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THE EFFECT OF REGULATION OF THE NILE RIVER DISCHARGE ON THE OCEANOGRAPHIC CONDITIONS AND PRODUCTIVITY OF THE SOUTHEASTERN PART OF THE MEDITERRANEAN SEA

UTJECAJ REGULACIJE DOTOKA RIJEKE NIL NA OCEANOGRAFSKA SVOJSTVA I PRODUKCIJU JUGOISTOČNOG DIJELA SREDOZEMNOG MORA

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Before the damming of the Nile River, the southeastern part of the Mediterranean Sea was one of the most productive areas in the Mediterranean Sea (Gorgy & Shaheen, 1964; El-Zarka & Koura, 1965; Gorgy, 1966; Halim *et al.*, 1967). The Nile discharge was the main reason for the high biological productivity of the shelf waters of the southeastern part of the Mediterranean Sea. The life cycle of sea organisms in this area depends mainly on the river discharge, particularly on the seasonal dynamics of plankton and pelagic fish migration. Therefore, the high decrease in the river discharge after 1965 affects greatly the physical, chemical and biological conditions in the southeastern part of the Mediterranean Sea.

INTRODUCTION

Annually, the Nile waters brought to the sea great amount of biogenic and organic substances as well as mineral particles. This provided good production of plankton organisms and benthos and created favourable conditions for the existence of fish, crustaceans and other marine organisms. The connection between abiotic factors and marine organisms living on the shelf is found historically throughout along period of time.

RESULTS

The Nile Discharge

The average yearly discharge of the Nile River measured at Edfina (30 km south of Rosetta outlet), and at Damietta (20 km south of Damietta outlet) for the period of 1912 to 1942 amounted to 62 km^3. Recently, this discharge was reached except in 1964. In the summer of 1964, the last normal discharge of the Nile flood into the Mediterranean Sea was unusually high (63.73 km^3). The average total discharge for the preceeding 8 years (1956—1963) amounted to 40.95 km^3. From 1965 on, the discharge remarkably decreased, and the average total discharge during the succeeding 8 years (1965—1972) amounted to 11.50 km^3 (Table 1). From Table 1, it can be observed that in 1965, the Nile River discharge decreased to about half and in 1966 to about one-fifth of that in 1964. From 1968 on, the annual amount of discharge averages only one tenth of the average value for the period prior to 1964.

Table 1. Annual total water discharge (in km^3) from the Nile River into the Eastern Mediterranean Sea for a period of 17 years (1926—1972).

a — Before the Aswan High Dam:

Year	1956	1957	1958	1959	1960	1961	1962	1963	1964
Discharge (km^3)	55.75	34.03	44.55	49.36	38.72	58.52	44.01	43.64	63.73

Average annual discharge — 40.95 km^3

b — After the Aswan High Dam:

Year	1965	1966	1967	1968	1969	1970	1971	1972
Discharge (km^3)	36.94	13.24	21.51	5.87	3.60	4.02	4.10	2.69

Avegare annual discharge — 11.50 km^3

Moreover, the annual cycle of the discharge has changed.

Before the High Dam, the Nile waters were regulated by a system of dams on its two tributaries, the Damietta and Rosetta branches (Fig. 1). The discharge usually occurred from July to August until December or January, and the maximum discharge was observed in September—October (25—30 percent of the total discharge).

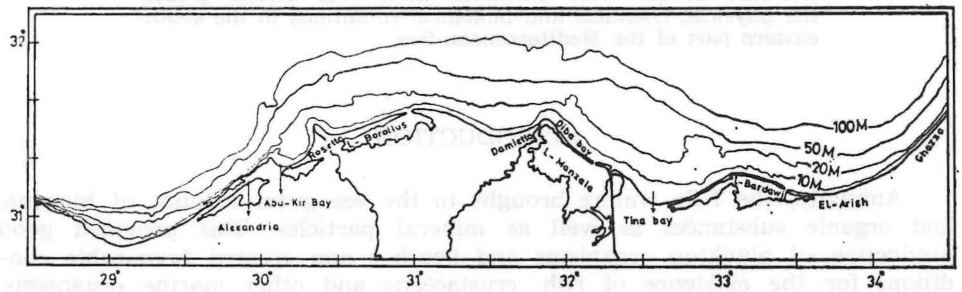

Fig. 1 - Map showing the south-eastern part of the Mediterranean Sea showing the two tributaries of the River Nile.

According to G e r g e s (1976), at present the discharge is only through the Rosetta mouth, and the maximum is registered in winter. For only two months (January and February), more than 50 precent of the total yearly discharge now flows into the Sea.

