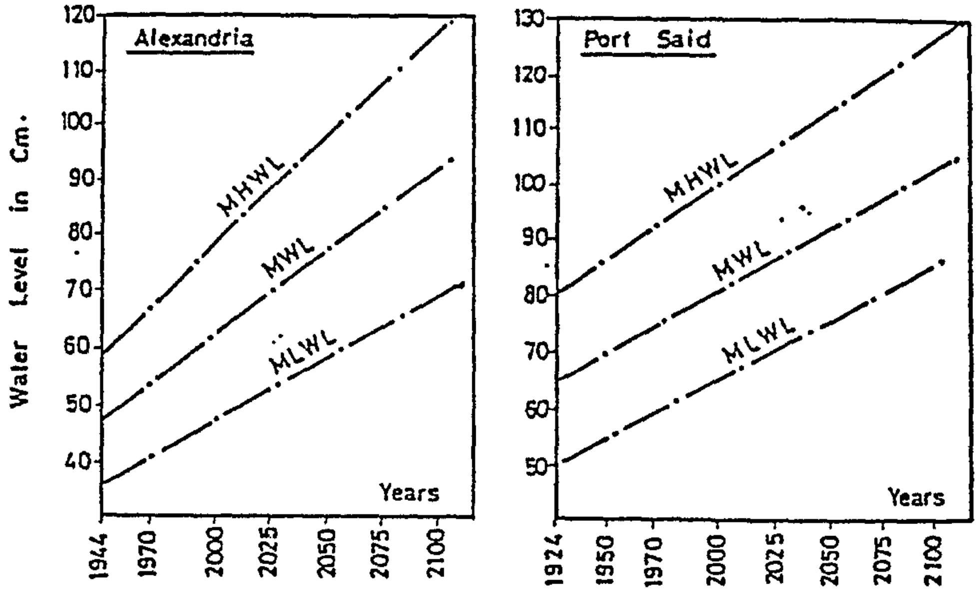

Fig. 68 Estimated sea level rise at Alexandria and Port Said by 2100 (after El-Fishawi and Fanos, 1989)

The development of the northwestern coastal area during the last decade have dramatically increased, making them more sensitive to change with the physical processes that affect the coastal zone. Furthermore, the effect of the greenhouse is a warming of the earth's surface and a consequent rise in sea level. Associated with sea level are the following primary aspects:

a. Shoreline changes due to erosion.
b. Changes in the frequency and depth of flooding from storm surges.
c. Changes in sediment transport rate and sediment balance.
d. Changes in dynamic forces affecting the coast.
e. Changes in offshore bathymetry and sediment texture.
f. Salt water intrusion into soils and surface.

Studying implications to sea level rise require and estimate of coastal area at risk, people at risk and capital values along the coast. In the vulnerability analysis, the low lying zones of the coast are expected to be vulnerable to flooding due to accelerated sea level rise. The coastal zones with high levels can be classified as not susceptible to flooding of the hinterland. Therefore, in order to execute a flood and flood risk analysis of Fuka-Matrouh coast, the following have to be considered (Delft Hydraulics, 1992).

3.2.4.1 Hydraulic Condition Zone

It can be described as a part of the coast which a specific set of hydraulic conditions applies. Assessment of hydraulic conditions provides quantitative information of the potential flooding situation for the coastal zones (Delft Hydraulics, 1992). As the south Mediterranean coast of Egypt can be characterised as a low energy coast with little variance of wave energy and storm surge levels along the coast, the hydraulic conditions can be summarised in a single system along Fuka-Matrouh coast. For each hydraulic condition zone along the Mediterranean coast of Egypt, a unique Initial Water Level Exceedance Frequency Curve (IEFC) applies which describes the exceedance frequency of tide and storm surge levels (Delft Hydraulics, 1992).

Generally, coastal zones are vulnerable to flooding and the flood level is determined by a number of factors:

A. Global hydraulic factors:

The factor which taken into account in the present study is the accelerated sea level rise of 16 cm by 1990-2003 and 48 cm by 1990-2100 (Wigley and Raper, 1992).

B. Regional geophysical factors:

Subsidence and tectonic uplift have to be taken into account. Only subsidence is valid on some Nile Delta coasts and Alexandria region (5.0 - 0.5 mm/yr, Stanley, 1988). Therefore, the rate of subsidence along the northwestern coast can be considered the least rate due to its stability.

C. Local hydraulic factors:

These factors include tide and storm surges.

Simply stated, an Initial water level Exceedance Frequency Curve (IEFC) can be determined along Fuka-Matrouh coast with the following formula:

$$IEFC = MHW + SURGE_{(f)} + SUBS + SLR$$

where MHW = mean high water (0.3 m at Alexandria)

$SURGE_{(f)}$ = water level given a specific storm surge frequency, by a duration of 2-3 days (f > 1/1000 years)

SUBS = subsidence ration of >0.5 mm/yr

SLR = sea level rise of 16 cm/40 yr and 48 cm/110 yr

3.2.4.2 Coastal Impact Zone

It is based on land elevation and should be subdivided into elevation zones, eg., up to +1 m, +1 to 2 m and +2 m to + 3 m. Coastal impact areas can be considered homogenous with respect to risk (flooding). Based on the future hydraulic conditions of the Egyptian Mediterranean coast including an accelerated sea level rise + 3 m forms the upper boundary of the low-lying coastal zone. This 3 m elevation is an estimate, based upon direct effects of accelerated sea level rise and storm surges, and indirect effects such as increased salt water intrusion into soils and surface. It may be also expected that this impact zone (up to 3 m elevation) will be in some way or another affected by an increase of the sea level.

3.2.4.3 Protection Systems

The protection section can be defined as a coastal defence system.

In case of an artificial defence system, the protection status is based on the crest height in combination with the local exceedance frequency curve of the tide, storm surges and wave run-up. The actual safety height of the system determines whether failure of the structure will occur, based on the local hydraulic conditions. In fact, the northwestern coast shows very limited protective works. These works are based on inadequate assessments of their effectiveness and consequently will face greater hazards with future rise in sea level.

In case of a natural defence system (coastal ridges and dunes), the failure mechanism is based on the lowest spot in the ridge or dune crest. By overtopping of the crest, these structures are considered as broken and inundation of the hinterland will occur.

For the areas at risk, it may be safely assumed that cities and touristic villages, which are potentially affected by flooding, have some kind of basic protection. A rough inventory of the lowest spots in the coastal ridge and dune areas along Fuka-Matrouh coast, based on topographic maps and cross sections, leads to the conclusion that these coastal structures are able to resist the present hydraulic conditions. Therefore, ridges and coastal dunes surrounding some coasts could partly stop flooding and damage to these coasts. The average height of the lowest spot is assumed to be between 1 m and 3 m above sea level.

3 2.5 Impacts on Erosion

Shore retreat has become common all over the world, particularly in the last decades and thereby the people are much threatened. Sea level rise has been identified as the principal forcing function in shoreline erosion along the coasts. However, the relationship between sea level rise and shore retreat is rarely one-to-one and must be tempered by a consideration of local factors. Along Fuka-Matrouh coasts, acceleration in beach erosion can be related to the nature of the beach, topography, foreshore and offshore slopes, sediment supply, nature of coastal sediments and affecting dynamic forces. In fact, the rate of erosion along the northwestern coast is still slow and estimated to be 1-3 m/yr. This rate is expected to increase by the year 2020-2090 to be 2-5 m/yr along Matróuh stretch (Delft Hydraulics, 1992)

One of the serious impacts of rising sea level is the accelerated beach erosion in near future. The summary of the destructive effects on shoreline can be briefly stated as erosion of the beach sediment itself, erosion of the protective coastal ridges and dunes and destruction of many houses located on the beach.

The nature of the beach plays an effective part in the rate of erosion. A wide beach which prevents the waves reaching the coastal dune and ridges will form an effective protection to the coast and hence will minimise erosion rate. If the beach is narrow enough to be removed by storm waves, the coastal dunes can be attacked by these waves which are the only ones capable of effective erosion. Therefore, the greater vertical extent of some Fuka-Matrouh beaches would afford a relative protection to these coasts. At the same time, the character and liability of coasts to erosion varies greatly. Where the shoreline of the studied area is irregular, the attack of the rising sea level will tend to be concentrated on the headlands (Ras El-Hikma, Ras Bakshuba and Ras Alam El-Room). This is partly due to the concentration of wave energy on the headlands by the refraction.

Rocky coasts vary in their degree of lithification and structure and therefore also show varying response to erosion. The local characteristics, including wave climate and rock type and structure, are the controlling variables. The only broad statement worth making is that rocky shorelines are likely to retreat less quickly than sandy ones for the same set of dynamic forces affecting the coast. The carbonate rocky ridges of the studied coast play an important part in controlling erosion during sea level rise.

Beach protective works (very rare, sometimes jetties) have been executed but all of them have not been rationally planned and designed. These structures will interfere with the movement of sediments and hence erosion will occur on the down-drift side.

The offshore relief is important in a consideration of coastal erosion. The effect of offshore relief on wave refraction may explain the concentration of wave energy at particular places, with subsequent variation in erosion along the coast. The wide deep continental shelf of the study area will render waves more erosion than where the water is shallow close offshore. Changes in offshore relief near the beach may be important in determining the location of areas suffering from erosion.

A rising sea level will deepen the water offshore, allowing waves to break closer offshore. It will increase their erosive capacity, hence leading to an acceleration of coast erosion in areas already affected, and perhaps starting it in areas previously immune.

The movement of sediments alongshore is partly responsible for coastal erosion. Coast erosion is most likely to take place where more sediment is moved alongshore out of the stretch than is being moved into it from the up-drift direction. The coast with a smooth outline is also liable to erosion because there is no obstruction to hold up the movement of sediments along the beach.

With rising sea level, it will be a general tendency for the fine-grained of the coastal sediments to move offshore, leaving the coarser grains on the beach. In contrast, the eroded beaches of the central part of the Nile Delta coast are finer-grained and better sorted than the accreted ones. These accreted beaches indicate a transport of coarser grains from some outside sources (El-Fishawi, 1977).

Sea level rise will bring a decrease in wave height due to increased water depth. As a result, the waves will relatively be steeper. These steeper waves are normally destructive, lowering the level of the foreshore surface and transporting sediments seaward. The larger the waves are, the greater will be the removal of sediments from the beach because of their greater energy. Destructive waves are normally associated with storms and high wind velocities. Strong winds, blowing onshore near the coast, generate steep waves. The wind itself has a marked effect on the destructive nature of the wave attack A strong onshore wind may also assist the destructive tendency of the waves by raising the water level above its normal height, and thus the sea can attack zones normally beyond its reach. Strong winds and the rapid changes in the atmospheric pressure associated with them can generate surges in some coasts

3.2.6 Impacts on Flooding

Coastal flooding is expected to increase due to future rise in sea level. Furthermore, flooding from storm surge is likely to increase, this is because the base level on which the surge will build is going to be higher. Sea level rise could increase the risk of flooding in the following ways:

a. There would be a higher base upon which storm surges would build. Surges would also penetrate further inland.

b. Beaches and sand dunes currently protected many areas from direct wave attack; by removing these protective barriers, flooding and erosion from sea level rise would leave some areas along coasts more vulnerable.

c. Wetlands and Sabbha along some coasts slow the penetration of flood water by blocking the waves; losses of these wetlands would thus increase coastal flooding and salinity.

d. Sea level rise could also increase flooding from rain storms.

In fact, along Fuka-Matrouh coast, lowlying lands, wetlands and Sabbha at some local zones (up to + 1 m elevation) are expected to increase flooding with rising sea level and surge effect.

Storm frequency and magnitude are important because the bulk of flooding and erosion will take place during storm events, following an increase of sea level rise. Therefore, a shoreline that experiences more storms of a higher frequency and magnitude will adjust to the new sea level position more rapidly than another with lower frequency storm occurrence. In the later case, there may be a longer lag-time between sea level rise and shoreline retreat, and the rate of erosion may therefore be less (EPA, 1983).

3.2.7 Impacts on Sediment Transport

Shoreline development can be determined as a function of time for any given sea level rise. It is expressed in m^3 shoreline retreat or advance, m^2 of beach area and m^3 of sediment lost or gained for any given stretch.

The following sediment transport rates across the boundary of Fuka-Matrouh stretch could be defined:

T^{in} = rate of longshore transport into the stretch
T^{out} = rate of longshore transport out of the stretch
T^{w} = rate of wind transport out of the stretch
T^{off} = rate of transport to deep offshore, out of the stretch
T^{n} = rate of artificial beach nourishment into the stretch

Combining all rates of sediment transport which are lost and gained by the stretch, yields the sediment balance (Delft Hydraulics, 1992) which determines the rate of recession of the stretch:

$$E = (T^{out} - T^{in} - T^{w} - T^{off} - T^{n} + WSL)/LH$$

where E = rate of recession
W = geomorphologically active width
L = length of the stretch
H = geomorphologically active height

Integration since the beginning of the period considered (t = 0) leads to the total recession of the coast at the end of period (t) as follows:

$$F = \int_0^t E dt$$

The longshore transport rate along Fuka-Matrouh coast is predicted to be small in ordinary conditions (8,400 m^3/yr) and not exceed 204,000 m^3/yr for vigorous conditions. On the other hand, it is very high along unstable stretches of the Nile Delta coast where it ranges between 0.6 - 3.6 x 10^6 m^3/yr. Sediment transport by wind action at the western coast of Alexandria do not exceed 4,100 m^3/yr. Taking into consideration the source of the coastal sediments from the western cliffs and the gained wind blown sand from the desert, it can be assumed that the sediment balance of Fuka-Matrouh coast could be in equilibrium with future rise in sea level.

3.2.8 Impacts on Offshore Bathymetry and Sediments

Due to rising sea level, increased depth of sea water will alter the hydrodynamic forces affecting sea bottom and possibly have structural implications. Changes in offshore bathymetry resulting from sea level rise could alter wave refraction patterns and direction of bottom currents and magnitude.

Elevation of sea level by an increment creates a gap at the sediment surface which represents a disturbance in the profile of dynamic equilibrium that had been established under previous sea level position. The gap has to be filled, and this will take place by removal of foreshore sediment to the offshore area, resulting in shore face retreat and landward advance of the water line (Fig. 69). Additionally, overtopping of the beach during storms, which build on a higher base level after sea level rise, transfers sediment in the landward direction, adding to the processes of shore migration.

