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DETAILED VARIATIONS IN MEAN TEMPERATURE AND HEAT CONTENT OF SOME EGYPTIAN LAKES.

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ABSTRACT

Detailed variations in the mean temperature and heat content were studied for some Egyptian lakes. These lakes are: Maryut, Idku, Burullus, Manzalah, Port-Fouad and Bardawil lagoon. The depth and volume development of a lake may have a considerable effect on its temperature curve and consequently on its heat content. The bigger lakes (Bardawil and Manzalah) with larger volume and greater mean depth contain more heat (40,565 and 26,744 cal. cm^{-2}) throughout the year. Cluster analysis illustrated that, Burullus and Manzalah lakes are very close to each other; Idku lake, in some extent, is similar to them. Bardawil lagoon dose not have any similarity with the other lakes.

INTRODUCTION

Six large depressions of relatively protected shallow water bodies, known as the northern Egyptian lakes, are connected with the Mediterranean Sea through narrow openings, termed boughaz. These lakes are: Maryut, Idku, Burullus, Manzalah, Port-Fouad and Bardawil. The first four lakes receive drainage water through agricultural drains as well as fresh water from the Nile River. The shallowness of these lakes and the rich food supply they contain render them excellent feeding and breeding grounds for many fish species. According to statistics of the Ministry of agriculture, the total fish catch landed from these lakes constituted about 53 % of the total fish yield of the country. Natural and cultural influences on these lakes and corresponding physical, chemical, hydrological and biological changes have been documented (Maclaren, 1981).

Studies of mean temperature and heat budgets of these lakes were not carried out until now. My objective was to study the detailed variations in the mean temperature and the heat content of some Egyptian lakes. These lakes are illustrated in Fig. 1.

MATERIALS

Original data on temperature have been taken from publications and unpublished data reports (Table 1).

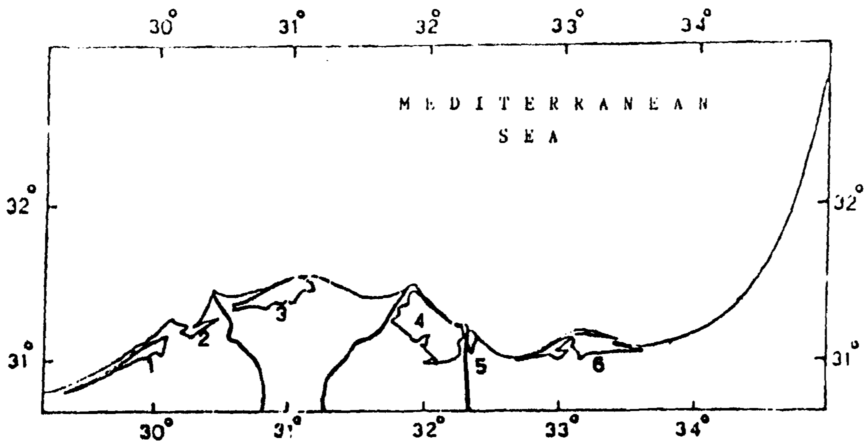

Fig. 1

Showing locations of the lakes under study. Lakes are: 1- Maryut; 2- Idku; 3- Burullus; 4- Manzalah; 5- Port-Fouad and 6- Bardawil.

Lake	Data source	Investigated period	Monthly sampled stations
Maryut	Hafez, 1982	October 1978 - September 1979	8
Idku	Mohamed, 1981	February 1979 - January 1980	19
Burullus	El-Maghraby et al., 1974	June 1967 - May 1968	10
	Darrag, 1984	September 1977 - August 1978	13
Manzalah	Abdel-Moati, 1985	January - December 1982	50
Bardawil	Ben-Tuvia et al., 1975	January - December 1974	1

Table 1.

Sources of data on temperature in some Egyptian lakes.

The daily sampling period for each lake started usually from 7 a. m. to about 5 p. m. in winter and extended to 7 p. m. in summer. Due to the large areas of the lakes, sampling continued for about 5-6 successive days each month.