Therefore, such a change in both the total amount and the pattern of the discharge affects to a great extent the physical, chemical as well as biological conditions in the southeastern part of the Mediterranean Sea.

The Physical Conditions

Temperature and Salinity

Fig. 2 shows a distinct horizontal and vertical distribution of temperature for each season. For example, the water temperature has great vertical gradients in the layer 50 to 75 m in autumn, while in winter, it is homothermal to the depths of 100 to 150 m, and sometimes even down to the 200 m level, below which the temperature starts to decrease slowly, Gerges (1976). The spring and summer seasons have also their own particular temperature distributions vertically as well as horizontally.

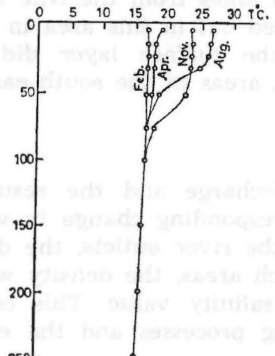

Fig. 2 - Typical vertical distribution of water temperature in the southeastern Mediterranean Sea for different months during 1966 (after Rzhonsnitsky, 1970).

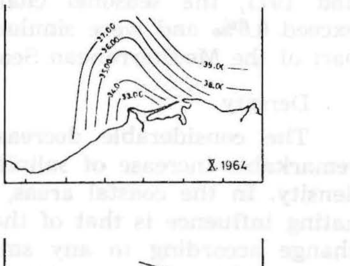

Fig. 3 - Surface salinity distribution off the mouth of the Nile River before the Aswan High Dam (October 1964) and after completion of the High Dam (November 1966).

Recently, it has been observed that in the vertical distribution of water temperature, the increase of the thickness of the warmed layer near the coast of the Nile Delta occurs in summer. This warming is due to the improvement in the conditions required for the vertical mixing of water, achieved through increasing the water density on the surface as a direct result of decreasing the amount of fresh water discharge. This warmed layer extends now to the 100 m level, and only below that level the water temperature starts slowly to decrease.

The most pronounced and direct effect of the damming of the Nile River is reflected on the salinity distribution in the southern Levant, particularly in the region close to the Nile Delta.

Fig. 3 shows the surface salinity distribution off the Nile Delta in two comparable autumn months, October 1964 and November 1966, and representing the conditions before and after the damming of the Nile. The figure clearly illustrates the changes in the horizontal distribution of salinity in this region. Furthermore, until the regulations of the Nile River discharge in the studied area at the time of Nile flood, three zones were distinguished clearly; the freshing zone, within its limits a gradual mixing of Nile waters occurred; a zone of intensive mixing of fresh and sea waters; and finally holistatic zone.

In 1964, the river discharge was the greatest since 1956 and the fresh water in October 1964 occupied a large area of the Sea, the width of which extended to about 70 km to the north of the Rosetta outlet. The 1966 distribution showed that this freshing zone has greatly diminshed relative to the amount of 1964. Mixing of fresh and sea water occurred only near the coast and almost all the investigated region, with the exception of a narrow coastal zone, was occupied by sea water of a salinity higher than 38.5‰ (Fig. 3). Only in February 1966, the freshing zone was represented clearly in the eastern part of the region; however, its width did not exceed 16 km.

In 1964 the difference between the maximum and minimum values of salinity in the area located at a distance of 10—15 miles from the Nile Delta was over 4‰. According to the investigations carried out in this area in 1966 and 1971, the seasonal changes of salinity in the surface layer did not exceed 0.6‰ and were similar to those in the open areas of the south-eastern part of the Mediterranean Sea.

Density

The considerable decrease of fresh water discharge and the resulting remarkable increase of salinity brings forth a corresponding change in water density. In the coastal areas, and especially near the river outlets, the dominating influence is that of the salinity. Thus in such areas, the density would change according to any small variation in the salinity value. This consequently affects the stability conditions, the mixing processes and the entire current system in the area.

Transparency

The Nile discharge decrease also had a great influence on the transparency of the sea water. The change in water transparency on the shelf was caused mainly by two factors; a sharp decrease in the solid discharge of the Nile River and the phytoplankton density especially in the coastal area after 1966.