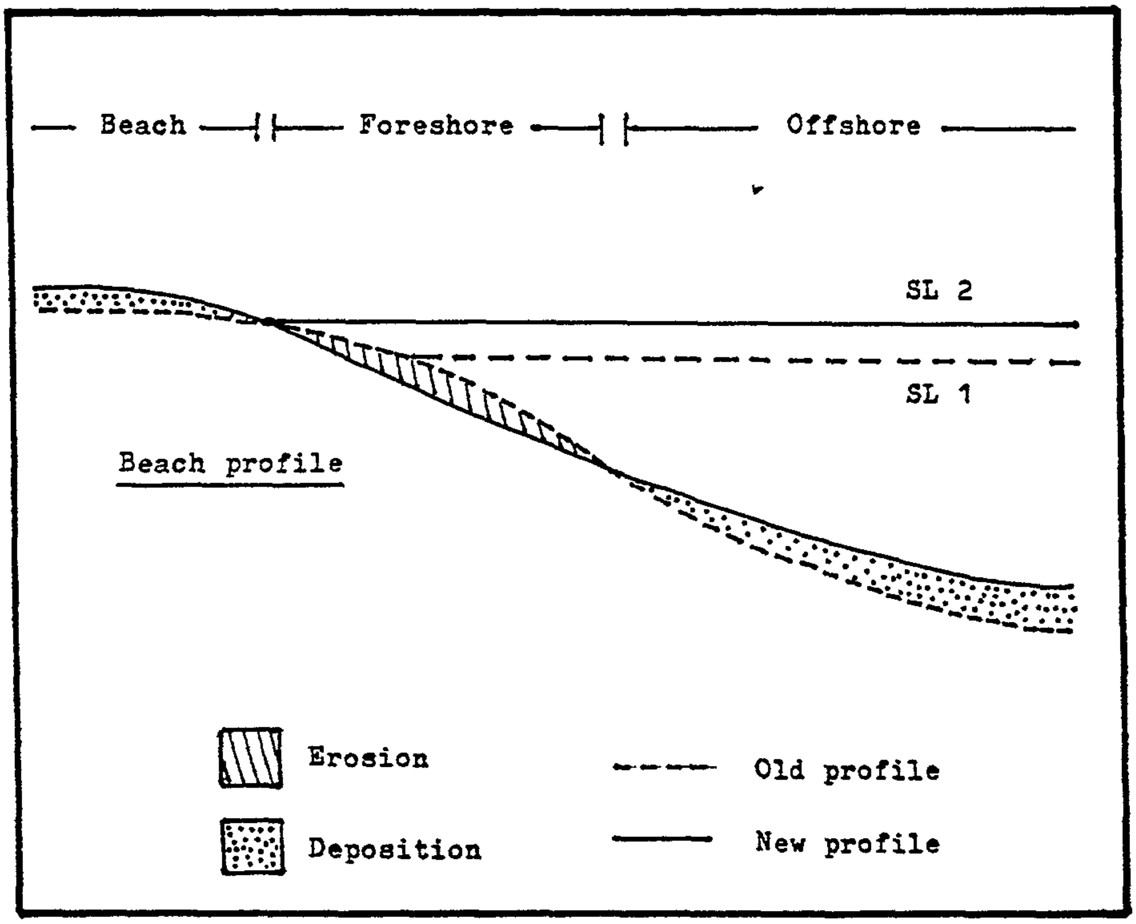

Fig. 69 The effect of sea level rise on bottom sediments

Due to higher wave action, as a consequence of rising sea level, the sediments of the steeper beach face, especially fine sediments will move downshore. As a result, there will be a major reduction in the percentage of fine-grained sediment load along the coast. The percentage of fine and very fine sediments along Fuka-Matrouh coast ranges between 18% and 48% and it is expected to decrease in beach sediments with rising sea level. At the same time, coarse-grained sediments are expected to increase (>12%).

3.2.9 Impacts on Dynamic Forces

Sea level rise and climate change would cause substantial impacts on dynamic forces affecting the coast (winds, storms, waves, current and tides). It is known that the magnitude of the wind setup contribution to the storm surge is inversely proportioned to the water depth. Mercado (1884) gives a simple equation relating to the change in maximum surge height with sea level rise:

$$\Delta\eta\max = \left(\frac{-\eta\max/h_o}{1+\eta\max/h_o}\right)S$$

where	$\Delta\eta$ max	=	change in maximum surge height
	h_o	=	depth of shelf
	η max	=	wind stress surge
	S	=	magnitude of sea level rise

Mercado (1989) discussed the effect of sea level rise on storm wave by using models. A rising sea level, due to increased depths, will result in less wave damping and higher wave energy at the shoreline. Also wave generation is bound to be increased: given a water depth of 10 m, a shelf width of 10 km, a wave period of a 8 sec., an initial wave height of 2 m, a friction coefficient of 0.01, then a sea level rise of 1 m will bring about a 3 % increase in wave height due to increased water depth. Under the same conditions, wind-generated wave heights can increase by 7.5%. As a first approximation, these two increase can be linearly combined. Hence one should expect larger wave heights near the shoreline.

Longshore current is also expected to be faster due to the effect of larger wave heights along the coast as a result of increased water depths. Wind driven current and wave induced current would predominate inside the foreshore zone.

Sea level rise could change tidal ranges by removing barriers to tidal currents and by changing the resonance frequencies of tidal basins. If the sea level rise inundates wetlands or erodes the ends of barrier islands, more water may flow into and out and thereby increase tidal range. A greater tidal range would increase the inundation of dryland, while increasing of intertidal wetlands. Tidal currents would also cause additional erosion by sand washing along the coast.

The coastal geomorphology of the Fuka-Matrouh stretch, with the presence of extremely deep water just offshore and relatively steep slopes of the coastal land, further diminishes the effect of sea level rise in storm surges as far as the direct effects it might have from changing depth values (bathymetry) on storm surge heights.

3.2.10 Impacts on Coastal Zone and Morphology

The coastal zone of the western regions consists of two distinct sections. The eastern 100 km section is a low area with wide sandy beaches, sand dunes and marshland further inland in certain areas. Further westward, the landscape becomes more uneven with several headlands protruding from the coast creating stable sandy beaches in between. The western half of the area is dominated by a rocky plateau extending from the hinterland to the coastline, characterised by several headlands. In between are small coves with sandy beaches.

Therefore, due to sea level rise, the eastern part will be subjected to coastal erosion and flooding of backshore area and depressions, whereas slight impacts are expected to take place at the western part owing to its morphology. It is important to mention that the coastal ridges surrounding the coast at some stretches will partly play an effective role in stopping flooding and damage to the coast.

The retreat of the beach-dune zone of Fuka-Matrouh coast essentially depends on the persistence of an adequate supply of sediments from cliff erosion and littoral drift from the western to the eastern area. If the littoral drift is insufficient, the dune obliterated and sediments removed seawards. Thus, the coastal erosion is accelerated and the breaching of beach-dune ridges by storm waves and the breakup of barrier islands could become more frequent. Equally, man-made structures and subsidence would worsen the often already precarious situation. Serious impact of sea level rise would be expected in small bays and narrow coastal plains where sediments move in a closed system with a scarce supply. The coastal lagoons and depressions would migrate landwards if the rate of sea level rise becomes low.

A consequence of rising sea level in coming decades would also be a much increased statistical recurrence of extreme events like severe storms and high tides. Therefore, acceleration in sea level rise would result in flooding of the coastal zones.

Small pocket beaches and small bays along Fuka-Matrouh coast will be the first to experience the impact of a gradual rise in sea level. It would reinforce erosion cycles so that the enclosed small sandy strips and bays might gradually be covered by rising sea level.

Barrier islands are dominated on some coasts along Fuka, Ras El-Hekma, Ras Alam El-Rum and Matrouh. They are narrow strips of detrital sediments rising above sea level. The instability and breakup of these barriers could become more frequent in coming decades due to sea level rise. Beaches in front of barrier islands could be subjected to accelerated erosion if the sea water covered the barrier island and thus the waves would directly attack the shore.

As a result of flooding of some coastal zones, inter-dune areas and inter-ridge depressions may suffer slight subsidence with future rise in sea level.

Low sandy coasts at the western side of Ras El-Hekma that are shaped by marine processes have the capacity to reform themselves after severe storms and to rise in phase with the average rise of sea level by gradual migrating landwards.

Calculations made in the coastal stretch of Fuka and westward region show the percentage of occurrence of slope classes, geological and geomorphological units (Tables 47-49). The most important zones which would be affected by future rise in sea level are slope class of 0-2 m and beach deposits Slope class area ranging between 0-2 m high above sea level represents the largest area at the coastal zone. It constitutes about 91% from the elevated plain and amounting about 132 km^2. Supposing an equal gradient slope is occurred within the 0-2 m slope class, estimates have suggested an area of about 11 km^2 to be affected by a sea level rise of 16 cm by 2030 and an area of 33 km^2 with sea level rise of 50 cm by 2100 As related to Tables 48 and 49, beach deposits, salt marshes and some alluvial deposits would be vulnerable to rise in sea level. Restricted coastal areas are expected to be eroded at Ras Alam El-Rum and Matrouh.

Table 47

Slope Classes Areas and % of occurrence Fuka Area (after Ramadan, 1992)

Slope Class	%	Area, km^2
0-2 m	90.97	131.95
2-4 m	6.94	10.07
4-8 m	1.57	2.28
8-12 m	0.51	0.74

3.2.11 Impacts on Coastal Touristic Villages

Recently, the rapidly tourist enterprises have established a more intensive use of the northwestern coast. This has affected its stability and rendered it more vulnerable to changes in sea level such as those that could be induced by global changes.

Table 48

Areas and Percentage of Geographical Units at Fuka Area (after Ramadan, 1992)

Age and type	%	km²
1. Quaternary		
a. Recent:		
- Beach deposits	2.52	3.70
- Salt marsh	0.33	0.49
- Alluvial deposits	62.13	91.17
b. Pleistocene:		
- Consolidated limestone ridge	7.91	11.60
- Consolidated limestone	7.54	11.07
2. Tertiary		
- Miocene limestone	19.56	28.70

Table 49

Areas and Percentage of Geomorphological Units at Fuka Area, Coastal Plain (after Ramadan, 1992)

Coastal Plain	%	km²
Low coastal plain:		
- beach deposits	2.00	2.89
- salt marsh	0.56	0.66
- alluvial deposits	9.37	13.50
- lagoonal depression	11.52	16.60
Elevated coastal plain:		
- rocky plain	60.20	86.70
- isolated hills	1.74	2.50
- first ridge	2.76	3.98
- dissected land	10.84	15.61
- ridge escarpment	1.11	1.60

Marakia, Marina, Marabella touristic villages, El-Allamein, Sidi Abdel Rahman, El-Hamra harbour, El-Dabbaa, the entrance to Qattara depression, Ras El-Hekma, Fuka, Bagoush, Matrouh and Sallum cities are the main cities and sites lying along the western coast of Egypt. Buildings of many touristic villages are located at a critical distance from the shoreline. Moreover, the coastal protective works at some of these villages are being based on inadequate assessments of their effectiveness and consequently would face greater hazards in future. This serious situation has appeared during the last decade because the existing legislation is not respected. Under accelerated sea level rise, damage of the shoreline buildings at many touristic villages, due to attack of sea waves, may become a serious problem.

Matrouh city lies at Matrouh Bay which is about 3 km wide and is connected to a shallow lagoon in the west. Many touristic places are located on the bay as well as on the sea shore at some 10-30 km to east and west. Lately, a slight erosion has occurred in the swimming beach of the Beausite Hotel, caused by the dredging of the navigation channel inside the bay, since the latest is used by the Navy as a refuge harbour. A project is under execution to protect this area. The project consists of a sand nourishment with construction of a groin at its eastern edge.

A strip of sandy beach is surrounding Matrouh city and is of high touristic importance. Due to the morphology of Matrouh (southern cliffs and low relief beaches), the urban areas are not expected to significant impacts from sea level rise.

Bagoush coast, west of Fuka, consists of sandy beaches and low coastal dunes. With a gradual sea level rise, the shoreline would be migrated landward and the backshore zone would be decreased in area, without change in coastal dune zone.

3.2.12 Area at Risk

In order to calculate the areas at risk in the various coastal impact zones, an assumption has to be made of the correlation of the exceedance frequency of the hydraulic condition and the area distribution over the impact sections (Delft Hydraulics, 1992). Suppose that near a zone of interest the sea level exceeds a level of 0.4 m once every 100 years ($F_{04} = 0.01\ y^{-1}$), and that the exceedance frequency of a level of 1.0 m is once every 1000 years ($F_{10} = 0.001\ y^{-1}$). Suppose further that between the levels corresponding with F_3 and F_4, the area is 1000 km^2. If the hole area has an elevation of approximately 0.4 m, the average area at risk per year (AAR) would be equal to $AAR_{04,10}$ = 10 km^2/yr (1/100 x 1000 km^2). On the other hand if the area has an elevation of approximately 1.0 m, the result would be $AAR_{04,10}$ = 1 km^2/yr (1/1000 x 1000 km^2). In general, the average area at risk per year will lie somewhere in between these two limits.

Following the same notations above, it is assumed that the exceedance frequency for level h_i is given by F_i and for level h_j by F_j. The number of people living between these levels is POP_{ij}. Let POP(F) denote the total population living below the level with exceedance frequency F, so:

$$POP = \int_{Fi}^{Fj} * \frac{dPOP(F)}{df}\, df$$

If POP (F) as a function of F is known, then the average number of people at risk per year can be computed as:

$$P_aR_{ij} = \int_{Fi}^{Fj} * \frac{dPOP(F)}{df}\, df$$

By inserting the values (per km^2) and the frequencies exceedance in decades with each coastal impact area and/or coastal elevation zone, an estimate of flooding and flood risk can be calculated (Pennekamp *et al.*, 1992) with a simple equation as follows:

$$P_aR_{ij} = \frac{9F_i}{\log(F_j / F_i)} * POP_{ij} = 3.9\ F_i\ POP_{ij}$$

3.2.13 Cost Aspects

Vulnerability assessment to future rise of sea level along the Egyptian coasts is carried out by Delft Hydraulics (1992). Values of lost land and costs of beach nourishment are estimated. In the present study, some stretches are selected to concern the northwestern coast, these stretches are Matrouh (includes Fuka), Allamein and Alexandria. The cases consist of a combination of:

a. Accelerated scenario for sea level rise of 1 m/100 yr.
b. Time horizon considered : 30 yr (2020) and 100 yr (2090).
c. With or without socio-economic development.

Table 50 illustrates the cost aspects; beach losses and cost assessment nourishment due to rising sea level as simplified from Delft Hydraulics (1992). As an estimation, the shoreline of Fuka-Matrouh would be retreated between -2 to -5 km^2 by the year 2020 and 2090, respectively. Therefore, the capital losses due to beach retreat range between 78 and 261 MEE without socio-economic development and found between 454 and 1512 MEE with socio-economic development by the year 2020 and 2090, respectively At the same time, the costs for beach nourishment (full measures) are expected to be 185 and 615 MEE for the same two periods.

Table 50

Beach losses and cost assessment nourishment due to sea level rise
(simplified from Delft Hydraulics, 1992)

A. Beach losses without socio-economic development

Stretch	Beach Length (km)	Shoreline Deviation (Km^2)		Capital Losses (beach retreat) (MEE)	
		2020	2090	2020	2090
Matrouh	123	-2	-5	78	261
Allamein	93	-1	-3	170	568
Alexandria	63	-4	-12	539	1795

B. Beach losses with socio-economic development

Stretch	Beach Length (km)	Shoreline Deviation (Km^2)		Capital Losses (beach retreat) (MEE)	
		2020	2090	2020	2090
Matrouh	123	-2	-5	454	1512
Allamein	93	-1	-3	644	2148
Alexandria	63	-4	-12	810	2700

C. Cost assessment nourishment (full measures)

Stretch	2020 (MEE)	2090 (MEE)
Matrouh	185	615
Allamein	165	549
Alexandria	734	2446

3.2.14 *Impact on soil*

Due to the low organic matter content in the different soil types existed in the studied area besides high $CaCO_3$ content and low soil moisture the 1-2°C increase of temperature is not expected to affect the decomposition of organic matter. Increase of air temperature will change the soil thermal regime. Soil thermal regime studies at El Omayed and El-Gharbaneat on the Northern coast noted that Van Wijk equation succeeded to predict the soil temperature if soil thermal diffusivity could be determined with good accuracy and quantitative evaluation could be determined for implication of increasing temperature (Mokanie, 1978)

Soil erosion is expected to increase as a result of the climatic changes. Higher temperature will reduce soil moisture content and the drier soil will be affected by wind and or water runoff. Sediments locals is expected to increase. Soil fertility and also salinity are expected to increase as a consequence of the anticipated temperature rise.