The annual climatological data concerning air temperature were recorded at the near lakes meteorological stations and made available through the Egyptian Meteorological Authority -Cairo, Egypt.

METHOD OF CALCULATIONS

Each body of water possesses certain heat content; thus it has a store of heat which it can export to its surroundings on cooling to $0^{o}C$. This increment of heat at a temperature of $t^{o}C$ is equal to the amount of heat in calories which must have been transferred to the water mass to heat it from $0^{o}C$ to $t^{o}C$ (Franz Ruttner, 1963).

The most notable early studies of mean temperature and heat budgets were those of Birge and Juday (1914, 1921) and Birge (1915). Hutchinson (1957) expanded the work of Birge (1915) and, with additional data, compiled an impressive list comparing the heat budgets of the lakes around the world. Stewart (1973) examined the detailed variations in the heat content of lakes Mendota, Monona and Waubesa near Madison, Wisconsin.

Mean temperature can be determined irrespective of morphometric irregularities by summing the product of temperature and volume fractions for a series of layers (Birge and Juday, 1914), as was done for Stewart's work (1973) and my present paper, or planimetrically according to Hutchinson (1957).

Assuming a value of unity for density and specific heat, the mean temperature may be considered as the content of heat per unit volume (cal. cm^{-3}). The total or gross heat content is the amount of heat per unit surface area (cal. cm^{-2}) above $0^{o}C$ and is derived by multiplying the weighted mean temperature times the mean depth in centimeters (Birge, 1915).

RESULTS

(1) Lake Maryut:

Lake Maryut is one of the four delta lakes of Egypt, it is a closed, brackish, very shallow lake with an average depth of about 60 cm. forming the southern periphery of Alexandria. During the last 50 years, lake area diminished considerably, partly due to silting and partly to land reclamation projects, now its area is only about 55 km^2. The present lake occupies a portion of the Mediterranean foreshore plain at latitude 31^{o} 10'N and longitude 29^{o} 55'E.

The mean air and water temperatures and the heat content for lake Maryut are shown in Fig. 2. The means of the minimum mean water temperatures and heat budgets ($14.60^{o}C$ and 0,876 cal. cm^{-2}) were observed in February. While their maximum means were $32.80^{o}C$ and 1,968 cal. cm^{-2} respectively in August. The annual heat budget, which is the total amount of heat that enters the lake between the time of its lowest and highest heat content, was 1,092 cal. cm^{-2}. Lake Maryut has the highest mean temperature in comparison with the other lakes and the lowest heat content. This is due to its shallowness (average depth 60 cm). After August the heat content curve descends with decreasing air and water temperatures (Fig. 2).

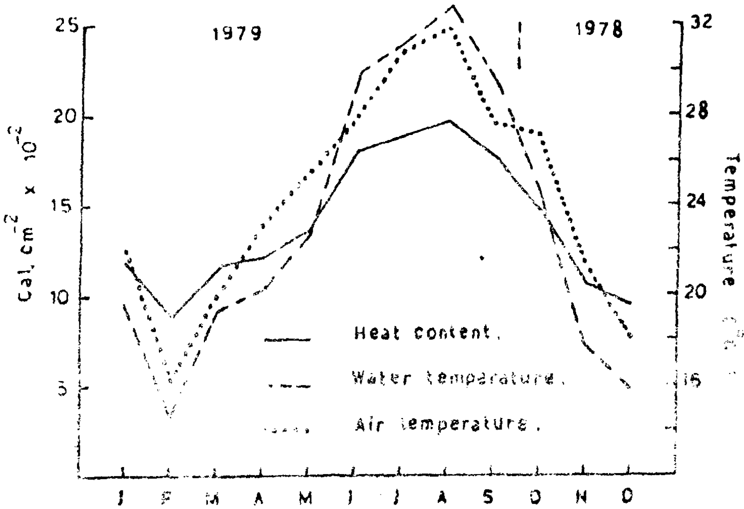

Fig. 2

The heat content (from 0 °C) of lake Maryut for October 1978-September 1979. The dashed lines represent the mean air and water temperatures of the lake.

