

FAT METABOLISM IN TILAPIA ZILLII GERV.

II. Fat Mobilization in *Tilapia zillii* in Relation to Feeding and Breeding Activities.

By

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INTRODUCTION :

The mobilization of fat in *Tilapia zillii*, i.e. its storage or withdrawal in the different fish organs, is mainly influenced by the feeding and breeding activities of the fish. Such mobilization is followed, in this study, through tracing the monthly variation of both the percentage of fat and its saturation in the liver, muscles and gonads in relation to the condition of these organs described in the first paper.

METHODS AND TECHNIQUE:

The fishes used for this study were collected during the period from May 1966 to June 1967. No attempt was made to separate light and dark muscle. An aliquot sample of flesh, liver and gonad, was taken and weighed. Each sample was then extracted by Soxhlet apparatus following the method of Folch et al 1956. The solvent used was chloroform methanol (2 : 1 v / v). Iodine value was determined by Hannus method. Wherever possible, operations were carried out under an atmosphere of nitrogen. These determinations were determined on a monthly basis, for fishes collected from Lake Mariut during the period May 1966 - June 1967.

RESULTS :

A. Fat Content in the Liver, Muscles and Gonads :

(a) *Fat Content in the Liver :*

The monthly average weights and the percentage values of fat (for both sexes) are given in table 1 graphically represented in relation to the variations of G.S.I. in Figure 1. It is obvious that prior to spawning, the period from January to May, the amount of fat in the female liver is generally higher than that in the male. This condition is reversed during the breeding period i.e. from June to September as the male liver contains more fat. It seems therefore that female liver is characterized by high storage and high withdrawal of fat than the male liver.

b) *Fat Content in the Muscles :*

The monthly values of the fat content in female and male muscles are graphically represented in Figure 2. It is evident that the maximum fat content in the muscles of both females and males occurs in the time interval between the two spawnings (July and August). The increase of the feeding activity of the fish after the first spawn in June seems to cause a rapid storage of a large quantity of fat in the muscles in preparation to the second spawning activity of September. Prior to the first spawning period (January-May), the amount of fat in the female muscle is higher than in the males. The drop in fat percentage taking place at the end of the breeding period in September is also more pronounced in the females, and this supports the view that the maturation of ovaries necessitates the withdrawal of more fat than the testis.

TABLE 1.—MONTHLY VALUES OF THE PERCENTAGE OF FAT IN THE LIVER OF FEMALE AND MALE *Tilapia zillii*, TOGETHER WITH THE WEIGHT OF LIVER IN GRAMS

Month	Females		Males	
	Percentage of fat in the liver	Weight of the liver in grams	Percentage of fat in the liver	Weight of the liver in grams
January	11.30	0.67	9.80	0.66
February	11.20	0.73	9.80	0.73
March	7.30	1.195	7.02	1.17
April	17.80	1.120	8.70	0.93
May	11.60	0.58	10.98	0.47
June	7.20	0.54	8.20	0.41
July	9.90	0.61	15.50	0.30
August	13.60	0.75	17.60	0.51
September	6.90	0.76	11.90	0.44
October	9.00	0.40	7.00	0.40
November	12.10	0.63	12.20	0.46
December	11.0	0.79	11.5	0.56