Soil of nearest depression from the sea shore as well as the soil of fans at the end of the wadis are expected to salinize due to sea level rise and increasing evaporation and evapotranspiration.

3 2 15 Summary

The western coast of Egypt is an example of a coastal plain zone still not entirely developed well. Therefore, topographic and anthropic versus sea level rise impacts could be very slight. The reason may be related to the topographic-sediment conditions of the coast and to lack of intensive occupation in parts that would be subjected to sea level rise and extreme events. The degree of vulnerability therefore depends on the following main factors which shape the coast during coming decades:

a. Sea level rise: a sea level rise of about 50 cm could cause the calcareous sandy beaches to migrate landward, reclaimed low-lands at west of Alexandria could be flooded. Marinas, harbours and shoreline roads would require major restructuring.

b. Sediment balance: the maximum sediment drift rate along the coast of Fuka-Matrouh (0.20×10^6 m^3/year) is still enough to maintain the shoreline. Generally, the sediment supply is from the western side due to cliff erosion. Slight change may affect the sediment balance in coming decades.

c. Subsidence and tectonic movement: no major true tectonic movement are recognised along the coast. It is reasonable to assume that only the eastern part of the ridges, those close to the Nile Delta, have suffered some displacement as a result of subsidence of the deltaic body. Therefore, the western coast could be only slightly affected with sea level rise.

3.3 HYDROSPHERE

3.3.1 Expected Climatic Changes

According to UEA scenarios for the studied area the changes for time horizons 2030 and 2100 are as given in item 1.3.

The parameters of the climatic changes would have quantitative and qualitative implications for the water balance in Fuka-Matrouh area. Water resources in the area are storages in the hydrological system of the area. Fig. 70 represents the simple system diagram of the hydrological cycle at the studied area after Lewin, 1975.

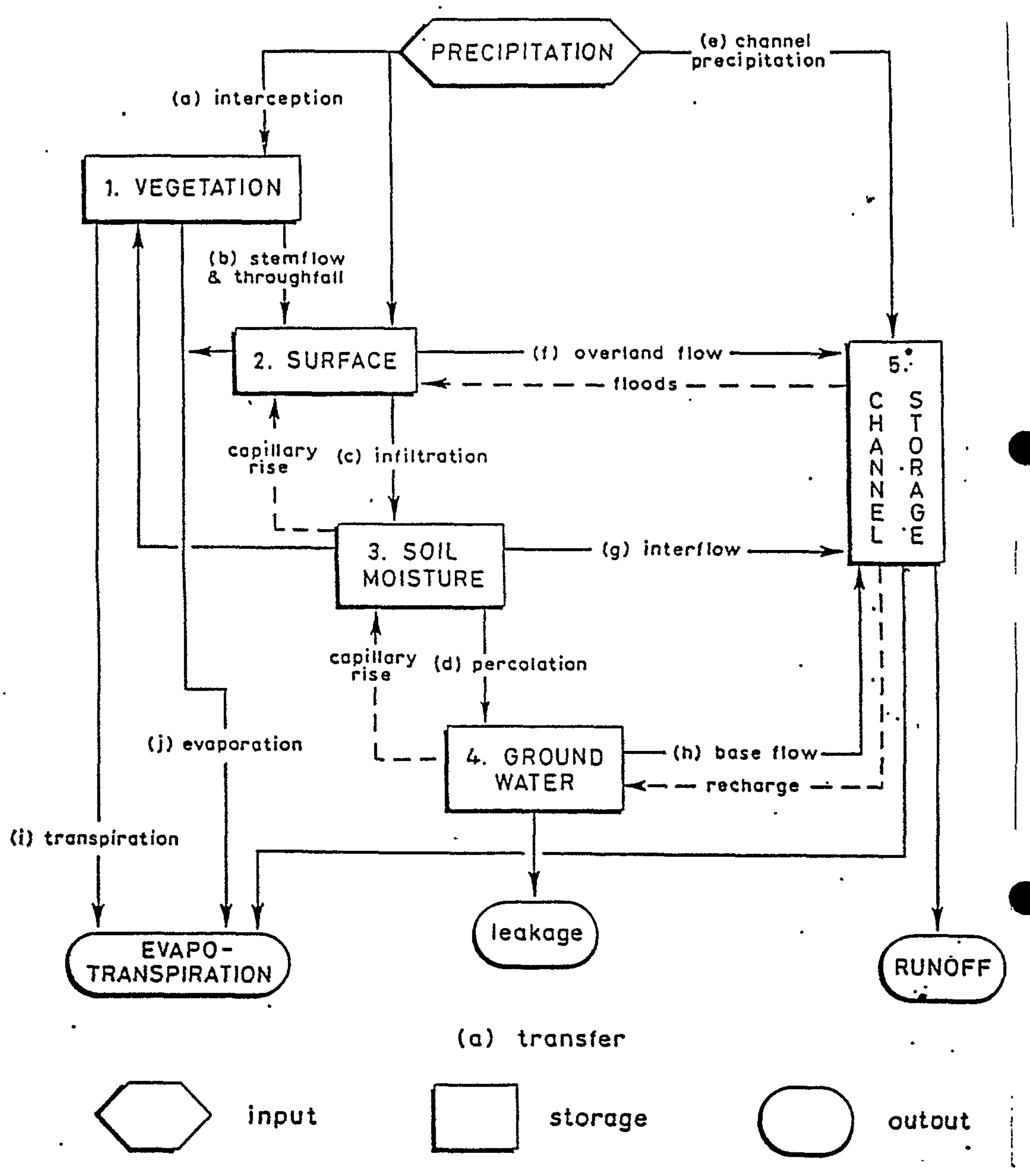

Fig. 70 Hydrological cycle at a local scale (after Ward, 1975)

At watershed scale the system normally has single inputs, evapotranspiration and runoff.

The expected climatic changes directly and indirectly affect the input and output elements of water balance. These climatic changes would have quantitative and qualitative implications. The need to quantify climate change implications and hydrological processes is still more pressing in view of the fact that in the studied area, water availability is only marginally adequate to meet basic human needs (about 100 m^3 per inhabitant after Enable's 1982). A modified and verified simulation models evaluate the local hydrological impacts of climate changes is needed. An example of such models is the water balance equation suggested by Sokolov and Hapman, 1974.

$$P = Q + E \quad \ldots\ldots (1)$$

where

P = precipitation
Q = runoff
E = evapotranspiration

This equation, of course can be subdivided to depict partial processes. Several water balance models can be used to assess the consequences of the global change impact on hydrological system. Salt water intrusion due to climatic changes could be simulated also by so called Hurbberts formula (Jeftic and others 1992).

$$Z = \alpha(hf - hs) - hs \quad \ldots\ldots (2)$$

where

Z = depth of the interface below mean sea level
$\alpha = \sqrt{f}\,(\sqrt{s} - \sqrt{f}) = 40$
hf = fresh water head (water-table elevation over mean sea level)
hs = salt water head

Gleick (1986, 1987 a, 1987 b cited from Jeftic and others, 1992) points out that once the region has been characterised in terms of water balances, the effects of climatic changes can be evaluated in three ways, namely:

a. After having verified the accuracy of the model by using long term historical data it should be possible to use this data to evaluate the effects of historical fluctuations in precipitation and temperatures on historical runoff and soil moisture.

b. After determining the sensitivity of runoff and soil moisture to theoretical changes in the magnitude and temporal distribution of precipitation and temperature, a wide range of hypothetical climatic changes can be assessed to evaluate the hydrological sensitivity of the water shed.

c. By incorporating even rough, regional desegregated changes in temperature and precipitation predicted by General Circulation Models, a first estimate can be made of the impacts of future predicted climatic change on regional hydrology.

The study of Wigky and Jones, 1985 (Jeftic and others, 1992) on the hydrological cycle response to changes in precipitation from Po to P1 due to a doubling of atmospheric CO_2 by

$$P1 = a\,Po \quad \ldots\ldots (3)$$

where a indicates change in evapotranspiration as shown in Fig. 71. The authors claim that runoff is more sensitive to precipitation changes than to evapotranspiration changes particularly for higher values of the runoff coefficient. They also state that precipitation changes have an amplifying effect on runoff.

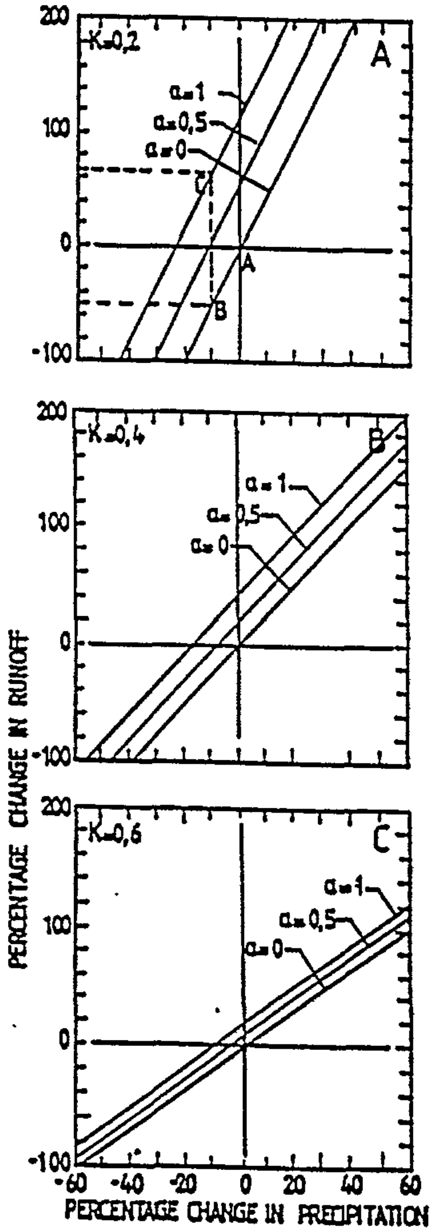

Fig. 71 Runoff changes are due to changes in precipitation (P) and evapotranspiration (E)
a = corresponds to no change in E
a = corresponds to 30% reduction in E
(maximum direct CO_2 effect)
Three values of runoff coefficient K are shown
Precipitation change alone is determined by a=0
Thus, the line AB shows the effect of a 10% reduction in P
The line BCV corresponds to a range of E reduction from 0% (point B) to 30% (point C)
(From Wigley and Jones, 1985, after Jeftic *et al.*, 1992)

3.3.2 Potential Evapotranspiration

$$ETO = \frac{\Delta}{\gamma} [0.95\ RA\ (0.16 + 0.62\frac{n}{N}) - OT^4\ (0.56 - 0.079\ \sqrt{ed})$$
$$(0.1 + 0.9\frac{n}{N})] + 0.26\ (ea - ed)\ (1.0 + 0.54)\ /\ \frac{\Delta}{\gamma} + 1\ ......(4)$$

Evaporation from water surface.

$$ETO = \frac{\Delta}{\gamma} [0.76\ RA\ (0.16 + 0.62\frac{n}{N}) - OT^4\ (0.56 - 0.079\ \sqrt{ed})$$
$$(0.1 + 0.9\frac{n}{N})] + 0.26\ (ea - ed)\ (0.5 + 0.54)\ /\ \frac{\Delta}{\gamma} + 1\ ......(5)$$

Table 51 shows the changes in potential evapotranspiration calculated by both above mentioned equations due to the expected increase in one degree C in air temperature.

Table 51

Changes in potential evapotranspiration (mm/day) and evaporation due to expected increase of one degree (in air temperature at Fuka-Matrouh area) applying Modified Penman using Mersa-Matrouh Meteological station normals

Month	Potential evapotranspiration (mm/day)			Evaporation (mm/day)		
	Normal	Expected	Change	Normal	Expected	Change
Jan	2.01	2.26	12.44	2.32	2.54	9.48
Feb	2.67	2.94	10 11	3.12	3.35	7.37
March	3.57	3.85	7.84	4.15	4.42	6.51
April	4.63	4.94	6.70	5.40	5.71	5.74
May	5.27	5.57	5.69	6.36	6.64	4.40
June	6.15	6.47	5.20	7.41	7.72	4.18
July	6.40	6.71	4.84	7.77	8.05	3.60
August	5.84	6.14	5.14	7.05	7.32	3.83
Sept.	4.99	5.24	5.01	6.00	6.21	3.50
Oct.	3.65	3.90	6.85	4.31	4.54	5.34
Nov.	2.54	2.77	9.06	2.98	3.18	6.71
Dec.	2.04	2.26	10.78	2.27	2.47	8.81
Mean	4.15	4.42	7.47	4.93	5.18	5.79

3.3.3 Impacts on water resources

Rainfall is the main source of surface and ground water resources. The most important climatic change would be that area of low rainfall might increase and shift northward. The magnitude of the decrease of rainfall according to the UEA scenarios for time horizon 2030 is very low and represents only 4% of the annual average rainfall (140 mm/day). The contribution of this small amount in runoff is about - 0.56 mm/year. which is non sensible. The decrease in rainfall for time horizon 2100 may affect the runoff. Low rainfall also would cause reduced ground water recharge and therefore less thickness of fresh water layer in the phreatic ground water aquifers in the studied area. The total amount of stored water runoff in the existing cisterns will decrease and the amount of drinking water will not be sufficient for people and animals.

As shown in Table 51 potential evapotranspiration will rise by 5-12.5% if the temperature increases one degree C. For time horizon 2100 potential evapotranspiration will rise by at least 10%. Despite an increased need for supplemental irrigation water, the average storage in the reservoirs will fall by up to 25% due to the decreased runoff and rainfall and increased evapotranspiration according to Jeftic (1992). Reduction of rainfall and increase of actual evapotranspiration during the summer period might cause deficiency in soil moisture and consequently a decrease in crop production is expected. More pumping of ground water of low recharge due to low rainfall will increase salinity and sea water intrusion Sea level rise for time horizons 2030 and 2100 as a sensible impact on the phreatic ground water aquifer result in increased sea - water intrusion and advance brackish water front. This will be particularly intense in galleries where salinisation of ground water is already occurring and will appear in other wells.

3.4 NATURAL ECOSYSTEMS

Since the paucity of knowledge on the natural ecosystems of the area, especially on a time series basis does not help in the synthesis of a quantitative estimation of the impacts of anticipated climatic changes, only the qualitative estimation of the impact will be discussed.

In addition to the serious degradation of the sand dunes in the area due to the expanding touristic resorts and villages, the expected sea level rise coupled with storm surges would adversely affect them.

The coastal lagoons at Matrouh and Ras Hawala may extend and transfer into bays.

Due to the rise in annual temperature (0.7-0.8°C in the year 2030 and 2-2.3°C in the year 2100, Guo *et al.*, 1993) and the decrease in annual precipitation (up to 4% in the year 2030 and up to 10% in the year 2100, Guo *et al.*, 1993), the natural flora of the inland may shift northward. Due to the sea level rise, the interdunal depressions may increase and may substitute a vast area of the inter-dunal and the alluvial plains. Consequently, the flora of the present inter-dunal depression may expand in these areas on the expense of the original endemic flora.

The terrestrial mammals in the area already suffer from the human impact. Due to the illegal hunting, the Dorcus Gazelle *Gazella dorcas* is presumed to have become locally extinct. Also the increasing urbanisation threatens the local mammals.