(2) Lake Idku:

Lake Idku, a shallow brackish-water lake situated about 30 km to the NE of Alexandria, has an area of about 126 km^2 and depth ranging from 50 to 150 cm, with an average depth of about 90 cm. The lake is connected to the sea by El-Maaddiya Channel (about 2 m deep and 20 m wide).

The annual heat budget for Lake Idku in 1979 as calculated by the method of Birge (1915), is 1,533 cal. cm^{-2}. As the temperature data suggest, heat accumulation is greatly affected by variations in weather during the period of investigation. The minimum mean values of temperatures and heat budgets (12.27°C and 1,104 cal. cm^{-2}) were observed in winter. Fig. (3), illustrates that air and water temperatures are about the same during the winter months. Heating of the lake begins during relatively warm and calm spring weather. The mean heat content increases with increasing temperature to reach its maximum value (2,637 cal. cm^{-2}) in July. During that month, the air and water temperatures reach their maximum values (26.40 and 29.30°C respectively) throughout the year. During August, there is a little loss of heat after which the lake begins to cool. This is evidently due largely to heat loss at the surface by the action of autumnal weather variation.

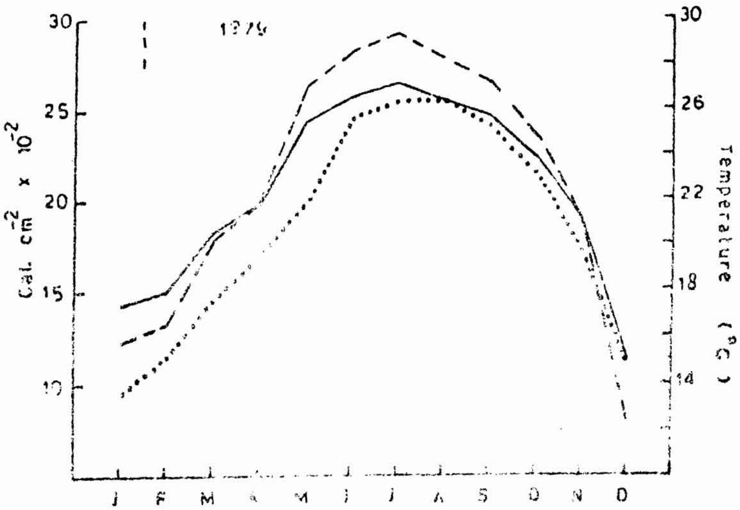

Fig. 3

The heat content (from 0 °C) of lake Idku for February 1979-January 1980. The dashed lines represent the mean air and water temperatures of the lake.

(3) **Lake Burullus:**

Lake Burullus occupies a more or less central position in the northern Delta along the Mediterranean coast of Egypt between longitudes 30° 30′ & 31° 10′ E and latitudes 31° 21′ & 31° 35′ N. It extends from east to west and is roughly rectangular in shape. It is about 60-70 km in length, the width ranging from 6 to 16 km with an average width of 11 km and has an area of about 462 km^2. The length of the shore line is about 150 km. Its depth ranging between 50 cm and 200 cm with an average depth of one meter.

The annual cycle of mean air and water temperatures and the mean heat budgets are shown in Figures (4 & 5). In Fig. (4), the minimum mean water temperature (14.20°C) and heat content (1,420 cal. cm^{-2}) for lake Burullus were observed in February. With increasing the air and water temperatures, the heat content increases to reach its maximum values (2,900 cal. cm^{-2}) in August. From September through December these variables decrease to reach 15.80°C and 1,580 cal. cm^{-2} respectively. The annual heat budget was 1,480 cal. cm^{-2}.

The means of minimum temperatures (14.50°C) and the heat content (1,450 cal. cm^{-2}) for the lake during the period from September 1977 to August 1978 were observed in January (Fig. 5). The maximum means were 29.00°C and 2,900 cal. cm^{-2} respectively in July, with an annual heat budget of 1,450 cal. cm^{-2}.

