FAO Fisheries Synopsis No. 90
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FIRS/S90
SAST - S. galilaeus - 1,70(59),052,02

SYNOPSIS OF BIOLOGICAL DATA ON *Sarotherodon galilaeus*

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME, 1974

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MAST	Information on methods and subjects
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SAST	Données sur certaines espèces et populations de poissons
MAST	Renseignements sur des méthodes et des sujets
OT	Données océanographiques
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CB	Lists of periodicals, special sections of "Aquatic Sciences and Fisheries Abstracts (ASFA)," special bibliographies and papers concerning documentation problems
MFS	Provisional editions of "FAO Manuals in Fisheries Science"
WAFR	Provisional reviews of fisheries resources and their level of exploitation, by regions or by species groups, within the World Appraisal of Fishery Resources system

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CB	Listes de périodiques, des sections spéciales de la «Aquatic Sciences and Fisheries Abstracts (ASFA)», des bibliographies particulières et des articles sur les problèmes de documentation
MFS	Editions provisoires des «Manuels FAO de science halieutique»
WAFR	Synthèses provisoires des ressources halieutiques et leur niveau d'exploitation, préparées, par régions ou groupes d'espèces, dans le cadre du Programme mondial pour l'évaluation des ressources halieutiques

Certains documents portent parfois d'autres numéros d'identification, par exemple s'ils ont été préparés pour une réunion dont les documents ont été marqués à l'aide d'un autre système.

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RE	Listas índices de expertos y de instituciones tomadas de los registros que se llevan en la Dirección de Recursos Pesqueros
IN	Ediciones provisionales de los inventarios y listas de datos de pesca acumulados y guardados por el Centro de Datos Pesqueros de la FAO
CB	Listas de periódicos, secciones especiales de la «Aquatic Sciences and Fisheries Abstracts (ASFA)», bibliografías especiales y trabajos relativos a los problemas de documentación
MFS	Ediciones provisionales de los «Manuales de la FAO de Ciencias Pesqueras»
WAFR	Reseñas provisionales de los recursos pesqueros y de su estado actual de explotación, por regiones o por grupos de especies, en el marco del sistema mundial para la evaluación de los recursos pesqueros

Algunos documentos tienen también otra identificación si, por ejemplo, son contribuciones a una reunión cuyos documentos han sido marcados con arreglo a otros sistemas.

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FIRS/S90
SAST - S. *galilaeus* - 1,70(59),052,02

SYNOPSIS OF BIOLOGICAL DATA
ON *Sarotherodon galilaeus*

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, July 1974

PREPARATION OF THIS SYNOPSIS

Sarotherodon galilaeus is one of the most widespread cichlid species on the African continent, forming a basis for many fisheries, both in Africa and Israel. Much attention has therefore been paid to this species and the resulting literature was considered sufficiently extensive for the compilation of a synopsis.

The author, during his work on the fisheries of Kainji Lake under the auspices of FAO/UNDP Project DP/NIR/66/524, had occasion to make extensive personal observations on this fish, and as a result, compiled the literature into the present synopsis.

The draft synopsis was technically edited by R. Welcomme, of the Aquatic Resources Survey and Evaluation Service of the FAO Department of Fisheries.

The author is extremely grateful to Dr. E. Trewavas of the British Museum (Natural History) for contributing Section 1 (Identity) and for her critical and encouraging comments on the remainder of the text.

Particular thanks are also due to the personnel of the Kainji Lake Research Project for their assistance in the collection of material and data.

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* As no information was available to the author these items have been omitted from the text

1 IDENTITY

1.1 Nomenclature

1.11 Valid name

Sarotherodon galilaeus (Linnaeus, 1758:282)

1.12 Objective synonymy

Sparus galilaeus Linnaeus, 1758:282
Chromis galilaeus Günther, 1862:273
Tilapia galilaea Boulenger, 1899:114; id. 1915:169, fig. 109; Pellegrin, 1904:330; Trewavas, 1942:530
Tilapia (Sarotherodon) galilaea Regan, 1920: Thys van den Audenaerde, 1968:XXXIX

1.2 Taxonomy

1.21 Affinities

- Suprageneric

(according to Berg, 1940)

Phylum Vertebrata
 Subphylum Craniata
  Superclass Gnathostomata
   Series Pisces
    Class Teleostomi
     Subclass Actinopterygii
      Order Perciformes
       Suborder Percoidei
        Family Cichlidae

- Generic

Sarotherodon Rüppell, 1851.
Type species Sarotherodon melanotheron Rüppell, l.c.

Sarotherodon was treated as a subgenus of Tilapia by Regan (1920), Trewavas (1966) and Thys van den Audenaerde (1968, Bibliography), but Thys divided it into six second-order subgenera and Trewavas (1972, 1973) has given reasons for ranking it as a genus. It includes all species of the former Tilapia that are known to be mouth-brooders.

Sarotherodon and Tilapia are distinguished from other African cichlid genera (except possibly one or two endemic genera from Lake Tanganyika) by the following combination of characters:

- Apophysis on base of skull for attachment of toothed upper pharyngeal bones formed from the parasphenoid bone.

- Three lateral line pores on the preorbital (lacrimal) bone.

- Teeth of jaws comprising an outer row of bi- or tricuspids and one to six inner rows of tricuspids (some, especially of the outer row may, in older specimens or breeding males, become replaced by unicuspids or may have the notched crowns worn down; but not in S. galilaeus).

- Lower pharyngeal bone with triangular, heart-shaped or discoidal toothed area, the teeth slender, more or less crowded, the posterior bluntly setiform or, more usually, bi- or tricuspid (in one species of Tilapia with four cusps).

- Intestine longer than body, often much longer.

- Predominantly herbivorous when adult diet varying from vascular plants (some Tilapia) to phytoplankton.

- The tilapia mark, a black blotch at junction of spinous and soft parts of dorsal fin, usually present in young and persisting in adult of some species of Tilapia.

Sarotherodon and Tilapia are distinguished from each other as shown below:

	Tilapia	Sarotherodon
Gill rakers on lower part of first arch	5-14 usually 5-12	12-27 usually 13-23
Anterior blade of pharyngeal bone relative to median length of toothed area	shorter	nearly as long, as long or longer
Mesethmoid bone	usually meeting vomer or dorsal surface of rostral part of skull	not meeting vomer
Eggs: long diameter	1.5-2.6 mm adhere to substrate	2.2-5.5 mm do not adhere to substrate
Parental behaviour	fan and guard eggs and embryos, guard broods	brood eggs and young in mouth of one or both parents

- Specific

Sarotherodon galilaeus is distinguished from other species of Sarotherodon as follows:

- Body deep, in adults 43-56.5 percent S.L., usually 45 percent.

- Caudal fin very slightly emarginate.

- Mouth small, length of lower jaw less than one third length of head, no sexual dimorphism in length of jaw and no change of any of the teeth from pluricuspid to unicuspid.

- Pharyngeal bone massive, with slender unicuspid crowded teeth; the length of the whole bone 38-42 percent length of head in adult (S. lepidura, S. occidentalis, S. tournieri and S. steinbachi have similarly massive pharyngeal bones).

- General body colour usually pale yellow or grey-green; characteristic vertical black bars on upper two thirds of flanks in some individuals or emotional states; these are irregular in shape, sometimes discontinuous, made up of black marks on some of the scales; no marking on caudal fin except a pink posterior margin; occasional melanic individuals or populations.

- Genital papilla of mature male not produced into a tassel.

- No colour differences between the sexes.

- Eggs brooded in the mouth of either or both parents.

- Not polyandrous, at least in one breeding season.

Key for separation of S. galilaeus from related species, i.e., having heavy pharyngeal bone and emarginate caudal fin.

1. (a) Gill rakers on lower part of first arch 18-19; vertical stripes on the caudal fin S. tournieri Daget /R. Cavally/

(b) Gill rakers 19-26 on lower part of first arch (usually more than 19); no vertical stripes on caudal fin; 29-33 scales in lateral line series

2. (a) Soft anal rays 13; caudal fin crescentically emarginate; 3 series of scales on cheek S. caudomarginatus Blgr. /R. Corubal and Sierra Leone/

(b) Soft anal rays 9-12; caudal fin feebly emarginate; 2 rows of scales on cheek, or occasionally 1 or 2 scales of a third row

3. (a) Depth of body 39-43.5 percent S.L., length of head 30-33.4 percent; dorsal half of body maize yellow; dorsal XVI-XVII 13-14, totals 30-31 S. occidentalis Daget /R. Casamance and R. Corubal/

(b) Depth of body 42.5-56 percent SL., length of head 32.5-39 percent; body colour silvery or brassy yellow; dorsal (XIV) XV-XVI, rarely XVII, totals 27-30, usually 28 or 29 S. galilaeus

Sarotherodon melanotheron (including S. m. heudeloti and S. m. nigripinnis) differs from these in having a more slender pharyngeal bone with fewer, less densely crowded teeth; fewer gill rakers (12-18 on lower part of anterior arch); fewer dorsal fin rays (totals 25-29, usually 26-28). The species inhabits brackish water from Congo to Senegal. Where breeding habits are known the male is usually the brooding sex.

Sarotherodon mvogoi Thys, on inland species of South Cameroon and on northern tributary of the Ogoue, has a pharyngeal bone like S. melanotheron, but more gill rakers (18-24 on lower part of first arch).

1.22 Taxonomic status

This is a well defined species by morphological data but is polytypic.

1.23 Subspecies

The following four subspecies have been identified and their taxonomic characteristics are summarized in Table I.

S. gal. galilaeus (Linnaeus, 1758) in Hasselquist, 1757

- Jordan, Nile, Lake Rudolf, West African savannah, Sahara, Senegal.
- Gambia, Upper Casamance, Upper Rio Geba, Niger, Volta, Benue, Chad.
- Shari, Ubangi, Uele.

S. gal. borkuanus Pellegrin, 1919

- Borkou depression.

S. gal. multifasciatus (Günther, 1902)

- Coastal forest - rivers from Sassandra (Ivory Coast) to Western Ghana, excluding Volta system and including Lake Bosumtwi.

S. gal. boulengeri Pellegrin, 1903

- Stanley Pool (Pool Malebo) and tributaries.

TABLE I

Summary of taxonomic characteristics of the subspecies of S. galilaeus

Locality	Subspecies	Length/Depth	Gill rakers on first gill arch	Dorsal fin rays	Anal fin rays	Scales in longitudinal series	Authority
Ivory Coast	S. gal. galilaeus	1.8	32 (total)		III 10-12		Daget and Iltis (1965)
Chad and Mayo Kebbi	S. gal. galilaeus	1.8-2.2	22-26 (lower part)	XV XVI 11-14	III 9-11	28-31	Blache (1964)
Upper Niger	S. gal. galilaeus	1.8-2.2	23-26 (lower part)	XV XVI 12-14	III 10-11	28-31	Daget (1954)
Nile	S. gal. galilaeus	1.8-2.5 (total length)	18-25 (lower)	XV XVII 12-14	III 10-12	30-34 30-32	Boulenger (1905) Trewavas
Ivory Coast	S. gal. multifasciatus	2.6	29 (total)		III 9-11		Daget and Iltis (1965)
Lake Bosumtwi	S. gal. multifasciatus	2.2-2.9	21-23 (lower part)	XV 13 or XVI 12	III 10-11	 28-31	Daget and Iltis (1965) Trewavas
Congo (Yangambi)	S. gal. boulengeri	2.3-2.5	20-23 (lower)	XVI XVII 10-11	III 8-10	30-33	Gosse (1963)
	S. gal. borkuanus			XV XVI	III 9-10	30-31	Pellegrin

TABLE II

Names of Tilapia, Sarotherodon and S. galilaeus in various areas and languages

Scientific	Authority	Area or country	Language	Name
S. galilaeus	Ben-Tuvia, 1959	Israel	Hebrew Arabic	Amnon hagalil Musht abiad
	Schuster, 1955	Jordan		Okkar
	Copley, 1952a	Nile		Bolti Malawi
	Holden, 1963 Jenness, 1970	Nigeria	Hausa	Falga Garagaza
	Stauch, 1966	Cameroon	Bata Dama Djoukoun	Kitrisse Darkou Agebe
	Welcomme, in press	Dahomey	Minah	Akpavi-Sewe
	Greenwood, 1958	Uganda	Lunyoro	Kaishata
Tilapia and Sarotherodon (as a group)	Ricardo-Bertram, 1942	Israel	English	St. Peter's fish
	El Saby, 1951	Nile delta lakes		Bolti
	Sandon, 1950		Dinkas	Atur
	Yaro, 1967, 1967a	Nigeria	English	Tilapia, Mango-fish
			Hausa	Garagaza, Karfasa, Bugu, Falga, Holinga, Bulkuba, Jinka, Bakaba
			Nupe	Tsokungi, Tsokun bokun, Tsokun, Zjuru, Zja-kpikpini
			Ijaw	Tome, Tabala, Tebembele, Okwabo
			Kanuri	Karwa, Karawa, Ngrish, Kembol
	Holden, 1963 Jenness, 1970		Hausa	Bugu, Gargaza[a], Karfasa
			Bussawa	Shepu
			Gungawa	Hikiuru
			Laru	Kpebi
			Lopawa	Shuri
	Stauch, 1966	Cameroon	Hôoussa (Sokoto)	Gargassa, Karpassa
			(Kabawa)	Holinga
			Djoukoun	Apoushi
	Welcomme, in press	Dahomey	Fon	Wé

a/ Used by Birnin Kebbi Hausa speaking Sokoto dialect which differs from that of Kano or Zario