The expected decline in precipitation and the anticipated increase in temperature may lead to a shrinking in vegetation cover, *i.e.* decreasing the food available for herbivorous mammals and in turn decreasing their population and consequently decreasing the population of carnivorous mammals.

The global warming may alter the migration rhythm of the wintering migratory birds. They may postpone their southward wintering trip and may start their northern returning earlier than their traditional time. They may also be affected by the changing ecosystems. For example, the wader birds which used to feed on the bottom fauna of the shallow lagoons in both Matrouh and Ras Hawala have to seek alternative feeding grounds due to the possible change of these shallow lagoons to rather deep bays by the effect of sea level rise.

The reptile community in the area may have some alterations due to slight changes in their behaviour as a response to the global warming. As an example, the changeable Agama *Agama* *mutabilis* is common in spring by late May and in autumn from early November. In summer they appear to hide underground (Flower, 1933, c.f. Kasparek, 1993). That means that the global heating may extend the aestivation period of this reptile, a matter which leads to alterations in physiological and ecological needs of the animal and at the same time protect it from its enemies for a time longer than usual.

The sequences of precipitation decrease and temperature increase may adversely affect the amphibians' ecosystem which is dependent on wet substratum and vegetation.

The type and density of soil fauna depend on the plant phenology which in turn is directly or indirectly linked to the seasonality and rainfall thresholds. In other words, the alteration in precipitation may lead to alterations in the soil fauna composition and density.

The available data on the marine ecosystems of the area Fuka-Matrouh are not adequate to predict the future situation due to climatic changes or even without these changes. Moreover, the possible impacts of the anticipated climatic changes on the marine ecosystems of the area will be consequences of the probable changes in its physico-chemical features. A mathematical model will assist in understanding the probability and extent of these changes. This model necessitates the establishment of a database for the area.

However, in the absence of such a model, one can only imagine that a rise in the mean sea level as well as in surface water temperatures and salinities, coupled with increased spring precipitation, decreased autumn and winter precipitations and a more prolonged dry season will all interact to increase the range of fluctuations in the physico-chemical parameters of the area. That may lead to erosion of the coastal sand dunes, recession of the shoreline and the disappearance of the beaches in some places. This may lead to an increase in sediment load and a decrease in the clarity of seawater in the inshore zone, as well as to an increase in the nutrient salts in the inshore zone (due to the wash of land soil) and to more pronounced water stratification and oxygen depletion during warm seasons due to higher surface water temperature.

The increased sediment load may lead to changes in the sea bottom profiles and to altered substrate types and changed benthic communities.

The above-mentioned physico-chemical fluctuations may affect the primary production in the area and consequently affect the animal life production and distribution. While the increased temperature and nutrients positively affect the plant production (phytoplankton, macroalgae and sea grasses), the decreased clarity of water negatively affects this production. On the other hand, the higher temperature may increase the probability of red tide phenomenon and may also, over a certain limit, destroy the beds of the eel grass *Posidonia oceanica* (based on the physiological demand of the plant, the grass beds will suffer regressive succession or even will be exterminated, den Hartog, 1970, c.f. UNEP, 1992).

The higher temperature may increase the probability of the appearance of jelly fish swarms (jelly fish is the favourite food of some sea turtles), and may in addition to the higher salinity, urge the Lessepsian immigrants to inhabit the area. These new immigrants may affect the marine community of Fuka-Matrouh in unpredictable way.

The sea turtles and their nesting grounds in the area are threatened by urbanisation and fishing activities more than the anticipated climatic changes.

3.4.1 Summary

In addition to the serious degradation of the sand dunes due to expanding touristic resorts and villages, the expected sea level rise coupled with storm surges would adversely affect them.

The coastal lagoons may extend and transfer into bays. The natural flora of the inland may shift northward. The interdunal depressions may increase and may substitute a vast area of the inter-dunal and the alluvial plains encouraging the flora of the present interdunal depressions to expand at the expense of the original endemic flora.

The illegal hunting and increasing urbanisation threatens the local terrestrial mammals.

The shrinking vegetation cover, due to hot and dry weather, may decrease the herbivorous mammals and consequently decrease the carnivorous mammals preying upon them.

The global warming may alter the migration rhythm of migrating birds and may alter their ecosystems due to flooding the shallow lagoons.

The global heating may extend the aestivation period of some reptiles, a matter which alter their physiological and ecological needs and protect them from their enemies for a time longer than usual.

The alterations in precipitation may alter the amphibians ecosystem as well as the soil fauna composition and density.

In the absence of a mathematical model for the inshore of the area, one can only imagine that the consequences of the climatic changes will interact to increase the range of fluctuations in the physico-chemical parametres of the area. That may lead to erosion of the coastal sand dunes, recession of the shoreline and disappearance of the beaches in some places. It also may lead to increase in sediment load of seawater, decrease in clarity of seawater in the inshore zone, increase in the nutrient salts (due to the wash of land soil), more pronounced water stratification and oxygen depletion during warm seasons due to higher surface water temperature.

The above mentioned physico-chemical fluctuations may affect the marine plant and animal life and their community in the area Fuka-Matrouh in an unpredictable way.

3.5 MANAGED ECOSYSTEMS

3.5.1 Agriculture

A decrease of rainfall and increase in temperature and sea level rise as climatic changes will affect the cultivated crops in the area. The change in rainfall distribution patterns and the increase in evapotranspiration expect a slight shift in agricultural zone in the area (Fig. 2.5.1). Due to the reduction of cultivated areas, agriculture is likely to change towards even more intensive farms. A change in crop production and yield is expected.

Due to the expected increase in soil salinity, a decrease of soil fertility is expected. Some tropical and sub tropical plant diseases will move north, and the distribution of insects and pests will be altered. There will be a need for new biological and/or chemical controls of pests and pathogens (Jeftic, 1992). The expected increase in mean annual evapotranspiration and a decrease in rainfall would have a slight impact on natural vegetation and consequently range and animal production activity will also be affected by climatic change. The present carrying capacity (Fig. 2.5.4) will be changed and a shift is expected in range zones (Fig. 2.5.1, Fig. 2.5.2).

3.5.2 Sea Fisheries

Predicted sea level rise for the year 2030 (up to 16 cm) and for the year 2100 (up to 48 cm) very probably would not impact commercially important fish species, but impact of temperature increase could be significant.

Temperature increase up to 0.9°C (in the year 2030) and up to 2 5°C (in the year 2100) will warm up sea water for at least 0.5°C and 1.5°C respectively.

Temperature increase of sea water will very probably affect commercial important fish species. Migration pattern of pelagic fish, as well as their spawning area, could be changed.

Pelagic fish species, such as sardines could be affected by the temperature increases, approaching coastal areas earlier and remaining longer than under present conditions. This would lengthen the traditional fishing season which is based on the use of nets under artificial light on moonless nights.

It is quite improbable that anticipated climatic changes (temperature increase and sea level rise) will not directly affect the demersal fish stocks until the year 2030. The extent of these changes is insignificant so that it is quite certain that marine ecosystems will not suffer significant changes which may at least affect fish resources.

The impact of climate changes on the market-significant fish species in the study area is also impossible to predict on the basis of available knowledge. The biological cycle of the market-significant demersal fish species is not fully known. Particularly little is known about the spawning conditions, leaving no room for predicting whether and to what extent the expected climate changes may influence the fish stock. In order to undertake the appropriate measures, it would be necessary to obtain more information on the biology of important fish species especially on their spawning patterns and feeding ecology. The changes in primary production and phytoplankton population as well as changes in the food chains would have some indirect effect, but it is impossible on the basis of the present knowledge to predict these changes.

Changes in the ecosystem expected to occur under the influence of the climate change will probably have some impact on the behaviour of fish. One impact of increased water temperature may be to accelerate the propagation of Lessepsian migrants from the east to west The presence of Lessepsian migrants in Fuka-Matrouh sector may itself affect local communities in various ways which are very difficult to define and predict. It is difficult to assess the impact of these migrants on our fisheries. At best they would diversify catches, at worst they may actively compete with more desirable fish species.

3.5.3 Sponge Fisheries

Life in nearshore marine environments is mostly dependent on physico-chemical parameters, such as salinity, temperature, nutrient levels, water turbidity, and bottom substrate types. Such parameters will be affected by the predicted changes of climate. Such changes are bound to influence both primary productivity as well as the distribution of animal and plant life in nearshore coastal waters.

Kheirallah, *et al.* (1989) found that the commercial sponges along the western Egyptian Mediterranean coast can flourish in regions with large surface area of rocky and consolidated substrata and high production of sea grasses and green algae. Sea grass meadows are relatively important ecosystems, both locally as well as regionally. These form extensive prairies of high productivity and support a rich community of animals, including economically important fishes, molluscs and sponges.

During the autumn and winter bad weather, significantly increased turbidity at some coastal localities may happen due to increased sediment inputs. Marine grass meadows are particularly sensitive to reduced water transparency, as a result of significant sediment loads in the water due to climatic changes. Any increased sediment inputs in the marine environment may be expected to lead to changes in offshore bottom profiles as well as to altered substrate types and therefore to changes in benthic communities including sponges.

On the other hand, a rise in water temperatures may be expected to favour such sea grass meadows, particularly those of Posidonia, where reproduction is known to be greatly sensitive to ambient temperatures.

3.5.4 Aquaculture

There are considerable potentials for aquaculture in coastal waters. However, there are a number of limiting factors; competition for the use of coastal zones, limited knowledge of intensive aquaculture, lack of cheap feed for rearing and water pollution still impede the expansion of this operation.

Although different forms of aquaculture have been practised in Egypt, it is only in the last few years that research and incentives have materialised to turn aquaculture into a profitable industry. The fish currently used in mariculture are sea bass (*Dicentrarchus labrax*) and sea bream (*Chrysopherus auratus*).

Sites suitable for mariculture should be selected on the basis of a thorough examination of their physical and hydrobiological properties.

The eastern lagoon of Matrouh can be used in pond culture for rearing sea bass, sea bream and grey mullet Also any other wetland in the area can be used for such fish culture. At the same time protected areas in Ras El-Hekma and Abu-Hashaifa Bays, as well as the western lagoon of Matrouh can be used in cage culture for rearing of sea bass and sea bream, on high protein artificial feeds.

Anticipated temperature increase, as well as sea level rise will not significantly affect aquaculture activities in Fuka-Matrouh sector. However, the Egyptian Authorities have to protect the wetlands that are separated from the sea by sand dunes and a limestone ridge. They are thought to be an important breeding, resting and wintering ground for migratory birds and are seriously threatened by future and current tourist development.

3.5.5 Summary

Sea Fisheries

Predicted sea level rise for the following years, up to the year 2100, very probably would not impact the commercially important fish species in the Fuka-Matrouh sector, but the impact of temperature increase could be significant. Temperature increase of sea-water will very probably affect the commercially important fish species. Migration pattern of Pelagic fish, as well as their spawning area, could be changed. However, the anticipated climate changes will not directly affect the demersal fish stocks, until at least the year 2030.

Changes in the ecosystem expected to occur under the influence of climatic change will probably have some impact on the behaviour of fish. One impact of increased water temperature may be to accelerate the propagation of Lessepsian migrants from east to west. The presence of Lessepsian migrants in Fuka-Matrouh sector may itself affect local communities in various ways, which are very difficult to define and predict with the present knowledge.

The impact of climate changes on the commercially important fishes inn the study area, is impossible to predict on the basis of available knowledge. The biological cycle of fish species is not fully known. It would be necessary to obtain more information, especially on the spawning patterns and feeding ecology of the commercially important fish species.

Sponge Fisheries

Life in nearshore marine environments is mostly dependent on physico-chemical parameters, such as salinity, temperature, nutrient levels, water turbidity, and battern substrate types. Such parameters will be affected by the predicted changes of climate. Such changes are bound to influence both primary productivity as well as the distribution of animal and plant life in near-shore coastal waters.

The statistical yearly data of the Egyptian sponge catch during the period (1980-1986) was more or less equal (about 5000 kg/year). A sudden and sharp decrease in the annual catch was recognised in 1987 (about 1087 kg), and the following years, reaching only 200 kg in 1992.

During the last few years (1987-1992) the status of our commercial sponge beds from Alexandria to El-Sallum was and still is very bad. The observations of the divers all over the area and the symptoms they have observed (shape and size of all the commercial sponges) emphasises the infection of our sponges with fungus diseases.

Aquaculture

Cage culture has been recently started in Egypt. However, this type of fish farming succeeded in fresh water, but in the sea it is still in the experimental stage. A number of limiting factors (competition for the use of coastal zones, limited knowledge of intensive aquaculture, lack of cheap feed for rearing, availability of the necessary fish seed, and water pollution) still impede the expansion of this operation in coastal waters.

The wetland separated from the sea to the east of Matrouh city, can be used in pond culture for rearing sea bass, sea bream and grey mullets. At the same time, protected areas in Ras El-Hekma and Abu-Hashaifa Bays, as well as the western lagoon of Matrouh can be used in cage culture for rearing sea bass and sea bream on high protein artificial feeds.

In spite of what has been mentioned, the anticipated temperature increase, as well as sea level rise, will not significantly affect aquaculture activities, if present, in Fuka-Matrouh sector.

3.6 ENERGY AND INDUSTRY

3 6.1 Energy

Electricity generated by thermo-electric stations and diesel generators as well as kerosine and wind are considered the main present source of energy in the study area.

The direct and indirect impact of the climatic changes in the area will be represented here only quantitatively due to the lack of quantitative data. The increase of temperature whether by 2.5°C in the period from 1990 to 2100 or by 0.9°C in the period from 1990 to 2030, will be represented here only qualitatively due to the lack of quantitative data. This increase in the temperature will shorten the season of indoor heating which will spare a defined energy quantity. Ordinarily heating season of this area lasts from mid October to mid April.

Temperature rise will, however, increase energy demand for air-conditioning in summer. Since, however, present energy demand for air-conditioning is almost smaller in contrast to heating energy demand, it may be assumed that the increase of air-conditioning energy demand will be considerably lower than that of heating energy demand, which means that the total energy demand will be reduced if the other circumstances and conditions remain without any change. The increase of the tourism industry will increase the use of electricity for air-conditioning, lighting, cooking, etc. Also more energy demand will be requested for the new developments in the industry, which is the greatest energy consumer and the source of pollution; and due to the new settlement, and touristic villages.

Thus the total annual requirement for energy will increase. Hence, other sources for energy will be needed such as solar energy, wind energy, nuclear energy, wave energy and hydro energy. These new types of energy sources are recommended because they are clean without carbon dioxide emissions to combat global warming.

3.6.2 Industry

The industry is the study area which depends mainly on the agriculture products. They are small ones, but for the future developments new heavy and light industries will be born.

The increase of the temperature is not expected to have a significant effect on the operation of the present industries. This temperature increase may favour the consumption of soft drinks and consequently increase the demands for soft drinks which in turn may encourage their production in the study area Sea level changes will be taken into account when constructing new factories for new industries especially if they are near the coastal zone.

3.7 TOURISM

The tourism industry is developing very quickly in Fuka-Matrouh area. Many hotels and touristic villages have been constructed and/or under construction. The number of tourists are always increasing, especially from the Arab communities. By the year 2010 the accommodation capacity will be increased to 52,000 beds in Marsa-Matrouh area, 22,500 beds in Hawala/Bagoush, and 5000 in Ras El Hekma area.