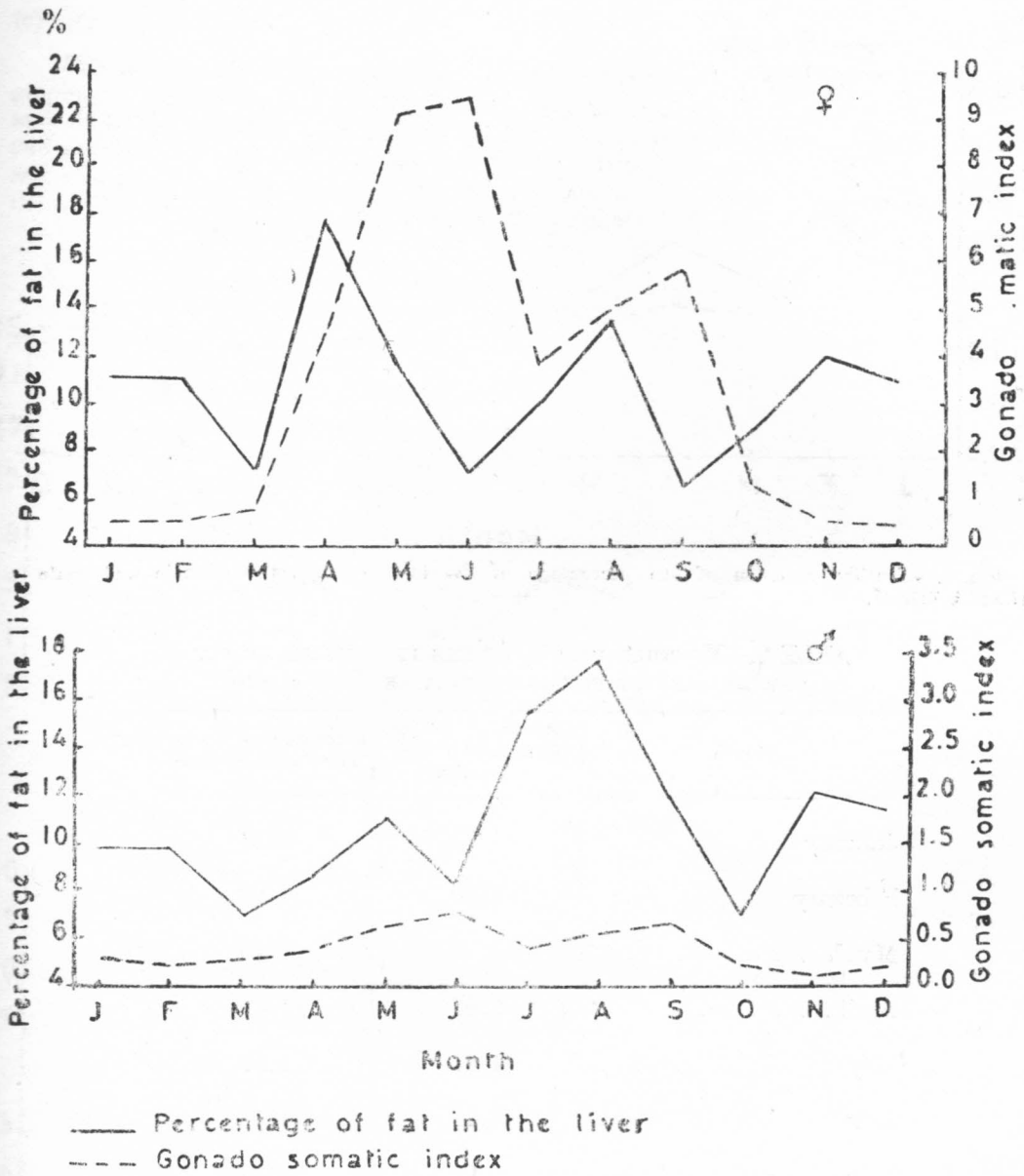


FIG. 1.—Monthly variation of the percentage of fat in the liver and G.S.I. of female and male *TILAPIA ZILLII*.

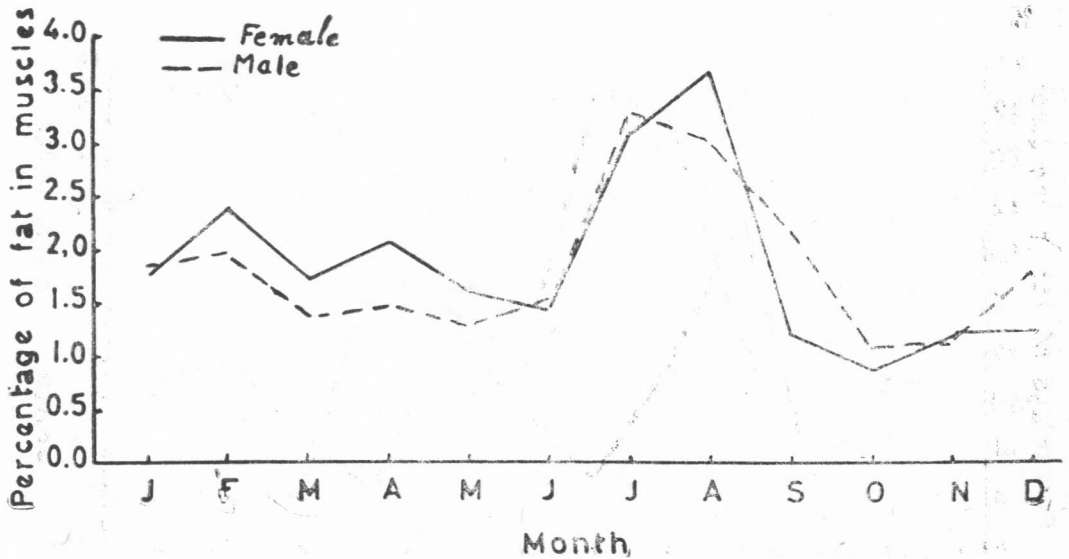


FIG. 2.—Monthly variation of the percentage of fat in the muscles of female and male *TILAPIA ZILLII*.

TABLE 2.—MONTHLY VALUES OF THE PERCENTAGE OF FAT IN THE MUSCLES OF FEMALES AND MALE *Tilapia zillii*.