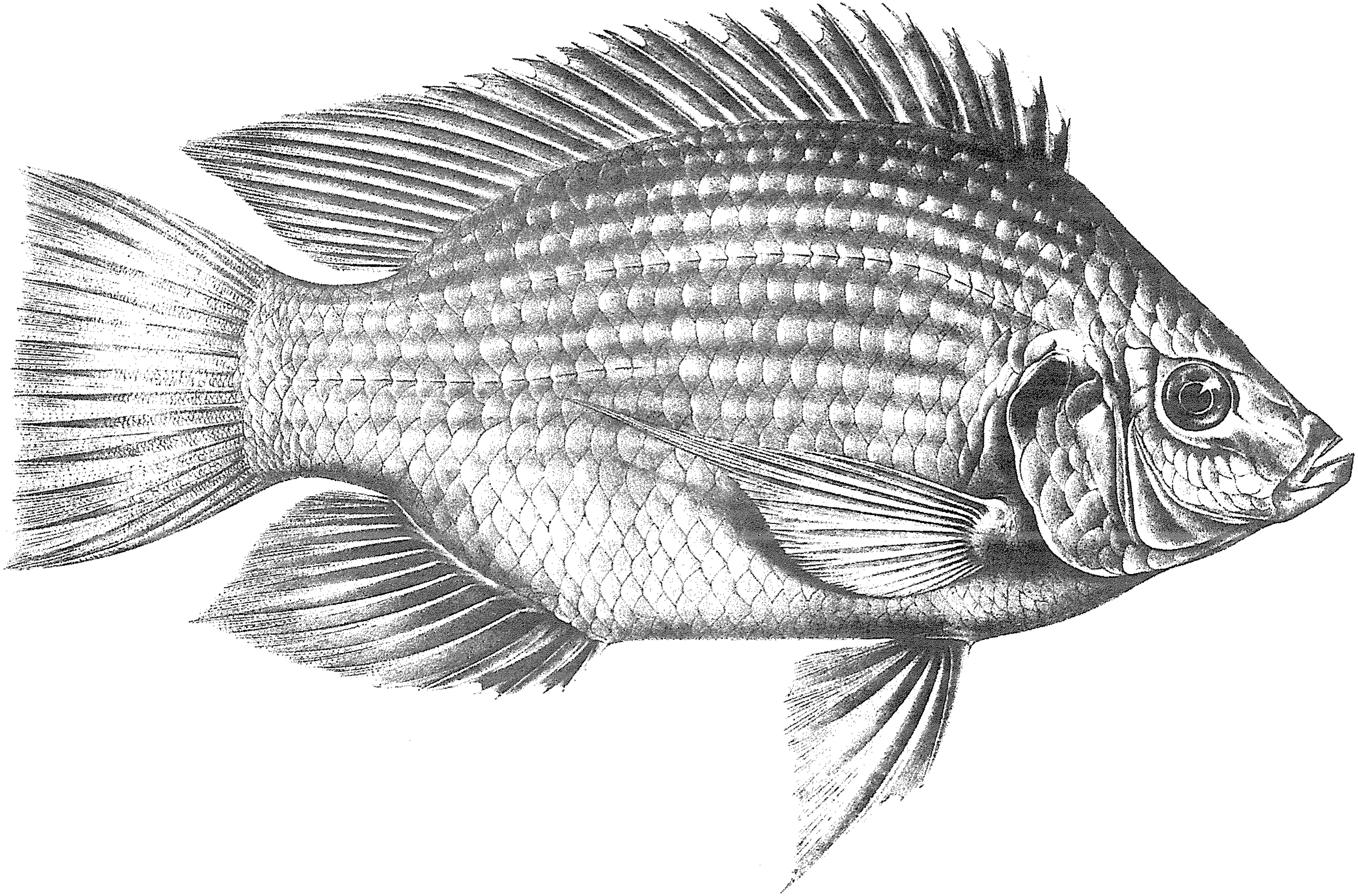

Figure 1 S. galilaeus (After Boulenger, G.A. (1907), The Fishes of the Nile. In Zoology of Egypt, published for the Egyptian Government by Hugh Rees, Limited, Pall Mall, S.W., London)

Sarotherodon sanagaensis (Thys, 1966) should perhaps be considered a subspecies of S. galilaeus. It is confined to River Sanaga, Cameroon and is distinguished by the dark purplish ground colour of the dorsum and dorsal fin and, in some specimens, a very small head.

1.24 Standard common names, vernacular names

S. galilaeus seems to have little usage of any common English name other than the former scientific name, Tilapia or Tilapia galilaea. Names used by various language groups are listed in Table II.

1.3 Morphology

1.31 External morphology

Fryer and Iles (1972, p. 26) point out that S. galilaeus has a deep body and large dorsal and anal fins (Figure 1) which enable it to maintain stability as it dips its snout toward the bottom when collecting food. The high dorsal fin rises well forward (about a fifth of the way along the body); the anal, pectoral and pelvic fins are relatively large and well forward and the flexible fan-shaped tail, whose area and shape can be altered during the stroke, are specializations toward smooth control of movement rather than speed, although the fish is capable of short bursts of speed. The dorsal spines are stout and excavated on alternate sides to permit each spine and its attached fin membrane to fit neatly into the excavation of the spine directly behind it when the fin is folded.

Ben-Tuvia (1959) describes the digestive tract of S. galilaeus as very long, folding several times in the abdominal cavity and showing little regional differences in its external shape. At the end of the short oesophagus there is a small stomach (which apparently serves for the digestion of the coarse particles of food). The relationship between the length of the gut and the length of the fish changes greatly with the size of the fish (Table III).

The tilapia mark, a round blackish spot on the anterior part of the soft dorsal fin in very young specimens, disappears after the fingerling stage.

1.33 Protein specificity

Badawi (1971) analysed blood serum of S. galilaeus and three other Tilapia/Sarotherodon species electrophoretically and the percentage proteins in each fraction were determined. Serum protein patterns, characteristic for particular species were clearly demonstrated and the four species differed as to the final mobility obtained and the amount of protein differed considerably. Although no reasons are given, Badawi suggests that diet may be a major contributing factor to variations observed in the amount of total protein.

Trewavas, Green and Corbet (1972) report the electrophoresis of eye lens proteins of a number of cichlids including S. galilaeus and S. multifasciatus. S. galilaeus is evidently recognizably different from all the others, including S. multifasciatus. The interpretation of the results is uncertain as to whether influenced by environment or genetic relationship.

1.34 Blood analysis

Badawi and Said (1971) compared the blood of S. galilaeus and three other Tilapia/Sarotherodon species. Mean erythrocyte count and size, haemoglobin content and haematocrit value varied markedly among the species. S. galilaeus had the lowest erythrocyte count (0.93 million/mm^3) with large oval cells 14.5 x 9.4 µ.

TABLE III

Changes in ratio of gut length to body length with size

T.L. of fish (mm)	Ratio of gut to body length	
	Mean	Range
10- 22	1.38	(1.04-1.77)
25- 29	3.06	(2.50-3.50)
45- 50	4.04	(3.85-4.40)
290-360	7.66	(6.30-8.20)

2 DISTRIBUTION

2.1 Total area

According to Copley (1952a) the family Cichlidae appears to have originated in South America. However, Chimits (1957) reports that so far as is known, no fossil Tilapia and Sarotherodon have been found outside Africa or Asia Minor, and these genera can therefore be considered as indigenous to these two areas (Figure 2 and Table IV).

In Asia Minor S. galilaeus is important in commercial fisheries in the Jordan drainage, including the Jordan River, the Sea of Galilee and the present Huleh Channel (Sarig, 1965, 1966). Yashouv (1960) notes that Tilapia and Sarotherodon are tropical fish and the lakes of Israel and Syria represent the northern limit of their distribution. S. galilaeus has been used widely for fish culture in Israel (Paperna, 1960; Sarig, 1955; Chervinski, 1964), less so in Syria (Job, 1967), and suggested as a pond species in Jordan where it occurs naturally (Schuster, 1955).

In the Nile River system S. galilaeus occurs from the brackishwater lakes near the delta, including Menzaleh, Burullos, Edku and Mariut (El Saby, 1951; El Zarka, Shaheen and El Aleem, 1970), through the Nile, Blue Nile and White Nile and in many tributaries and in Lake Nasser-Nubia (Sandon, 1950; Boulenger, 1915; Entz and Latif, 1972) and into the upper reaches of the Nile at Lake Albert (Lowe, 1955), where it is by no means common (Greenwood, 1958). There are no reports of its occurrence in other headwater lakes (Edward, Kyoga, Victoria); these are isolated from the Nile drainage by the Semliki Rapids and Murchison Falls. The species has been used for fish culture in both Egypt (Shaheen, Imam and Hashem, 1960) and in Sudan (Job, 1970) and presumably spread this way.

S. galilaeus is present in Lake Rudolf (Lowe, 1958; Hamblyn, 1962) which was formerly connected with the Nile drainage, perhaps not many thousand years ago (Fryer and Iles, 1972, p. 469).

In the Niger River system S. galilaeus is recorded from the upper reaches at Bamako, Mali (Daget, 1951), is abundant in the lakes and channels of the central Niger delta near Timbuktu (Daget, 1954, 1957, 1962; Monod, 1945), and occurs through the system and its tributaries including the Sokoto, Kaduna and Benue Rivers in Nigeria (Boulenger, 1902, 1915; FAO/UN, 1970; FAO/UNDP, 1970; FAO, 1972; Henderson, 1973; Welman, 1948). It is reported from the upper reaches of the Benue River in Cameroon including the Benue, Faro and Mayo Kebbi sections (Daget and Stauch, 1963).

The species is less widely reported in the Congo River drainage, but occurs in Stanley Pool (Pool Malebo) on the lower Congo, in the Ubangi River at Yakoma, and the Uele and Rubi Rivers (Fryer, 1963). Reports of its natural distribution south of the Congo drainage were not verified by the author.

In the internal Lake Chad drainage S. galilaeus occurs around the lake shoreline (Hopson, 1967) and in the affluent El Beid and Yobe Rivers (Durand, 1970; Tobor, 1970). Fryer and Iles (1972, p. 583) report that Lake Chad has at times been in free communication with the Nile, Niger and Congo River systems, especially the first two. They quote Blache et al. (1964) that Lake Chad has been termed the hydrographic turntable of Africa, so freely have these systems been united. Hopson (1967) reports a present tenuous connexion between the Benue River and marshes of the Mayo Kebbi, but that the falls of Gauthiot form an effective barrier to colonization of the Logone from the Benue. However, the widespread distribution of S. galilaeus is easily explained by these past connexions.

S. galilaeus occurs in many lesser drainages in west central Africa. In Cameroon it inhabits lakes associated with the lower Mungo and Meme Rivers near Mount Cameroon (Trewavas, Green and Corbet, 1972) and the Sanaga River, Thys (1966 and 1968) and is used as a pond culture species in that country (Meschkat, 1967; Bard, 1960). Burchard (1967) reports that S. galilaeus occurs practically throughout Nigeria. It has been recorded from the Oueme River in Dahomey (Daget, 1951) and has been tried in pond culture in Togo (Meschkat, 1967). In Ghana it is important in the commercial fishery of Volta Lake (Lawson et al., 1969), is used in pond culture in several areas (Denyoh, 1967), and occurs in dams and streams on the Accra plains (Trewavas, Green and Corbet, 1972; Prah, 1969). A possible subspecies, S. gal. multifasciatus occurs in Lake Bosumtwe, a crater lake in Ghana (Irvine, 1947; Whyte, in press). The species occurs in the Ivory Coast (Daget and Iltis, 1965) where it has been used in fish culture work (Meschkat, 1967), and in Sierra Leone, Guinea (Daget, 1950, 1951), Togo and Dahomey (FAO/UN, 1971). Boulenger (1915) reports it from the Corubal and Geba Rivers in Portuguese Guinea. It is reported from the Gambia River (Boulenger, 1915; Daget, 1957) and the Senegal River (Boulenger, 1915; Daget, 1951). S. galilaeus is present in Mauritania (Estève, 1952) and is indigenous to the lowlands of Morocco, where it is used in pond culture (Meschkat, 1967).

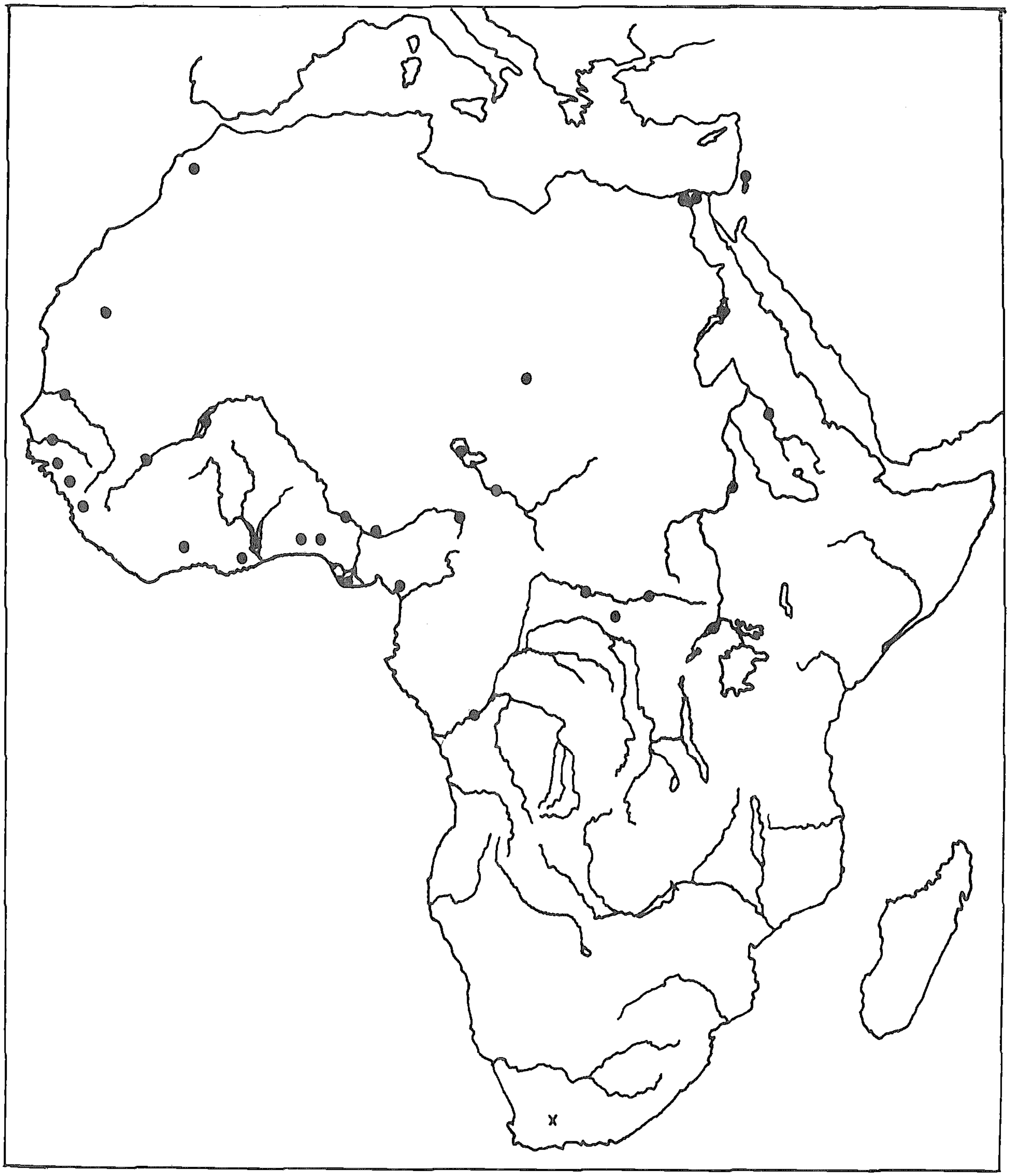

Figure 2 Representative distribution of S. galilaeus
in Asia Minor and Africa

● Natural
x Introduced

TABLE IV

Geographic distribution of *S. galilaeus* by FAO letter code
(Rosa, 1965, Appendix I)