As regards the impact of climatic changes on tourism, the following could be observed:

a No doubt the increase in the temperature will affect the tourism industry. The rise in temperature may make the summer season longer. This will encourage large numbers of international or national tourists to come and stay longer periods on the seaside because of its moderate temperature compared with those in most other part of the country far away from the coast. The daily trippers, of the international tourists who come to visit Luxor and Aswan and wants to enjoy the blue sea water and white sand of Fuka-Matrouh area, may be also increased. Accordingly, a number of pressures are reflected on the local population, such as the increase in water consumption and in sewage disposal.

b. It is generally recognised that the change in climate conditions and particularly the predicted sea level rise will not make a significant impact on tourism development since it will not result in the loss of sites or land considered as suitable tourist ones. This is because the majority of these sites are located on relatively high land which may be naturally protected from the maximum predicted (48 cm) rise in sea level. However, it is anticipated that the sea level rise will cause the disappearance of a small, narrow, sandy beach below the new water line. The relatively serious problem may be the intrusion of the salt water into ground water and the elevation of water tables leading to the deterioration of historical heritage located in the area. This process will not be the product of the sea level rise alone, but might be accelerated as a result of sea level rise acting in conjunction with other factors in the area.

3.8 TRANSPORT AND SERVICES

The area under study is well connected to the west and the east of Egypt by highway (the international road), paved roads, railway line, air-line and ships. Super jet-bus, ordinary buses, trains and de-luxe trains, aeroplanes, taxis and ships are all used as means of transportation.

There are no parameters available which would make possible any quantification of the impacts of climatic changes on the transportation and services. Possible qualitative, direct and indirect impacts will only be represented.

Matrouh airport will not be directly affected by anticipated rise of the sea level because it is located inland far from the sea. Rise in temperature by 0.9 and 2.5°C during the periods from 1990 to 2030 and from 1990 to 2100 respectively is not an important factor. However, it is difficult to forecast whether temperature increase and precipitation intensification will cause fog or low clouds which may affect air transport.

The level of both the railway and the international road are higher than the sea level, which means that they would not be affected by the 48 cm rise in the sea level in the area.

The increase of temperature would necessitate a considerable financial output to upgrade all trains, buses and all means of transport to be air-conditioned. Also the asphalt layer on the roads may be melted which may cause more accidents.

Increase in precipitation particularly in winter will effect an increase in the number of traffic accidents on the paved and unpaved roads and tracks.

Matrouh port is naturally protected from the sea but its quays may need to be raised because of the sea level rise

3.9 SANITATION AND HEALTH

Bedouin communities have no liquid or solid waste disposal system to date. The tourists in the area are using the primitive methods such as septic tanks to get rid of the domestic wastes. If this method was not studied well it could lead to pollution problems of the ground water in the area. A new integrated network is under construction for Matrouh city and the adjacent tourism zone. Water for domestic use could be obtained from different sources. The consumption of the water in the area is expected to increase due to:

i. new developments
ii. increase of population and tourism
iii. the inventory of new industries
iv. more land to be reclaimed and cultivated
v. expected increase in temperature which requires more water for irrigation and new crops to stand the high temperature

The increase in temperature will speed up the rate of anaerobic decomposition of the organic matter in the sewage system leading to dangerous levels of methane build-up and risk of explosion similar effects will occur on the solid waste disposal site. Also increase rainfall will increase leaching of the landfill site with possible pollution of the ground water.

Increased temperature will affect the treatment process of the waste water treatment plant with possible consequences on quality of the effluent.

As a result of increase temperature we can expect increase of all decomposition process of the organic matters in environment with all accompanying processes and side effects. Higher temperature for the sanitation of the urban environment have negative effects and generally decrease sanitary level of the environment. This will affect flood store and processes as well as food waste store, collection, transfer and disposal. Similarly will be with all dead organic matter in the environment. It also means that sanitary problems will be increase in houses, industry (especially food industry) and environment with possible health effects.

Expected climatic change may influence sanitation in the region. Sea level rise will result in corrosion of the water supply pipes and as a result of this process sea intrusion can happen as well as temporary contamination and losses from the system, especially in Matrouh city and/or the new developments near the seaside. It also may cause sewage system to be flooded. Such an event could create greater risks of epidemics of enteric disorders such as typhoid.

The increase in temperature may take the insect-borne diseases become more widespread, either because the vector will be able to survive better at higher latitudes or because parasites may be able to complete their life cycle more easily.

Increased sun exposure during leisure time causes the rise in the incidence of both melanomas and non-melanotic skin cancer. Also the exposure to increased ultra violet radiation may cause the damage of the cornea and lens and increased incidence of cataracts.

It is very difficult to predict the size of these effects but they will happen in regard to scenarios If changes are bigger then the negative consequences also will be bigger.

3.10 IMPACT OF EXPECTED CLIMATE CHANGE ON HUMAN DEMOGRAPHIC AND SETTLEMENT PATTERN

The changes in the climatic conditions in Fuka-Matrouh area are expected to have only a very limited impact on vital behaviour of population. The time scale on which the changes are expected to occur, will enable the population to adapt to these changes. On the other hand, the figures of expected climatic change in Fuka-Matrouh region indicate that the area will still remain within the limits normally taken as that for human habitation. The expected climatic changes will probably have no significant effect on the population distribution and demographic pattern.

By the year 2030, neither a temperature increase (0.7-0.8°C) nor a sea level rise (+16 cm) would be expected to affect population and settlement patterns. Nevertheless, by the year 2100 the indirect consequences of climatic change are likely to be more important. A sea level rise of max 47 cm may stimulate intrusion of salinity in ground water and the rise of water table level. However, within Fuka-Matrouh region this will not reflect a serious problem of agricultural land productivity because most agricultural land are relatively high and far enough from the sea shore to be naturally protected from the expected sea level rise.

It is worth stressing that expected sea level rise in the study area is bound to have impact on the tourism villages which are directly located on the shore. An increase in temperature would lead to increase personal discomfort and affect refrigeration units. This would necessitate the increase of demand on energy and water supply in the tourism season. On the other hand the increase of water table would increase the sewage problems of the tourism villages as the sewers are the common system dominates for sewerage disposal. Buildings on the shore will also be affected and will likely have increased maintenance cost.

4. RECOMMENDATIONS FOR ACTION

4.1 SUGGESTIONS FOR ACTION TO AVOID, AND ADAPT TO THE PREDICTED EFFECTS

To limit greenhouse gas emissions are likely to include one or more of the following elements.

a. Improving energy efficiency: this reduces demand for energy and hence, the amount of CO_2 generated during energy production.

b. Using cleaner energy sources and technologies, this reduces CO_2 emissions and emissions of pollutants that cause environmental problems.

c. Technology development and transfer.

4.1.2 Lithosphere

It is important to state that an impact preventing approach to sea level rise is preferred. The limits of such a preventive approach are governed by the risk factor set by the decision makers. In case of implementation of preventive response, it requires:

a. Realistic sea-level rise scenarios and consequentially the local extent of sea level rise to be expected and the time-frame of its occurrence.

b. Determination of what certain water level will do to the shoreline and coastal areas beyond it.

c. Assessment of the economic and social impacts and thus values of lands and constructions.

From the point of view of geology and geomorphology, the following suggestions would be implemented to prevent, avoid, mitigate and adapt to the predicted effects during future rise in sea-level.

a Design of coastal protection measures in critical coasts.

b. Suitable stabilisation methods (by using plants, wood fences, spraying, etc) should be undertaken for the coastal dunes which act as barriers against sea attack.

c. Control the underground water exploitation to reduce the expected subsidence and salt water intrusion in coastal areas.

d. Gradual landward transfer of some touristic projects which are located at critical areas.

e. The existing legislation has to be respected by leaving a distance of more than 200 m between the shore and any construction.

f. Development of the inland areas south of Alexandria-Salum road.

g. Technology transfer to mitigate the impacts.

The development plan for the northwestern coast has to take into consideration the preparation of a coastal zone management including strategic plans for the following aims:

a. Manage the present and future siting of development activities in the coastal zone.

b. Stop the encroachment of the sea on the important shore areas, mainly due to the man-made interfering structures.

c. The effect of a higher sea-level on natural systems as wave climate, sediment drift, wind regime and storm frequencies.

d. Ensure that coastal erosion control measures are cost efficient and socially and environmentally acceptable.

e. For different development purposes within the shore zone; mainly tourism, swimming areas, breakwater and fisheries.

f. For the various coastal projects identifying the costs, benefits, design and tender documents.

4.1.3 Hydrosphere

a. Upgrading the awareness of decision makers concerning the possible impacts of climate change on the whole coastal area to design plans and find out means to minimise adverse impacts and maximise possible benefits with minimum cost.

b. Carry out extension programs to upgrade awareness of water users concerning scarcity of fresh water resources and introduce cultural practices of water conservation.

c. Establish long term program based on the expected changes.

d. Establish monitoring stations or centre to be supervised by NWCA and scientific institutions using remote sensing and GIS technique to follow up and apply suitable tests to predict the impact of climatic changes.

e. Adapting a well defined scenario of land use based on expected changes in natural resources.

f. Select suitable tolerant without drought crops, shrubs and forage plants to maximise yield and minimise adverse impacts.

4.1.4 Natural Ecosystem

a. To overcome the scarcity of knowledge on the natural ecosystems a monitoring programme on the area should be started and a database concerning the different basic physical, chemical and biological parameters of both the terrestrial and marine environments in the area should be established. These data have to be fed into a geographical information system and mathematical models have to be set up.

b. As environmental impact assessment has to be performed prior to any supposed activity in the area.

c. To minimise the impacts on the coastal sand dunes and their ecosystems, a considerable pace should be left between the shoreline and any planned building or infrastructure in the area. That supposed pace will give the sand dunes a chance to shift towards landside.

d. The existing sand dunes have to be protected by vegetation cover and artificial means have to be used to enhance formation of new sand dunes.

e. The laws protecting the wildlife (such as birds, mammals, tortoises and turtles) have to be strictly implemented.

4.1.5 Managed Ecosystem

At the present state of our knowledge, the availability of baseline information on marine ecosystems and their environment in Fuka-Matrouh sector, is at best incomplete, and in some cases, completely lacking. There is urgent need to develop fully the local potentials in marine science, especially physical, chemical and biological oceanography.

With reference to fisheries and fish culture, the most urgent measures are:

a Invest in fisheries as aquaculture research is currently inadequate, so a blanket recommendation is to encourage and to invest research in these fields.

b Establish a fishery and fish culture research centre at Matrouh city to ensure the good use of marine resources.

c The technology of rearing fish in cages is simple and does not require much space or capital. Such new and beneficial activity can be easily made for individual or cooperative fishermen in the wind protected areas of Fuka-Matrouh sector, as well as in the western lagoon of Matrouh.

d Control all resources of human activities which are seriously damaging marine resources.

e To avoid or mitigate the negative effects of climate changes on marine resources, it would be necessary to establish a proper monitoring system and employ the appropriate measures to avoid damaging of the resources.

4.1.6 Energy and Industry

Predicted effects should be taken into account in the preparation of the future industry development as they are the greatest energy consumers and at the same time a significant source of pollution in the study area. As one of the measures to combat or mitigate global warming would be primarily a reduction in carbon dioxide and other gases emissions. So it is suggested to use the following clean energy sources:

a. The solar energy because the study area is distinct for the long hours of sunrise throughout the year (3500 hours on average).

b. The wind energy because the wind on the northwest coast is the highest in the entire country.

c. Wave energy from the sea especially for the coastal areas.

Also the new settlements, touristic villages, beaches, new sport sites and new developments near the coast should undertake the modification due to the sea level rise.

4.1.7 Tourism

The climate changes and sea-level rise could be of considerable importance for the tourist development. An increase in temperature would increase the number of national and international tourists which in turn will increase water and electricity consumption and cause pressure on the sewage system. These factors are likely to create serious problems of water shortage and increase the demand on electricity. It is necessary to be aware of their possible impact and to determine specific policy and measures which could help to avoid or mitigate the negative consequences. New networks for both water and sewage separately could be planned and constructed in the study area for the future. New energy sources could be used in the coastal zone such as wave energy to produce electricity and water desalination.

Tourist areas could be divided into immediate coastal zone and wider zone in the back. The first group would consist of bearing capacity areas with facilities of complementary services, beaches and bathing places. These places are not, at present, under direct threat since almost all the buildings are out of immediate coastline. Bathing places as well as sport and recreational areas have such natural/relief features could be nourished to minimise the erosion effects. Tourist buildings, housing and other construction in the coastal area is by this plan directed inland by applying principles of decentralised concentration building, which assures free space of natural values between built-up settlements of tourist complexes.

4.1.8 Transport and Services

Transport would be affected both by the direct impact of climate changes and indirectly, when as elements of transport are likely to be significantly affected by actions designed to retain emissions of greenhouse gases.

Sea-level rise necessitates the increase of the level of the constructions near the sea side especially Matrouh port structures (breakwaters, quays etc.).

Matrouh airport should be widened to combat with the increase of the number of tourists and the investors for the new developments. Local roads should be widened and paved to facilitate the motion in the study area. Also the railway line could be doubled and increase the velocity of the trains and their number

4.1.9 Sanitation and Health

A new sewerage system should be planned, designed and implemented according to the new developments, and increase of tourists and settlements taking into consideration the sea-level rise and increase in temperature.

4.1.10 Population and Settlement

It is not anticipated that the expected climate changes in Fuka-Matrouh region will have any direct effect on human demographic characteristics. Climate change will not also cause neither large scale movements of population nor alter the general strategy of the future socio-economic development of the area. However, indirect consequences of climatic change are likely to be more important. The climate changes would lead to increase demand on water, energy and would increase the maintenance cost of sewerage systems and buildings close to the shore. Certain adaptive options may have to be taken in order to reduce the possible impacts of climatic and sea-level changes. Those options can be summarised in the following:

a. Prevent establishing of new touristic villages on the seashore.

b. Prevent any kind of capital investment project in the coastal area near the seashore.

c. Adoption of expected safety elevation for drainage and sewerage system.

d. Consolidating water and energy supply systems.

4.2 SUGGESTION FOR FOLLOW-UP TO THE PRESENT STUDY

4.2.1 Atmosphere

a. Installation of rain-gauges network specially for the coast by 10, 20, 30, 50 and 70 kms to study spatial variability of rainfall.

b. A more detailed study of the long-term series of rainfall, wind, sky cover and turbidity.

c. Establish appropriate monitoring of critical pollutants.

d. Research to reduce scientific and socio-economic uncertainties about climate change.

4.2.2 Lithosphere

a. Construction and operation of a field station at the study area for field data collection, surveying and data analysis.

b. Monitoring of sea level measurements and subsidence.

c Long term measurements of dynamic forces affecting the coast.

d. Use mathematical models to predict the impacts on beach, coastal dune and sediment balance in future.

e. Detailed topographic maps have to be investigated.

f Monitoring of soil conditions is required in order to achieve a better understanding of the effects of expected climate changes on agriculture.

g. Evaluation of the coastal lands for different types of use.

h. Recommend the best coastal protection plan.

i. Study and recommend a coastal zone management plan.

j. Prepare detailed designs, technical specification and tender documents for coastal protection works.

4.2.6 Energy and Industry

More studies and data about the consumption of electricity should be collected whether for the present or future situation.

It would be necessary to elaborate the possibility of using new energy sources such as solar, wind and wave energy.