Month	Percentage of fat in muscles of the females	Percentage of fat in muscles of the male
January	1.75	1.87
February	2.39	1.99
March	1.76	1.40
April	2.08	1.49
May	1.63	1.31
June	1.46	1.55
July	3.08	3.30
August	3.66	3.06
September	1.20	2.20
October	0.87	1.10
November.	1.18	1.17
December	2.24	1.82

(c) *Fat Content in the Gonads:*

The monthly variation of the percentage of fat content in the ovaries and testes graphically represented in figure 3. It is obvious that in the time intervals before and after the breeding activity of the fish (i.e. respectively January-March and October - December). The gonads contain a high percentage of fat which are more pronounced in the males. In the time interval from June to September, the percentage of gonadal fat approximates in the females and males.

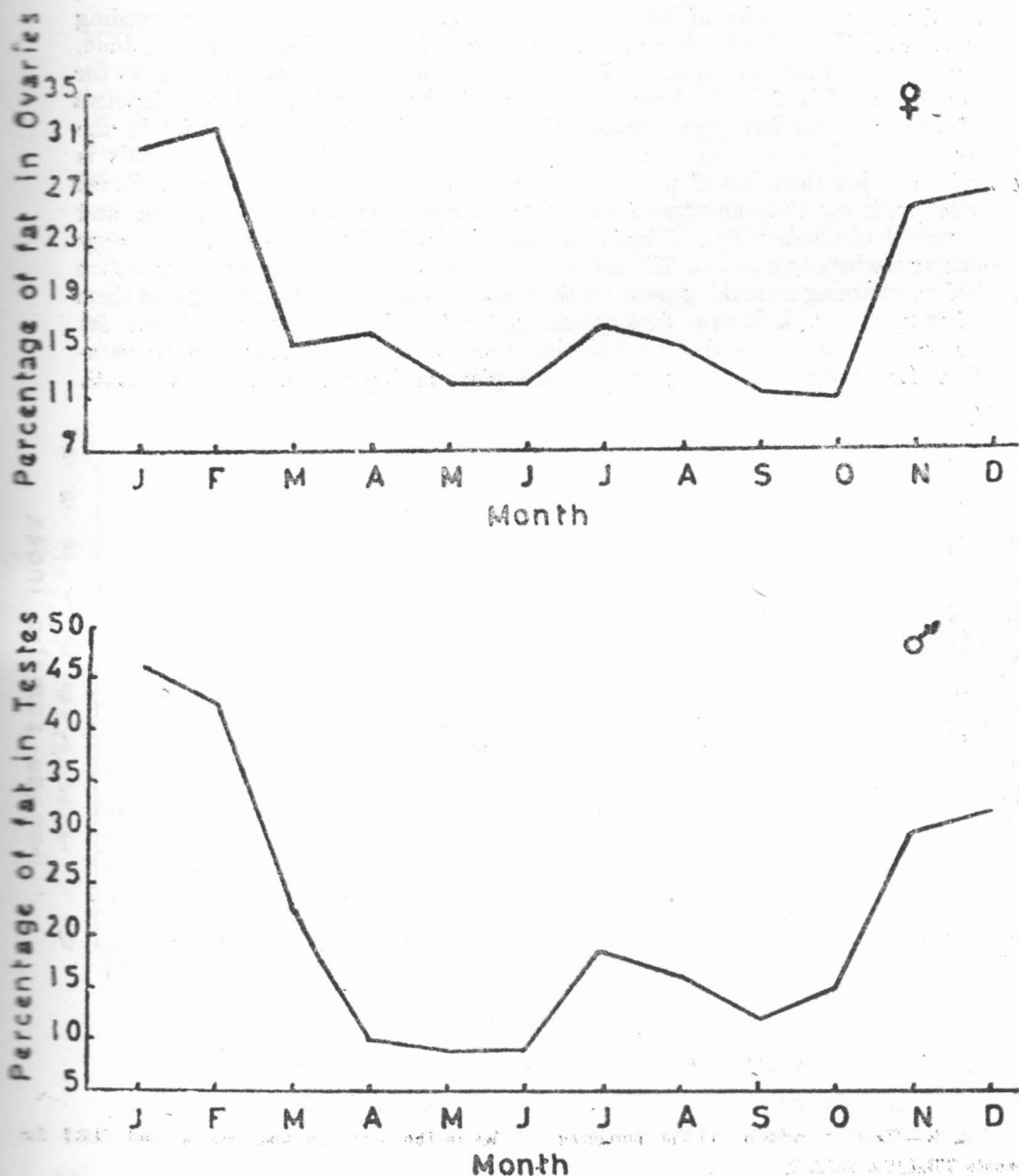


FIG. 3.—Monthly variation of the percentage of fat in the ovaries and testes of *TILAPIA ZILLII*.