Land area	Countries	Representative reference
410	Southwest Asia	
411	Syria	El Boulock and Koura, 1961; Job, 1967.
413	Israel	Ben-Tuvia, 1959; Paperna, 1960; Chervinski, 1964; Sarig, 1955, 1965.
414	Jordan	Schuster, 1955.
110	Northwest Africa	
113	Morocco	Meschkat, 1967.
120, 130	Northeastern and east central Africa	
122/123/131	Egypt, Sudan, Uganda	El Saby, 1951; Entz and Latif, 1972; El Zarka, Shaheen and El Aleem, 1970; Sandon, 1950; Jensen, 1958; Job, 1967; Boulenger, 1915; Lowe, 1955.
125/131	Ethiopia, Kenya	Lowe, 1958; Hamblyn, 1962.
140	West Central Africa	
141	Mali, Senegal, Mauritania, Ivory Coast, Dahomey, Upper Volta, Niger, Guinea	Daget and Iltis, 1965; Boulenger, 1915; Daget, 1951, 1957; Lemasson, 1960; Meschkat, 1967; Monod, 1954; Blanc and Daget, 1957.
142	Portuguese Guinea	Boulenger, 1915.
144	Sierra Leone, Ghana, Togo, Gambia	Boulenger, 1915; Trewavas, Green and Corbet, 1972; Denyoh, 1967; Lawson *et al.*, 1969; Prah, 1969; Daget, 1950; Meschkat, 1967.
145	Nigeria, Cameroon	Boulenger, 1915; Burchard, 1967; Trewavas, Green and Corbet, 1972; Bard, 1960; Daget, 1961; Stauch, 1966; Welman, 1948; Tobor, 1970; Thys, 1968.
146/147	Chad, Congo (Brazzaville and Kinshasa), Central African Republic	Hopson, 1967; Durand, 1970; Daget, 1959; Meschkat, 1967; Tillon, 1957.
150	South Africa	
154	Cape Province (Republic of South Africa)	Jubb, 1965; Union of South Africa, 1962; Siegfried, 1962

Possible migration routes to the present wide distribution of S. galilaeus in Africa were through former connexion of the present endorheic Lake Rudolf drainage with the Nile River system, and the past connexions of the Nile, Niger and Congo systems with the Lake Chad drainage. Dispersal between Asia Minor and Africa, and throughout west central Africa systems draining into the Atlantic Ocean is less easily explained. It may be that the tolerance of S. galilaeus to salinity (Chervinski, 1961; Daget, 1951; El Saby, 1951), while not equal to that of some other Tilapia or Sarotherodon species (notably T. zillii and S. melanotheron), may have facilitated migration between coastal streams especially during the Nile floods. Chervinski (1961) quotes Myers (1938) that the family Cichlidae are supposed to have originated in salt water and penetrated to fresh water secondarily.

S. galilaeus has been introduced to Cape Province (Union of South Africa, 1962) where it presumably survives naturally (Jubb, 1965; Siegfried, 1962) and has been used in fish culture at Jonkershoek (Union of South Africa, 1962). Fukusho (1968) records that S. galilaeus has been imported into Japan, but that members of the genus Tilapia (and Sarotherodon) there must be transferred to hot spring water for overwintering.

The distribution pattern is further complicated when subspecies distribution is considered, as outlined in section 1.23.

2.2 Differential distribution

2.21 Spawn, larvae and juveniles

The eggs of S. galilaeus are taken up in the mouth of the parents immediately after fertilization and brooded there until the yolk sac of the fry is completely absorbed, when a length of about 12 mm T.L. is reached (Ben-Tuvia, 1959).

Johnson (1974) found the favoured habitat of fry to have gently sloping (less than 5 percent gradient) mud and organic debris bottom of 1-6 inches deep, protected on the lakeward side by emergent weeds; although Loiselle (1972) found a preference for open shoreline habitats in Lake Volta.. Here the fry receive protection from aquatic piscivores, the benefit of warm water, and nearby weeds for shelter from non-aquatic predators. Fry were very abundant near such areas where women were washing clothes; presumably the detergent used increased food production, or perhaps agitation of the water by humans made food easy to collect. Loiselle (1972) found that where length-frequency of juveniles is plotted against mean water depth a clinal distribution results with smaller individuals in the shallowest water and a progressive increase in length with increased depth.

2.22 Adults

Fryer and Iles (1972, p. 220) report that in Lake Tiberias S. galilaeus form large very densely packed shoals estimated to cover an area of more than an acre whose purpose is not clear. These shoals presumably assemble only by day. They suggest that S. galilaeus is the species concerned in the Biblical account of the miraculous draught of fishes (Luke Ch. 5 vs. 7) wherein Peter is reported as saying "Master, we have toiled all the night and taken nothing" - but that in the morning, when the incident appears to have occurred, a shoal could have assembled and an enormous catch made. Ben-Tuvia (1959) found that at the end of the winter season (during March) the large schools of S. galilaeus in Lake Tiberias disperse and pairs begin to appear near the shores in search of suitable spawning places, in shallow water rich in plants where the bottom is covered by sand and gravel.

2.3 Determinants of distribution changes

2.31 Current

S. galilaeus is better adapted to a lacustrine than a riverine environment although it occurs in both. Jenness (1970) notes that S. galilaeus avoids rapids in the Niger River. Welman (1948) reports they may be found in abundance during the dry season in backwaters and on shallow flats in Nigerian rivers, and Motwani (FAO, 1970) records their importance in the Niger-Benue basin in swamps and floodplains rather than in the rivers. The rapid increase of S. galilaeus in the newly-formed Volta Lake, has been well documented (Petr, 1966, 1967, 1967a, 1968, 1969; Denyoh, 1969; Evans, 1969, 1971; Lawson et al., 1969; Vanderpuye, 1972; Vanderpuye and Evans, 1969). This increase is attributed to a change from riverine to lacustrine habitat which favours the development of herbivorous fishes, such as S. galilaeus. Reynolds (1967) quotes Wuddah (1967) that the riverine pattern of spawning during floods has been obliterated in Volta Lake; presumably this has helped the population of S. galilaeus to increase.

Durand (1970, 1971) notes changes in abundance of S. galilaeus (particularly young fish) in the intermittent El Beid River connecting Lake Chad and the North Cameroon flood plain; they are taken in the commercial catches at Dago during the 3-4 months the river flows. El Saby (1951) records the chief time for catching Tilapia (or Sarotherodon) in the lake fisheries of Egypt is from November to the end of February when they emerge from the marshes as the flood comes down.

2.32 Substrate

Lowe (1959) reports that S. galilaeus are found in the main part of Lake Albert off sandy shores, while Motwani (FAO, 1970) says that sandy or slightly muddy bottoms which survive periods of low flow constitute a suitable habitat for Tilapia (or Sarotherodon) species. Motwani and Kanwai (1970) quote Blache et al. (1964) that a sandy bottom covered with filamentous algae (for example after the flood season) constituted a typical habitat for S. galilaeus. Holden (1963) found in dry season pools of the River Sokoto that numerically S. galilaeus have a substrate preference of sand over intermediate over mud bottom, and that whereas they were dominant in a sand-substrate pool in 1954, they were replaced by S. niloticus in 1956 when the substrate had changed to mud. However, S. galilaeus is abundant in four Nile delta brackishwater lakes whose bottoms consist mainly of brownish mud (El Saby, 1951).

2.33 Vegetation

Hopson (1967) notes the virtual absence of cichlids in the wide expanses of open vegetation-free water of Lake Chad, which in the northern basin forms an uninterrupted sheet of over 1 500 square miles. Cichlids here (including S. galilaeus) are almost entirely restricted to a narrow belt close to the shore or to shallow, well vegetated regions. Lelek (FAO, 1972) found that cichlids (including S. galilaeus) in Kainji Lake were abundant on shorelines with aquatic vegetation but were scarce or absent where little vegetation occurred. Ita (1971) caught the majority of S. galilaeus sampled from a small pond near Ibadan amidst the vegetation where there was a thick muddy bottom resulting from decayed organic matter (the entire substrate was mud). Taylor and Denyoh (1968) found that S. galilaeus in Volta Lake swim and feed amongst flooded bushes. However, Holden (1963) found that the average size of S. galilaeus in a pool of the Sokoto River increased considerably from 1956-57 when an increase from total plant to partial plant cover occurred. He suggests that the "openness" of the water is important for this species.

2.34 Depth

Lelek (FAO, 1972) found almost all S. galilaeus caught by gillnet sampling in Kainji Lake were in surface rather than bottom sets. Taylor and Denyoh (1968) note that S. galilaeus was rarely caught by commercial fishermen in Volta Lake in water deeper than 10 feet. Petr (1967) reports that S. galilaeus in Volta Lake prefers shallow bays where phytoplankton and plankton detritus are abundant, and that there is no evidence that any fish in the lake have been able to utilize the phytoplankton of the extensive offshore regions.

El Saby (1951) reports that S. galilaeus occurs in four shallow Nile delta lakes (Menzaleh, Burullos, Edku and Mariut), all of which have a water depth almost everywhere less than a metre, and only a few centimetres over very wide areas. Persistent strong winds may completely dry off many hundreds of acres, which a day or two before were covered by water sufficiently deep for small fry, millions of which undoubtedly perish.

In Lake Albert the Tilapia (or Sarotherodon, including S. galilaeus) in any one shoal are of very similar size and there is a close relationship between the size of fish and depth of water in which they live, the smaller the fish the shallower the water (E.A.F.R.O., 1950). Greenwood (1958) says S. galilaeus occurs in the shallow inshore waters of Lake Albert.

2.35 Turbidity

Lawson et al. (1969) found in Volta Lake that when water turbidity is low, cichlids (including S. galilaeus) disappear from shallows and most probably shelter in deeper waters, avoiding the clean surface waters.

2.36 Salinity

The high tolerance of S. galilaeus to salinity is often commented on although quantitative data are scarce. Chervinski (1961) in Israel tested the growth of small S. galilaeus for 12 days in 50 percent sea water. The species occurs in the Nile delta lakes which are permanently or seasonally connected to the sea and vary greatly in salinity over the year (El Saby, 1951), the highest being Lake Menzaleh at 9.5 to 22.5 percent. El Zarka, Koura and Shaheen (1970) quote El Zarka (1961) that S. galilaeus disappeared in Lake Qarun owing to high salinity, although T. zillii survived there. Ben-Tuvia (1959) quotes El Zarka (1956) that T. zillii can survive in 29 percent salinity but that S. galilaeus is more vulnerable to high salinities, although it can live in brackish water. Trewavas (1966) quotes Wunder (1960) that S. galilaeus in Egypt is equally at home in fresh and brackish water.

2.37 Temperature

Yashouv (1960) found that S. galilaeus in Israel ponds underwent a temporary cold stupor when subjected to a sudden temperature drop from 20.5°C and 17°C to 9.5°C; after an hour at the low temperature the fish recovered as the temperature rose. In another experiment temperatures over a total time of about $1\frac{1}{2}$ h were dropped rapidly from 17°C to 7°C and back to 10°C; the fish at the lowest temperature were reduced to fin movements while lying on their side; they recovered at 10°C. Smaller fish (5 cm) were affected more easily than larger fish (17 cm). In November of 1958 a drop in air temperature, combined with wind, plunged pond temperatures from 9°C to 5°C and the temperatures remained around 6°C to 8°C for nearly two days; mortality of *S. galilaeus* was presumably complete. *S. galilaeus* was affected earlier and more completely than *S. aureus*. Ben-Tuvia (1959) reports that the cold spell combined with strong winds in December 1958 in Israel caused a high mortality of *S. galilaeus* in kibbutz ponds. Fukusho (1958) notes that *Tilapia* (and *Sarotherodon*) (including *S. galilaeus*) in Japan must be overwintered in hot spring water. Lawson *et al.* (1969) report that in Volta Lake during the period when the dry Harmattan winds blow from the north resulting in surface water cooling, cichlids (including *S. galilaeus*) disappear from the shallows most probably into deeper water to avoid the cool surface water.

Ben-Tuvia (1959) found that in Lake Tiberias spawning is accelerated during the days of the heat waves known as "Chamseens", at which time *S. galilaeus*, in larger numbers than usual, approach the shores where they are caught in great quantities by the fishermen. Fukusho (1968) found that for *S. galilaeus*, acclimated at 25°C for 20 days, the maximum swimming performance was attained at 32°C. Of seven other *Tilapia* (and *Sarotherodon*) species similarly tested, five developed maximum swimming performance at lower temperatures and one was the same as *S. galilaeus*.