4.2.7 Tourism

The existing touristic villages near to the coast should be protected either by detached breakwater or any other protective works according to the field data concerning the dynamic forces and sediment transport.

More data is required about the water consumption of the tourism in order to predict the water demand and the size of the sewers required taking into consideration the sea level rise and increase in temperature.

4.2.8 Transport and Services

There is a priority to create a database on every possible endangered transportation facility. It would comprise all relevant characteristics of these facilities, all the development programmes for renewals, reconstructions, adaptations.

In addition, it becomes a necessity to collect all information from the past period about climatic conditions and especially on occasional dynamic sea impacts to the transportation facilities such as high sea levels and the conditions in which they appear, the strongest storms recorded in open sea and in protected port,..

4.2.9 Sanitation and Health

More data collection is needed on this aspect because of the scarcity of the available one.

Monitor the changes of water quality and use appropriate water purification methods.

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APPENDIX I

TEMPERATURE AND PRECIPITATION SCENARIOS FOR NORTHERN EGYPT

1. Introduction

Climate models, and those based on general circulation models (GCMs) in particular, are mathematical formulations of atmosphere, ocean and land surface processes that are based on classical physical principles. They represent a unique and potentially powerful tool for the study of the climatic changes that may result from increased concentrations of CO_2 and other greenhouse gases in the atmosphere. Such models are the only available means to consider simultaneously the wide range of interacting physical processes that characterise the climate system, and their objective numerical solution provides an opportunity to examine the nature of both past and possible future climates under a variety of conditions.

2. The Use of GCM in Regional Scenario Development

It is generally accepted that the results from GCMs offer the best potential for the development of regional climate scenarios, since they are the only source of detailed information on future climates which can be extrapolated beyond the limit conditions which have occurred in the past.

GCMs are complex, computer-based models of the atmospheric circulation which have been developed by climatologists from numerical meteorological forecasting models. The standard approach is to run the model with a nominal "pre-industrial" atmospheric CO_2 concentration (the control run) and then to re-run the model with doubled (or sometimes quadrupled CO_2) the perturbed run. In both, the models are allowed to reach equilibrium before the results are recorded. This type of model application is therefore known as an equilibrium response prediction.

The fact that the GCMs are run in equilibrium made must in itself be regarded as a potential source of inaccuracy in model predictions. It can be argued that the predicted regional patterns of climate change will differ from those that will occur in a real, transient response world. Results are becoming available from transient response predictions, where the CO_2 concentration increases gradually through the perturbed run and where the oceans are modelled using ocean GCMs, and which therefore should provide a more realistic estimate (Gates *et al.*, 1992). These indicate that the large-scale patterns of change are similar to those obtained from comparable equilibrium experiments, scaled down by an appropriate factor. Differences do exist, largely because equilibrium model runs ignore important oceanic processes such as ocean current changes, differential thermal inertia effects between different parts of the oceans and between land and ocean, and changes in the oceanic thermohaline circulation. These differences are greatest in areas where the ocean thermal inertia is large, such as the North Atlantic and high southern latitudes (Mitchel *et al.*, 1990). They are relatively small in most regions (and in the Mediterranean basin in particular).

The present study therefore is restricted to the use of results from equilibrium GCMs experiments. The results from 4 GCMs developed for climate studies have been used to develop the scenarios used in this report. They are from the following research institutions:

UK Meteorological Office (GISS);
Goddard Institute of Space Studies (GISS);
Geophysical Fluid Dynamics Laboratory (GFDL); and
Oregon State University.

The models vary in the way in which they handle the physical equations describing atmospheric behaviour. UKMO, GISS and OSU solve these in grid-point form, whereas GFDL uses a spectral method. All models have a realistic land/ocean distribution and orography (within the constrains of model resolution); all have predicted sea, ice and snow; and clouds are calculated in each atmospheric layer in all models.

One problem with the application of GCMs to the study of climate impacts is the coarse resolution of the model grid. The grid scale of the four models listed above ranges from 4° latitude x 5° longitude (OSU) to 7.83° latitude x 10° longitude (GISS). GCM, therefore, have a spatial resolution of several hundreds of kilometres, which is inadequate for regional climate change studies, especially in areas of high relief. We present here a set of high resolution scenarios for northern Egypt, based on the statistical relationship between grid-point GCM data and observations from surface meteorological stations.

3. Construction of Sub-grid Scale Scenarios

Kim *et al.* (1984) looked at the statistical relationship between local and large-scale regionally-averaged values of two meteorological variables: temperature and precipitation. They then used these relationships, developed using principal component analysis techniques, to look at the response of local temperature and precipitation to the predicted change at GCM grid points. The area of study was Oregon State. Although the paper contains certain statistical flaws, the underlying ideas of relating local and large-scale data statistically is sound. The methods of Kim *et al.* has been extended and refined by Wilks (1989) and Wigley *et al.* (1990).

The methods of Kim *et al.* and Wigley *et al.* have modified for application in the Mediterranean region. In the model validation exercise carried out for the Mediterranean region by Palutikof *et al.* (1992), it was established that no single GCM can be identified as being always the best at simulating current climate. This being the case, there is little merit in presenting scenarios based on only one model. Presentation of scenarios for each of the four models avoids the issue, since the task deciding which model is "best", and/or of synthesising the information to obtain a best estimate, is left to the impact analyst. We have therefore combined the information from the four models into a single scenario for each variable, according to the method described below.

The problem with scenario construction based on a number of models is that the results may be biased by the different equilibrium responses of the individual models. The global warming due to 2 x CO_2 for the four GCMs ranges between 2.8°C for the OSU model and 5.2°C for the UKMO model run. We would therefore expect that the warming indicated by the UKMO GCM for the Mediterranean basin will be greater than that suggested by the OSU model, even though the sensitivity of the region to climate change when compared to the global sensitivity might be the same. The individual model perturbations have therefore been standardised by the equilibrium (global annual) temperature change for that model, prior to the calculation of the four-model average.

A generalised computer programme was needed that would be applicable throughout this geographically complex area, and could be used with meteorological records of variable length and density. After investigating a number of approaches to the problem, we adopted the procedure summarised below (Palutikof, *et al.*, 1993).

a. Data sets of monthly mean temperature and total precipitation have been compiled for the area surrounding the Mediterranean basin. Stations used in this study of northern Egypt are listed in the Annex to Appendix I. Where possible, each record should be complete for the period 1951-88. Any station with a record length less than 20 years in the period 1951-88 for over six months out of twelve was immediately discarded.

b. Then, for every valid station, the temperature and precipitation anomalies from the long-term (1951-88) mean were calculated. For this part of the work, which is the first step in the construction of the regression equations (the calibration stage), only the data for 1951-80 were used. The 1981-88 data were retained to test the performance of the regression models (the verification stage, see Palutikof *et al.*, 1992). For the calculation of the temperature anomaly **Atij**, the simple difference was used:

$$Atij = tij - Tj$$

where **tij** is the mean temperature of month **j** in year **i**, and **Tj** is the long-term mean for month **j**. The precipitation anomaly **APij** was expressed as ratio of the long-term mean.

$$Apij = (Pij - Pj) / Pj$$

where **Pij** is the monthly total precipitation in month **j** of year **i**, and **Pj** is the long-term mean for that month. If **Pj** is less than 1 mm, this equation is modified to:

$$Apij = (Pij - Pj) / 1.0$$

c. The individual station anomalies are used to calculate regionally-averaged anomalies. The procedures described from here to the end of point 6 are station-specific, and must be repeated for each station in the data set. A 5° latitude x 5° longitude square is centred over the station for which regression equations are to be developed (the predicted station). All the stations which fall within this square are used to calculate the regional averages. If the number of stations is less than three, for temperature, or four, for precipitation, the procedure is halted. For temperature, the anomalies from all stations in the 5° x 5° square are averaged month-by-month to produce an area-average time series. For precipitation, the substantial degree of spatial variability makes it advisable to area-weight the stations' anomalies before calculating the regional mean for each month. To do this, the 5° x 5° region is divided into 20 x 20 smaller squares. The precipitation anomaly value assigned to a particular square is that of the station nearest to it (with the restriction that the distance separating a square from its nearest station should be no greater than 1° - where the distance is greater the square is ignored). The area average is then the mean of the values in the 400 (or fewer, if any fail the minimum distance criterion) squares. This method is similar to the standard Thiessen polygon method.

d. Regression analyses were performed using station temperature and precipitation anomalies as the predictands. These analyses were carried out on an annual and seasonal basis: winter (December - February), spring (March - May), summer (June - August) and autumn (September - November). By considering the monthly values as separate observations within each season, we were able to extend the number of observations and so preserve a high number of degrees of freedom. The predictor variables are the regionally-averaged anomalies of temperature and precipitation.

e. In order to determine the perturbation due to the greenhouse effect at each station, the results from GCMs were employed. It assumed that a GCM grid-point temperature or precipitation value is equivalent to a regionally-averaged value derived from observational data. For each of the four GCMs (GFDL, GISS, OSU and UKMO), the perturbed run and control run grid-point temperature **t** and precipitation **p** values are interpolated to the station position. Then, we obtain, for temperature:

$$Atmi = ti(2 \times CO_2) - ti(1 \times CO_2)$$

where **Atm** is the perturbation due to CO_2 or the "temperature anomaly" for model **i** and, for precipitation:

$$Ptmi = [Pi(2 \times CO_2) - Pi(1 \times CO_2)] \times 100/Pi(1 \times CO_2)$$

where **Ptm** is the standardised perturbation due to CO_2 or the "precipitation anomaly".

The values for **Atm** and **Ptm** for each GCM are then substituted in the regression equations to obtain a prediction for the station perturbation of temperature (°C) and precipitation (%) due to CO_2.

f. The predicted change in temperature and precipitation for each model is divided by the equilibrium (global mean) temperature change for that model. The results are then averaged across the four models to obtain a composite value.

g. The procedures from points 3 to 6 are repeated for each station throughout the Mediterranean. The results can then be plotted and contoured to obtain a map of the expected patterns of temperature and precipitation change due to the greenhouse effect.

In order to arrive at this procedure, a rigorous investigation of the validity of the method has been carried out. In particular, we have looked at:

- the use of other predictor variables in the regression equation;
- performance and verification of the regression equations;
- autocorrelation in the data; and
- multicollinearity in the predictor variables.

These aspects are discussed in detail by Palutikof *et al.* (1992).

4. Climate Change Scenarios for Northern Egypt

The sub-grid-scale scenarios, constructed according to the method outlined in section 3 are shown in Figs. 1-5. The temperature perturbations are presented as the model average change, in Celsius, per °C global annual change. The precipitation perturbations are shown as the percentage change for each 1°C global annual change. This procedure is described in greater detail, and the approach justified in section 3.

The scenarios are presented as the regional change in a particular climate variable to be expected in response to a 1°C change in mean global temperature. As such, they do not provide any information on when such changes might be expected to occur. However, such information can be extracted from scenarios presented in this form. The results from four transient response GCMs presented in IPCC 92 (Gates *et al.*, 1992) show a constant rate of warming in the later decades of around 0.3°C per decade. This is in line with the findings of IPCC 90, based on the "business-as-usual" CO_2 forcing scenario and an energy balance atmospheric model coupled to an upwelling-diffusion ocean model (Bretherton *et al.*, 1990). Although the impossibility of placing calendar dates on this figure must be emphasised, it suggests that a 1°C temperature change may be achieved in a period of around thirty years.

It should be noted that the figure of 0.3°C per decade does not take into account possible opposing anthropogenic, influences, in particular the forcing from sulphate aerosols and stratospheric ozone depletion. Wigley and Raper (1992) made temperature projections based on IPCC 92 emissions scenario IS92a (Leggett *et al.*, 1992), taking into account the ozone-depletion feedback and best-guess sulphate aerosol effects. They used their upwelling-diffusion energy-balance climate model (as used in IPCC 90, see above) and found the warming between 1990 and 2100 to be in the range 1.7-3.8°C.

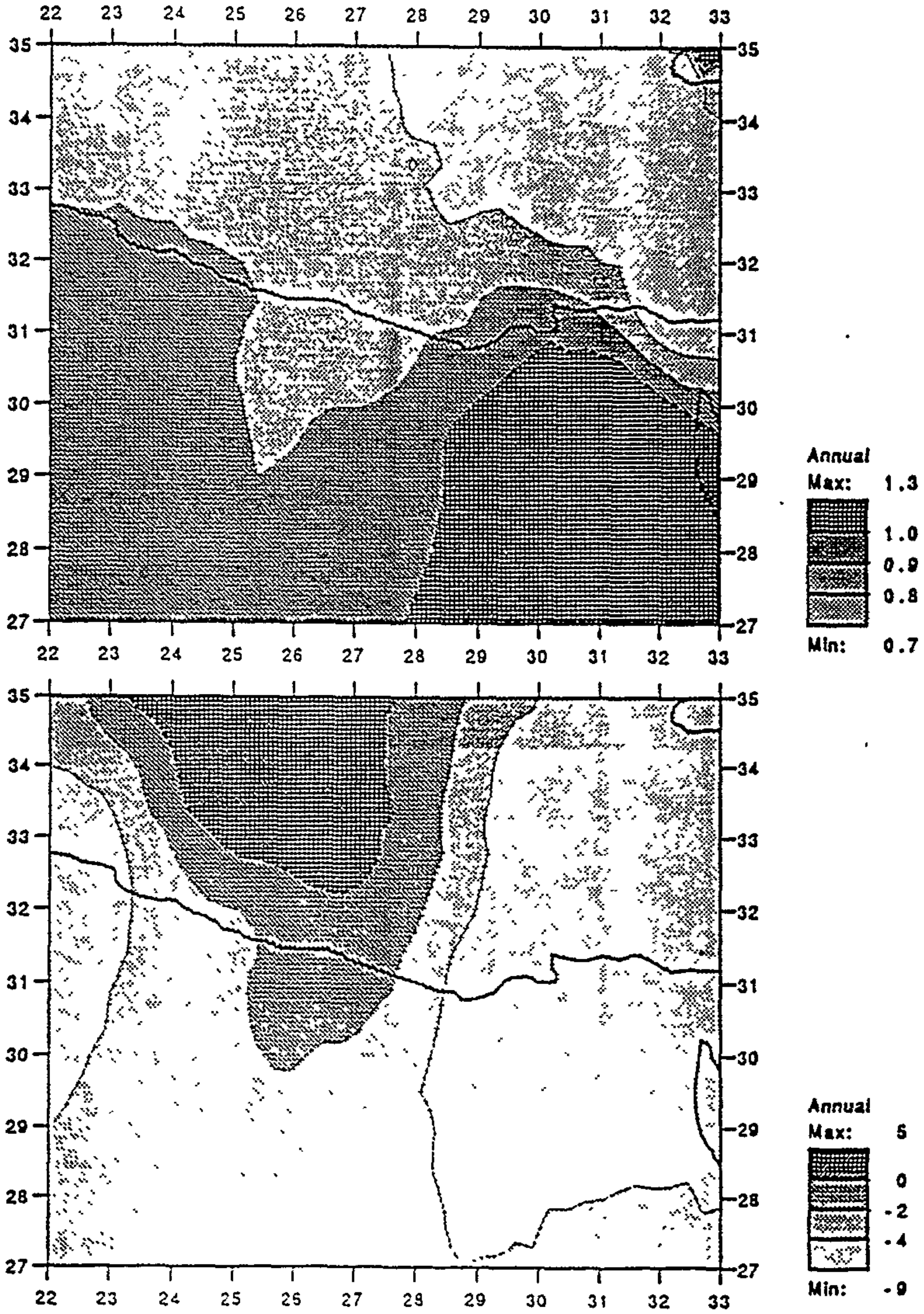

Fig. 1 Regional climate scenarios for northern Egypt: annual. Upper map shows change in temperature (°C per °C global change) and the lower map shows change in precipitation (% per °C global change)

