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SARDINE FISHING OF THE SOUTHEASTERN MEDITERRANEAN SEA

RIBOLOV SRDELE U JUGOISTOČNOM DIJELU SREDOZEMNOG MORA

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Sardine is the first in its importance to the Mediterranean Sea fisheries. However, during the last twenty years, a drastic decline in sardine landings along the Egyptian Mediterranean coast has been observed. Several factors are responsible for this decline. The most important one is the construction of the High Dam.

INTRODUCTION

The sharp decrease in the sardine fisheries of the southeastern part of the Mediterranean Sea for the last twenty years is a well known fact. The problems encountered in attempting to answer the question »What happened to the sardine« are varied and complex.

In this paper, the various causes responsible for the decline in the sardine catch are reviewed, and the major environmental factors that have been introduced through man's activity and led to this drastic decline in the catch evaluated.

Three species of the genus *Sardinella* constitute the catch along the Egyptian Mediterranean Coast of which *Sardinella aurita* (Cuv. and Val.) constitutes about 75% of the total catch, the remainder consists of *Sardinella eba* (Cuv. and Val.) and a small percentage of less than 0.5% of *Sardinella granigera* (Cuv. and Val.) (Bishara, 1985). *Clupea pontica* (Eichwald) is obtained west of Alexandria at depths from 15 to 30 fathoms (El-Zarka and Koura, 1965).

The Nile discharge

Data from the Irrigation Department of the Egyptian Ministry of Public Works indicate that the average yearly discharge of the Nile measured at Edfina (30 km south of Rosetta Outlet) and at Damietta (20 km south of Damietta outlet) for a period of 31 years (1912—1942) amounted to 62 km.^{3} This volume of discharge has not been reached recently, except in 1964.

In the summer of 1964, the last normal discharge of the Nile flood into the Mediterranean Sea occurred. It was unusually high reaching 63.73 km^3. The average yearly total discharge for the preceding 8 years (1956—1963) amounted to 40.95 km^3. From 1965 on, the discharge has decreased considerably, and the average total discharge during the next 7 years (1965—1971) amounted to 12.75 km^3 (Table 1). From table 1, it can also be seen that in 1965 the Nile River discharge decreased by about a half, and in 1966 to about one fifth of that in 1964. From 1968 on, the annual total discharge has averaged only one-tenth of the average value for the period prior to 1964.

Table 1. Annual total water discharge (km^3) of the Nile River into the eastern Mediterranean Sea for a period of 16 years (1956—1971)

a. Before the Aswan High Dam erection

	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 erection

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

Average annual discharge 12.75 km^3.

Moreover, the annual cycle of the discharge has also changed. Before the building of the High Dam, the Nile waters were regulated by a system of small dams on its two tributaries, the Damietta and Rosetta. The discharge usually occurred from July — August until December — January, and the maximum discharge was observed in September—October (25—30% of the total discharge occurring at that time). Now the water is discharged only through the mouth of Rosetta branch and the maximum amount is recorded in winter. More than 50% of the total yearly discharge now flows into the sea during January and February (Gerges, 1976).

Drastic and complex changes in the conditions of the innermost region of the Levant have resulted from the complete retention of the excess flood water. Changes in the hydrographic conditions, in the biological economy, and in the composition of the fauna and flora have occurred.

To understand the changes which are now taking place, a comparison with the pre-Aswan High Dam conditions is necessary. The reader is referred to Halim (1960) and Halim *et al.* (1967) for investigations of the direct effects of the flood outflow and for further references. Data on the pre-High

Dam hydrographic conditions were collected around Alexandria by Dowidar (1965); El-Kirsh (1966) and Hassan (1972).

The offshore conditions were investigated during the Shoyo-Maru expedition by Gorgy and Shaheen (1964), and from the »Ichthyolog« by Halim *et al.* (1967). Subsequent surveys were made in 1966 (Morcos and Hassan, 1973; Emara *et al.*, 1973; Morcos and El-Rayiss, 1973).

It is well known that the water temperature in the south-eastern part of the Mediterranean fluctuates seasonally accross a relatively wide range (8—10°C), which is related principally to the annual cycle of solar radiations.

Before damming, there were distinct horizontal and vertical distributions for each season. The water temperature, for example, showed a considerable vertical gradient in the 50—75 m layer in autumn, while in winter, it was homothermal to depths of 100—150 m, and sometimes even down to 200 m, below which the temperature decreased slowly. The spring and summer seasons also had their own temperature distribution; both vertically and horizontally.