2.38 Oxygen requirements

Denzer (1968) found the oxygen demand for *S. galilaeus* of average weight 10.2 g at 25°C to be 29.6 cm^3 per 100 g live weight per hour. This is about 80 percent that of similar-sized European trout, but much higher than for *S. niloticus*. Yashouv (1960) reports that oxygen uptake of 10-12 g *S. galilaeus* at 14°C was 106-184 mg/kg/h.

2.39 Predation

In Lake Albert *S. galilaeus* of 14-18 cm were found close inshore. This habit may be related to the presence of numerous predators. Also, the *Sarotherodon* appear to be driven right inshore at night by these predators (E.A.F.R.O., 1950).

2.4 Hybridization

2.41 Hybrids

- frequency of hybridization; species with which hybridization occurs; methods of hybridization.

Suspected hybrid offspring from a chance cross between *S. galilaeus* and *S. aureus* (referred to as *S. niloticus*) has been reported in fish culture ponds at Dor, Israel by Yashouv and Chervinski (1959) and Chervinski (1964, 1965). However, the latter author notes failure to produce offspring when attempts were made to cross *S. aureus* and *S. galilaeus* in ponds and aquaria. He used the presumed offspring of *S. aureus* x *S. galilaeus*, which are referred to as the B/27 group (named after the pond in which they were found) to produce crosses with *S. galilaeus*. Offspring of the B/27 group x *S. galilaeus* had several intermediate characters between the adults of these two groups.

Fryer and Iles (1972, p. 169) note the need for reinvestigation of this cross between a maternal mouth brooder and a biparental brooder reported by Yashouv and Chervinski (1959) before its validity can be accepted.

3 BIONOMICS AND LIFE HISTORY

3.1 Reproduction

3.11 Sexuality

S. galilaeus is heterosexual. Sex can be determined externally according to Chervinski (1965a) by the shape of the dorsal and anal fins in fish above 60 g weight. Those of the male are pointed, while those of the female are rounded and more expanded. In bigger fish these differences are more distinct.

Yashouv and Hefetz (1959) describe the method of distinguishing the sex of S. galilaeus at a size of 7 cm or greater by differences in the openings of the urogenital papilla; this is most easily done with spawning fish. At the tip of the genital papilla behind the anus, the male has a small urogenital pore the size of a pin prick which serves as a common opening of the urinary and sexual organs. In the female the small urinary pore is at the tip of the genital papilla while the separate genital pore is located in front of the urinary pore. The genital pore is covered by two lobes and appears to extend lengthwise (Figure 4).

Ben-Tuvia (1959) describes the sexual glands of S. galilaeus as paired and more or less symmetrical. The ovaries are posteriorly joined together by a short common duct which leads to the outside, ending with a small genital papilla. The ovaries contain a small quantity of eggs and even at the time of sexual maturity they do not occupy the entire length of the body cavity.

Although Ben-Tuvia (1959) states that fish less than 10 cm T.L. have gonads which are two thin transparent strips and the sexes cannot be separated by the naked eye, the present author has found that in the immature female the gonads extend forward about two thirds of the body cavity length while the immature male gonads extend the full length of the body cavity.

3.12 Maturity

In Lake Tiberias in Israel, Ben-Tuvia (1959) found both male and female S. galilaeus begin to spawn after reaching 18-22 cm. He examined 125 fish with eggs in the mouth, of which 6.4 percent were of this size, the rest larger. Age determination of fish this size show that they become sexually mature at the end of their second year of life. In Lake Albert S. galilaeus as small as 18 cm were found to be ripening (E.A.F.R.O., 1950), while Lowe (1955) records females from Lake Albert (Lowe, personal communication) of 16 and 17 cm T.L. as having ripe eggs.

In Volta Lake 87 S. galilaeus of 15-24 cm T.L. were examined for stage 1 (actively developing) oocytes; 50 percent maturity was reached at 19.8 cm T.L. (Lelek and Wuddah, 1968). Detailed examination of 46 ovaries showed the stages indicated in Table V.

Lelek and Wuddah (1968) quote other authors that the minimum size of breeding female in Lake Chad is 15.4 cm (Blache et al., 1964) and in Lake Albert is 18.0 cm (Lowe, 1949). In Kainji Lake, Nigeria, Lelek (FAO, 1972) observed that the smallest mature S. galilaeus was a female in the 11-15 cm S.L. group, of which 11 fish were captured. In the 16-20 cm group, of 35 fish examined 31.4 percent were mature, while in the 21 cm group of 43 fish, 69.8 percent were mature.

In ponds sexual maturity is reached at a smaller size and younger age than in lakes. Lemasson (1960) states that among breeding S. galilaeus and S. gal. multifasciatus at the Kokondekro fish culture station in the Ivory Coast, about 90 percent are less than 50 g weight and less than a year old. Yashouv (1958) notes that S. galilaeus begins to spawn in Israel ponds at the onset of its second year when it reaches a weight of about 80-100 g, and that under suitable temperature conditions spawning may even occur during the first year. In one instance young-of-the-year S. galilaeus were found, 16 cm in length, with fully developed ovaries. He remarks that sexual maturity depends not only on the age of the fish but primarily on its size. Lemasson (1957) says S. galilaeus in Israel ponds begin to reproduce very young at a weight of 50-60 g.

Iles and Holden (1969) found both male and female S. galilaeus 11 cm T.L. and 15 g in weight from dry season pools of the Sokoto River, Nigeria, to be brooding eggs or fry. Such precocious breeding is termed neoteny by Fryer and Iles (1972, p. 368), defined as the ability to breed successfully while still at the juvenile stage of development (not "stunted" fish). They report these small breeders to be one half the length and one eighth of the weight at which this species breeds in this area under normal river conditions.

3.13 Mating

Mating appears to be monogamous during production of any one spawning clutch. Evidence suggests that there is more than one clutch produced per year, at intervals of several weeks, and probably new mating pairs form each time. Selection of partners in aquaria is described by Apfelbach (1966a) as follows: a ripe female is courted by several males, one of which

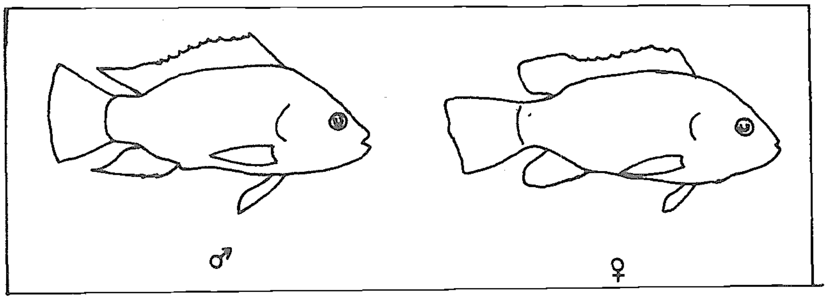

Figure 3 Differences in the shape of the anal and dorsal fins of S. galilaeus (drawn from photographs in Chervinski, 1965)

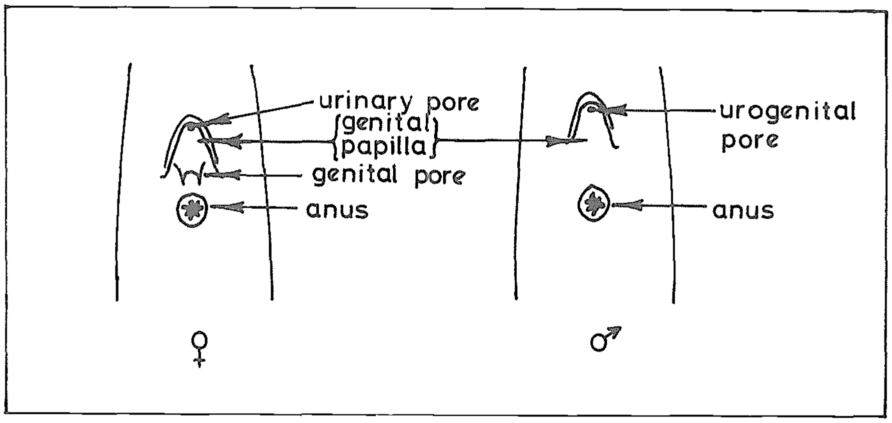

Figure 4 Differences in genital openings of S. galilaeus (from Yashouv and Hefetz, 1959)

TABLE V

Maturity stages of 46 ovaries of S. galilaeus in Volta Lake
(after Lelek and Wuddah, 1968)

Stage	Number of fish	T.L. (cm)	
		Mean	Range
Immature, not fitted to spawn	6	14.3	10.7-20.5
Immature, gradually maturing	4	19.5	18.0-20.5
Mature, first spawning takes place usually	24	20.0	16.5-25.0
Mature, in top reproductive condition	4	21.0	18.8-24.5
Mature, decreasing relative egg number	8	24.7	20.0-28.5

eventually is successful. The female then begins to make a nest, at which stage she may change partners. Finally, she settles on one male and both defend a territory from other S. galilaeus. After the eggs are deposited, fertilized and collected for oral incubation, there is no further bond between parents. Apfelbach describes S. galilaeus as a gregarious species, without fixed mating. Ben-Tuvia (1959) says that at spawning time the large schools in Lake Tiberias disperse and pairs move to the spawning areas, while Yashouv (1958) reports that in Israel ponds pair formation occurs as spawning season approaches and each couple has its own area in which a nest is prepared.

Ruwet (1968) indicates that both parents are territorial until the young are independent, while Apfelbach (1968) as reported in Fryer and Iles (1972, p. 136) reports the opposite, namely that the bond between the two parents is weak or nonexistent and brooding is independent. These conflicting reports may be the reason Burchard (1967) suggests that it is not entirely clear whether the male and female remain together as a pair after spawning.

Apfelbach (1968, as reported in Fryer and Iles, 1972, p. 136) has recorded that with S. multifasciatus a subspecies of S. galilaeus pair formation takes place a considerable time before spawning, persists through brood care, and the parents jointly defend loose shoals of young fish for several days.

3.14 Fertilization

Fertilization is external; the female lays her eggs which are immediately fertilized by the male (Ben-Tuvia, 1959). They are immediately taken up in the mouths of the parents, Apfelbach (1966) finding this to occur after each spawning act while Fishelson and Heinrich (1963) note that the eggs are left in the spawning pit until the whole process of spawning is completed.

El Saby (1951) records that the Egyptian fishermen, finding eggs in the mouth, are convinced that they are laid by a sort of vomiting process.

3.15 Gonads

Ben-Tuvia (1959) differentiated six stages of ovary development as follows:

1. The gonads form two thin, transparent strips; ovaries and testes cannot be differentiated by the naked eye. This stage is characteristic of young fish smaller than 10 cm T.L.

2. The ovaries are still thin but small eggs are already visible. This stage is peculiar to fish from 10-17 cm.

3. The ovaries are larger and contain yellow eggs of different sizes, but whose diameter does not exceed 1.8 mm.

4. (a) The ovaries are developed and full of greenish eggs whose diameters range from 1.8-2.2 mm; among them are small, white eggs 0.4-1.4 mm in diameter. This stage is characteristic of adult fish (17 cm length and over) preparing to spawn.

   (b) The ovaries are similar to those of stage 4. (a) but the appearance of larvae in the mouth of the female indicates that the fish has already spawned once and is preparing to spawn again.

5. Spawning stage; the mature eggs are large and green. They can be expelled by a slight pressure along the abdomen.

6. A short transitional stage, immediately after the spawning; the ovaries contain small white eggs and occasionally partly dissolved remnants of the large green eggs. The membrane of the ovaries is covered by prominent blood vessels.

Many authors consider that S. galilaeus spawns more than once per season. Daget (1957) states that the Tilapia (and Sarotherodon) in the central Niger River delta have several successive broods of young at intervals of a few weeks. Yashouv (1958) found that in Israel fish ponds females lay eggs in batches a few times during the year; fish in the second year of life spawn twice. Sarig (1955) quotes Reich (1954) that in shallow spawning ponds S. galilaeus spawned several times in one summer; the overall annual number of fry obtained per pair of brood stock does not exceed 2 000. Lowe (1955) writes that observations on ovaries suggests that many of the East African Tilapia and Sarotherodon (including S. galilaeus) have three, four or more batches of young in succession, but how long it may take for a particular batch to ripen is not known with any degree of accuracy. Ben-Tuvia (1959) quotes Pellegrin (1903) and Liebman (1933) that the ovaries are quickly replenished after spawning and that there is a possibility of additional spawning in the same season. He notes that measurements of eggs in ovaries at different stages of development, and during various periods of the year in Lake Tiberias, indicate that S. galilaeus lays eggs more than once in a spawning season.

The development of several batches of eggs in one spawning season has caused problems in fecundity studies. Two appraoches have been made, the determination of numbers of eggs in the ovary and counts of eggs and fry found in the mount of brooding fish.

Ben-Tuvia (1959) estimated the number of larger (stage 4) eggs in the ovaries of several fish, omitting very small eggs which probably do not leave the ovary during the process of egg laying. The results show that the number of mature eggs varies with the size of fish (see Table VI).

Fryer and Iles (1972, p. 163) state that in S. galilaeus the increase in egg number per clutch is almost directly proportional with increase in body weight, so that a female double the weight of another produces very nearly twice as many eggs. However (p. 365) available data strongly suggest that the dwarf forms produce relatively more and much smaller eggs than in the case when normal sizes are attained.

Lelek and Wuddah (1968) term S. galilaeus as a plurimodal species and designate four size groups of eggs. The smallest eggs (group 1) were not possible to count but the others, which could be counted, provide information on future spawning potential (groups 2 and 3) and eggs available for immediate spawning (group 4). Sizes of eggs in each group and average numbers for different sizes of fish are given in Table VII.

