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The production of *Liza ramada* (Risso) in Lake Mariut, Egypt

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Summary—The production of the grey mullet *Liza ramada* in Lake Mariut, Egypt, is followed from its introduction in 1920 until 1935, special attention being paid to the years 1928–31 and 1933, when age censuses were available.

After an initial build-up to a steady state between 1923 and 1926, it is thought that a decline set in about 1927–8 due to a lowering of the lake-level, and that this ended in lower levels of the population from 1930 to 1933 and a further fall in 1934 and 1935. The decline in numbers estimated in the O group catch represented a heavy mortality in the first year, and it is thought that this occurred very soon after the fry were introduced into the lake, as the rate of growth of fish caught in their first year in the lake showed no fall, but a slight increase between 1928 and 1933.

On the delta coast of Egypt there are several large and extremely shallow lakes usually connected with the sea during the whole or a part of the year by shallow channels. They are of great fertility, 60–270 kgm per hectare compared with 100 to 400 kgm per hectare for cultivated carp ponds in Germany, and 5 to 250 kgm per hectare for cattle on grassland (Mortimer, 1954). Among the species that go to make up the yield are those of the genus *Tilapia* which can give over 9,000 kgm per hectare in the fertilized ponds of the Belgian Congo (Mortimer, 1954) and the grey mullets, a species of which constitutes 50–60% of a yield of 1,500–4,000 kgm per hectare for the brackish ponds in the New Territory of Hong Kong (Bromhall, 1954). It is one of the most important species of this latter group, *Liza ramada* (Risso) formerly called *Mugil capito* Cuv. and known locally as the " Tobar " which is the subject of this contribution.

The habit of the Tobar is to enter the lakes from the sea in great numbers between January and April. During this time it will be found to increase in modal size from 16 to 20 cm during the course of the run. The fry which enter the lakes already possess scales, the gut is short and simple and both animal and vegetable plankton is eaten. Subsequent growth is rapid and the intestine becomes lengthened and convoluted as the fish changes its feeding habits to that of a mainly vegetarian browser.

The length range of the commercially caught population is from 14–30 cm long and the average size, which also happens to be near that at which both sexes may first be commonly found mature, can be taken as 20 cm. Growth to the end of the first year (" O group ") appears to vary a good deal and fish may be from 14–20 cm, indeed in exceptional circumstances in fresh water ponds 28 cm has been reached in this time. In the second year (" I group ") length can increase by from 1 to 6 cm, and in the third (" II group ") 1 or 2 cm. Generally, however, there appears to be little growth after maturity has been reached.

When in October and November sexually mature fish leave for the sea in large shoals, most of these are at the end of their second year. Spawning must take place in the immediate coastal belt, as no record is known of any individual of this species being caught in the trawl, or by any other method of fishing employed outside the littoral zone. Although I was fortunate enough to find and describe the planktonic egg from a population introduced into Lake Quarun (WIMPENNY, 1936), none has been found in the water of the coastal belt either near Lake Mariut or anywhere else in the world, and the location of the actual spawning grounds, bearing the number of eggs that must necessarily be present to account for the origin of the huge runs of young fish into fresh water, remains a mystery.

There is, therefore, a gap in our knowledge of the life cycle of this species between the departure of the spawning shoals and the arrival of swarms of small scaled individuals in the out-flowing fresh water at the beginning of January.

Lake Mariut during the period to which this account refers was an area of approximately 59,000 acres of water rarely more than 50 cm deep and situated behind the town of Alexandria. The Department of Irrigation maintained it around a level of 3 metres below sea-level (rather above this in the early part of the period, rather below later), and it acted as a drainage reservoir for the farm lands of the north-west part of the Nile delta. The drain water reaches the lake chiefly through a large channel called the Omoom drain. A channel at sea-level runs from the sea to the lake-side at a place called Mex. Here powerful pumps force the water from a canal on the lake-side up into the sea canal. It was usual for these pumps to work from August to April, as during the rest of the year the evaporative power of the sun, estimated to have been 750,000 to 1,000,000 tons per day, was considered sufficient to keep the lake at the required level.