The most interesting feature recently observed in the vertical distribution of water temperature, however, is the increase in the thickness of the heated layer near the coast of the Nile Delta in summer. This heating is due to the improvement in the conditions required for vertical mixing of the water, achieved through increasing the water density at the surface as a direct result of decreasing the amount of the fresh water discharge. This heated layer now extends to the 100 m level, and only below that level the water temperature starts to decrease slowly.

The most pronounced and direct effect of the damming of the Nile River is reflected in the salinity distribution, particularly in the region close to the Delta. Until the regulation of the Nile River discharge in the south-eastern part of the Mediterranean at the time of the Nile flood, three zones could be clearly distinguished, the freshing zone, where a gradual mixing of Nile waters occurred; a zone of intensive mixing of fresh and sea water; and a holistatic zone. In 1964, the river discharge was gratest since 1956 and in October 1964, the fresh water occupied a large area of the sea, which extended to a width of about 70 km to the north of the Rosetta outlet. Recently, this freshing zone has greatly diminished, and mixing of fresh and sea water has occurred only near the coast. Almost the entire region under investigation with the exception of a narrow coastal zone, was occupied by sea water of salinity higher than 38.50‰ (Halim *et al.*, 1967).

In the coastal areas, particularly near the river outlets, the density changes in response to any small variations in salinity. Consequently, this affects the stability conditions, the mixing processes and the entire current system in October 1964, the fresh water occupied a large area of the sea, which shelf changed considerably. This was due to two factors, the sharp decrease of the amount of suspended sediment discharged from the Nile River, and the change in the phytoplankton population, especially after 1966 in the coastal area.

General features of circulation in the southern Levant before the building of the High Dam were 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. This variation in level led to a rise in the horizontal pressure gradient toward the north, which forced the water from Rosetta to move in the northwest direction where it spreads, by its own momentum, into an area of about 50 km from the outlet, before being deflected eastward by Coriolis force. Thus the »Nile stream« was formed which, as its way eastward, received more flood-water from Dalmietta. This influx reinforced the stream and increased its velocity to 3.2 knots. Conditions at Damietta were somewhat different from those at Rosetta. The Damietta branch was directed northeast, and its output usually amounted to about half that of the Rosetta branch. The flood-water did not spread so far seaward and there was no sharp change of 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‰).

As the stream proceeded northward, it set up surface counter-currents in the highly saline waters off Israel and Lebanon. These converged with the stream, producing a cyclonic counterclockwise vortex which is characteristic of the circulation in the region. Now, the Nile waters do not cause this rise in the water level near the coast.

As a result, the horizontal pressure gradients are much lower, and the Nile stream has practically disappeared. For the same reason, the current velocities in the Delta region have decreased considerably (Gerges, 1976).

Before damming, about 57×10^6 tons of suspended solid particles entered the Mediterranean each year (Mohamed, 1967). The solid and organic discharge of the Nile is the main source of sediments of silt of organic origin in the south-eastern part of the Mediterranean. Since the construction of the High Dam, over half of the yearly solid discharge from the Nile settles in lake Nasser.

Consequently, the concentration of suspended solid particles in the Nile has been greatly reduced, and now the sea receives less than 10% of the volume of silt material which entered it before damming.

Due to this, the phosphate content now falls within the low eastern Mediterranean range (0.04—0.10 μg at/l), and consequently the whole food chain is affected. As early as 1965, the September phytoplankton bloom had dropped to about 10% of its 1964 value (Table 2).

Table 2. Diatom blooms (Cell/L) of nearshore waters off Alexandria (after Halim, 1976)

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

MATERIALS AND METHODS

The present paper is based on the data collected during two expeditions carried out along the south-eastern part of the Mediterranean Sea by R/V »Ichthyolog« in the 1965—1966 and 1970—1971 years.

In addition, statistics on sardine production collected by the Alexandria Institute of Oceanography and Fisheries for the last twenty years (1962—1983) was also used. The data of the above period are reliable because of the application of modern statistical sampling procedures.

RESULTS AND DISCUSSION

According to El-Zarka and Koura (1965), it was noticed that sardine production is closely associated with the Nile outflow into the Mediterranean during the flood season.

The production begins when the flood water flows into the Sea. On the other hand, when the Nile flood from Rosetta and Damietta was reduced to a minimum or entirely prevented, the sardine catch was affected (Table 3).