According to Shukry (1950), before the regulation of the Nile, about 57×10^6 tons of suspended sediments were discharged yearly into the Mediterranean Sea. A large amount of the sediment was carried during the flood period; one cubic metre of Nile water contained, at the peak of the flood, up to 4 kg of suspended solid material. Fig. 4a of October 1964, the year of the highest flood, shows that the Nile waters then occupied a large area of the sea, and illustrates that the transparency of sea water to the north of Rosetta, on the line dividing the fresh and sea water, has changed rapidly from 10 m to 35 to 40 m within a distance of only 300 to 500 m. This was not the case after the regulation took place (Figs. 4b and c). The construction of hydrotechnical structures on the Nile River and its branches brings about an active sediment accumulation in artifical ponds. At the present time, over half the yearly solid discharge of the Nile settles down in Lake Nasser. Consequently the concentration of the suspended solid particles in the Nile water has greatly reduced and at present, the Sea receives less than 10 percent of the volume of silt material which entered it before the Nile discharge control. Such a sharp reduction of the solid material discharge has already resulted in an increase of the Sea water transparency by 15—20 m (as compared to 1964) and adversely affected the formation and dynamics of sediment and shores near the Delta and north of it.

Water Masses

Halim, Guergues and Saleh (1967) defined five water masses during the flood season of 1964 including:

1 — An »epithalassa« of very low salinity and of a high gradient, corresponding to the upper horizontal segment in the T-S diagram shown in Fig. 5a.

2 — The layer of maximum salinity, corresponding to the zone of flexion in the T-S diagram (Fig. 5a). The temperature was slightly lower but showed little variation within this layer.

3 — The layer of subsurface salinity minimum, corresponding to that portion of the T-S diagram (Fig. 5a) with inward curvature. Salinity decreased slowly while temperature dropped rapidly.

4 — Nielsens »intermediate« layer of salinity maximum, indicated by a slight distinct increase in salinity at about 200 to 300 m.

5 — Deep water layer, found below the 400 m level, the characteristics of which did not change throughout the year.

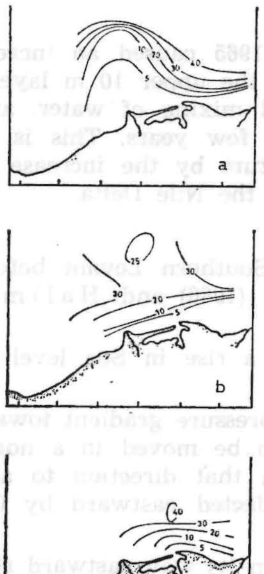

Fig. 4 - Distribution of seawater transparency (Secchi disc. readings in m) off the mouth of the Nile River for October 1964 (a), August 1966 (b) and September 1970 (c).

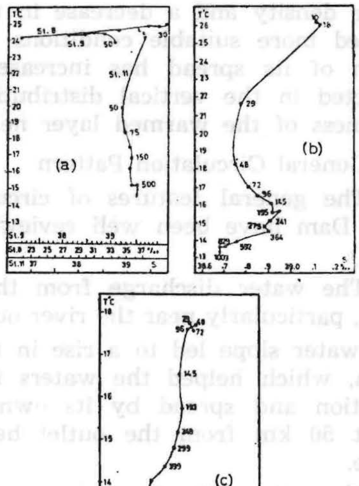

Fig. 5 - T-S diagrams for the southeastern Mediterranean Sea near the coast of Egypt before regulation of Nile discharge (a) (after Halim, Guergues and Saleh, 1967), and after regulation during summer (b) and winter (c).

Recent investigations, carried out after the regulation of Nile discharge, have shown clearly that the surface water mass, the so called »epithalassa« layer, mentioned above, completely disappeared (Fig. 5b). Now, there are only four water masses during the summer including:

1 — The surface water mass which extends from the surface to 30 to 50 m depth and has a temperature range of 22 to 28°C and a salinity of 38.8 to 39.1‰.

2 — A water mass of low salinity formed through the transformation of Atlantic water, with a temperature range of 17 to 23°C and a salinity range of 38.6 to 38.8‰. The core layer of this water mass lies at 50 to 75 m.

3 — An intermediate water mass of high salinity, at depths from 150 to 400 m with a temperature range of 15 to 17°C and a salinity range of 38.9 to 39.00‰.

4 — A deep water mass, below 400 m within the limits of this water mass, in the layer 400 to 1200 m, the temperature range is 13.6 to 14.5°C and the salinity 38.68 to 38.87‰.

During winter, due to the decrease of the vertical stability, and the resulting mixing processes, the surface waters sink to great depths and there are only two identifiable water masses (Fig. 5c). These can be called the upper and deeped water masses.

Hydrodynamical Conditions

Stability and Mixing Processes

The considerable increase in salinity after 1965 caused an increase in water density and a decrease in the stability in the upper 10 m layer. This created more suitable conditions for the vertical mixing of water, and the depth of its spread has increased for the last few years. This is visibly reflected in the vertical distribution of temperature by the increase of the thickness of the warmed layer near the coast of the Nile Delta.