The effect of these arrangements was that there was no contact between sea and lake when the pumps were not working, but for the rest of the time the water flowed with considerable velocity from the lake to the sea. The sea water never flowed into, nor was it on a level with the lake; thus the penetration of marine animals was obstructed. In these circumstances spawning shoals of Tobar found it easy to leave the lake in the spawning season, but the fry, attracted to the outflow of fresh water in the Mex channel, were prevented from passing in through the pumps, and gathered against the walls of the channel with their heads facing upstream as near the pumps as possible. There they collected in great numbers, and until 1920 this obstacle to their progress stopped other than stray individual Tobar, that had wandered into the lake by the inland drains, from populating the lake.

In 1920 the Director of Fisheries Research of that day, Mr. PAGET, organized a service of transplantation which consisted in sweeping up the fry from alongside the walls of the marine canal by long-handled nets having a mosquito netting bag and a rectangular head. The fry thus caught were carried to the lake-side of the pumps in buckets, and poured into boats with perforated zinc removable sides. When the boats were sufficiently charged with fry, they were towed some distance out into the lake and the fry released. The bags of the nets were marked so that a record of the number of fry could be kept. This introduction, made at a cost of a few hundreds of pounds annually, resulted in a fishery for two species of grey mullet running into tens of thousands each year.

For the fifteen years 1920–35 there are available (Egypt, Government Press, 1922–26) (a) statistics concerning the weights and values of the different species of fish collected at the landing places on Lake Mariut; (b) the record of numbers of fry introduced; (c) information on the number of fishing boats at work (from the licensing system) and (d) particulars relating to the water level and supply (from the Department of Irrigation). In addition to this, for the years 1928–31 and 1933, there are some observations on the age, length and weight composition from samples of the commercial catch. The age, length and weight data for 1930, 1931 and 1933 are published here for the first time. On this basis therefore and, as far as the data permits, it is proposed to follow the annual production of Tobar in Lake Mariut for the first fifteen years after its introduction, and to examine the changes revealed, paying special attention to the years 1928–31 and 1933.

Fig. 1

Relation of fry to catch

The relation of fry introduced each year to the corresponding catch is shown in Fig. 1. In a general way the fry introductions built up parallel to the catch until 1927, and thereafter fell away to lower levels in the thirties. There are, however, two years, 1921 and 1930 in which the unusually high values of 28·6 and 51·1 millions are associated with unexpectedly low catches. Inspection of the graph gives the impression that catch rises roughly in proportion to fry introduced up to about 25 million, but that two higher values than this correspond to lower catches, perhaps due to high mortality from more acute competition among the more numerous fry.

A correspondence between the catch and the number of fry introduced is not difficult to imagine, and it seems reasonable to suppose that it could happen in two ways. First of all it is to be noted that a substantial yield of catchable fish, 47 tons per 4·7 million fry, occurred in the year of first introduction, and it is reported that a number of these left the lake to spawn in the first year. The introduction of fry in any one year may therefore be expected to have a substantial effect on the yield. Secondly, as a fair proportion of the fish spawn in their first year, a successful year-group may be indicated by a good catch and the origin of a successful spawning. This would mean there might be a correspondence between the catch in one year and the number of fry that appeared in the succeeding year.

In fact when the catch and contemporary fry were correlated, a low but positive correlation of little significance was obtained. It is not without interest, in view of the preceding remarks, to report that for the relation between the catch and the fry introduced a year later the correlation was somewhat higher.

From age, length, and weight samples given in Table II, and in the Egyptian Fisheries Reports for 1920, 1928–31, and 1933, estimates of the numbers of O group fish caught in 1920, 1928–31 and 1933 have been devised and shown in Table I. The numbers have been obtained by dividing the estimated mean individual weight into the weight of the Tobar landings for the periods August–December of the appropriate years. These estimates may be compared with the corresponding fry introductions.

It will be seen that in 1920 nearly a million fish of commercial size were taken out of the lake within nine months of introducing about 4·7 millions. This is to say that it needed rather less than five fry to produce a marketable O group fish. By 1928 it took 50 fry to do this, and the O group caught had fallen to about 400,000—a fall which continued steadily until 1933. The number of fry necessary to produce one commercial O group fish increased until in 1930 it was nearly 800, but thereafter it went back to 269 in 1931 and 132 in 1933. These observations suggest that the conditions for survival must have deteriorated throughout the period. Against this it must be remarked that the estimated proportions of O group fish in the August–December catch, where they may form part of the spawning shoals, fell from 42% to 17% between 1928 and 1935, and it may be that more O group stayed on in the lake to become I group in this period. Nevertheless, from 1929 to 1931, when the percentage of O group was steady, it appears that the O group numbers continued to fall, and survival conditions were still getting worse.