DISCUSSION :

The monthly variation of the fat content in the liver, muscles and gonads in relation to gonad maturity is graphically represented for the female and male in respectively figures 4 & 5. It is noticed that the variation of the fat content in the liver is more significant and more obvious than that in the muscles. The amount of fat in the female fish just prior to ripeness (April) is maximum in the liver and fairly high in the muscles. Since this is accompanied with maximum hepatosomatic index; it indicates mobilization of lipids from the fat depots which are destined to breeding processes. When the fish becomes fully ripe i.e. G.S.I. is at its maximum in June, the amount of fat content in the liver and muscles are minimal. This shows the withdrawal of fat from the liver to the ovaries for its utilization in the development of the eggs in the fully ripe ovaries. The decrease of the percentage of fat in the ovaries may however be due to the fact that the rate of increase in lipids is relatively less than that of protein, glycogen and others. This view is confirmed when we know that the eggs of *Tilapia zillii* are demersal; heavily yolked and deprived of oil droplets. *Tilapia zillii* uses also its fat depot as a source of energy during the breeding period. The fish shows parental care; it becomes very active before spawning in making nests on the bottom to lay the eggs in and guard them after spawning. After the first spawning, the fish feeds actively and the fat content in the liver and the muscles increases considerably in August in preparation for another spawning which takes place in September. In this month

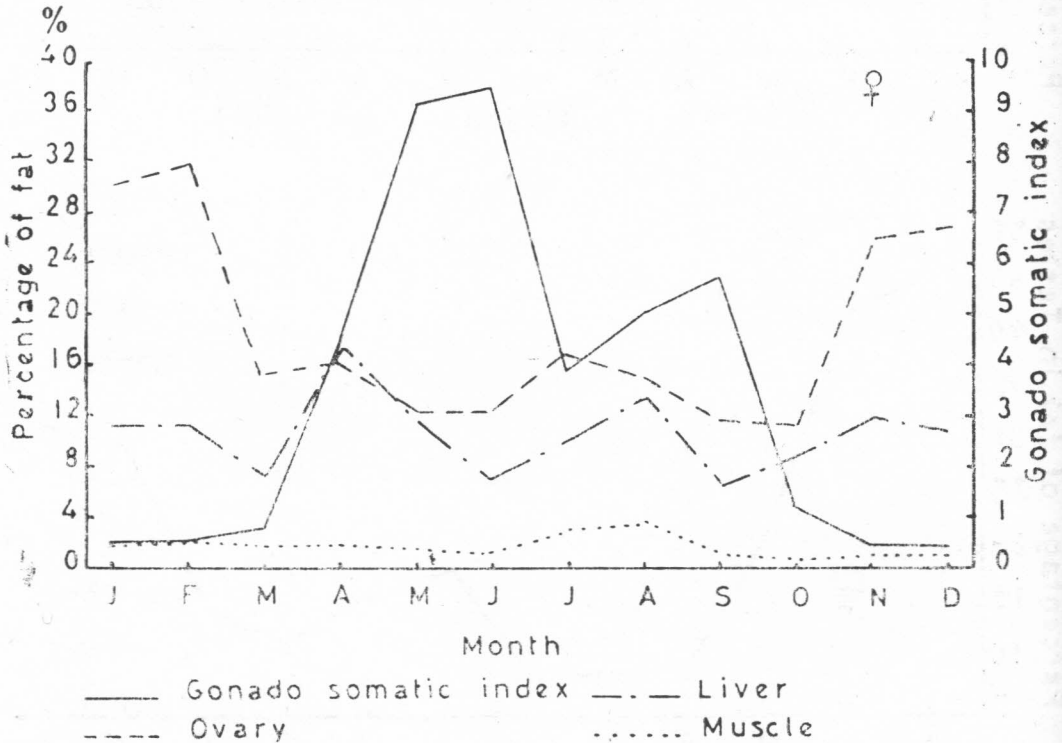


FIG. 4.—Monthly variation of the percentage of fat in the liver, muscles, ovaries and G.S.I for female *TILAPIA ZILLII*.

coinciding with the high G.S.I.; the percentage of fat in the muscles and the liver decreases. This may mean that another withdrawal of fat takes place from the muscles and the liver to the ovaries for the development of ova, and to provide the energy necessary for the second breeding activity. In the male fish, the monthly variation in the percentage of fat in the muscles, liver and testes is nearly the same as in the female but the magnitude of variation is less pronounced.

In April, when the gonads begin to mature the percentage of fat in the liver is very high and that of the muscle is fairly high, in the fully ripe fish of June, the fat content in these organs drops and is accompanied by high increase of G.S.I. i.e. the fish is fully ripe. Again the percentage of fat in the muscles, the liver and the gonads begins to increase in July and August when the fish is preparing itself for another spawning. In September, the fat content in these organs decreases to minimum at the same time the G.S.I. is maximum i.e. the fish fully ripe.

It seems that ovogenesis exhausts the fish more than spermatogenesis. This is obvious in the maturing fish of March and April in which the fat content of the muscles and liver is higher in female than male while the spawning female in June has on the other hand lower fat content in these organs than in the male. The same is also obvious during the second breeding activity from July to September.