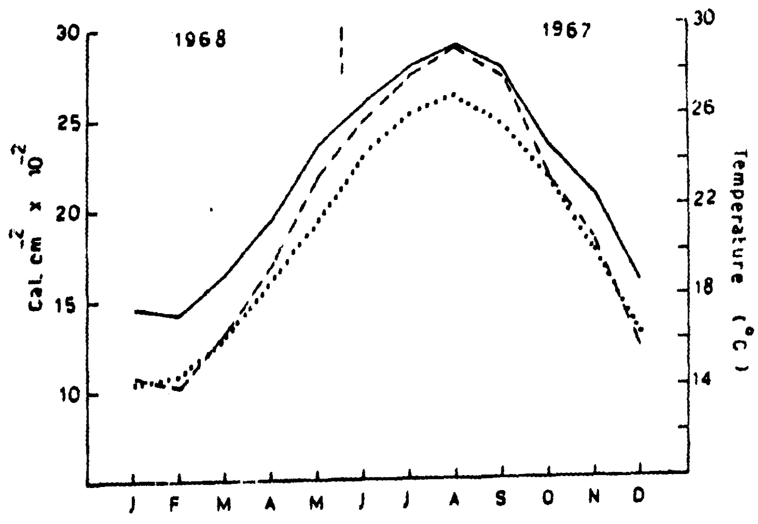

Fig. 4

The heat content (from 0 °C) of lake Burullus for June 1967- May 1968. The dashed lines represent the mean air and water temperatures of the lake.

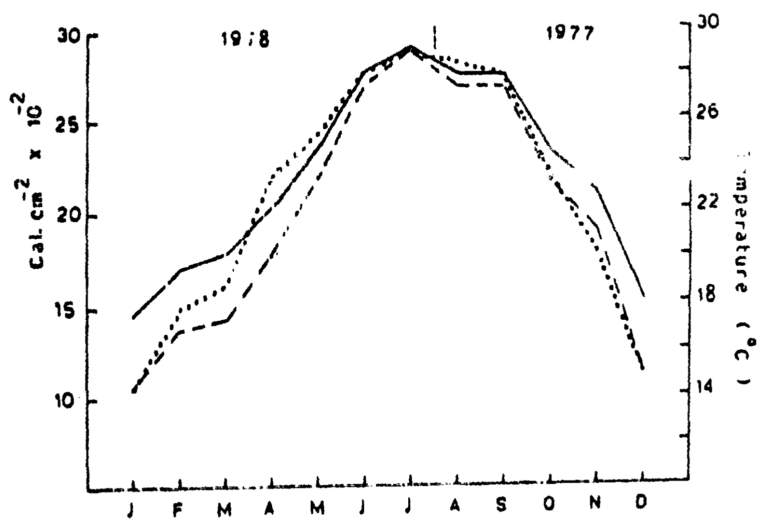

Fig. 5

The heat content (from 0 °C) of lake Burullus for September 1977-August 1978. The dashed lines represent the mean air and water temperatures of the lake.

Apparently the older calculated annual heat budget of lake Burullus (1967-1968) are of the same order of magnitude indicated by the more recent data (1977-1978). Thus no significant warming or cooling trend is suggested from these data. The only observed difference was that, the minimum and maximum means of air and water temperatures and consequently the heat content during the period (1967-1968) were observed in February and August, while they were observed in January and July during the period (1977-1978).

(4) Lake Manzalah:

Lake Manzalah is the largest of the northern Delta lakes in Egypt. The lake occupies the northern area between Damietta barnch of the Nile and the Suez Canal (long. 31° 45'; 32° 15' E, lat. 31° 00'; 31° 35' N). It is borderd by the Mediterranean Sea to the north while its southern and southwestern borders are surrounded by cultivated land. The lake is rectangular in shape with its longer axis (about 65 km) directed from northwest to southeast. Its greatest width is approximately 45 km and it has an area of about 700 km^2. The lake is shallow with an average depth of about one meter. 25 % of the lake is less then 60 cm in depth; 50 % within the range of 60-100 cm while the remaining 25 % is more than 100 cm deep (Shaheen & Yosef, 1978).