General Circulation Pattern

The general features of circulation in the Southern Levant before the high Dam have been well reviewed by Gorgy (1966) and Halim *et al.* (1967).

The water discharge from the Nile caused a rise in Sea level at the coast, particularly near the river outlets.

The water slope led to a rise in the horizontal pressure gradient toward the north, which helped the waters from Rosetta to be moved in a northwest direction and spread by its own momentum in that direction to an area about 50 km from the outlet before being deflected eastward by Coriolis Force.

Thus, the »Nile Stream« was formed which in its way eastward received more flood water from Damietta. This influx reinforced the stream and increased its velocity to 3.2 knots, Halim *et al.* (1967). Conditions at Damietta were somewhat different from Rosetta. The Damietta branch was directed northeast, and its output usually amounted to about half that of Rosetta branch. The flood water did not spread as far seaward and there was no sharp change in direction. The stream moved further to the east remaining close to the coast and then ultimately became directed northward, but its salinity was still very low (34.2‰). While the stream proceeded northward, highly saline waters off Israel and Lebanon were set into a surface countercurrent which converged with the stream, producing a cyclonic counterlockwise vortex, characteristic for the circulation in this region, Gerges (1976).

At present, the Nile waters do not cause such a rise in the water level near the coast. As a result, the horizontal pressure gradients are much less and the Nile stream has practically disappeared. For the same reason, the current velocities in the Delta region decreased considerably. Based on some measurements of currents in the area during the last cruise of the R/V ICHTHYOLOG in the Southern Levant in 1971, the total current velocity rarely exceeded 0.5 knots.

The present circulation pattern shows a permanent current flowing in summer very close to the coast from west to east. It is observed between the coast and the 50 to 75 m isobath. In winter, there is an indication of a westward current north of 32° N Latitude and water flow to the west was observed. This was confirmed in a recent study of the circulation in the Eastern Mediterranean in the winter season (Gerges, 1976).

The Chemical Conditions

Oxygen

According to the investigations carried out in Southeastern part of the Mediterranean Sea in 1964 (the last normal discharge of the Nile River), the production of oxygen by phytoplankton was much more effective than in 1970.

In October 1964, the oversaturation of water with oxygen in the 10—20 mile circumlittoral zone amounts to 135—125 percent. In the zone of intensive mixing of diluted and sea waters, it was noticed that the oxygen saturation ranging from 125 to 105 percent. While in September 1970, the oxygen saturation in the studied area did not exceed 102 percent. It was observed also, that there was no difference between the oxygen content in the surface waters of the coastal zone and in the open Sea. According to our investigations, the vertical distribution of oxygen in the two compared years was very different especially near the coast. In 1964 the dissolved oxygen content in the coastal area reduced with depth (up to 60—80% at the levels of 20—30 m). During the flood period, the great positive stability in the layer 0—10 m prevented the mixing of surface and near bottom waters. Recently, the vertical oxygen distribution in the area near to the Delta changes to a negligible degree and sometimes increases with depth.

Biogenic Salts

After the control of the Nile River discharge, the concentration of biogenic salts was remarkably reduced. According to the data of Alexandria Institute of Oceanography and Fisheries, the phosphate content in the river water recently amounts to an average of 0.7 μg-at P/l, Silicates about 30 μg-at Si/l and nitrites — 4 μg-at NO_2/l.

The reduction of the content of nutritive salts was caused first of all by their intensive consumption in the river itself, especially in Lake Nasser. The latter accordingly will gradually turn into a highly productive pond with great possibilities for artificial fish breeding.

In 1966, the actual phosphate discharge into the Mediterranean Sea was equal to 280 tons and Silicates about 100 thousand tons.

In 1971 the Nile discharge was equal to 4.1 km^3. With this volume of water, up to 90—100 tons of phosphates and about 3.5 thousand tons of Silicates were discharged into the Sea (according to the investigations of R/V ICHTHYOLOG in 1970—1971).

At the present time, the annual discharge of phosphates into the sea is 80 times less and that of silicates is about 100 times less than during the period of normal discharge.

The actual nutrient base in the Southeastern part of the Mediterranean Sea has deteriorated to a greater degree due to reduction of the content of fine silt particles in the riverwaters.

The Nile discharge reduction has mostly affected the chemical base condition of the 10—15 mile circumlittoral zone of the Sea. According to Halim (1960), the phosphate content near the mouth of Damietta, at a distance of 3—6 km from the coast, in August 1957 and 1959 varied from 1.5 to 2.1 μg-at P/l. In October, during the phytoplankton bloom the concentration of this element dropped to 0.38—1.1 μg-at P/l. The Silicate content varied from 220 μg-at Si/l in August to 35—36 μg-at Si/l in October.