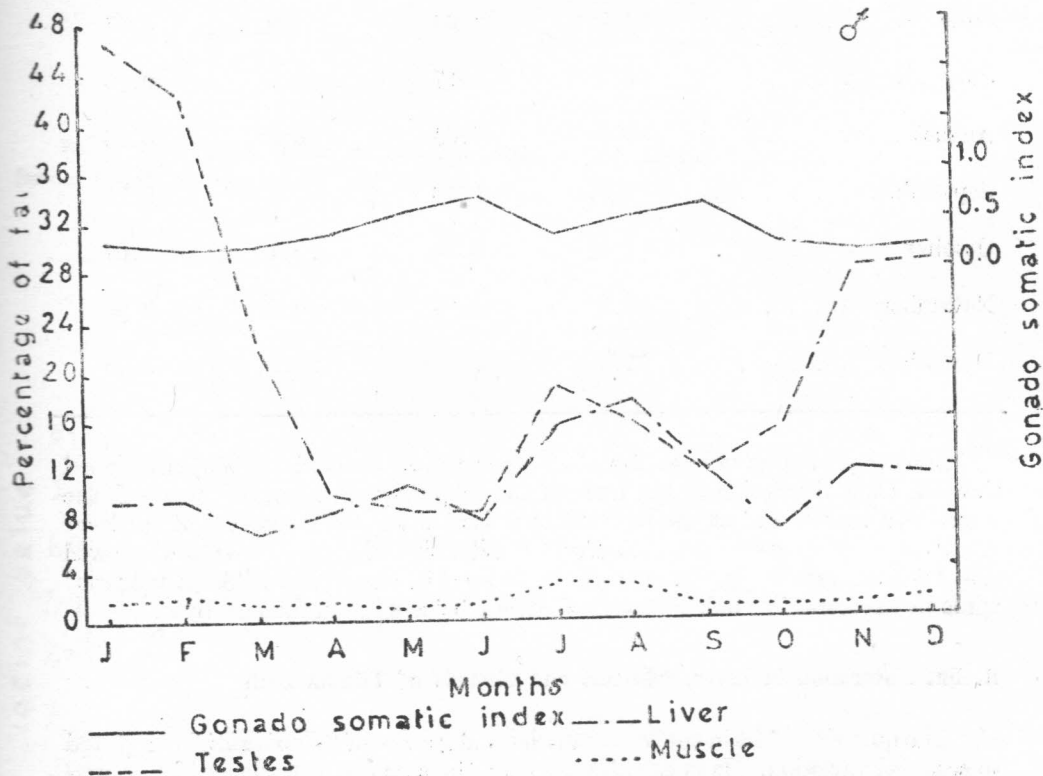


FIG. 5.—Monthly variation of the percentage of fat in the liver, muscles, testes and G.S.I. for male TILAPIA ZILLII.

TABLE 3.—MONTHLY VALUES OF THE PERCENTAGE OF FAT IN OVARIES AND TESTES TOGETHER WITH THEIR AVERAGE WEIGHTS IN GRAMS IN *Tilapia zillii*.

Month	Females		Males	
	Percentage of fat in the ovaries	Average weight of the ovaries	Percentage of fat in the testes	Average weight of the testes
January	30.4	0.13	46.7	0.07
February	32.0	0.15	42.5	0.07
March	15.3	0.24	22.6	0.09
April	16.2	1.20	10.0	0.12
May	12.55	2.31	8.9	0.16
June	12.4	2.00	8.9	0.17
July	16.7	1.17	18.7	0.10
August	15.0	1.63	16.2	0.16
September	11.5	1.38	11.9	0.14
October	9.0	0.30	15.1	0.07
November	12.1	0.13	30.0	0.05
December	11.0	0.14	32.0	0.06

Similar results have been found in other fishes; Deflandre (1903) mentioned that the fatty deposition in the liver of the carp "*Cyprinus carpio*" precedes the sexual maturation and at the time of reproduction the fatty reserves of the liver are transmitted to gonads and labelled for utilization of eggs. Weil (1914) showed that fat accumulation is almost confined to liver in the sole fish "*Solea vulgaris*" while in mackerel "*Scomber Scomber*" it is labelled in muscle and liver.

B. Fat Saturation in Liver, Muscles and Gonads of *Tilapia zillii*

The quantity of fat in the liver, muscles and gonads of *Tilapia zillii* is subjected to seasonal variation. It is essential to trace the seasonal variation of fat saturation in the liver, muscles and gonads for understanding its mobilization i.e. its accumulation in and withdrawal from these organs.

The monthly variation of fat saturation in the liver, muscles and gonads of females and males are graphically represented in figures 6 and 7.