TABLE VI

Estimated number of larger (stage 4) eggs in the ovaries of S. galilaeus (after Ben-Tuvia, 1959)

Total length of fish (cm)	Number of fish	Number of mature eggs per fish	
		Average	Range
18-21	5	1 093	770-1 350
25-26	8	2 757	2 394-3 300
28-32	10	4 340	3 100-5 010

TABLE VII

Numbers of different sizes of eggs in various size groups of *S. galilaeus*

Group	Diameter of eggs (mm)	Size group of fish (cm T.L.)				
		up to 14	14.1-18.0	18.1-22.0	22.1-26.0	26.1+
1	0.02-0.22					
2	0.23-0.58	730[a/]	1 837	1 700[a/]	1 850[a/]	730
3	0.59-1.00					
4	1.01+			1 030	1 975	2 488
2+3	0.23-1.00	617	2 170[a/]	2 500[a/]	3 000[a/]	3 200[a/]
2+3+4	0.23+	617	2 177	2 790	3 673	5 755

a/ Approximation from graphs presented by Lelek and Wuddah, 1968

They found that there were large individual differences in fecundity; generally smaller individuals have in store more but less developed eggs than the larger fish. The largest fish had larger numbers of ripening eggs (group 4) but lacked oocytes (group 1). Fish of length from 18-26 cm T.L. are considered the most important for shoal production while larger fish lack potential for future production. Fish approaching maturity for the first time, but which had not spawned yet (around 20 cm T.L.), had an average number of 800-900 group 4 eggs; this probably represents the batch size for that length of fish.

Lowe (1955) records the number of ripe ova from *S. galilaeus* (originating from Lake Albert) as follows:

Length of fish (cm T.L.)	Number of ripe eggs
16	538
17	623
20	703
23	1 000
24	974
30	1 560

The number of eggs produced during each spawning may be deduced from the number of eggs or larvae in the mouth of brooding parents, although some may be lost on capture of the adult. Ben-Tuvia (1959) examined 28 such fish which carried from 150-1 086 eggs or larvae, usually 600-700. Assuming the fish spawn at least twice per season and each parent broods 600-1 000 eggs, reproductive rate for a pair will be 2 400-4 400 eggs per year. He considers it possible that the fish may spawn more than twice per season. However, the fact that only one parent picks up the eggs on some occasions might affect these estimates. Iles and Holden (1969) found that in 20 brooding fish from the Niger River system in Nigeria, the number of eggs in the mouth varied from 25, in a fish 22 cm T.L., to 958 in a fish 21 cm T.L. Assuming each parent takes half the eggs up to 2 000 may be produced in one bunch, although this does not appear likely from the number of ripe eggs found in ovaries of fish of this size by other workers.

Yashouv (1958) found that in Israel ponds the number of descendants per pair of fish (presumably in one year, although this is not stated) are as indicated in Table VIII.

She points out that this is not total production since mortality up to the time of counting is not included in the descendants; an estimated 10-15 percent of the fry are damaged during harvest. Larger fish and less crowded areas produced more offspring.

Peters (1971) found the relationship of testis weight : body weight for ripe *S. galilaeus* from Lake Tiberias to be expressed by the formula testis weight = 0.069 + (0.0015 body weight). Loss of testis weight after spawning was so small it could not be measured by the methods used. The unusually small size of the testes in *Tilapia* and *Sarotherodon* generally when compared to other fish is suggested as being correlated with the relatively smaller number of eggs to be fertilized and the efficient method of insemination by spraying sperm closely on the eggs. The testis weight of *S. galilaeus* was among the lowest of six *Tilapia* and *Sarotherodon* species reported; Trewavas, Green and Corbet (1972) quote Heinrich (1967) that this is one character distinguishing *S. galilaeus* from *S. niloticus* and *S. mossambicus*.

TABLE VIII

Number of descendants per pair of fish in Israel ponds
(after Yashouv, 1958)

Age of parents	Average weight (g) on introduction	Number of descendants per pair
1	94	326
1	120	530
1	125	950
1	94	692
1	116	1 844
4-3	700	1 447
4-3	800	1 240
4-3	800	6 909

3.16 Spawning

Information presented in Section 3.15 indicates that spawning may occur two or more times per year by each mature female. Fryer and Iles (1972, p. 346) note that in temperate zone waters S. galilaeus behaves like temperate fishes with spring spawning and gonad maturation in autumn and early spring. Even here, however, the spawning season is prolonged. Ben-Tuvia (1959) records the spawning season in Lake Tiberias (Israel) as commencing at the end of March or beginning of April and continuing until mid-August; throughout this long period fish can be found with eggs in their mouth. The most intensive spawning occurs in April, May, and the first half of June. Ben-Tuvia quotes Ricardo-Bertram (1944) that the spawning season lasts from December to May with a peak in March and April, but notes his own observations are not in accordance with these findings. In Israel ponds Chervinski (1964) states that June is included in the usual spawning period of S. galilaeus, and Yashouv (1958) gives the season of reproduction as commencing in mid-April or the beginning of May, depending on the extent to which the water has warmed; in 1957 it had already began in February when winter temperatures were higher than usual. The season is prolonged in ponds, up to mid-September.

In the Nile system in Egyptian lakes El Saby (1951) says the Tilapia and Sarotherodon species breed from April to November, but principally during the early summer. Length-frequencies of Lake Albert Tilapia and Sarotherodon suggest the breeding season is not well defined (E.A.F.R.O., 1950). Tobor (1970) examined large females from the Yobe River (Lake Chad drainage) with eggs in the mouth in February. Ita (1971) working on a small tropical pond near Ibadan, Nigeria deduced from examination of ovaries, and the presence of fry in the littoral zone, that spawning occurred throughout the year; seasonal variation in condition was lowest in June when the least food volumes were noted, suggesting spawning at this time.

In Volta Lake, Lelek and Wuddah (1968) determined the coefficient of maturity by the formula $\frac{\text{Weight of gonad (grammes)}}{\text{Weight of gutted body (grammes)}} \times 100$ and found two peaks, a higher one in July and a smaller one in March; they believe that spawning occurs all year and that the peaks represent seasonal higher breeding activity.

In the Niger River at the site of the future Kainji Lake, Banks, Holden and McConnell (1966) report the capture of two brooders with eggs in the mouth; although no date is given, the work was carried out between 6 July and 11 September. In Kainji Lake, Lelek (FAO, 1972) found no pronounced breeding season, while Ita (1972) on the basis of small fish caught (1-3 cm), concludes that breeding occurs here all year long with a peak from September to November. Johnson (1974) found small fry (up to 14 mm S.L.) in Kainji Lake each month from August to March, with a suggestion of greatest spawning activity in October, November and February, corresponding to the period of filling and full supply level of the lake.

Ben-Tuvia (1959) shows that temperatures influence the start of the spawning season in Lake Tiberias, making it later in cold winters and earlier in warm winters; spawning is accelerated during the days of the heat waves known as "Chamseens". The peak spawning period occurs simultaneously with maximum water levels in May; this provides large ponds rich in vegetation, high in temperature, and shallow for protection from predators, for the offspring. Lemasson (1959) notes that at latitudes 5°S to 12°N with temperatures of 20°C to 30°C, the species of *Tilapia* and *Sarotherodon* (including *S. galilaeus* and *S. gal. multifasciatus*), reproduce all year long. Petr (1967a) attributes a marked increase in the population of *Tilapia* and *Sarotherodon* (mainly *S. galilaeus*) in Volta Lake in 1965 at least partly to an increase in the level of the lake in the second half of 1964; this provided juvenile fish with optimal conditions for development among freshly flooded grass and bushes. Lelek (FAO, 1972) and Johnson (1974) suggest that spawning in Kainji Lake is most intense during the rise and full supply level at Kainji Lake, associated with recently-flooded vegetation.

Ben-Tuvia (1959) found spawning grounds in Lake Tiberias to be near shore in shallow water, rich in plants, with a sand and gravel bottom. The spawning patch is levelled by the parents. Fishelson and Heinrich (1963) in behaviour studies of *S. galilaeus* from Lake Tiberias, write that the eggs remain in a spawning pit until spawning is completed. Apfelbach (1966) says that ripe females build a nest and Yashouv (1958) states that a nest is prepared. El Saby (1951) says that *Tilapia* (and *Sarotherodon*) in Egyptian lakes scoop out shallow basins in the soft bottom and use them as nurseries. Fryer and Iles (1972, p. 136) quote Apfelbach (1968) that *S. gal. multifasciatus* parents jointly prepare a shallow trough on a sandy bottom, in which the eggs are laid.

3.17 Spawn

Ben-Tuvia (1959) found the size of the oval-shaped eggs from *S. galilaeus* to be as indicated in Table IX.

He describes oocytes (0.04-1.4 mm diameter) as white; more developed eggs (up to 1.8 mm) as yellow; and ripe eggs as green.

Fishelson and Heinrich (1963) describe the olive-coloured eggs of *S. galilaeus* as having adhesive fibres by which the eggs adhere to themselves and to the bottom. These are less adhesive than substrate brooder eggs and so can be picked up for oral incubation without difficulty; within the mouth cavity the connexion between the eggs is loosened, perhaps by chewing movements. Trewavas, Green and Corbet (1972) quote Kraft and Peters (1963, fig. 26e) as having illustrated eggs of *S. galilaeus* as bearing sparsely distributed bunches of filaments.

Lowe (1955) notes that ripe ova of *S. galilaeus* are olive green, and that the maximum size is 3.0 x 2.2 mm. Among 11 species of *Tilapia* and *Sarotherodon* listed, only one had smaller eggs than *S. galilaeus*.

Fryer and Iles (1972, fig. 220) quote data from Peters (1965) and Ben-Tuvia (1959) that suggest that, whereas the size of eggs remains constant regardless of the size of fish in Lake Tiberias, the size of eggs from pond fish is considerably smaller. They also (p. 107) quote Peters (1963) that the eggs of all mouthbrooding species of *Tilapia* (= *Sarotherodon*) are very yolky and have a water content of only 50-60 percent.

TABLE IX

Size of oval-shaped eggs from *S. galilaeus*
(after Ben-Tuvia, 1959)

Stage of maturity (see section 3.15)	Width of eggs (mm)		Length of eggs (mm)	
	Average	Range	Average	Range
4	1.48	1.35-1.80	1.93	1.70-2.40
4a	1.65	1.47-2.10	2.08	1.83-2.44
5	2.08	1.88-2.26	2.63	2.33-3.05

3.2 Pre-adult phase

3.21 Embryonic phase and
3.22 Larval phase

After fertilization, the eggs are taken up into the mouth of the parent fish and held there until they have hatched and the fry have lost the yolk sac. Apfelbach (1967) writes that with closed mouth and tilted body the fishes defend the mating products from other fishes. He notes that nervous parents keep the young in the mouth much longer than do aggressive parents; mostly the young are released between the fourteenth and sixteenth day after spawning and are not taken into the mouth again, although young released before the fourteenth day are taken into the mouth at night. Fishelson and Heinrich (1963) recorded 11 cases of mouthbrooding in which the eggs were kept in the mouth until the fry were completely developed, which on the average takes approximately 15 days at 25°C to 26°C. The shortest development observed took 10 days at a temperature of about 29°C.

Ben-Tuvia (1959) reports that newly-hatched larvae rest on large yolk sacs which disappear when they reach a length of 11 mm T.L. The young leave the mouth of the parent after reaching 12 mm T.L. and begin independent lives in schools.

Fishelson and Heinrich (1963) note that after the offspring are released they keep together in a school and that contact behaviour (when the young approach the mouth of the parent and try to enter at times of disturbance) is rare. The parents show some interest in a shoal, in aquaria returning to the shoal after chasing away an intruder, but the bond between parent and offspring is very weak. However, Wickler (1956) reports that the S. galilaeus observed by Fishelson and Heinrich (1963) were observed to take fry back into the mouth but not until evening. Ruwet (1968) notes that fry can learn to follow a model, but only after several hours exposure; this is in contrast to other species that show an innate disposition to form a precocious attachment to the first moving object they meet. This author states that S. galilaeus is territorial until the young are independent.

A great deal of controversy has revolved around which sex of the parents mouthbrooded the young. In Israel populations of S. galilaeus Ben-Tuvia (1959), Apfelbach (1966a) and Fishelson and Heinrich (1963) found both males and females took up and brooded eggs; these authors quote Lowe (1955) and Greenwood (1958) who in turn cites Daget (1954) that among African populations of S. galilaeus only the female mouthbroods. Iles and Holden (1969) have shown conclusively that populations in the Niger River drainage are biparental brooders and are of the opinion that both sexes share this duty throughout their range. Ben-Tuvia (1959) found that among forty-nine mouthbrooders examined, 71 percent were females and 29 percent were males; while Fishelson and Heinrich (1963) found that among 15 spawnings in three cases only the female took up eggs, in four cases only the male took up eggs, and in eight cases both sexes brooded; this is nearly a 1:1 sex ratio. Iles and Holden (1969) examined 20 mouthbrooding fish of which 13 were male and seven were female; they suggest this is not a significant difference and quote other findings to suggest that sex differences in brooding care do not exist in S. galilaeus.

Ben-Tuvia (1959) notes that eggs in the mouth are well protected and well supplied with oxygen, although the necessity of mouthbrooding to normal development is unknown; fertilized eggs taken from the mouth of brooding fish have continued to develop in a jar of lake water, and so perhaps eggs expelled when adults are captured may possibly develop in the lake. He quotes Liebman (1933) as suggesting that some of the eggs are swallowed by brooding fish, but considers that the lack of a significant difference between numbers of eggs and advanced fry in the mouth of brooders, and the loss of weight of brooding fish, indicates this is not so. El Saby (1951) notes that, while mouthbrooding is a measure of protection in nature, it has the disadvantage that a brooding fish taken by commercial fishing during the critical period brings along the whole brood which is consequently lost.

Fryer and Iles (1972, p. 154-5) figure a nonfunctional rudimentary dorsal head gland of the type found in larval S. galilaeus, quoting Fishelson (1966) and Peters (1965), and interpret this to show that mouthbrooders were derived from substratum spawners, in which the head glands are functional for attachment.

Johnson (1974) noted that the lower pharyngeal teeth of S. galilaeus have not assumed the typical adult shape until a size of about 25 mm S.L. is reached. The scales on fry form at a size of 11-12 mm T.L., at approximately the time they leave the parent's mouth (Ben-Tuvia, 1959).