After the control of the Nile discharge, the phosphate content on the surface is equal to an average of 0.05—0.15 μg-at P/l.

The decrease of the Nile River discharge deteriorated the nutrient base of the area located north of the 50-meter isobath to a lesser degree than that near the Delta. Thus, in October 1964 the content of phosphates beyond the limit of the turbid Nile water spreading was equal to 0.13—0.21 μg-at P/l (within the zone of mixing the river and sea waters — 0.3 μg-at P/l), according to the data of the R/V ICHTHYOLOG. In November 1966 and September—October 1970 the concentration of this element in the surface layer of this area did not exceed 0.10 μg-at P/l (in the littoral zone — 0.15—0.20 μg-at P/l, in 1966 and 1970 respectively).

Thus, after the control of the Nile discharge, the biogenic base of the southeastern part of the Mediterranean Sea sharply deteriorated. This was the main reason for the reduction of the primary productivity of this area.

The Primary Production

According to the investigations carried out in the southeastern part of the Mediterranean Sea, the phytoplankton density on the Egyptian shelf was exceptionally high (Halim, 1960; Gorgy, 1966; Halim *et al.*, 1967)

There was a distinct connection between the distribution, the number and the seasonal dynamics of algae and the Nile discharge. The highest concentrations of phytoplankton were recorded near the Delta in autumn during the flood, with number about several hundred thousand cells per litre. According to Halim (1960), the observations undertaken near the Damietta mouth at the end of the 50-ies, showed the influence of the river discharge on the development of phytoplankton. These data allow to compare the number of algae in the sea water before and after the intensive dilution of the circumlittoral zone. At the beginning of August (before the Nile waters entered the Sea) the surface layer 5—6 km north of the Damietta mouth contained 60—70 thousand cells per litre. In four days after the river waters discharge into the sea, the cell numbers increased up to 1.2 million and three weeks later, they reached 2.5 million cells/l. During the following period as the content of nutrient salts decreased because of their increasing consumption, the number of algae decreased, being less than at the end of August or the beginning of September.

Halim et al. (1967) worked on the distribution of phytoplankton on the whole water shelf in October 1964. The biggest concentrations of algae were observed north of the mouth of Rosetta, the area being 25—30 miles wide and the phytoplankton concentration varying from 500 thousand to one million cells/l.

In 1966 (after the regulation) the maximum algae content in the layer of 0—10 m of the circumlittoral zone did not exceed 180 thousand cells per litre and was observed in January.

It is worth saying that in April 1965 the flow of the Nile waters to the Mediterranean Sea through the Damietta branch was stopped completely. At present only the river branch of Rosetta is functioning, only during the winter season.

In November 1966 the phytoplankton numbers in the same area were only 40 thousand cells/l. In the remaining seasons of the year in question, it did not exceed 10—11 thousand cells/l, Savich (1970). According to Salah (1971) the phytoplankton numbers on the shelf located north of the Nile Delta in 1970—1971 was remarkably reduced as compared with those in 1966.

The development of plankton was increasingly affected not only by the reduction of the river discharge but also by a change of its monthly distribution. In accordance with, there was a change of the seasonal dynamics of phytoplankton. An intensive bloom of plankton previously observed in autumn is, at present, practically not recorded.

According to Halim (1976) as early as 1965, the September phytoplankton bloom dropped to about 10 percent of its 1964 value (Table 2).

Table 2. Diatom blooms (cells/l) in nearshore waters off Alexandria after Halim (1976).

Year	Winter bloom	September bloom
1957, 1961, 1962	0.250×10^6	9 to 10×10^6
1965	0.002×10^6	0.090×10^6
1969—1970	0.011×10^6	0.002×10^6

The seasonal changes of phytoplankton numbers just as well as the salinity variations reduced on the greater part of the shelf the Nile discharge control has been affected. The latter, in addition to that caused substantial changes in the distribution of algae in the studied area. During the years of the normal discharge, especially during the flood period, the numbers of phytoplankton were less going farther away from the coast in the direction of the open Sea. In 1966 this regularity was upset. In particular in August and November 1966 the areas rich in phytoplankton were located not only near the Delta but also above the deep-sea sections of the shelf.

The effect of damming on the Mediterranean Sea fisheries

The changes which took place in the content of phytoplankton after the discharge control resulted in a sharp deterioration of the nutritive base of pelagic fishes specailly sardines, in the southeastern part of the Mediterranean Sea.