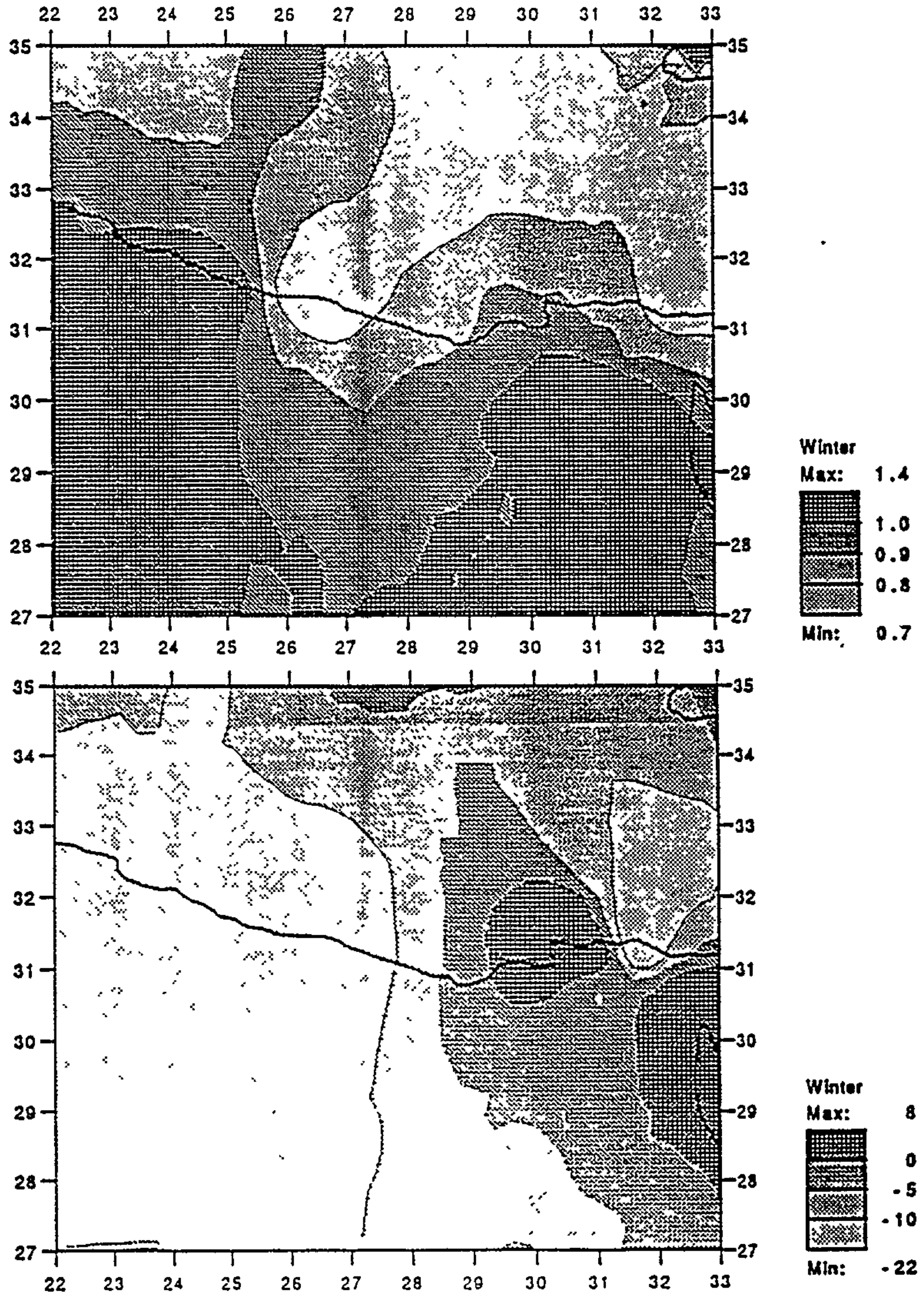

Fig. 2 Regional climate scenarios for northern Egypt: winter. Upper map shows change in temperature (°C per °C global change) and the lower map shows change in precipitation (% per °C global change)

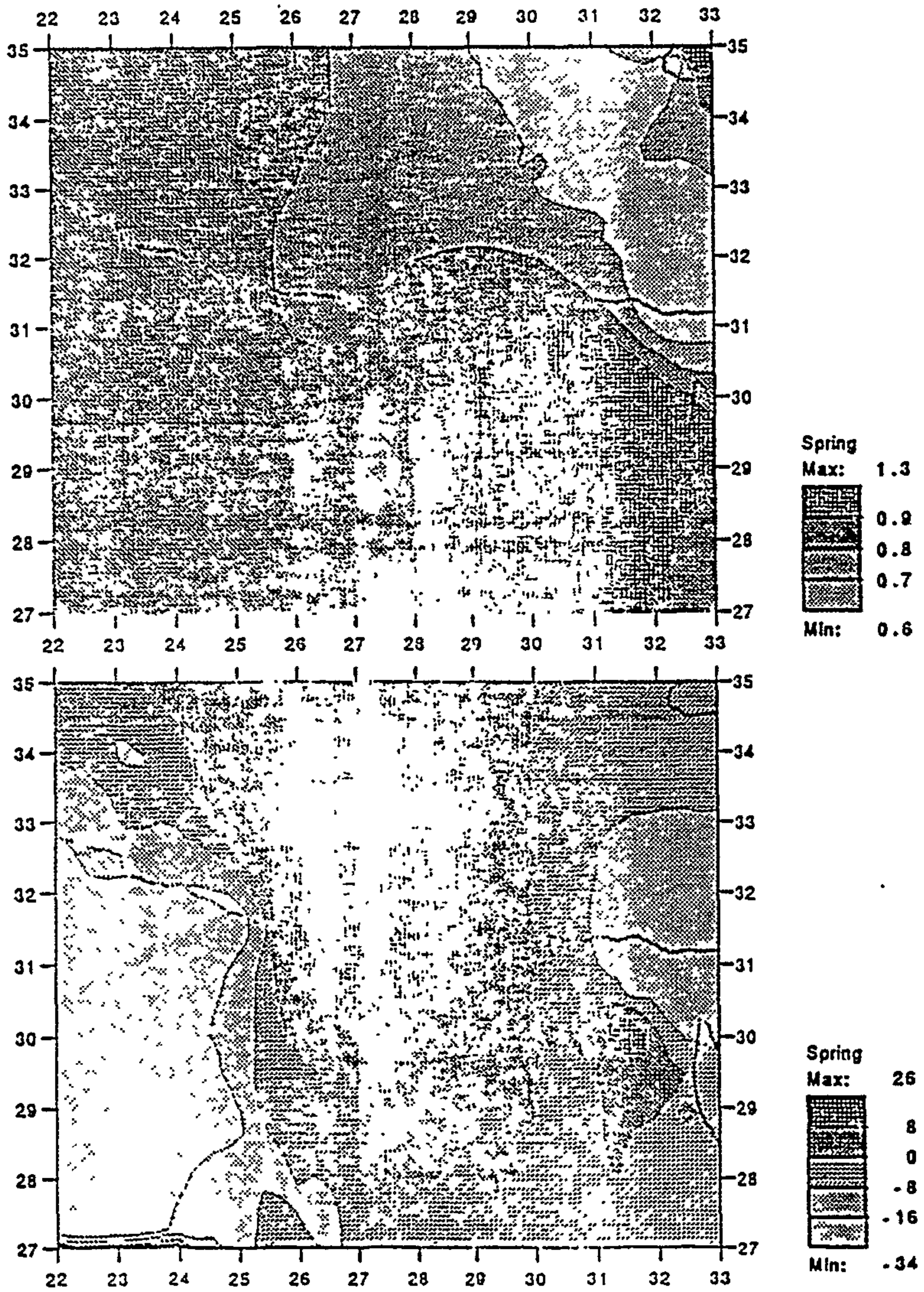

Fig. 3 Regional climate scenarios for northern Egypt: spring. Upper map shows change in temperature (°C per °C global change) and the lower map shows change in precipitation (% per °C global change)

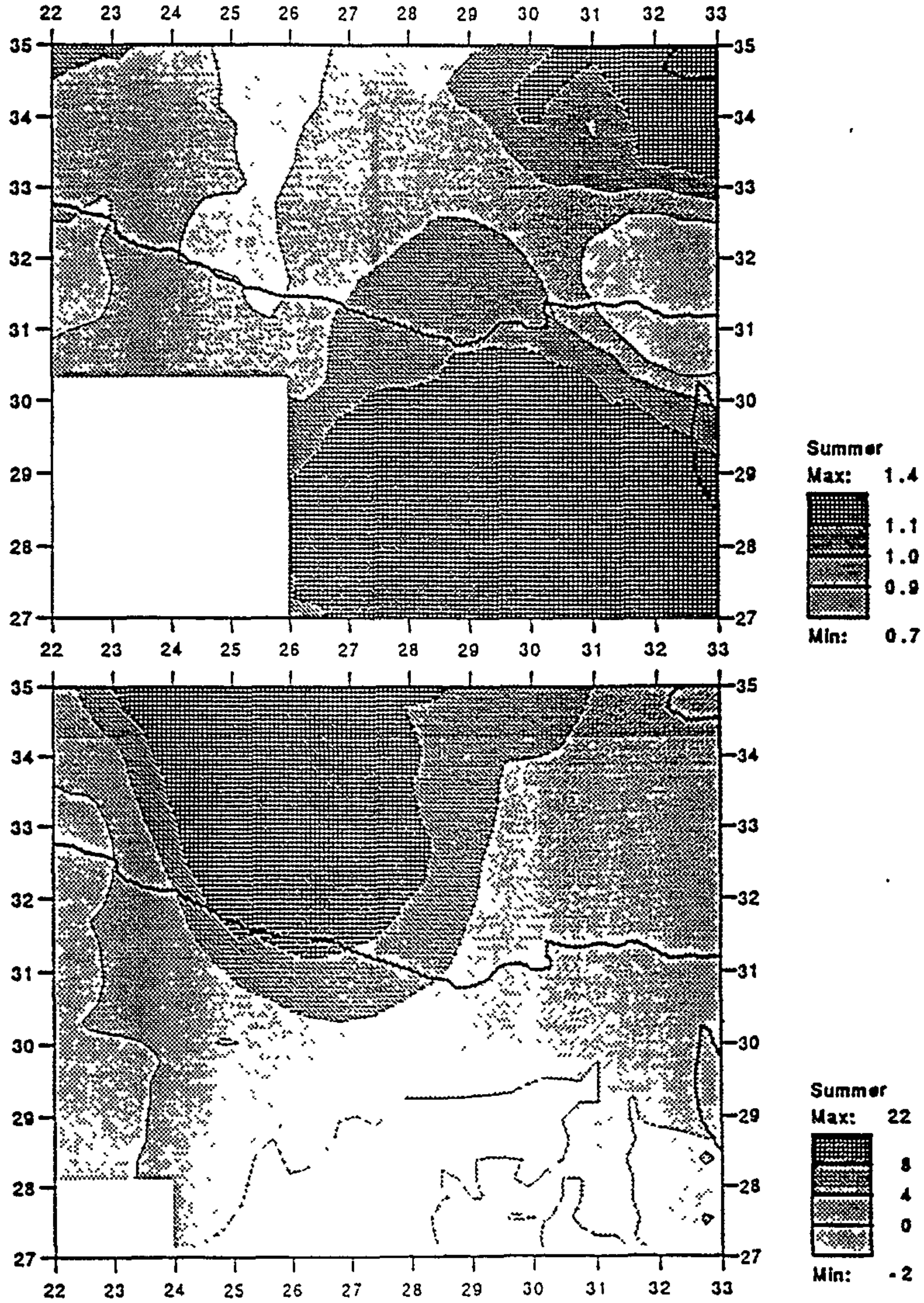

Fig. 4 Regional climate scenarios for northern Egypt summer Upper map shows change in temperature (°C per °C global change) and the lower map shows change in precipitation (% per °C global change)

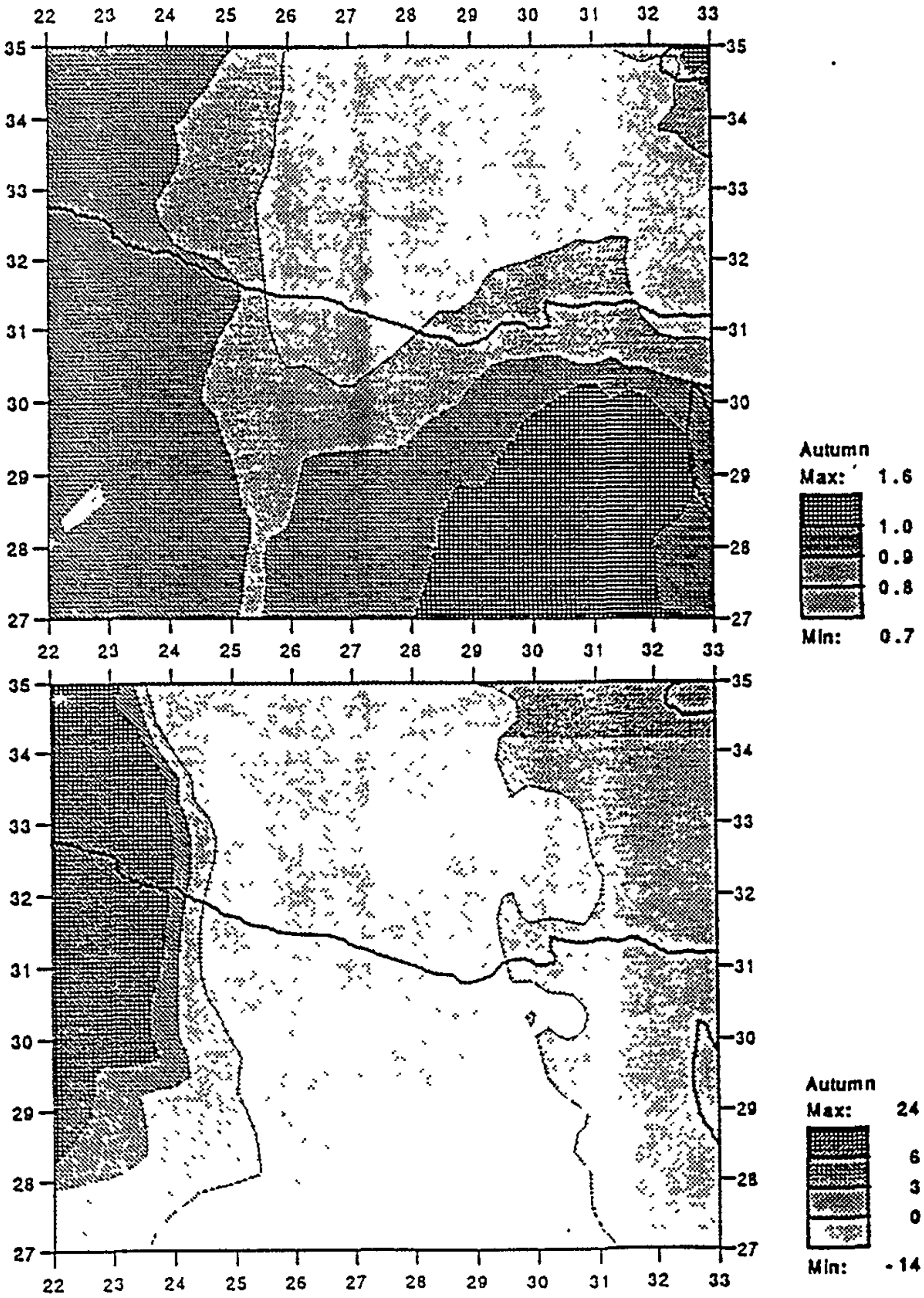

Fig. 5 Regional climate scenarios for northern Egypt: autumn. Upper map shows change in temperature (°C per °C global change) and the lower map shows change in precipitation (% per °C global change)

The results from these time-dependent experiments can be combined with the scenarios of the magnitude of change presented in this report, and superimposed on a baseline (present day) climatology in order to arrive at a scenario of climate for a particular future time. A recent example of the application of this approach to the development of "snapshot" scenarios for Europe is the ESCAPE project (CRU, 1992). This approach requires that the spatial pattern of the enhanced greenhouse signal remains constant with time, but the available model evidence suggests that this is a reasonable assumption to make (Mitchell *et al.*, 1990; Gates *et al.*, 1992).