Catch, Effort and Lake-level

The catch (Fig. 1) may be broken up into five periods, three of adjustment and change and two in which some stability is indicated. These are, first a period of increase from 1920 to 1923, during which the fry introductions built up the population, followed from 1923 to 1926 by a period of stability during which the catch fluctuated around a level of rather under a 100 tons. Then in 1927 there was a rise immediately succeeded by a sharp fall through 1928 and 1929 to 1930. From 1930 to

1933 the catch stabilized again at around 30 tons a year, and finally in 1934 and 1935 there were indications that a decline had set in once more.

The catch per boat also shown in Fig. 1 corresponds to the catch, and indicates that the latter is also a reasonable measure of the stock density in the lake. Considering the catch as a measure of the stock, we may therefore try to account for the catch changes just mentioned as stock changes, finding it profitable to examine these in relation to the annual mean water levels shown in Fig. 1. The water levels of such a shallow lake as Mariut must be considered as of very great importance in deciding the actual size of the habitat. The period of increase to 1923, due to fry introduction, followed by the stability or slight increase to 1926, were years in which the lake level oscillated between —2·75 and —2·90 m. In 1927, however, there was a sudden descent of 12 cm in this level, and in 1928 and 1929 of another 5, bringing the lake to —2·99 m. It is thought that this lowering of the lake made the fish more vulnerable to capture in 1927, and so explained the great increase in availability of the fishable stock. By 1928 the effect had begun to wear off, and the Annual Fishery Report for that year recording a failure of the whole fishery of the lake says, " This failure has not been confined to one or two particular species but has been one of the organic production of the lake itself. The usual rich growth of *Ruppia maritima* and floating algae was very much diminished and in some parts and at some times absent." The lake level returned to —2·94 again in 1930, but thereafter fell sharply away again to a new low record of —3·21m in 1933 and remained at —3·18m for the last two years.

The evidence on lake level, therefore, looks as if the fish stock had to make some new adjustments to its environment—a critical lowering of the lake level which appears to have begun around —2·94 or —2·95.

Age, growth and maturity

Samples taken from the lake at or around the spawning season in 1928–1931 and in 1933 are given in Table II. Length measurements were made to the centimetre below, and 0·5 cm added to allow for the distribution of length within the centimetre. Age was determined by scale readings, it having been proved by direct observations in ponds that a ring is laid down in the first scaled winter. The weights, direct in the case of the 1933 sample, were derived from the lengths in the remaining samples, using an age-length relation taken from samples of this species collected from Lake Mariut and near the entrance to Lake Menzala in November 1931.

The numbers at the different ages show that there are few that have been in the lake three winters or more (III+ group), and that the majority of the fish that are leaving or preparing to leave the lake to spawn have been therein for one winter after their introduction, and are on the eve of their second. This group has increased its proportion by weight during the period from 45 to nearly 60%, whilst that of the fish of the O group that are not quite one year old has declined from 42 to 17%. This relative decline of the O group in the spawning and pre-spawning shoals, seems most likely to be due to successively smaller O group recruitment enhancing the importance of the I group, which each represent an O group of superior strength in the previous year. The estimates of the numerical strength of the O group given in Table I support this suggestion; but it would be unwise to take these estimates too exactly, in view of the many errors involved when using such small samples as are available to me.

Another possible alternative or supplementary cause of this change might be a deferment of maturity of O group fish resulting from the increasingly adverse conditions in the lake.

With regard to growth there is also the appearance of a change in my samples between 1928 and 1933. For all ages the trend is upwards (Table II).

The continued diminution in the numbers of O group coming into the catch between 1928 and 1933 is difficult to reconcile with the apparent stability of the stock from 1930 to 1935, and it may be that this has been achieved by a deferment of maturity causing more of the O group to stay in the lake and away from the spawning shoals until they become I group, and by an increase in the growth rate. The observations however are quite insufficient to make this any more than a reasonable conjecture.