In the present work, variations in daily water temperatures were sometimes more pronounced than day to day variations. The magnitudes of these variations vary according to seasons. Maximum daily variations of surface water temperature i. e. variations between morning and noon temperatures occurred in spring and summer seasons and amounted to 6.50 and 6.80°C, respectively. This reflects the heating effect of the sun in such a shallow basin. The water temperature was warmer than the air throughout the year (Fig. 6). The means of temperatures and the heat budgets of lake Manzalah are shown in Fig. (6). The means of minimum mean temperature (14.90°C) and heat content (1,490 cal. cm^{-2}) for the lake of the year 1982 were observed in December. while the maximum values (29.29°C and 2,929 cal. cm^{-2}) were observed in August. The heat content of the lake varied between the maximum in summer and a minimum in winter, with an annual heat budget of 1,439 cal. cm^{-2}.

(5) Port-Fouad Lagoon:

Port-Fouad lagoon lies east of Port-Fouad at the north-east end of Suez Canal. It extends about 13 km along the Suez Canal and 14 km along the Mediterranean Sea coast. It lies within longitude 32° 20'; 32° 30' E and latitude 31° 07'; 31° 15' N. It has an area of about 88.2 km^2, the maximum water depth reaches about 130 cm and the mean depth is 70 cm. The lake has a triangular shape with two outlets, one to the Mediterranean Sea with an average width of about 25m, and a depth of about 3 m and 1/2 km in length. The other outlet is to the Suez Canal. It is slightly deeper and shorter than the first.

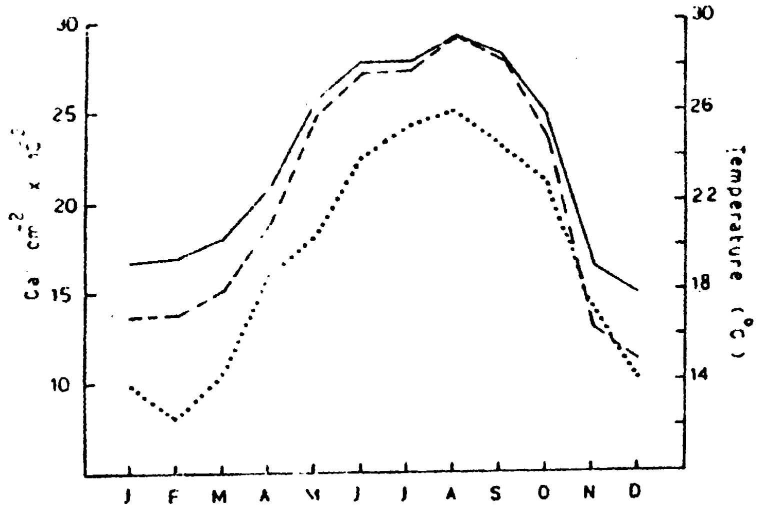

Fig. 6

The heat content (from 0 °C) of lake Manzalah for January - December 1982. The dashed lines represent the mean air and water temperatures of the lake.

The major features of heat distribution in Port-Fouad lagoon are due partly to the seasonal temperature variations (Fig. 7) and partly to the periodic cycles of heat accumulation. The mean temperature and heat content values ranged from 12.45°C and 872 cal. cm^2 in December to 30.50°C and 2,137 cal. cm^{-2} in July. From January through April there was little change in the heat content. From June to September, the maximum values of heat content were observed. The seasonal variation in heat storage is clearly evident, and the annual heat budget was 1,266 cal. cm^{-2}.

(6) Bardawil Lagoon:

The Bardawil hypersaline lagoon in the northern Sinai desert is situated between 32° 40′ and 33° 30′ E and between 31° 03′ and 31° 14′ N. It is about 90 km long with a maximum width of 22 km and has an area of about 650 km^2. It has an average depth of about 150 cm. Its continued existence is made possible by maintaining two inlets from the Mediterranean Sea by dredging.