Table 3. Sardine catch and monthly outflow od Nile water into the Mediterranean in 1962

Month	Nile outflow in million m^3 from: Rosetta mouth	Damietta mouth	Both mouths	Sardine catch (Kg)
January	3,395	67	3,462	27,400
February	484	none	484	1,500
March	60	none	60	68,100
April	none	none	none	121,500
May	none	none	none	122,000
June	none	none	none	237,500
July	506	none	506	111,400
August	4,894	1,231	6,125	70,200
September	11,563	4,983	16,546	6,460,000
October	8,585	3,932	12,517	8,098,400
November	2,219	1,988	4,207	2,736,100
December	956	373	1,329	112,000

It was well established that considerable effects of the Nile outflow on sardine catch were observed a month after its flow into the Sea. This was attributed to the phytoplankton bloom on which sardine feed intensively. Their stomachs were found to contain mainly diatoms (El-Maghraby, 1960). The diatoms appear in large quantities after the outflow of the Nile flood water in the areas infront of both river mouths (Steuer, 1935; Halim, 1960). Their concentration in the sea water varies considerably during the flood season. The phytoplankton standing crop was found to increase progressively from 1 240 000 cells/litre just after the Nile outflow (August) to 1 572 000 cells/litre in September to 2 347 000 cells/litre in October (Halim, 1960). It was also found that the phytoplankton concentration in different months was reflected on the degree of plumbness and fatness of the fish themselves. In September sardine were thin and lean. In the following months, fat content of fish increased progressively and maximum weight was attained in November (El-Saby, 1937, El-Maghraby, 1960)

Table 4. Sardine catch and its percentages of the total fish catch (in metric tons) from the southeastern Mediterranean waters of Egypt (1962—1983).

Year	Sardine catch	%	Year	Sardine catch	%
1962	18166	48.02	1973	599	8.95
1963	13000	39.39	1974	987	14.41
1964	7372	28.35	1975	644	11.91
1965	7635	30.91	1976	695	9.73
1966	1233	8.20	1977	1364	18.62
1967	812	6.65	1978	2244	19.07
1968	463	3.41	1979	6501	32.61
1969	600	7.04	1980	4580	26.22
1970	500	7.16	1981	5639	31.70
1971	1505	14.28	1982	2442	21.79
1972	1403	13.62	1983	2793	23.20

Table 4. shows the sardine catch and its percentage relative to the total fish catch from the south-eastern Mediterranean waters of Egypt. Maximum catch was obtained in 1962 being 18,166 tons representing 48.02% of the total fish landings. From 1966 till 1978, a clear progressive reduction in sardine landings occurred. The minimum catch of only 463 tons was recorded in 1968 representing 3.4% of the total fish catch. In the period 1978—1983 sardine fisheries seemed to be thriving once more reaching 5,639 tons in 1981, representing 31.7% of the total fish catch. This increase in the sardine production can be attributed to two factors, the first the general decline in fish catch from the south-eastern part of the Mediterranean Sea and the second, the introduction of a new fishing gear.

The cessation of Nile water flow into the Mediterranean has brought drastic changes in the hydrography and biological economy of the Egyptian Mediterranean waters (Gerges, 1976; Halim, 1976).

The study carried out in the area comprising two mouths of the Nile river (Rosetta and Damietta) which is highly affected by the Nile outflow revealed that in the period from 1962 to 1965, the sardine catch reached 16,321 tons in the above mentioned area in 1962; 9,946 tons in 1963; 6,639 tons in 1964 and 7,061 tons in 1965 (Table 5). In 1966, as a result of the construction of the High Dam, the sardine catch began to decline sharply reaching 989

Table 5. Sardine catch in the Nile affected area

Year	Sardine catch	Total fish catch	%	Year	Sardine catch	Total fish catch	%
1962	16,321.3	27,759.3	58.8	1973	57.8	2,127.0	2.7
1963	9,946.0	21,491.4	46.3	1974	410.7	2,857.0	14.4
1964	6,639.7	16,423.6	40.4	1975	75.8	2,175.0	3.5
1965	7,061.7	16,924.6	41.7	1976	197.4	4,768.1	4.1
1966	989.5	7,574.0	13.1	1977	165.4	2,616.2	6.3
1967	555.4	5,207.0	10.7	1978	388.0	6,020.0	6.4
1968	133.7	7,661.7	1.7	1979	4,574.0	14,436.0	31.7
1969	16.6	4,069.7	0.4	1980	3,023.7	12,363.6	24.5
1970	20.6	3,633.0	0.6	1981	4,646.3	13,116.4	35.4
1971	35.3	3,730.0	0.9				

tons in 1966, 133 tons in 1968, and a minimum of 20 tons in 1970 (Bishara, 1985). Only in 1979, that the sardine catch began to increase again reaching 4,574 tons in 1979, 3,023 tons in 1980, and 4,646 tons in 1981.