3.23 Adolescent phase

Ben-Tuvia (1959) examined stomachs of five small S. galilaeus (11-21 mm long) and found copepods and cladocera most abundant, with only a small quantity of phytoplankton; the larger fish mainly fed on phytoplankton. Ita (1971) also found that fry, mostly 1-2.9 cm but some 3-6.9 cm, ate crustacea, insect larvae and algae whereas larger fish ate mainly filamentous algae and detritus.

3.3 Adult phase

3.31 Longevity

Ben-Tuvia (1959) read scales and otoliths of S. galilaeus from Lake Tiberias and found female fish 7-years old. Evans (1969) estimates that the bulk of Tilapia (= Sarotherodon) (mostly S. galilaeus) in the Volta Lake commercial catch are in their third or fourth year and that a single year-class might be expected to contribute to the fishery for at least 4 or 5 years. Jensen (1958) reported fish from the Noussa Hydrodrome near Alexandria, Egypt, to be 6 years old.

3.32 Hardiness

Fryer (1960) in discussing a number of Tilapias (including S. galilaeus) states that "the adaptability of many species of Tilapia to fish-pond conditions and the way in which introduced species often establish themselves also reveals the unspecialized nature of members of this genus".

S. galilaeus is easily kept in aquaria and small holding tanks; numerous investigators have used them in carrying out aquarium behaviour studies (Fishelson and Heinrich, 1963; Chervinski, 1961; Apfelbach, 1966; Destexhe-Gomez and Ruwet, 1967, as reported by Fryer and Iles, 1972, p. 204; Yashouv, 1960).

3.34 Predators

Identification of Tilapia and Sarotherodon species in the stomach contents of predators is difficult and little specific information is available. Burchard (1967) and Ita (1971) mention the importance of Hemichromis fasciatus as a predator on young cichlids. El Saby (1951) writes that "in nature the chief enemies of the Bolt /Tilapia/ are their own cousins, only very slightly larger than themselves and probably a month or so older. In spite of the most careful shepherding on the part of the parents, many of the young fish stray and are immediately snapped up...". Lemasson (1960) reports the addition of 10 percent Hemichromis to pond populations of Tilapia (and Sarotherodon) (including S. galilaeus) at the Kokondekro fish culture station (Ivory Coast) to prevent overcrowding and subsequent stunting.

Motwani (FAO/UN, 1970) records various fish species from the Niger River with stomach contents containing Tilapia and Sarotherodon; these include Lates niloticus, Gymnarchus niloticus, older Hydrocynus forskali, Eutropius niloticus, Bagrus docmac, and Mormyrus rume. Turner (FAO/UNDP, 1970) found four Hydrocynus that had eaten Tilapia (Sarotherodon) in Kainji Lake, Nigeria, but generally noted very little predation on these. Johnson (1974) records two S. galilaeus seen and reports of others in Kainji Lake with the caudal peduncle missing; this is attributed by the commercial fishermen to attacks by Hydrocynus brevis. Reynolds (1967) found an 8 mm S.L. Tilapia in the stomach of a Pellonula afzeliusi (a clupeid) in Volta Lake.

Tobor (1972) writes that although Tilapia (= Sarotherodon) are always abundant in the inshore waters of Lake Chad at Malamfatori, they did not appear to be relished by piscivores. Among 72 Hydrocynus forskali stomachs examined, 4 had eaten Tilapia (Sarotherodon) one Hydrocynus forskali 49.5 cm T.L. had consumed an S. galilaeus 11.2 cm T.L. (23 percent ratio of prey : predator length). In 57 Bagrus bayad stomachs 3 contained Tilapia (Sarotherodon). Among 132 Lates niloticus examined 3 had eaten S. galilaeus; the sizes of predator and prey are as below:

Lates niloticus T.L. (cm)	S. galilaeus T.L. (cm)	% prey: predator length
41.8	9.5	22.7
46.6	11.6	24.8
77.2	16.0	20.7

Of four S. galilaeus eaten by the Lates niloticus, two were ingested head first and two tail first. A freshly-ingested S. galilaeus was apparently eaten at 03.00 hours and a freshly-ingested unidentified Tilapia (or Sarotherodon) at 07.00 hours.

In the eastern archipelago of Lake Chad, Lauzanne (1972) found that Hydrocynus brevis and Lates niloticus fed on Tilapia and Sarotherodon species; the largest Lates niloticus captured (54 kg) had eaten two S. galilaeus of 425 g and 400 g.

Denyoh (1967) found that overcrowding of Sarotherodon was experimentally controlled by Lates niloticus, Hydrocynus brevis and Hydrocynus forskali.

The habitat of S. galilaeus fry in water a few inches deep near the lake edge as described by Johnson (1974) is suggested as a means of predator protection; Ben-Tuvia (1959) also indicates that the shallow-water habitat of fry protects them from pursuit by larger fish.

3.35 Parasites, diseases, injuries and abnormalities

- Parasites

Table X lists helminth parasites found on S. galilaeus, mainly based on Khalil (1971).

TABLE X

Helminth parasites reported from *S. galilaeus*
(mainly after Khalil, 1971)

	Family	Genus and species	Infection site	Area	Authority
Monogenea	Gyrodactylidae	*Gyrodactylus cichlidarum*	Skin and gills	Ghana	Paperna, 1968, 1969
	Dactylogyridae	*Cichlidogyrus bychowskii*		Ghana	Paperna, 1968
		C. dionchus		Ghana	Paperna, 1968
		C. longicornis longicornis		Ghana	Paperna, 1968
		C. tiberianus		Ghana	Paperna, 1968, 1969
		C. tilapiae	Gills	Ghana	Paperna, 1965, 1968, 1969
			Gills	Israel	Paperna, 1960
		C. tubicirrus magnus	Gills	Ghana	Paperna, 1968, 1969
Digenea	Clinostomatidae	*Clinostomum complanatum*	Muscles	Sudan	Khalil, 1969
		C. tilapiae (metacercaria)	Branchial region and eye socket	Ghana	Ukoli, 1966, 1966a
				Niger R.	Ukoli, 1969
		Euclinostomum heterostomum		Niger R.	Ukoli, 1969
Nematoda	Seuratidae	*Gendria tilapiae*		Mali	Baylis, 1930, Chabaud, 1956
	Heterocheilidae	*Amplicaecum* sp. (larva type II)	*Sinus venosus*	Sudan	Khalil, 1969
	Quadrigyridae	*Acanthogyrus tilapiae*		Tanzania	Baylis, 1948
				Congo	Golvan, 1957

Obeng (1966) presents a graph of *Clinostomum* infection of *S. galilaeus* in Volta Lake from November 1965 to February 1966, suggesting a cyclical pattern of infection periodicity. Prah (1969) lists the parasites of *S. galilaeus* in Volta Lake and several ponds in Ghana as including *Lernaea* sp., *Clinostomum* sp., *Ergasilus* sp., pentastomid larvae, and a monogenetic trematode. He indicates that *S. galilaeus* were less heavily parasitized than *T. zillii* and *S. melanotheron* in Nungua dam.

Capart (1956) reports the copepod parasite *Lamproglera monodi* on the gill filaments of *S. galilaeus* from the Niger River, and Fryer (1963) records these from Congo or Niger River specimens.

- Injuries and abnormalities

An injury noted by Johnson (1973) on Kainji Lake specimens was that the caudal peduncle was missing but healed over, attributed by the commercial fishermen and Dr. D.S. Lewis (personal communication) to attacks by *Hydrocynus brevis*; several species of fish with the caudal portion torn off possibly by this predator, have been noted in the lake.

3.4 Nutrition and growth

3.41 Feeding

Petr (1967) records that *S. galilaeus* in Volta Lake eat 96.4 percent plankton and plankton detritus, and prefer shallow bays where this type of food is abundant; occasionally a substantial part of the plankton and plankton detritus is protozoa. He notes that there is no evidence that any of the fish in the lake have been able to utilize the phytoplankton of the extensive offshore regions. Evans (1971), however, says that in Volta Lake *S. galilaeus* feeding habits indicate primary dependence on periphyton and Aufwuchs, present chiefly on the extensive surfaces of submerged trees and vegetation; he suggests that the eventual disappearance of the trees and associated food organisms may reduce the stocks of *S. galilaeus*.

Ita (1971) described the aquarium feeding of fish over 20 cm as maintaining an oblique posture while mud is scooped up with the mouth and coarser particles and sand are eliminated through the gills. Holden (1963) records the browsing on epiphytes growing on the stems of grasses and rushes by small S. galilaeus in the shallows of the River Sokoto (Nigeria) during floods. Yashouv (1958) indicates that S. galilaeus filters food floating on the water surface of aquaria more efficiently than other Tilapia (Sarotherodon), and that in Lake Tiberias they may be seen eating the substrate on stones and rocks; in fish ponds they feed on the layers of algae that develop at the bottom of the ponds.

Hickling (1962) says that Tilapia (Sarotherodon) have a special apparatus, described by Gosse (1956) as microbranchiospines, which enable them to filter out of the water plankton organisms as small as 15 µ in size; S. galilaeus is not specifically mentioned, but it also possesses these structures.

Ben-Tuvia (1959) found that feeding in Lake Tiberias was most intensive during the period from February to May when a thick layer of fat accumulates around the gut. The gut of breeding fish is usually empty and only in the posterior part of the digestive tube is it possible to trace remnants of food consumed before spawning; the fat around the gut disappears during the reproductive season. Ita (1971) recorded the lowest food volumes and calculated the lowest condition factors of S. galilaeus in a pond near Ibadan, to occur in June during the rainy season. He suggests this may coincide with the period of greatest reproductive activity. Yashouv (1960) states that S. galilaeus continues feeding at temperatures of 14°C and in Lake Tiberias stores body fat in winter at temperatures of 16°C to 18°C before spring spawning. Holden and Green (1960) indicate that Tilapia and Sarotherodon in the Sokoto River breed at the beginning of the rains so that the fry are subjected to a period when the plankton is greatly diluted and their preferred food item is at a very low concentration; the data for the whole year suggest that the river is not very productive and that for fish that are entirely plankton feeders growth will be severely limited throughout their life cycle, and this appears to be so in S. galilaeus.

3.42 Food

S. galilaeus is classed as a planktonophage (plankton feeder) by some authors (Daget, 1957, 1961; Motwani, FAO, 1970). Evans (1971) refers to them as Aufwuchs-detritus herbivores; Petr (1967a), Holden and Green (1960), and Lowe (1959) note S. galilaeus as preferring phytoplankton, and FAO (1955) lists them as vegetable feeders.

Welman (1948) examined eight S. galilaeus from the Kaduna River (Nigeria) which had eaten filamentous green algae and mud and Gauthier-Lièvre (1949) lists the algae occurring in the stomach contents of fish from the Niger River. Adiase (1969) lists 280 S. galilaeus from Volta Lake and Nungua Reservoir as having eaten diatoms, desmids, algae and detritus. Ben-Tuvia (1959) found that 21 large fish in Lake Tiberias fed principally on plankton, among which microscopic algae and especially Peridinium westi were prevalent; the alimentary tract of the fish examined contained almost all forms of the plankton characteristic of Lake Tiberias during the same season. Chervinski (1961) fed experimental S. galilaeus in concrete holding tanks on corixids, and found they grew well; plankton developed in the tanks and intestinal contents of the fish were found to contain digested diatoms (Navicula and Plaurosygma) and undigested algae such as Spirulina.

Lauzanne (1972) classes S. galilaeus from the eastern archipelago of Lake Chad as 100 percent detritivores. The detrital flakes eaten were composed of two portions: one portion was composed of fine plant debris, dead sedimented algae and crustacean plankton, faeces of different organisms present in the lake, and colloidal red clay; the other portion was living organisms including bacteria, benthic diatoms, protozoans and rotifers. The proportion of different constituents was not determined but microscopic examination seems to show a predominance of planktonic algae debris. The fish eat the top organic film and, at the same time, ingest some of the underlying sediment. Analysis of several fresh stomach contents by oxidation showed that 41 percent of the average dry weight was organic material.

Ita (1971) made a comprehensive study of the food of S. galilaeus from a tropical pond near Ibadan, in which he found the majority of the stomachs to contain only detritus of finely divided plant remains together with a residue of decayed plankton, protozoa, bacteria and other dead organic matter. Microscopic examination of bottom deposits in the stomach and rectum showed no apparent differences in their nature. Other food eaten included the filamentous algae Spyrogyra, Pithophora and Comsopogon; higher plants (Pistia and Nymphaea) were completely absent. Variation in food items taken by different length groups of fish expressed as percent frequency of occurrence is shown in Table XI.

Fish 31 cm long and larger appear to depend almost entirely on detritus; Ita classes S. galilaeus as a detritus-feeding primary consumer, rather than as a plankton feeder. However, in Lake Kotto all specimens of S. galilaeus (6) had phytoplankton as the main content. Traces of

TABLE XI

Variation in food items taken by different length groups of *S. galilaeus* in a tropical pond near Ibadan (after Ita, 1971)

	11-15.9 cm	16-20.9 cm	21-30.9 cm	31.0+ cm
Fish eggs	-	-	-	3.2
Closterium	-	-	13.3	-
Spyrogyra	68.8	60	56.7	3.2
Pithophora	62.5	30	36.7	-
Comsopogon	50.0	10	26.7	3.2
Detritus	68.8	100	83.2	100.0
Higher plant remains	18.8	30	10.0	-
Sand particles	18.8	45	40.0	51.6
Amorphous remains	31.3	20	33.3	-
Number of fish	16	20	30	30

higher plant tissue, a few rotifers and copepods were also found, but made an insignificant contribution to the diet (Corbet *et al.*, 1973)

Ita (1971) compared the percentage carbon and nitrogen content in the bottom deposits upon which the fish were feeding and that in the stomach contents; a difference of 20 percent more carbon and 2 percent more nitrogen in the stomach contents suggested a concentration of materials by a filtering mechanism while feeding. A similar comparison of stomach and rectal deposits showed a drop of over 20 percent carbon, and 11 percent nitrogenous material was extracted during the process of digestion; despite the similar appearance of stomach and rectal contents, some food value was assimilated by the fish.