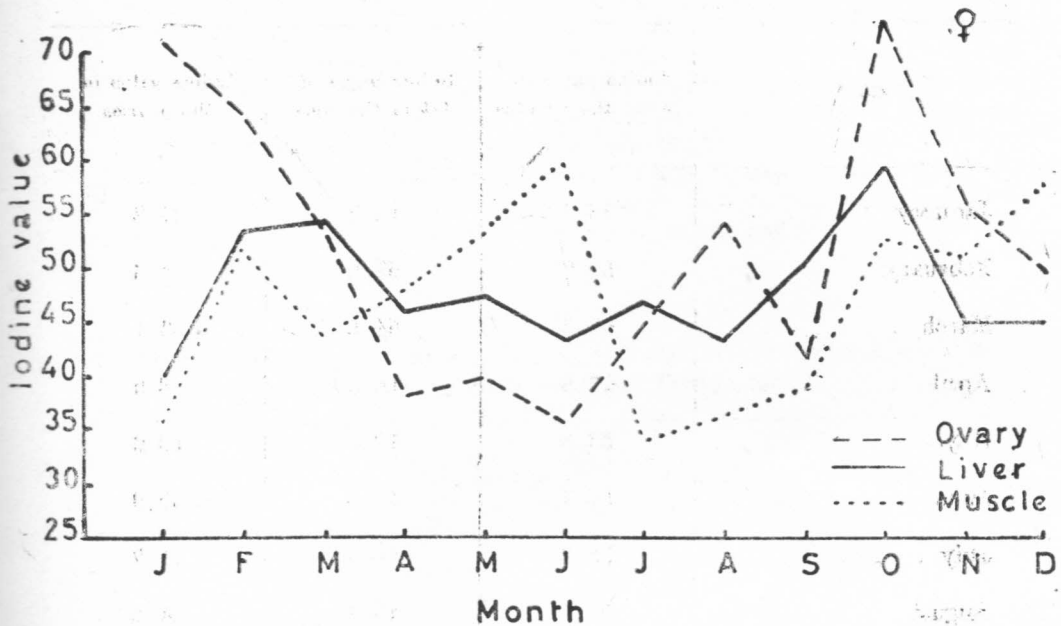


FIG. 6.—Monthly variation of the iodine value of fat in the liver, muscles and ovaries in female *TILAPIA ZILLII*.

— Liver
 - - Muscles
 Testes

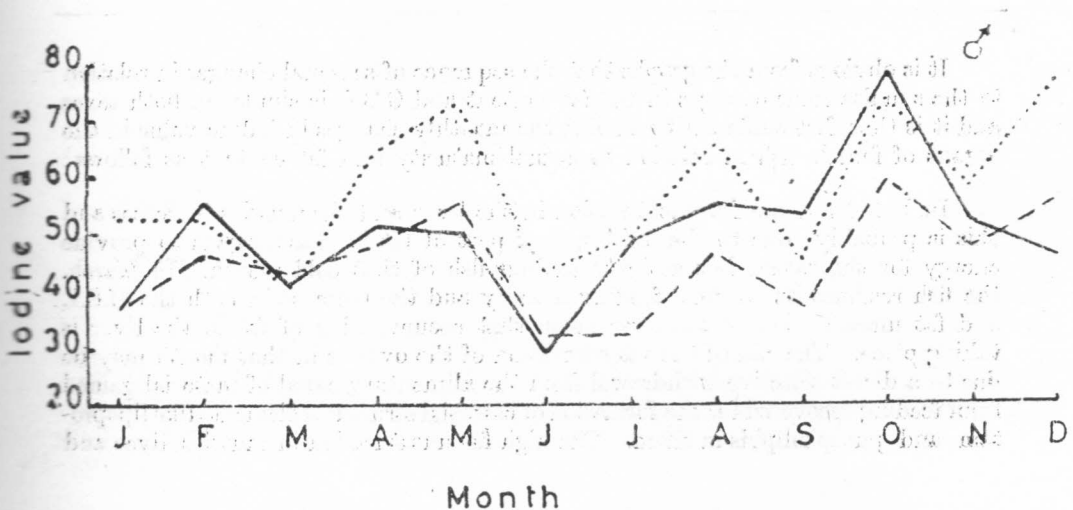


FIG. 7.—Monthly variation of the iodine value of fat in the liver, muscles and testes in male *TILAPIA ZILLII*.

TABLE 4.—MONTHLY VARIATION OF THE IODINE VALUE OF FAT IN THE MUSCLES, LIVER AND OVARIES OF FEMALE *Tilapia zillii*.