El-Zarka & Koura (1965) determined a relation between sardine catches and itra-year distribution of the River Nile discharge before the control. The relationship between the catch and discharge is indirect as the discharge provides the development of phytoplankton, the main food for sardine.

A mass entrance of Sardines in the circumlittoral zone of the sea was recorded during the flood. The biggest catches of Sardines were recorded a month after the maximum discharge. In 1962 the maximum average monthly discharge of the River Nile was in September and the biggest sardine catch was observed in October. For three months (September—November 1962) the river discharge contributed about 73% of the annual value, within this period about 95% of the annual sardine catch was produced in the shelf.

The total catch for all fish species has dropped to about 30 percent of the 1962 value (Table 3), but it is the sardine fisheries which have been sharply affected by the disappearance of the Nile bloom. It is likely that the new conditions will favour the less euryhaline forms and immigration of Erythrean species is expected to become more active and more successful (Halim, 1976).

Table 3. Catch of sardine in accordance with the total catch from the Egyptian Mediterranean waters (data from the Annual Statistical Report, Institute of Oceanography and Fisheries, Alexandria Egypt).

Year	Total catch (metric tons)	Catch of Sardine metric tons	Catch of Sardine %	Year	Total catch (metric tons)	Catch of Sardine metric tons	Catch of Sardine %
1962	37832	18,166	48.02	1972	10300	1,403	13.62
1963	33000	13,000	39.39	1973	6695	599	8.95
1964	26000	7,372	28.35	1974	6848	987	14.41
1965	24700	7,635	30.91	1975	5407	644	11.91
1966	15045	1,233	8.20	1976	7142	695	9.73
1967	12213	812	6.65	1977	7325	1,364	18.62
1968	13586	463	3.41	1978	11765	2,244	19.09
1969	8521	600	7.04	1979	19937	6,501	32.61
1970	8100	580	7.16	1980	17466	4,580	26.22
1971	10540	1,505	14.28				

This decrease in the fresh water discharge greatly affected the hydrographic conditions of the Mediterranean waters over the Egyptian Continental shelf.

These environmental changes have lead to considerable decrease in the population of pelagic fishes especially sardines in the area to the extent that the role of sardine in the Mediterranean fisheries was restricted to about 7% of the total compared to about 48% before the regulation of the Nile discharge (Table 3). (El-Maghraby 1960; Ribaat 1960; El-Zarka & Koura 1965).

In the present time, demersal fishes belonging to the families *Mullidae, Soleidae, Synodontidae, Serranidae* and *Leognathidae* constitute the main bulk of the catch from the Mediterranean Sea.

The effect of damming on shrimp fisheries

Shrimp catch from the Egyptian Mediterranean waters is mainly formed of *Penaeus trisulcatus* (Leach); *Penaeus japonicus* (Bate); *Penaeus semisulcatus* (De Haan); *Meta penaeus monoceros* (Fabricius); *Metapenaeus stebbingi;* (Nobili) and *Trachypenaeus curvirostris* (Stimpson). The shrimp fisheries occupied the second position after sardine constituing about 19% of the total catch from the Mediterranean Sea in 1962 (Table 4).

Table 4. Catch of shrimp in metric tons in comparison with catch of sardine and total catch of the Egyptian Mediterranean waters (1962—1980). (Data from annual fishery statistics of Egypt.)

Year	Total catch	Catch of sardine		Catch of shrimp	
		Catch	%	Catch	%
1962	37832	18166	48.02	7237	19.13
1963	33000	13000	39.39	8547	25.9
1964	26000	7372	28.35	3183	12.24
1965	24700	7635	30.91	4990	20.20
1966	15045	1233	8.20	3733	24.81
1967	12213	812	6.65	2882	23.6
1968	13586	463	3.41	3135	23.08
1969	8521	600	7.04	1127	13.23
1970	8100	580	7.16	833	10.28
1971	10540	1505	14.28	967	9.17
1972	10300	1403	13.62	983	9.54
1973	6695	599	8.95	653	9.75
1974	6848	987	14.41	783	11.43
1975	5407	644	11.91	748	13.83
1976	7142	695	9.73	1063	14.88
1977	7325	1364	18.62	770	10.51
1978	11765	2244	19.07	962	8.18
1979	19937	6501	32.61	1630	8.18
1980	17466	4580	26.22	1901	10.88

From 1965 onward it was subjected to a continous decrease, so that in 1970 only 833 tons were landed. In 1962 the first indications of the population composition disturbance appeared. They constituted in the notable decrease of the percentage of large shrimps belonging to the Genus *Penaeus* and in the increase of the role of smaller species (mainly, *Metapenaeus stebbingi* Nobili and *Trachypenaeus curvirostris* Stimpson). If in 1962 the bulk of the catch was represented by shrimps of the *Penaeus* and *Metapenaeus* genera, and the smaller species accounted for only 7% of the total catch. In the 1963 the percentage of the latter increased to 14% and in 1964 to 20%.