Annual Scenarios of Climate Change

The scenarios for changes at the annual level are shown in Fig. 1. The temperature change along the coast west of Alexandria (the region of interest) is indicated to be less than the global change, *i.e.* in the range 0.7-0.8°C per °C global change. The scenario of precipitation indicates drier conditions at the annual level, with a change in rainfall in the range of 4% to 0% per °C global warming.

Seasonal Changes of Climate Change

The seasonal changes in temperature in the Fuka-Matrouh area, as predicted by the four GCMs, broadly reflect the changes which are seen at the annual level. Only in the summer months of June, July and August (Fig. 4) does the temperature change approach the global level, with suggested increases of between 0.9°C and 1.1°C per global change shown along the north-western coast of Egypt. In the winter months of December, January and February (Fig. 2) the predicted increases of temperature are 0.7-0.8°C per °C global change, *i.e.* less than the global change. The smallest amount of warming in the study region is found in the spring season (Fig. 3), of between 0.6°C and 0.8°C per °C global warming. In autumn (Fig. 5), the warming is between 0.7°C and 0.9°C in the Fuka-Matrouh region.

The annual change of around -4 to 0 per °C global change in precipitation is made up of increased rainfall in the spring and summer seasons (lower maps, Figs. 3 and 4), and drier conditions in winter and autumn (lower maps, Figs. 2 and 5). In winter, the suggested reduction in precipitation along the coast west of Alexandria is between 0% and 22% per °C global change, with a gradient from east to west of increasing aridity. In spring, an increase of more than 8% is indicated for virtually the whole of the area of interest. Summer conditions are also shown to be wetter as a result of the enhanced greenhouse effect, with increases of between 0% and 8% per °C global change, with greatest increase in the west of the coastal region. In autumn, the suggested changes are again negative, with a reduction of between 0% and 14% per °C global change. The greatest changes in this season are seen close to Alexandria.

5. Conclusions

We have applied the methods developed by Kim *et al.* (1984) and Wigley *et al.* (1990) to the problem of construction sub-grid-scale climate change scenarios for northern Egypt. Regression equations were developed to predict station temperature and precipitation anomalies from regionally-averaged climate anomalies. We proceeded to substitute GCM perturbed-run minus control-run values of temperature and precipitation in the regression equations to obtain a prediction of the change due to the greenhouse effect at each station. The results were scaled by the equilibrium global temperature change of each of the four GCMs, and an average change per °C global change obtained, calculated from the results for the four models. The procedure was repeated for every station in the data set, and the results contoured to produce scenarios for northern Egypt.

Annual and seasonal scenarios for both temperature and precipitation change were produced. The specific region of interest is the Egyptian coastline west of Alexandria. Here, for temperature, the annual change is indicated to be less than the global change *i.e.* in the range 0.7-0.8°C per °C global change. Broadly, the same pattern is seen in each season. Only in summer does the warming in the

Fuka-Matrouh area approach the global level (with changes in the region 0.9-1.1°C per °C global change.

The scenarios of precipitation indicate drier conditions at the annual level, with a change in rainfall in the range of -4 to 0% per °C global warming. This relatively small change is accounted for by decreases in winter and autumn, whereas conditions in spring and summer are shown to be wetter as a result of global warming. In winter, the greatest change is seen in the west, towards the border with Libya, with a reduction in rainfall of over 10% per °C global warming. In autumn, the changes are between 0% and -14% per °C global warming. The increase in rainfall in spring is over 8% per °C global warming over the whole of the Egyptian coastline west of Alexandria. In summer, the increase is greatest in the west (over 8%), dropping to 0 to 4% per °C global warming close to Alexandria.

The problems associated with the construction of regional scenarios of climate change due to the enhanced greenhouse effect are discussed at length by Palutikof *et al.* (1992), in their report to UNEP on the construction of climate change scenarios for the whole Mediterranean region. The confidence that we can place in sub-grid-scale scenarios of precipitation is particularly low. These scenarios should be considered only as indicators of changes that might occur.

ANNEX TO APPENDIX I

STATIONS USED IN SCENARIO CONSTRUCTION FOR NORTHERN EGYPT

Note that not all these stations will necessarily be used in the final scenario construction. They must first fulfill the criteria for acceptance laid down in Section 2 of this report, and by Palutikof *et al.* (1992).

CYPRUS

	Station	E	N	HT	PRN	TEM	P%	T%
1.	PAPHOS	32.4	34.8	10	1951-1989	1951-1989	100	100
2.	PRODHROMOS	32.8	35.0	1380	1967-1989	1959-1989	96	99
3.	LIMASSOL	33.0	34.7	10	1951-1989	1951-1989	100	98
4.	NICOSIA	33.4	35.2	160	1951-1989	1951-1989	100	100
5.	LARNACA	33.6	34.9	3	1951-1989	1951-1989	100	97

EGYPT

	Station	E	N	HT	PRN	TEM	P%	T%
6.	SALLOUM	25.2	31.5	6	1951-1987	1951-1987	99	89
7.	SIDI-BARANI	26.0	31.6	23	1951-1987	1951-1987	100	99
8.	MERSA-MATRUH	27.2	31.3	30	1951-1988	1951-1987	99	97
9.	NOUZHA	30.0	31.2	7	1951-1987	1951-1987	100	56
10.	ROSETTA	30.4	31.4	3	1951-1987	-	74	0
11.	DAMIETTA	31.8	31.4	5	1951-1987	-	99	0
12.	PORT-SAID	32.3	31.3	6	1951-1987	1951-1987	99	98
13.	SAKHA	30.9	31.1	-999	1951-1987	-	96	0
14.	TANTA	30.9	30.8	8	1961-1986	1951-1986	100	100
15.	ZAGAZIG	31.5	30.6	13	1961-1986	1951-1986	100	100
16.	CAIRO	31.4	30.1	74	1951-1988	1951-1986	99	83
17.	GIZA	31.2	30.0	22	1951-1986	1975-1986	100	100
18.	HELWAN	31.3	29.9	141	1951-1988	1951-1986	99	96
19.	FAYOUM	30.8	29.3	23	1961-1986	1951-1986	100	100
20.	MINYA	30.7	28.1	40	1951-1987	1951-1986	100	100
21.	ASSUIT	31.1	27.2	70	1951-1986	1951-1986	100	100
22.	QENA	32.7	26.2	74	1951-1986	1951-1986	100	100
23.	LUXOR	32.7	25.7	88	1951-1986	1951-1986	99	100
24.	ASSWAN	32.8	24.0	194	1951-1988	1951-1986	95	100
25.	SIWA	25.5	29.2	14	1951-1987	1951-1986	100	100
26.	BAHARIA	28.9	28.3	130	1951-1986	1951-1986	100	99
27.	DAKHLA	29.0	25.5	112	1951-1988	1951-1986	96	99
28.	KHARGA	30.6	25.4	73	1951-1986	1951-1986	100	100
29.	ISMAILIA	32.3	30.6	12	1951-1986	1951-1986	64	42
30.	TOR	33.6	28.2	3	1955-1986	1956-1986	48	41
31.	HURGHADA	33.8	27.3	3	1951-1986	1951-1986	99	100
32.	KOSSEIR	34.2	26.0	-999	1955-1986	1961-1986	100	99

GREECE

	Station	E	N	HT	PRN	TEM	P%	T%
33.	KERKYRA	19.9	39.6	2	1955-1987	1951-1988	100	96
34.	YANENA	20.7	39.6	-999	1956-1987	-	100	0
35.	AGRINION	21.7	38.6	47	1956-1987	-	99	0
36.	ARAXOS	21.4	38.2	23	1955-1987	1951-1970	100	100
37.	ZAKYNTHOS	20.9	37.8	8	1956-1982	1951-1982	89	79
38.	LARISSA	22.4	39.6	74	1955-1987	1951-1987	100	100
39.	AGXIALO	22.8	39.0	-999	1956-1987	1956-1987	100	100
40.	TRIPOLIS	22.2	37.6	660	1957-1987	1957-1987	100	100
41.	KALAMATA	22.1	37.0	5	1951-1989	1951-1988	92	95
42.	METHONI	21.7	36.8	34	1951-1987	1951-1987	100	99
43.	TANAGRA	23.5	38.3	-999	1957-1986	1957-1986	99	99
44.	ATHENS	23.7	38.0	107	1951-1986	1951-1988	100	97
45.	HELLENIKON	23.7	37.9	10	1951-1989	1951-1987	97	100
46.	KYTUIRA	23.0	36.2	-999	1955-1987	1955-1987	100	100
47.	SKYROS	24.6	38.9	5	1955-1987	1955-1987	100	100
48.	MILOS	24.5	36.7	-999	1955-1987	1955-1987	99	99
49.	MITILIA	26.4	39.2	-999	1955-1987	1955-1987	100	100
50.	NAXOS	25.5	37.1	9	1955-1987	1955-1987	100	100
51.	SOUDA	24.1	35.6	161	1958-1986	1958-1986	97	97
52.	ANOGIA	24.9	35.3	-999	1951-1985	-	96	0
53.	HIRAKLION	25.2	35.3	48	1955-1986	1951-1988	100	97
54.	IERPETRA	25.8	35.0	-999	1956-1987	1956-1987	99	99
55.	SITIA	26.1	35.2	28	1951-1985	-	87	0
56.	KARPATHOS	27.2	35.5	20	1971-1988	1971-1988	95	95
57.	RHODES	28.1	36.4	12	1955-1988	1955-1988	99	100

ISRAEL

	Station	E	N	HT	PRN	TEM	P%	T%
58.	LOD	34.9	32.0	49	1951-1989	1951-1988	93	100
59.	JERUSALEM	35.2	31.8	809	1951-1989	1951-1980	97	100
60.	EILAT	35.0	29.5	11	1951-1989	1951-1988	86	99

ITALY

	Station	E	N	HT	PRN	TEM	P%	T%
61.	CROTONE	17.1	39.0	155	-	1961-1985	0	100

JORDAN

	Station	E	N	HT	PRN	TEM	P%	T%
62.	IRBID	35.9	32.6	585	1955-1989	1955-1989	100	98
63.	AMMAN	36.0	32.0	771	1951-1989	1951-1989	100	100
64.	DEIR-ALLA	35.6	32.2	-224	1952-1989	1952-1989	98	98
65.	MAAN	35.8	30.2	1069	1960-1989	1960-1989	100	100
66.	WADI-YABIS	35.6	32.4	-200	1960-1989	1960-1989	95	98
67.	MAFRAQ	36.3	32.4	686	1960-1989	1960-1989	100	100
68.	ER-RABBAH	35.8	31.3	920	1960-1989	1961-1989	100	94
69.	AQABA	35.0	29.6	51	1960-1989	1960-1989	100	100
70.	JORDAN-UNIV	35.9	32.0	980	1960-1989	1961-1989	100	89

LEBANON

Station	E	N	HT	PRN	TEM	P%	T%
71. BEIRUT	35.5	33.9	24	1951-1985	1951-1985	80	84
72. RAYACK	36.0	33.9	921	1951-1984	1951-1985	76	80
73. TRIPOLI	36.0	34.6	10	1951-1982	1951-1980	77	76

LIBYA

Station	E	N	HT	PRN	TEM	P%	T%
74. BENINA	20.3	32.1	132	1951-1989	1951-1988	85	88
75. BENGHAZI	20.0	32.1	10	1951-1973	-	100	0
76. AGEDABIA	20.2	30.7	-999	1951-1988	1954-1988	99	58
77. SHAHAT	21.9	32.8	625	1951-1988	-	98	0
78. DERNA	22.6	32.7	9	1951-1988	1951-1988	31	56
79. TOBRUQ	24.0	32.1	14	1951-1973	-	100	0
80. ADEM	23.9	31.9	155	1951-1988	1951-1975	96	93
81. GIALO	21.6	29.0	62	1951-1988	1964-1988	98	86
82. KUFRA	23.3	24.2	382	1951-1989	1951-1988	86	79

SAUDI ARABIA

Station	E	N	HT	PRN	TEM	P%	T%
83. TABUK	36.6	28.4	774	1966-1989	1966-1989	59	48
84. WEJH	36.5	26.2	8	1966-1989	1966-1989	60	50

SYRIA

Station	E	N	HT	PRN	TEM	P%	T%
85. ALEPPO	37.2	36.2	393	1951-1989	1952-1988	97	99
86. LATTAKIA	35.8	35.6	9	1952-1989	1952-1988	90	94
87. DAMASCUS	36.2	33.5	724	1951-1989	1951-1988	97	99
88. SAFITA	36.1	34.8	-999	1959-1988	1959-1988	100	100
89. IDLEB	36.7	35.9	-999	1955-1988	1957-1988	100	100
90. HAMA	36.8	35.1	-999	1955-1988	1956-1988	100	100
91. HOMUS	36.7	34.8	-999	1955-1988	1955-1988	100	100
92. NABEK	36.7	34.0	-999	1955-1988	1959-1988	100	100
93. SUEIDA	36.6	32.7	-999	1958-1988	1958-1988	100	100
94. TELSHEHAB	36.0	32.7	-999	1958-1988	1958-1988	100	100

TURKEY

Station	E	N	HT	PRN	TEM	P%	T%
95. IZMIR	27.3	38.4	25	1929-1989	1929-1988	97	98
96. MUGLA	28.4	37.2	646	1951-1989	1951-1988	94	96
97. AFYON	30.5	38.8	1034	1951-1989	1951-1988	97	98
98. ISPARTA	30.6	37.8	1043	1951-1989	1951-1988	97	98
99. ANTALYA	30.7	36.9	43	1929-1989	1930-1988	97	98
0. ANKARA	32.9	40.0	894	1926-1989	1926-1988	98	98
1. KONYA	32.5	37.9	1022	1951-1989	1951-1988	93	98
2. KAYSERI	35.5	38.7	1070	1951-1982	1951-1988	97	91

3.	ADANA	35.3	37.0	66	1929-1985	1929-1985	96	97
4.	SIVAS	37.0	39.8	1285	1929-1989	1930-1980	98	100

E - latitude
N - longitude
HT - height above sea level (m)
PRN - length of precipitation record
TEM - length of temperature record
P% - percentage of precipitation record present
T% - percentage of temperature record present