Month	Iodine value of fat in the muscles	Iodine value of fat in the liver	Iodine value in the ovaries
January	36.2	40.2	71.2
February	51.8	53.5	64.3
March	43.8	54.5	53.4
April	47.8	46.0	38.5
May	53.8	47.6	40.0
June	59.7	43.5	35.9
July	33.9	46.9	44.7
August	36.7	43.7	54.6
September	39.1	50.4	41.4
October	53.2	59.7	73.0
November	51.2	45.3	55.9
December	57.7	55.0	50.0

It is obvious from the graphs that the sequence of seasonal changes in relation to the simultaneous changes in the fat content and G.S.I. is similar in both sexes and it is therefore sufficient to outline the monthly changes in iodine value in the organs of female fish in relation to sexual maturity and fat content as follows:

In February, the fat unsaturation in the liver and the muscles increases and this is probably due to the oxidation of part of fat in these organs to provide energy for the rather less actively feeding fish of that cold month. In March, the fish resumes its normal feeding activity and the increase in both the H.S.I. and fat unsaturation of the liver mean that accumulation of fat in the liver is taking place. The rise of the fat saturation of the ovaries in that month may be due to a direct selective withdrawal from the alimentary canal of material gained from feeding recovered for the formation of essential structural elements like lipoprotein and phospholipids in them. The high fat unsaturation in muscles, liver and

ovaries in May probably means on the other hand a withdrawal of fat from the muscles to the liver and its accumulation in the ovaries. This is also shown from the decrease of the condition of the fish flesh, H.S.I. and percentage of fat in both the muscles and the liver and the rise in the G.S.I. At the magnitude of the first spawning in June, the fat unsaturation in the muscles becomes higher while that of the liver is moderate and that in the ovaries is the least. This could be explained as due to the storage of different ratios of saturated and unsaturated lipids in these organs i.e. the muscles contain a high ratio of unsaturated fat while the ovaries contains a high ratio of saturated lipids. In July, the fat unsaturation in the liver muscles and the ovaries increases and reaches a high degree of unsaturation in August. This means that accumulation of fat in these organs is taking place during this period as a result of the active feeding of the fish to prepare itself for the second spawning activity.

TABLE 5.—MONTHLY VARIATION OF FAT UNSATURATION IN THE MUSCLES, LIVER AND TESTES OF MALE *Tilapia zillii*.

Month	Iodine value of fat in the muscles	Iodine value of fat in the liver	Iodine value of fat in the testes
January	36.8	36.9	51.1
February	46.8	56.0	53.4
March	43.6	40.8	40.8
April	47.9	51.4	64.3
May	55.5	49.8	72.6
June	32.4	29.2	43.1
July	32.2	48.5	48.9
August	46.6	54.8	65.7
September	37.3	53.4	45.9
October	59.3	78.1	73.8
November	47.1	51.5	58.3
December	55.7	45.9	78.4

During the climax of the second spawning in September, the fat unsaturation in the liver and the muscles is high indicating withdrawal of fat from the liver and the ovaries. This is also obvious from the increase of G.S.I. accompanying the drop in the condition of the fish, H.S.I. and the percentage of fat content in the liver and the muscles. The fat unsaturation in the ovaries is low in that month and this is probably due to its transformation to saturated lipids essential for the formation of ova. In October, the fat unsaturation in the liver, muscles and ovaries is high as the spent fish feeds actively and accumulates fat in its muscles to recover its normal condition which is also clear from the rise of the condition of fish. The residual fat left in ovaries and the liver of spent fish is highly unsaturated.

DISCUSSION :

The breeding and feeding activities in the several species of warm temperate and cold water fishes are found to undergo cyclic changes regular from year to year. They affect greatly the condition and fat content of the organs (i.e. the muscles, the liver and the gonads). The increase in the feeding activity no doubt improves greatly the condition of the somatic organs of the fish such as the muscles and liver due to the increase in the fat reserve stored in them. This is directly in opposition to the effect of the breeding activity in which the maturing gonads utilize considerable material including the fat reserve of various organs to attain full ripeness.

The cyclic changes in these two biological activities and their effects on the condition and fat reserve of different organs are clearly demonstrated in the prolific fresh water tropical fish *Tilapia zillii*. The breeding period of the population of this fish from different aquatic habitats of Egypt extends from May to September. The breeding activity in this fish affects the rate of feeding which almost ceases at full ripeness and during spawning. It also affects the condition of both the fish muscle and liver which at the climax of spawning activity have relatively small weight values. During the quiescent phase of the gonad, the fish feeds normally or even excessively as happens in the spent individuals just after spawning. Part of the material gained from feeding are stored in the form of fats in the different body organs. The low water temperature prevailing in the Delta Lakes in winter (the main habitats of the cichlid fish in Egypt) seems, however, to be unfavourable for this tropical species and its feeding activity slows down. The decrease in the condition of muscles and liver of *Tilapia zillii* during the breeding period means that the gonads, to a certain extent, depend on material drawn from these organs to attain full ripeness.

The weight of the maturing gonads progressively increases and maximum weight is attained at full ripeness. A significant increase takes place in the weight of the ovary of female individuals at full ripeness and this is reflected on the fish weight, which increases during this period. This is in contrast to the two warm water sardine species represented in Egypt namely *Sardinella maderensis* and *Sardinella aurita* in which the small weight of their fully ripe ovaries does not compensate for the obvious decrease in the fish weight during their breeding in summer (El-Maghraby, 1960, 1969).