For comments on food eaten by small *S. galilaeus* see section 3.23.

Copley (1952) indicates that *S. galilaeus* will take a worm or grasshopper as bait. Also, Wunder (1960) reported that it ate polychaetes in a saline Nile delta lake. Johnson (1974) observed the capture of 29 *S. galilaeus* (ranging in length from 120-200 mm S.L.) by two boys angling with small clupeids, *Sierrathrissa leonensis*. This occurred in an area noted for clupeid fishing and apparently the *S. galilaeus* were conditioned to feeding on the clupeids. This suggests that the species is an opportunistic feeder in special circumstances, and also that a sport fishery may be possible.

3.43 Growth

- Relative growth

The standard length ; total length relationship reported by three authors is as follows:

(a) Ben-Tuvia (1959) in Lake Tiberias - S.L. = 0.76 + 0.83 T.L. for 113 specimens between 105-360 mm T.L.

(b) Motwani (FAO, 1970) in the Niger River - S.L. = 0.80 T.L.; T.L. = 1.25 S.L.

(c) Johnson (1973) in Kainji Lake - S.L. = 0.78 T.L.; T.L. = 1.28 S.L.

The relationship of maximum girth ; total length is reported by El Zarka, Koura and Shaheen (1970) to be G (mm) = -28.386 + 10.048 T.L. (cm).

The relationship between scale length (r) and standard length (l) is reported as $r = 0.1686 l^{1.222}$ for immature fish. For adults the relationship is r = 0.52991 + 1.21 (Daget, 1962).

Length : weight relationship is reported by Ben-Tuvia (1959), who examined 722 specimens from Lake Tiberias and found that from 1 January to 31 May the relationship was Weight (g) = 0.02249 T.L. (cm^3) whereas during June to August Weight (g) = 0.02086 T.L. (cm^3). This indicates that the fish were in better condition during the months preceding the spawning season and at its beginning than during the latter months of spawning.

TABLE XII

Approximate weight (g) of S. galilaeus at various length intervals

Authority	Total length (mm)						
	100	150	200	250	300	350	400
Ben-Tuvia, 1959 (Lake Tiberias)		75	175	350	610	980	
El Zarka, Shaheen and El Aleem, 1970 (Lake Mariut)	17	62	155	315			
Daget, 1954 (Niger River)			181	321	595	973	
Reynolds, Adetunji and Ankrah, 1969 (Volta Lake)	17	75	160	360	575	886	1 200
Johnson (1973) (Kainji Lake)	20	70	170	335	600	960	1 370

Ben-Tuvia determined that the weight does not change exactly as the cube of the length but that the formula for all fish caught except those in June to August was Weight (g) = 0.00001687 T.L. (cm)$^{3.087}$, and that converted to logarithms the formula was log Weight (g) = $-1.7773 + 3.087$ log T.L. (cm). He remarks that the average weights of S. galilaeus in Lake Tiberias are much lower than corresponding average weights of the same species in the area of Niger (Monod, 1949).

El Zarka, Shaheen and El Aleem (1970) report the length-weight relationship of 860 fish from Lake Mariut over a two-year period to be Weight (g) = 7.153×10^{-6} T.L. (mm)$^{3.1838}$, and note that S. galilaeus increased in weight at a rate more than the cube of the length, whereas the rate of increase of S. niloticus was nearly equal to the cube of the length.

The approximate weight (g) of S. galilaeus at various total length intervals by five authors is shown in Table XII.

- Absolute growth

Several methods of determining the age of S. galilaeus have been utilized. In Africa on Niger River system Banks, Holden and McConnell (1966), Holden (1955, 1963), and Monod (1945) report that annual rings appear to be laid down on the scales but results of age determinations are not given. Ita (1971) assumed rings on the scales of fish in a pond near Ibadan represented annual marks. Fryer and Iles (1972, p. 350) quote Blache et al. (1964) as using scale rings for Lake Chad fish. Evans (1969) says that no definitive method of determining the age of Tilapia (Sarotherodon) in Volta Lake is available; he quotes Wuddah (1967) as determining probable age classes of S. galilaeus from length frequencies, and also quotes Petr (1968) as estimating growth of recognizable size groups from monthly sampling of commercial fish in the Kete Krachi area of Volta Lake. In Egypt, Jensen (1958) used scale rings to back-calculate ages of fish assuming a straight line relationship of scale: body growth.

In Asia Minor, Ben-Tuvia (1959) used scales and otoliths to age S. galilaeus from Lake Tiberias, noting that some of the flat bones (opercle, preopercle and hypural) also show annual zones. The otoliths showed translucent concentric rings and opaque rings; the former are probably formed in winter although a small number of fish collected in September to November showed an annual ring (on both otoliths and scales). The scales are cycloid with the annuli appearing on the posterior section as a series of distinct concentric grooves, more widely spaced and more deeply inscribed than neighbouring circuli. Validity of the annulus was cross-checked by comparing determinations from scales and otoliths which in almost all cases showed the same number of annuli. The length-frequency distribution of 2 296 fish is within reasonable agreement with the age determinations and fish culture experiments in ponds showed the formation of winter marks at the same time as occurred in the lake. Fryer and Iles (1972, p. 350) quote El Bolock and Koura (1961) as using scale rings to age S. galilaeus in Syria.

Growth of S. galilaeus from various areas is shown in Table XIII.

TABLE XIII

Growth of *S. galilaeus* in various localities

Locality	Method of age determination	Sex	Total length (mm) at age (years)							Authority
			1	2	3	4	5	6	7	
Lake Tiberias	Scales and otolith rings	♂ ♀	138 140	227 224	274 265	315 291	325 310	341 323	353 329	Ben-Tuvia, 1959
Syria	Scale rings	♂ + ♀	91	206	266	315	334	347		El Bolock and Koura, 1961
Lake Mariut	Scale rings	♂ + ♀	83	216	253	277	281	298		Jensen, 1958
Lake Chad	Scale rings	♂ + ♀	132	223	270	302	314			Blache *et al.*, 1964
Pond at Ibadan	Scale rings	♂ ♀	250 -275	250 -310	270 -318					Ita, 1971
Volta Lake[a]	Length-frequency	♂ + ♀	120	185	230	275				Evans, 1969 (quoting Wuddah, 1967)

[a] Approximation, not specified whether S.L. or T.L.

TABLE XIV

Condition factor for *S. galilaeus* from a pond near Ibadan
(after Ita, 1971)

	Both sexes	Males	Females	
			With eggs	Without eggs
1968 May	3.11	3.1	2.2	-
June	2.36	-	2.3	2.5
July	2.73	2.5	2.5	2.6
August	2.53	2.8	2.4	2.3
September	2.75	3.1	2.5	2.8
October	2.67	2.8	2.5	2.3
November	2.67	2.6	2.6	2.7
December	2.63	2.6	2.7	4.9
1969 January	2.47	1.9	3.6	2.4
February	2.63	4.9	3.5	2.3
March	2.46	2.1	2.6	2.2
April	2.68	2.2	2.7	2.6
May	2.61	2.2	2.9	2.4
June	2.64	2.1	2.4	3.1
Average	2.64	2.7	2.7	2.7

The superiority of male growth is notable in the data from Ben-Tuvia (1959), a phenomenon noted as common among the Tilapia and Sarotherodon by Fryer and Iles (1972, p. 373).

- Condition factors

Condition of fish in Lake Tiberias is discussed under section 3.43 (Relative growth).

Ita (1971) calculated the condition factor $= 100 \frac{W}{L^3}$ for S. galilaeus from a pond near Ibadan with the results as shown in Table XIV.

When the condition was calculated by size of fish, the peak condition was found to be in fish of the 100–150 mm length group (see Table XV).

The condition factor for S. galilaeus from Lake Mariut was calculated by El Zarka, Shaheen and El Aleem (1970) by the formula $K = \frac{W(g) \times 10^5}{T.L.(mm)^3}$. The average K was 1.84 for 634 fish (see Table XVI).

Yashouv (1960) notes that S. galilaeus continues feeding and growth at temperatures of 14°C and in Lake Tiberias stores body fat in winter at temperatures of 16°C to 18°C before the spring spawning and grows in length under these conditions. Various authors have noted stunting of S. galilaeus in ponds when overcrowded (Yashouv, 1956, 1958; Chervinski, 1961; Federal Fisheries Service, 1963; Lemasson, 1960; Fryer and Iles, 1972, p. 364 quoting Peters, 1963). Yashouv (1958) points out that sexual maturity and spawning at the onset of the second year of life in ponds retards growth; on completion of spawning rapid growth is made.

3.44 Metabolism

See section 2.38.

3.5 Behaviour

3.51 Migrations and local movements

Little specific information is available. Durand (1970, 1971) indicates some migration occurs between Lake Chad and the swamps upstream connected by the intermittent El Beid River. The habitat of S. galilaeus in swamps and floodplains of the Niger River (FAO/UN, 1970) indicates a lateral migration from the river to the swamps, and return, governed by water levels. Holden (1963) classes the Tilapia (Sarotherodon) species (including S. galilaeus) in the Sokoto River as nonmigratory. Evans (1971) suggests that the Tilapia (Sarotherodon) in Volta Lake undergo limited movements. See also section 2.31.

3.52 Schooling

See section 2.22.

3.53 Responses to stimuli

See sections 2.31 and 2.37

TABLE XV

Condition factor for S. galilaeus calculated by size of fish

Length of fish (mm)	Mean K	Number of fish
10–100	2.15	70
100–150	2.8	9
150–200	2.5	90
200–250	2.5	49
250–310	2.3	185

TABLE XVI

Condition factor for S. galilaeus from Lake Mariut
(after El Zarka, Shaheen and El Aleem)

T.L. (mm)	Number of fish	K	T.L. (mm)	Number of fish	K
78– 87	14	1.71	178–187	17	1.75
88– 97	24	1.76	188–197	9	1.67
98–107	48	2.05	198–207	9	1.74
108–117	112	1.94	208–217	6	1.78
118–127	143	1.94	218–227	5	1.68
128–137	93	1.86	228–237	2	1.87
138–147	68	1.85	238–247	1	1.95
148–157	47	1.81	248–257	2	1.96
158–167	19	1.74	258–267	2	1.96
168–177	11	1.75	268–277	2	1.97

4 POPULATION

4.1 Structure

4.11 Sex ratio

No specific information exists on sex ratios in S. galilaeus populations and there is no indication of the spatial segregation of sexes that is known to occur for other species of Sarotherodon.

4.12 Age composition

For remarks on age composition see sections 2.21, 3.12, and 3.31.

4.13 Size composition

The length at which S. galilaeus are caught varies with local conditions, size characteristics of populations and net meshes used. For example, S. galilaeus are recorded as entering the fishery at a length of 280 mm T.L. in Lake Volta by Vanderpuye (1972) although fish of smaller size (110–140 mm) were being caught in 1966 (Petr, 1968). El Zarka, Koura and Shaheen (1970) record average lengths of commercially caught fish as 110 mm T.L. in the lakes of the Nile delta.

Size at maturation is discussed in section 3.12.

The maximum size of S. galilaeus recorded is a fish of 335 mm standard length (410 mm T.L.), weighing 1 618 g from the Niger River by Daget (1954).

Length-weight relationships are described in section 3.43.

4.2 Abundance and density

4.21 Average abundance

No absolute estimate of abundance in lake or river exists but some estimates of local population densities have been made. Loiselle (1972) found that S. galilaeus comprised 0.2–40.7 percent of ichthyomass in inshore areas of Lake Volta. From this, Vanderpuye (1972) was able to calculate that the average standing crop in the 0–1.8 m depth range was 23.8 kg/ha. Estimates by Holden (1963) show standing crops of S. galilaeus to be between 17 and 928 kg/ha in dry season pools on the Sokoto River floodplain, but these are unrepresentative of the population as a whole as they are derived from a drain-in situation where fish are concentrated in such pools by decreasing water levels.

4.22 Changes in abundance

Changes in abundance within established populations have not been recorded. However, the evolution of stocks in Lake Volta as traced by Petr (1968), Denyoh (1969) and Evans (1971) indicate an increase in numbers of S. galilaeus since the filling of the lake. A similar increase has been noted from Lake Kainji (Banks, Holden and McConnell, 1965; FAO, 1972).

4.3 Natality and recruitment

4.31 Reproduction rates

See section 3.15 for fecundity data.

4.32 Factors affecting reproduction

See sections 3.12 and 3.16.

4.4 Mortality and morbidity

4.43 Factors affecting morbidity

- Parasites and diseases

See section 3.35.

- Physical factors

See section 2.31.

5 EXPLOITATION

5.1 Fishing equipment

5.11 Gears

S. galilaeus is the subject of mainly artisanal-type fisheries using a range of gear and operating from simple craft. In Lake Kinnereth (Israel) both seine nets of wing mesh 27 mm and centre mesh 20 mm, and trammel nets with wall mesh 120 mm and centre mesh 30–37 mm are used for catching this species (FAO, 1955). *S. galilaeus* are also caught in gillnets in several lakes and in Lakes Volta and Kainji their use is particularly developed enabling selective characteristics to be described (see section 5.4). In Lake Kainji nets may be set passively or actively. In the active form the water surface is beaten to drive fish into the nets (Johnson, in press). Traps are widely used for the capture of *Tilapia* and *Sarotherodon* species and are recorded for Nigeria from the Sokoto River by Holden (1961) and the Yobe River by Tobor (1970). Wire mesh traps are also used in the delta lakes of the Nile (Jensen, 1958; El Zarka, Koura and Shaheen, 1970). Other methods mentioned as being used in the capture of *S. galilaeus* are longlines (Hopson, 1967) and castnets (Johnson, 1974) and a variety of other gear including clapnets, traps and brush parks catch *Sarotherodon* species (Tobor, 1970; Stauch, 1966; FAO, 1971).

5.12 Boats

Simple artisanal craft (dugout canoes and small planked boats) are used in this fishery. Motorization with outboard motors is limited.