For Bardawil lagoon, measurements of water temperatures were taken from a single station during the period from January to December 1974. The sampling station was that described by Ben-Tuvia and Gilboa (1975).

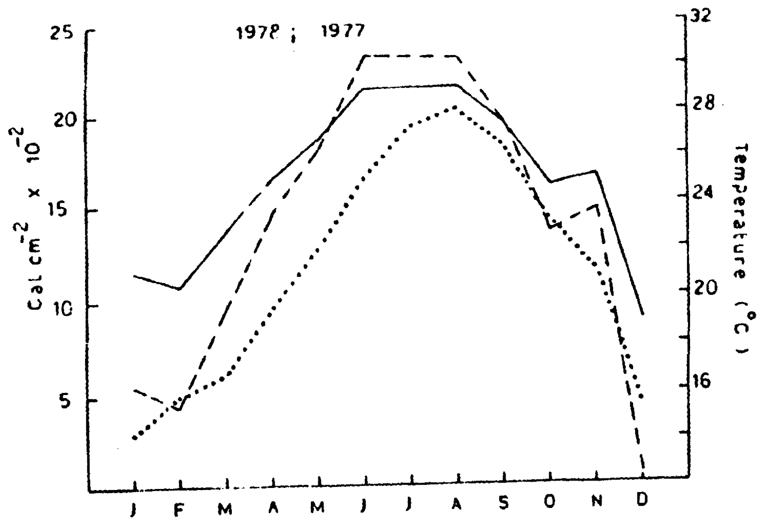

Fig. 7

The heat content (from 0 °C) of Port-Fouad lagoon for May 1977-April 1978. The dashed lines represent the mean air and water temperatures of the lagoon.

Air temperature fluctuates between the lowest winter minimum of 11.90°C to the summer maximum of approximately 25.50°C. The shallow water of the lagoon is sensitive to the air temperature and solar radiation. The mean monthly water temperature as recorded at Mat-Iblis in the centre of the lagoon fluctuates between a January low of 12.70°C and a June high of 30.00 °C (Fig. 8). From the figure, the mean heat content varies between 1,890 cal. cm^{-2} in January and 4,500 cal. cm^{-2} in June, with an annual heat budget of 2,610 cal. cm^{-2}.

Clusteral analysis:

In order to determine the degree of similarity between these lakes, depending on the mean heat content, the cluster analysis is used. The monthly distribution of the mean heat content in the lakes under study are listed in Table (2).

From this table the following Euclidian distance matrix can be computed.

		1	2	3	4	5	6
	1	0	2410.3	2904.0	3000.4	1054.0	7112.3
	2		0	720.0	868.0	1495.0	4786.5
D =	3			0	635.5	2048.0	4267.9
	4				0	2232.7	4174.7
	5					0	6291.9
	6						0

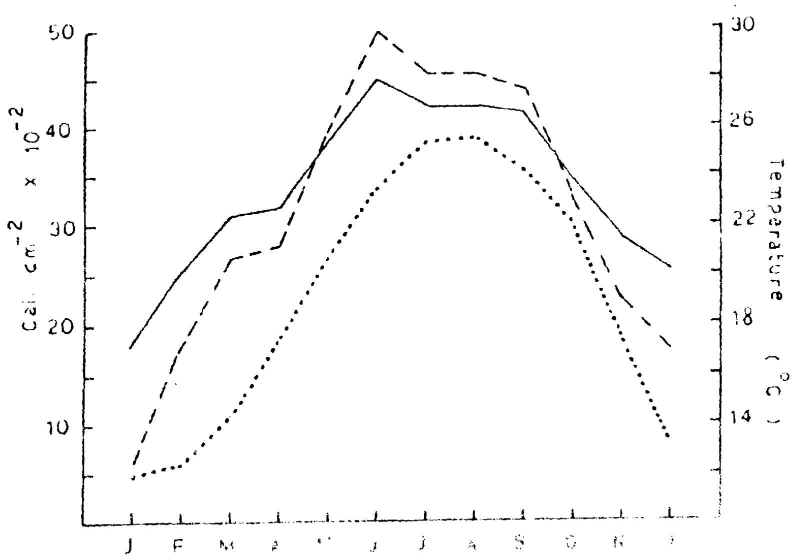

Fig. 8

The heat content (from 0 °C) of Bardawil lagoon for January - December 1974. The dashed lines represent the mean air and water temperatures of the lagoon.