Different authors have studied the variation in the condition and amount of total lipids in the muscles and (or) liver of the fish in relation to sexual maturity. There is no need to repeat statement of the results of these authors, since they are considered in details in the previous paper.

Bougis (1952) in his work on *Mullidae* has also reviewed several previous works done in this connection and accordingly classified the fishes with respect to the main organs of stocking the lipids in two groups:

Gadus type: which include various species of Cod family and this type is characterised by accumulation of fat in the liver before the formation of genital products. The muscles in these fishes have low and constant amounts of lipids.

The *Mullus* type: in fishes of this category, the liver does not function as accumulator of fat, the muscles show important variations in their fat content and the role of the liver seems only to be receiving lipids from the muscles and renders them available for the gonads during vitellogenesis.

The two Egyptian *Sardinella* species mentioned before could be regarded as belonging to the *Mullus* type. El-Saby (1934) has shown that the fat content in these two species were very low during their summer breeding period, it increases by about 30 % of the total weight during autumn when they feed excessively on the bloom of plankton organisms. This has been verified by El-Maghraby (1969) who found that the increase in the weight of the two *Sardinella* species from summer to autumn is about 1/3 of the fish weight.

It appears from the significant seasonal variation in the condition of the liver and muscles of *Tilapia zillii* that both of them store fat which is withdrawn from them during the breeding period to be utilized in gonad maturation.

Accumulation and withdrawal of reserve material from the liver and muscles of *Tilapia zillii* are also detected from the relatively high unsaturation of their fat content. These high unsaturation values usually prevail whenever the fish increases its feeding activity and also at the time of gonad maturation. The high fat saturation occurring in the liver and gonad at the climax of breeding activity is most probably due to the presence of saturated phospholipids and lipoproteins essential for the formation of ova and sperm.

SUMMARY

The cichlid fishes of the Genus *Tilapia* occupies a prominent position in the inland and lake fisheries of U.A.R. of these fishes, *Tilapia zillii* Gerv. plays an important role since, it has a wide distribution, owing to its euryhaline nature, in the brackish water lakes, even in the saline environment of Lake Quarun. The study of the biology of this prolific species has received much attention. It is attempted in this study to estimate the fat metabolism of this important species in relation to the biological features which control it.

The chief results obtained from this study could be summarized in the following :

1. The monthly changes in the amount of fat in the muscle, liver and gonads has been followed.

- (a) The fat of the muscles is fairly high in winter and early spring. It drops significantly in May accompanying the first spawning activity of the fish. As a result of the increase in the rate of feeding of the fish after the first spawning activity, the percentage of fat in the muscle rises considerably and the maximum values are thus recorded in July and August. The lowest percentage of fat in the muscle are those of the spent fish in October.
- (b) The fat content of the liver is subjected to two profound rises occurring respectively in April (or May) and August. They indicate a high fat reserve accumulated prior to the first and second spawning activity. The rise in the fat content of August results from the heavy feeding of the fish after its first spawning.

The most significant drop in the fat reserves of the liver coincided with the climax of the two spawning activities i.e. in June and September.

- (c) The percentage of fat content of the immature gonads during their winter rest phase are high. It gradually decreases in spring, with the gradual progress of gonad maturation. But as a result of the high gonad weights recorded in the breeding season (May-September), the quantity of fat in them is several times greater than at other season. The lowest fat content are those of the autumn which represent the spent condition of the fish.

2. Estimation of the fat saturation of the muscles, liver and gonads in different months as a mean to detect the mobilization of fat accompanying and following the breeding and the feeding activities of the fish was also attempted. The possible reasons for the recorded variations are as follows :

- (a) The increase in fat unsaturation in the muscle and the liver of the maturing fish taking place in March and April means accumulation of fats in these organs in preparation to the breeding activity.
- (b) In the maturing and fully ripe fish, the increase fat unsaturation in the liver and the muscles of May and (or) June indicates on the other hand withdrawal of fat from these organs to the gonads.
- (c) The decrease in unsaturation recorded sometimes during the breeding period in the liver may be due to the formation of phospholipids and lipoproteins necessary for ovogenesis and spermatogenesis.
- (d) The spent fish feeds vigorously in autumn and part of the material gained accumulates in the liver and muscles and hence the high fat accumulation recorded in these organs at that time.
- (e) The increase in fat unsaturation in February in the liver and muscles may be due to the oxidation of fat to supply the extra energy needed in this cold month.

The high unsaturation of fat in the gonads recorded in autumn and winter possibly means that they are passing a quiescent phase following or preceding the activity in the breeding season.

Fat saturation in the gonads is obvious during the breeding period (May-August) and this is due to the formation of phospholipids and lipoprotein necessary for formation of the ova and sperm.

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