During the period 1962—1964 some Nile water was retained for intensification of the irrigation. (Abd-El-Razzek, 1974).

The investigations carried out in the southeastern part of the Mediterranean Sea in 1956—1966 (Drobisheva, 1970) revealed a sharp increase of the role of *M. stebbingi, P. longirostris* and *T. curvirostris,* the percentage of which accounted for 50% of the total yield. By comparing the data obtained from the two expeditions in the studied area 1965—1966 & 1970—1971, the shrimp habitat conditions were very different.

In 1966 they were still almost normal, while in 1970—1971 they suffered considerable change caused by five year reduction in the river flow. All representatives of the Genus *Penaeus* (*P. semisulcatus, P. kerathurus* and *P. japonicus*) have a long spawning which begins in April and ends in Autumn. In 1970, the spawning period was longer than in 1966, being still very intensive in September.

Metapenaeus monoceros and *Trachypenaeus curvirostris* have their spawning period in late summer and autumn, i.e. August, September. In 1966 and 1970 it almost coincided. There were some differences in the spawning period of *Perapenaeus longirostris,* between 1966 and 1970, because in 1966 it occurred in autumn lasting to November, while in 1970 it began earlier and was shorter in duration.

Our investigation in 1970—1971, also showed considerable changes in the biology and distribution of the main species.

The population size of all species, except *Parapenaeus longirostris* & *Penaeus japonicus* decreased. *Penaeus kerathurus* and *Metapenaeus monoceros* decreased to a greater extent than *Metapenaeus stebbingi* and *Trachypenaeus curvirostris.*

The accumulation of *Penaeus japonicus* moved to the east (Borollos and Damietta areas). The accumulations of *M. monoceros* maintained better in the east of its area. *T. curvirostris* in the west (Abu-Kir-Rosetta area). *M. stebbingi* penetrated deeper to the east of the investigated area, *M. monoceros, M. stebbingi* and *P. japonicus* had the greater importance, to the west of it *P. longirostris* and *T. curvirostris.*

At the present time the location of the main shrimp mass coincides with the location of fresh water zones.

According to the study carried out in 1970—1971, a considerable change in the shrimp quantitative distribution was noticed and explained to a great extent, by a reduced density of their accumulations which depended on alteration of the abiotic conditions and first of all changes in salinity.

Due to the influence of overfishing and deterioration of the reproductive condition, the *P. semisulcatus* population size fall off sharply as early as in 1966, and in 1971 no accumulations were found (Abd-El-Razzek, 1974).

Comparing the population size reduction for the different species, it appears that representatives of *Penaeus* species and *M. monoceros* (which inhabit those sea areas where the zone of fresh and sea water mixture was found in the period of normal flood) decreased in their number to greater extent.

As already stated, in these areas intensive sedimentation of silt particles rich in organic matter took place. Now the above species inhabit very poor water with a much high salinity.

As the spawn of the shrimps takes place here, the above conditions are of great importance for the survival of their larvae.

The shrimp habitation conditions in the coastal zones to a depth bigger than 20 m have changed to a less degree.

At the present time, suspended and organic matter brought by the River Nile and lake water are not taken far from the shore as before but settle down at lower depth. Due to this the inhabitation and reproduction conditions of *M. stebbingi* are more favourable and its population size was decreased to a far less extent than that of other *Penaeus* shrimps.

The changes which occurred in the shrimp population conditions affect the dynamics of processes which are taking place.

Now, it can be seen that the reserves of small species are in better conditions, on the other hand, the reserves of *Penaeids* which have the highest commercial value have been sharply decreased.

CONCLUSIONS

Before 1965, the southeastern part of the Mediterranean Sea was considered as one of the most productive areas. The River Nile discharge was the main reason for the high biological productivity of the shelf waters. This is due to the great amounts of organic substances and mineral particles brought to the shelf waters of the sea by the River Nile discharge through its two tributaries (Dameitta and Rosetta branches).

In 1966, the Nile discharge was reduced approximately twice, whereas in 1966 about five times and compared to the volume of discharge in 1964 (the last normal Nile flood).

From 1968, the average annual discharge is equal only to 1/10 of the average value for the period prior to 1964.

Moreover, the annual cycle of the discharge has changed. At present, the discharge is only through the Rosetta branch. This sharp change in both the total amount and the pattern of the discharge affects to a great extent the physical, chemical as well as biological conditions in the southeastern part of the Mediterranean Sea.