Depending on this matrix, the Dendrogram between the lakes and distances was constructed (Fig. 9). From the Dendrogram, it is clear that Burullus and Manzalah lakes are very close to each other; Idku lake, in some extent, is similar to them. Bardawil lagoon has no similarity with the other lakes.

Table 2.

Monthly distributions of the mean heat content (cal. cm^{-2}) in the lakes under study.

	L. Maryut	L. Idku	L. Burullus	L. Manzalah	L. Port-Fouad	L. Bardawil
January	1,176	1,418	1,450	1,673	1,149	1,890
February	0,876	1,482	1,700	1,705	1,084	2,565
March	1,152	1,824	1,770	1,809	1,368	3,105
April	1,218	1,971	2,030	2,098	1,649	3,180
May	1,362	2,434	2,360	2,572	1,844	3,870
June	1,794	2,573	2,760	2,773	2,132	4,500
July	1,878	2,639	2,900	2,777	2,137	4,225
August	1,968	2,542	2,740	2,929	2,129	4,225
September	1,770	2,450	2,740	2,817	1,932	4,140
October	1,464	2,226	2,320	2,465	1,586	3,465
November	1,068	1,868	2,110	1,636	1,658	2,850
December	0,954	1,104	1,510	1,490	0,872	2,550

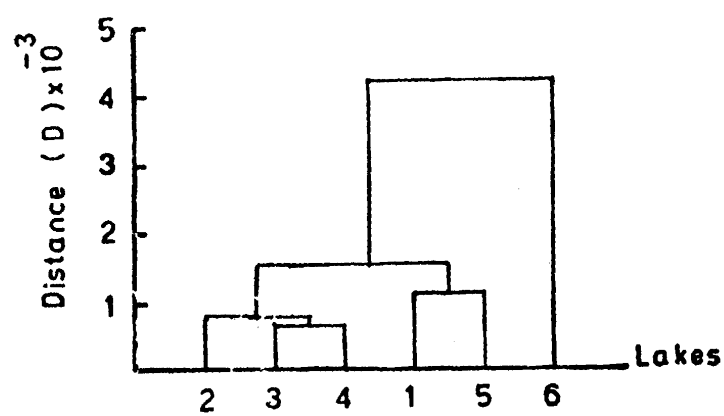

Fig. 9

Dendrogram showing the similarity between the lakes under study.

CONCLUSION

This is the first attempt to study the detailed variations in the mean temperatures and heat contents for some Egyptian lakes. The mean temperatures and the annual heat budgets for the various Egyptian lakes for which adequate information exists are set out in table (3).

Table 3.

Mean temperature (^oC) and annual heat budgets (cal. cm^{-2}).

Lake	Maryut 1978-1979	Idku 1979-1980	Burullus 1967-1968	Burullus 1977-1978	Manzalah 1982	Port-Fouad 1977-1978	Bardawil 1974
Mean depth	60 cm	90 cm	100 cm	100 cm	100 cm	70 cm	150 cm
Maximum mean temperature	32.80 ^oC	29.30 ^oC	29.00 ^oC	29.00 ^oC	29.29 ^oC	30.53 ^oC	30.00 ^oC
Minimum mean temperature	14.60 ^oC	12.27 ^oC	14.20 ^oC	14.50 ^oC	14.90 ^oC	12.45 ^oC	12.60 ^oC
Annual heat budget (cal. cm^{-2})	1,092	1,533	1,480	1,450	1,439	1,266	2,610

There is an inverse correspondence of mean temperature and heat content for these lakes (Figures 2-7). for example, lake Maryut and Port-Fouad lagoon have the highest mean temperatures and the lowest heat content. This is not an unusual phenomenon but rather illustrates what one would expect when considering the lake mean depth and the way in which mean temperature and heat contents are related (Gorham, 1964).