The Incidence of Mortality

The decline in the landings and almost certainly of the whole stock of *L. ramada* in Lake Mariut does not appear to have been directly attributable to changes in the supply of fry, for, as we have seen, four million fry at the commencement of the period is estimated to have produced about a million O group fish and in 1933 only a little over thirty thousand. Indeed we have seen that there is some indication that the strength of the stock in the lake may have influenced the supply of fry.

Undoubtedly the shrinking habitat of the lake caused by successive reductions in its level has been the cause of the big and successive reductions of numbers indicated by the estimates of O group fish shown in Table I. We then come to the question at what period in the life of the O group fishes is this reduction in numbers brought about.

On the observations here available I am inclined to think that the mortality takes place very early in the period. If there were a mortality acting slowly over the whole first year's life, such, for instance, as overcrowding on a ground where the food supply was not adequate for the whole population, there would be a corresponding effect on the growth-rate which has not been observed. In these circumstances I believe that an early mortality, perhaps of a catastrophic kind, occurs very soon after or possibly during the actual introduction. It must be remembered that the little mullet on first introduction has a short gut and is able to eat plankton animals, but that later it develops a long and much convoluted intestine and becomes a vegetable and detritus browser. This change-over takes place at a very early age, and would produce a condition when a food shortage caused by a shrinkage of the available shallow water habitats due to a reduction of the lake-level might be critical, and cause an immediate thinning out of stock sufficient to explain the successive reduction in O group strength.

If this is so, it would mean that each year the lake accepted a certain number of recruits corresponding to the lake level. After this acceptance was over, there appears to have been enough food for the survivors to make normal growth. Indeed, as we see in Table II, there are indications that growth has been rather better as the lake level has fallen.

The mechanism of this sort of mortality is of the greatest interest in the study of the populations of our food fishes. The parts played by the nature of the organic and inorganic environment, and in particular the role of competition, presents problems for solution by careful observation and experiment.

Table I. Analysis of conditions for *L. ramada* fishery in Lake Mariut.

	1920	1928	1929	1930	1931	1933
Fry introduced (millions)	4·698	20·884	17·734	51·100	10·225	4·101
Total Catch (metric tons)	47·604	133·006	64·751	26·666	33·700	36·934
Aug.–Dec. catch (metric tons)	47·604	31·355	31·587	17·580	11·110	13·525
O group % by weight in Aug.–Dec. catch	100·0	42·0	23·4	23·4	23·8	17·2
Estimated numbers of O group caught (millions)	0·952	0·411	0·147	0·065	0·038	0·031
Fry for each O group fish caught	4·73	50·8	120·6	786·0	269·0	132·1
Mean length of O group fish	18·0*	16·3	18·8	21·2	20·9	21·3

* Mid-point of size range mentioned by Paget in the text of the Egyptian Fisheries Report for 1921.

Table II. Age, length and weight distribution of *L. ramada* samples from Lake Mariut.

	Age groups	*O*	*I*	*II*	*III+*	*Total*
1928	Numbers	184	85	15	9	293
Aug.–Dec.	Mean length (cm)	16·3	20·9	21·5	20·3	
	Mean weight (g)	32	75	77	67	
	% weight of sample	42·0	45·5	8·2	4·3	
1929	Numbers	162	200	98	20	480
November	Mean length (cm)	18·8	21·7	22·5	22	
	Mean weight (g)	50	80	90	84	
	% weight of sample	23·4	46·2	25·5	4·9	
1930	Numbers	41	53	36	6	136
November	Mean length (cm)	21·2	22·0	22·9	22·7	
	Mean weight (g)	63	84	96	94	
	% weight of sample	23·4	40·3	31·3	5·0	
1931	Numbers	44	62	24	5	135
November	Mean length (cm)	20·9	23·4	25·1	25·7	
	Mean weight (g)	70	101	123	132	
	% weight of sample	23·8	48·2	22·0	5·0	
1933	Numbers	21	63	18	1	103
November	Mean length (cm)	21·3	22·3	24·0	26·5	
	Mean weight (g)	76	88	110	146	
	% weight of sample	17·2	59·8	21·4	1·6	

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