CONCLUSIONS

In the present study concerning sardine fishing along the south-eastern part of the Mediterranean during the period 1962—1983, it can be considered that there are two important factors affecting the occurrence and abundance of sardine shoals:

1. Quantity and quality of food.

2. Some environmental changes that have acted in such a way as to reduce greatly the survival rate of sardine eggs and larvae.

Sardine feed exclusively on plankton. Before 1965 the south-eastern part of the Mediterranean Sea was considered as one of the most productive areas. The Nile River discharge was the main reason for the high biological productivity of the shelf waters. This was due to the large amounts of organic substances and mineral particles brought to the shelf sea waters by the Nile River discharge through its two tributaries (Damietta and Rosetta branches).

As a result of the erection of the High Dam, the summer of 1964 saw the last normal discharge of flood water into the Mediterranean. The Nile water started to decrease in 1965, and at present, it is discharged exclusively from the Rosetta branch, while the Damietta branch remained closed.

The cessation of the Nile water inflow into the Mediterranean exerted very serious effects on the plankton production in the Egyptian Mediterranean waters.

According to Halim *et al.* (1967), the plankton bloom of the Nile seems to be confined to a more or less wide coastal belt, fed in addition to the main Nile outlets, by the minor outlets of the Delta lakes, drains and fresh water canals. North from Rosetta it extends some 60 km seaward and shows concentrations of 600 to 800 cells cm^{-3}, increasing two-to three-fold nearer to the shore, at Damietta the number was 2400 cells cm^{-3} and at Alexandria, it was 9000 cells cm^{-3}. This number was reduced to an average of 20 cells cm^{-3} after the High Dam (Savich, 1970). This reduction in the plankton production affects the conditions of sardine feeding. This effect was evident on the population level, decreasing the annual sardine catch from 18,166 tons in 1962 to a minimum of 695 tons in 1976 but never exceeding 2,793 tons in 1983.

After damming in 1965, the sardine catch in the area of Rosetta and Damietta was decreased to 989 tons in 1966 and drastically fell to 16 tons, 20 tons and 35 tons in 1969, 1970 and 1971 representing 0.4, 0.6 and 0.9% of the total catch respectively (Table 5).

This low level was more or less retained till 1979 when the sardine catch again increased to reach 4,574 tons in 1979; 3,023 tons in 1980 and 4,646 in 1981 representing 31.7, 24.5 and 35.4% of the catch respectively. A mass entrance of sardine in the circumlittoral zone of the Sea was recorded during the flood.

The changes which took place in the composition of phytoplankton after the Nile discharge regulation resulted in a sharp deterioration of the nutritive basis of pelagic fishes especially sardine in the south-eastern part of the Mediterranean.

Construction of a dam across a naturally flowing river tends to decrease the discharge of surplus water into the sea, thus reducing nutrient concentrations in estuaries and coastal waters and diminishing plankton blooms as well as fish catches.

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RIBOLOV SRDELE U JUGOISTOČNOM DIJELU SREDOZEMNOG MORA

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KRATKI SADRŽAJ

Izneseni su rezultati istraživanja različitih faktora sredine koji utječu na smanjenje ulova srdele uz mediteranske obale Egipta u zadnjih dvadeset godina. Upotrebljeni podaci obuhvaćaju razdoblje od 1962—1983. godine.

Srdela čini glavni udio lovine u jugoistočnom dijelu Sredozemnog mora. Tri vrste roda *Sardinella* su zastupljene u lovinama: *Sardinella aurita* (75%o ulova), *Sardinella eba* i *Sardinella granigera*. Također je u ulovu prisutna *Clupea pontica*.

Različiti faktori sredine utjecali su na smanjenje ulova srdele, od kojih je najvažniji utjecaj brane Aswan High Dam. Podizanjem brane na rijekama umanjuje se izlijevanje viška vode u more. To ima za posljedicu smanjenje koncentracije nutrijenata u obalnim vodama i prema tome smanjenje cvjetanja planktona što direktno djeluje na ishranu srdele. Konstatirano je da je smanjenje dotoka vode rijeka Nil u Mediteran zbog brane High Dam ozbiljno utjecalo na smanjenje stope preživljavanja populacije srdele i smanjenje njene veličine. Naime, produkcija planktona se drastično smanjila poslije izgradnje brane. Promjene u sastavu fitoplanktona nakon regulacije dotoka Nila izazvale su pogoršanje baze ishrane pelagične ribe posebno srdele.

Godišnji ulov srdele se naglo smanjio, dostignuvši najniži nivo pet godina nakon izgradnje. Prilagođavanje populacije novoj sredini trajalo je dugi niz godina. Nakon toga se ulov stabilizirao na drugom mnogo nižem nivou.