The depth and volume development of a lake may have a considerable effect on its temperature curve, and consequently on its heat budget. The bigger lakes (Bardawil and Manzalah) with larger volume and greater mean depth contain more heat (40,565 and 26,744 cal. cm^{-2} respectively). The smaller shallower lake (Maryut) has low heat content (16,680 cal. cm^{-2}) throughout the year.

Cluster analysis illustrated that, Burullus and Manzalah lakes are closed to each other; Idku lake, in some extent, is similar to them. Bardawil lagoon does not have any similarity with the other lakes. This could be due to the very high salinity values of Bardawil lagoon. Under optimum conditions the lagoon's salinity is mostly between 45 $‰$ and 55 $‰$ throughout the year (Pisanty, 1980). Meanwhile, the other lakes contain fresh or brachish waters.

REFERENCES

Abdel-Moati, A.R. 1985. Studies on the chemistry of lake Manzalah waters "Egypt". Ph. D. Thesis, Alexandria University, Egypt, 433 p.

Ben-Tuvia, A. and A. Gilboa, 1975. Progress report on the fisheries research in the Bardawil lagoon. Haifa Israel Oceanographic and Limnological Research, Internal report, 15 p. (in Hebrew) (mimec).

Birge, E.A. 1915. The heat budgets of American and European lakes. Trans. Wis. Acad. Sci. 18: 166-213.

Birge, E. A. and C. Juday, 1914. A limnological study of the Finger lakes of New York. Bull. U. S. Bur. Fish. 32: 525-610.

Birge, E. A. and C. Juday, 1921. Further limnological obesrvations on the Finger lakes of New York. Bull. U. S. Bur. Fish. 37: 209-252.

Darrag, A.A. 1984. The occurrence and distribution of some trace metals "Fe, Mn & Cu" in lake Borullos and their relation to organic matter. Ph. D. Thesis, Alexandria University, Egypt, 388 p.

El-Deek, M.S. 1979. Physical and chemical variation of Port-Fouad lake, Egypt. M. Sc. Thesis, Cairo university, 107 p.

El-Maghraby, A.M.; M. T. Hashem & H. M. El-Sedfy, 1974. Sexual maturity, spawning migration and fecundity of Mugil capito (cuv.) in lake Borollus. Bull. Inst. Oceanogr. & Fish. ARE, 4: 33-56.

Franz Ruttner. 1963. Fundementals of limnology. Third Edition, 295 p.

Gorham, E. 1964. Morphometric control of annual heat budgets in temperate lakes. Limnol. Oceanogr. 9: 525-529.

Hafez, H.H. 1982. Distribution of heavy metals in lake Maryut and Nozha hydrodrome and their accumulation in fish. M. Sc. Thesis. Alexandria University, Egypt, 177 p.

Hutchinson, G.E. 1957. A treatise on limnology. V. 1. Wiley, 1015 p.

Maclaren Engineers Planners and Scientists Inc. 1981. Lake Manzalah study, EGY/76/001-07 Draft final report to the Arab Republic of Egypt, Ministry of Development and new communities and UNDP Office for projects Execution, Toronto, Canada, 12 vols.

Mohamed, E.M. 1981. Exchange of water masses between lake Idku and Abu Qir Bay. M. Sc. Thesis, Alexandria University, Egypt, 129 p.

Pisanty, S. 1981. The Fishery and management of the hypersaline lagoon of Bardawil. Fifteenth Session, Palma de Mallorca, Spain, 18-20 September 1980, GFCM/XV/80/22,: 1-36.

Shaheen, A.H. and S. F. Yosef, 1978. The effect of the cessation of the Nile flood on the hydrographic features of lake Manzalah, Egypt. Arch. Hydrobiol., 84 (3): 339-367.

Stewart, K.M. 1973. Detailed time variations in mean temperature and heat content of some Madison lakes. Limnol. & Oceanogr., 18 (2): 218-226.