In the greater part of the area, there was an increase in salinity as compared to 1964 by an average of 2—3‰. Transparency in the mouth area, except for the narrow coast belt, increased to 10—20 m. The stability of sea water in the layer of 0—10 m noticeably decreased. Due to the decrease in the force of the horizontal pressure gradient caused by a sloping level near the Delta, the sea current velocity decreased greatly and its direction to the east became more pronounced owing to the sharp decrease of the discharge the vertical hydrological structure of waters in the investigated area changed. The surface water mass of lower salinity which was observed in this area before the Nile control has disappeared. The most prominent changes have taken place in the distribution of hydrochemical characteristics. At the present time, the quantity of silicates is 80 times less and that of phosphates is 100 times less than during the period of the normal discharge.

Contrasting with the high supersaturation in oxygen resulting from increased productivity in the past (120 to 130%), the surface oxygen is now the annual minimum (90 to 105%). As a result of this, the quantity of phyto and zooplankton and the chemical base of biological productivity has been deteriorated.

The phytoplankton density is now 100 times less than before the River Nile control.

The changes of living conditions of marine organisms on the Egyptian shelf have adversely affected the population, distribution and biology of majority of fishery times, specially pelagic fishes (mainly sardines).

With the decrease of the »bloom« intensity, the feeding conditions of sardine have sharply deteriorated resulting in stopping mass sardine migration, as previously observed in the coastal zone. At present, pelagic fishes play a negligible role in the marine fisheries of Egypt, making up about 7% of the total catch.

At present, bottom fishes belonging to the families *Mullidae*, *Soleidae*, *Synodontidae* and *Leognathidae* constitute the main bulk of catch.

Moreover, the population of commercial crustaceans, i.e. shrimps, has been greatly reduced especially those belonging to family *Penaeidae* (the main bulk of shrimp catch before the damming of the River Nile).

The biology and distribution of the above mentioned shrimps are closely connected with the historically formed living conditions in the Delta of the Egyptian shelf. Therefore, the decrease in the Nile river discharge affected the spawning periods and redistribution of shrimps. Owing to the shift of the maximum Nile water discharge to the winter months, the spawning of species belonging to genus *Penaeus,* usually prohibited during the summer months was delayed to embrace autumn season, and for *M. stebbingi,* even the winter. This excluded any mass formations of summer concentrations of the main shrimp species. Because of the changes in the living conditions of the main stocks of *P. trisulcatus* and *M. monoceros* inhabiting the detphs of 20—50 m were greatly reduced on account of the most significant changes of the oceanographic regime existing there. Their population decreased 10 times and 4 times respectively. Stock *M. stebbingi* living near the narrow coastal regions suffered to a lesser degree. The population of *P. japonicus* has remained quite unchanged, this species is closely connected with the coastal lagoons in its development. Owing to the changes in the composition and population of shrimps of the coastal regions of the Egyptian shelf, the significance of the large species (belonging to genus *Penaeus*) in the catch has been greatly decreased, whereas the role of small species *(M. stebbingi, T. curvirostris,* and *P. longirostris)* in the catch increases to large extent.

However, recently certain processes have been developed to compensate the decrease in the river discharge, for example the role of convection inter mixing has increased and the inflow of diluted waters into the sea from coastal lakes has grown.

In our opinion, there is now some increase in the river discharge after the final filling of Lake Nasser, this explains the increase in the catch of sardine and shrimps along the shelf recently.

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UTJECAJ REGULACIJE DOTOKA RIJEKE NIL NA OCEANOGRAFSKA SVOJSTVA I PRODUKCIJU JUGOISTOČNOG DIJELA SREDOZEMNOG MORA

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KRATKI SADRŽAJ

U ovom radu izučavaju se promjene fizičkih, kemijskih i bioloških parametara (svojstava) jugoistočnog dijela Sredozemnog mora do kojih je došlo uslijed znatnog smanjenja dotoka rijeke Nil. Nil je, naime, dugo vremena snabdijevao vode šelfa istraživanog područja velikim količinama organskih supstanci i mineralnih čestica. Život morskih organizama ovog područja uglavnom je ovisan o dotoku rijeke a posebno o sezonskoj dinamici planktona i pelagične ribe.

Izgradnja brane na Nilu izazvala je promjene temperature, saliniteta, gustoće i prozirnosti mora kao i režima strujanja. Utjecala je također i na kemijska svojstva jugoistočnog Sredozemnog mora. Dotok koji je ovom izgradnjom smanjen znatno je utjecao i na ribarstvo istraživanog područja.