5.2 Fishing areas

S. galilaeus is fished throughout its range of distribution but is of particular importance in Lake Kinnereth and the Jordan River (Sarig, 1965), the delta lakes of the Nile (El Saby, 1951) and Lake Volta (Petr and Reynolds, 1969; Vanderpuye, 1972). The species is less important, but forms a significant part of the fishery in Lake Chad (Blache *et al.*, 1964; Hopson, 1967), the River Niger (FAO/UN, 1962, 1971) and Lake Kainji (FAO/UN, 1970; Ita, 1972). In the latter its importance is thought to be increasing (Johnson, 1974).

5.3 Fishing seasons

El Saby (1951) notes that for the Egyptian delta lakes "the chief time for catching these fish (*Tilapia* and *Sarotherodon* spp.) is from November to the end of February when they emerge from the marshes as the floods come down". Correlation of increased catch with high water levels is also noted for Lake Tiberias (Ben-Tuvia, 1959) and for Lake Volta (Evans, 1971); however, fisheries for *Tilapia* and *Sarotherodon* are normally pursued throughout the year in most tropical areas.

5.4 Fishing operations and results

5.42 Selectivity

Several workers (Taylor and Denyoh, 1968; Evans, 1969; Lelek and Wuddah, 1969; Denyoh, 1969) describe selectivity in Lake Volta gillnets and data given by Evans (1971) are presented in Figure 5. The following modal lengths are given by Johnson (1974) for *S. galilaeus* caught in gillnets and castnets in Lake Kainji:

Stretched mesh size (inches)	Gillnet modal midpoint S.L. (mm)	Castnet modal midpoint S.L. (mm)
1½	70	90
2	100	
2½	130	120
3	140–150	150
3½	170	
4	200, 270	
5	220, 270	240, 300
6	270	
7	310, 270	

Shaheen (1970) gives a mean length of 10.3 cm for *S. galilaeus* caught in wire traps with a mesh of 17.4 mm and a mean length of 13.3 cm for fish caught in traps with a mesh of 22.3 mm.

5.43 Catches

El Saby (1951) states that 60 percent of the catch of the Nile delta lakes consists of *Tilapia* and *Sarotherodon* species of which *S. galilaeus* is the most important. In Israel the catch of *S. galilaeus* in Lake Kinnereth was as follows (Sarig, 1966: 1963 – 154 tons; 1964 – 184 tons; 1965 – 207 tons. According to Petr and Reynolds (1969) cichlids were dominant in the catch in the southern part of Lake Volta and *S. galilaeus* contributed 40.9 percent of the fish landed at Gégé. Denyoh (1969) confirms the dominance and Evans (1971) estimates that 50 percent of the fish caught in the lake are of this species although Vanderpuye (1972) graphs figures lower than this for all *Tilapia* and *Sarotherodon* species in 1969–70.

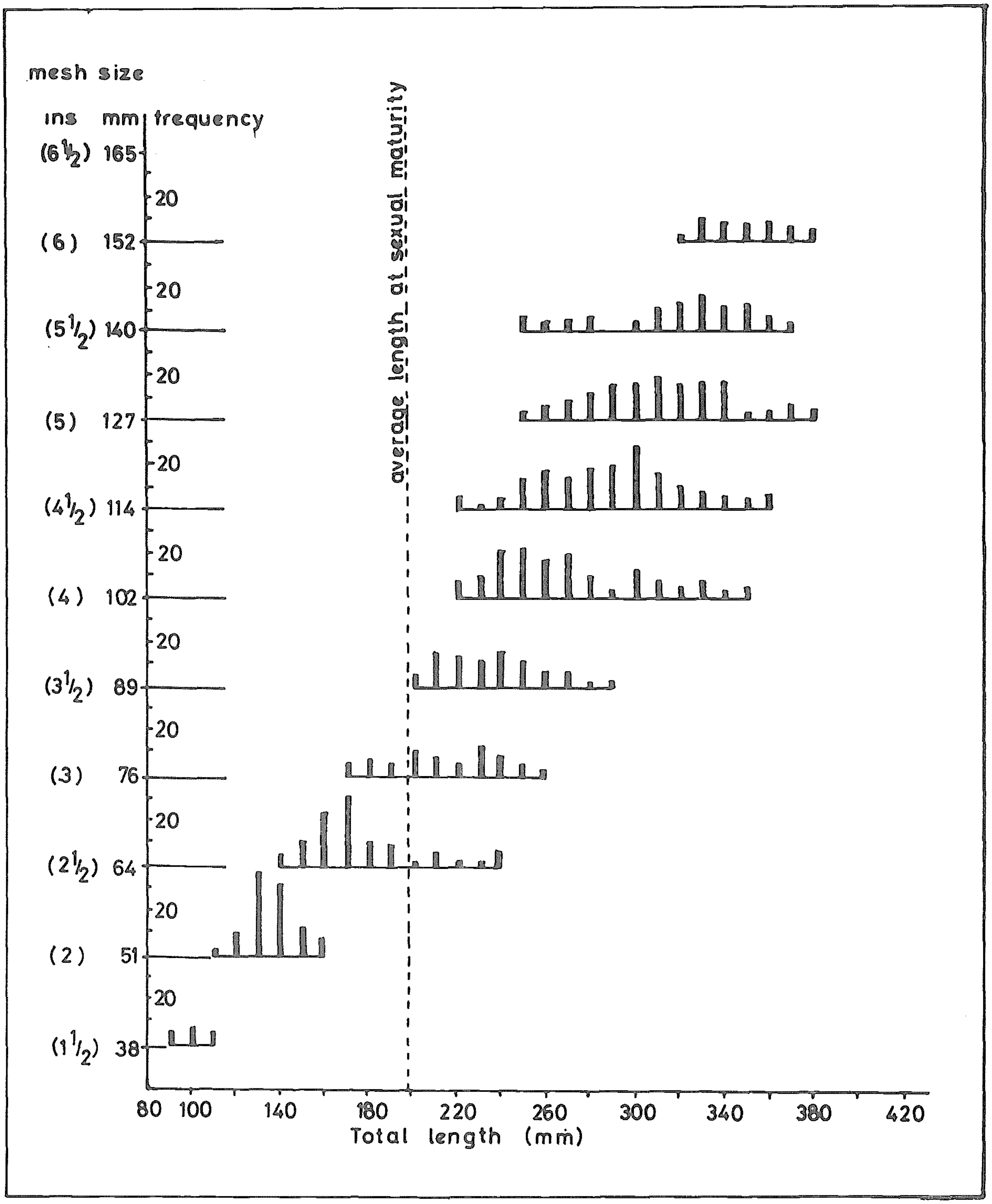

Figure 5 Length-frequency distribution of S. galilaeus in Volta Lake and selection by various mesh sizes (after Evans, 1971)

6 PROTECTION AND MANAGEMENT

6.1 Regulatory measures

The following regulations for fishing in the Egyptian delta lakes are quoted by El Saby (1951)

(i) all fishing is prohibited May-June, the active period of spawning;

(ii) fishing is prohibited in certain areas of delta lakes where non-migratory fish spawn;

(iii) mesh size limited by law to protect underdeveloped fish;

(iv) harmful fishing methods which catch undersized fish or large spawning fish are forbidden.

In Israel, a minimum mesh of 45 mm bar was introduced for trammel nets with a subsequent increase in average size of cichlids (Ben-Tuvia, 1959).

Few other regulations are actually in force, and the general ban on use of moving gear and mesh size restriction in Ghana are thought to need re-evaluation (Vanderpuye, 1972). On the basis of mesh selectivity an increase in minimum permissible size of *S. galilaeus* caught is proposed by El Zarka, Koura and Shaheen (1970). A minimum mesh size of over 3 inches stretched mesh is recommended for Lake Kainji gillnets and castnets (Johnson, 1974).

7 POND FISH CULTURE

7.1 Procurement of stocks

Stocks of *S. galilaeus* used in pond culture are presumably from wild populations; no references to genetic selection were noted. Pond culture of this species in Israel was carried on as early as 1950 (Ben-Tuvia, 1959) and experimental stocks have been kept at fishery stations at Dor and Sdeh Nahum. Yashouv (1958a) found that fish stocked at a size of 64–68 g average weight reached marketable size in one season, but that raising the fish to the desirable stocking size complicated the system of culture.

Denyoh (1967) reports that *S. galilaeus* was stocked in Ghana ponds at Turi-Kalsari near Lawra and that offspring from here were successfully stocked in reservoirs in the Wa and Bawku districts. At the Panyam Fish Farm in Nigeria, original stocks were obtained from streams of the Benue River drainage; they are now established in the streams supplying the fish ponds and cannot be eradicated (Nigeria, Federal Fisheries Service, 1963).

7.3 Spawning

Spawning appears to be natural. The fish breed at as small a size as 50–60 g (Lemasson, 1957) and during the first year (Yashouv, 1958). The problem generally is overproduction of fry.

7.4 Holding of stock

Fukusho (1968) records that stocks of *Tilapia* (and *Sarotherodon*) (including *S. galilaeus*) in Japan must be overwintered in hot springs, and Yashouv (1960) reports mortalities of pond stock in Israel at temperatures of 5°C to 8°C.

7.5 Pond management

Yashouv (1958) did not succeed in developing a dense population of plankton in ponds with large populations of *S. galilaeus* despite intensive fertilization.

Chimits (1957) quotes Reich (1954) that in Israel ponds when no artifical food is given but there is intensive fertilization, a mixed culture of carp and *S. galilaeus* gives yields 18–56 percent higher than culture with carp alone. Sarig (1955) showed that in mixed cultures of carp and *S. galilaeus* to which artificial feeding was applied in addition to fertilization, the *S. galilaeus* retarded the growth of the carp. He concludes, because of slow growth and mortality of fingerlings stocked, that *S. galilaeus* has not justified the hopes placed on it as a secondary species in carp ponds. Yashouv (1958a) recommends that when raising *S. galilaeus* as a secondary fish in carp ponds, the fry added should be not more than 5–7 g in weight and should be removed at a weight of 110–130 g to prevent spawning and overcrowding. Chervinski (1961) suggests that a mixture of *S. galilaeus* and *S. aureus* might be cultured in brackish water where carp cannot thrive.

Shaheen, Imam and Hashem (1960) stocked *S. galilaeus* in Egyptian rice fields but found that such culture was not profitable as growth was too slow for the short season available.

Lemasson (1960) and Denyoh (1967) used piscivores in pond cultures of *S. galilaeus* to control overcrowding and stunting.

7.6 Foods and feeding

Chervinski (1961) fed experimental fish in cement holding tanks on corixids. Yashouv (1958) notes that *S. galilaeus* feeds on the layers of algae that develop at the bottom of the pond and this enables the fish to benefit from supplementary food (oil cakes, grains, etc.) that sink to the bottom; she also indicates that *S. galilaeus* filters floating plankton.

7.8 Harvest

Generally, results of raising *S. galilaeus* in small water bodies have been discouraging Denyoh (1967) found of fry distributed in Ghana that "production figures obtained for these reservoirs........have not been very encouraging". Poor results with *S. galilaeus* culture were obtained at the Panyam Fish Farm in Nigeria, as the problem of uncontrolled breeding was never solved; the population established in nearby streams could not be eradicated and proved harmful to carp eggs and larvae (Nigeria, Federal Fisheries Service, 1963). Lemasson (1959) notes that in Africa *S. galilaeus* and *S. gal. multifasciatus* cultured in similar situations as *S. niloticus* and *S. machrochir* have a slower growth rate. Shaheen, Imam and Hashem (1960) found that losses of stocked fish and slow growth resulted in a total yield close to the weight of fish stocked in Egypt.

Sarig (1955) and Lemasson (1957) indicate that *S. galilaeus* culture in Israel is not successful; Yashouv (1958) points out that capture of fry resulted in 10–15 percent damaged by the nets, and that there are problems of overwintering the fish during exceptionally cold winters.

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SYNOPSIS OF FISHERIES BIOLOGICAL DATA

This is one of a series of documents issued by FAO, CSIRO and USFWS concerning species and stocks of acquatic organisms of present or potential economic interest. The primary purpose of this series is to make existing information readily available to fishery scientists according to a standard pattern, and by so doing also to draw attention to gaps in knowledge. It is hoped that synopses in this series will be useful to other scientists initiating investigations of the species concerned or of related ones, as a means of exchange of knowledge among those already working on the species, and as the basis for comparative study of fisheries resources. They will be brought up to date from time to time as further information becomes available either as revisions of the entire document or their specific chapters.

The relevant series of documents are:

FAO	**Fisheries Synopsis No.**	FR/S
	replacing, as from 1.1.63, FAO Fisheries Biology Synopsis No.	FB/S
CSIRO	**Fisheries Synopsis No.**	DFO/S
	and	
USFWS/FAO	**Fisheries Synopsis No.**	NMFS/S

Synopses in these series are compiled according to a standard outline described in Flb/S1 Rev. 1 (1965).

FAO, CSIRO and USFWS are working to secure the cooperation of other organizations and of individual scientists in drafting synopses on species about which they have knowledge, and welcome offers of help in this task. Additions and corrections to synopses already issued will also be most welcome. Comments including suggestions for the expansion of the outline and requests for information should be addressed to the coordinators and editors of the issuing organizations.

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Consolidated lists of species or groups covered by synopses issued to date or in preparation will be issued from time to time. Requests for copies of synopses should be addressed to the issuing organization.

The following synopses in this series have been issued since January 1971:

FIRM/S84	Synopsis of biological data on haddock *Melanogrammus aeglefinus* (Linnaeus, 1758)	December 1971
FIRM/S85	Synopsis of biological data on the green turtle *Chelonia mydas* (Linnaeus, 1758)	December 1971
FRm/S87	Synopsis of biological data on *Laminaria hyperborea*	December 1971
FIRM/S88	Exposé synoptique des données biologiques sur la moule *Mytilus galloprovincialis* (Lamarck, 1819)	December 1972
FIRM/S89	Exposé synoptique des données biologiques sur la laminaire digitée *Laminaria digitaria*	May 1973
FIRS/S90	Synopsis of biological data on *Sarotherodon galilaeus*	July 1974

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