LAKE TURKANA

A REPORT ON THE FINDINGS
OF THE LAKE TURKANA PROJECT
1972 – 1975

VOLUME 4

EDITED BY A J HOPSON

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1972-1975

GOVERNMENT OF KENYA AND
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EDITED BY A.J. HOPSON

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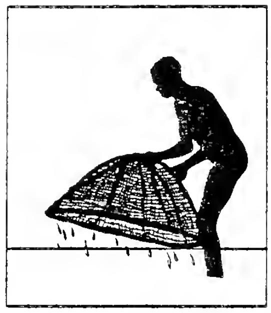

CHAPTER 10

THE BIOLOGY OF SILURIFORM FISHES

by
J.M.Lock

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10. THE BIOLOGY OF SILURIFORM FISHES IN LAKE TURKANA

J M Lock

INTRODUCTION

Catfish belonging to the suborder Siluroidea are widely distributed in Africa and are of importance in commercial and subsistence fisheries. Siluriform fish are readily distinguishable by a complete lack of true scales. They may also have complicated anterior spines on the dorsal and pectoral fins which are lockable into position and which frequently bear serrations or barbs. Representatives of this group are extremely common in Lake Turkana and form an important part of the ichthyofauna. A total of ten species were identified from the region of the lake during the present survey (Table 10.1). Three of these, Auchenoglanis occidentalis, Synodontis frontosus and Mochocus niloticus were confined to the northern fringes of the area in the delta of the River Omo, while the remaining seven species occurred within the actual lake.

Two further fishes Heterobranchus longifilis (C and V) and Andersonia leptura Boul. are known to occur in the region of the Omo delta. The former, which was collected by Zaphiro and Macmillan from the middle Omo, (BOULENGER, 1911) was almost certainly the fish known as Labe to Turkana fishermen and marketed in small quantities at the Todenyang Co-operative. Unfortunately no recognisable specimen was ever available for critical examination during the present study. Andersonia leptura, a small and easily overlooked species, was recorded from the Omo delta by PELLEGRIN (1935).

Despite the widespread distribution of silurids in Africa relatively little is known about their biology. Of these species inhabiting Lake Turkana only Synodontis schall and Bagrus docmac have been studied elsewhere. BISHAI and GIDEIRI (1965 a and b, 1968) provided details of the growth, feeding and reproduction of Synodontis schall in the River Nile at Khartoum and WILLOUGHBY (1974) has examined the population inhabiting Lake Kainji, Nigeria. Bagrus docmac in Lake Victoria has been studied by a number of workers who give valuable information on its feeding and breeding (CORBET, 1955, 1958, 1960, 1961; CHILVERS, 1968; CHILVERS and GEE; ELDER, 1960, 1962, 1974). Little published work is available on the remaining species, although a few fish from the same genera have been studied in other parts of Africa. TWEDDLE (1975) aged Bagrus meridionalis Gunther from Lake Malawi. VAN DER WAAL (1974) has examined the breeding habits of Clarias gariepinus (Burchell) in South Africa and VAN DER WAAL and SCHOONBEE (1975) its age and growth. MUNRO (1967) gives details of the diet. FRANK (1974) has aged Synodontis nebulosus Peters, and Schilbe mystus (Linn) from Lake Kariba, and WHITEHEAD (1959) has studied the migratory behaviour of the latter fish in Lake Victoria. Previous studies of the Lake Turkana fish populations were carried out by WORTHINGTON and RICARDO (1936) and by MANN (1964). Their observations include information on the biology and distribution of several of the catfish species.

The aims of the present study were as follows:

1. To complete an inventory of siluriform fish occurring in Lake Turkana.

2. To investigate the biology of species likely to be of importance in a commercial fishery.

3. To determine the most appropriate means of catching such species commercially.

This study is based on field work carried out between May 1972 and July 1974. Of the six siluriform species occurring regularly in the actual lake, Bagrus bayad and Synodontis schall are the most common. Details of their biology, including growth, breeding and diet were collected during the course of the field work and these results, together with information relevant to their commercial exploitation, are discussed at length in the following account. Information on the less important but widespread species, Schilbe uranoscopus and Chrysichthys auratus is also given. Clarias lazera and Bagrus docmac were less commonly caught and all available information is presented. It has proved impossible to obtain biological data on the remaining four species which were encountered only rarely during the course of the field work. Distributional records and other data concerning these species are included in the study where available.

A detailed account of the physical and chemical environment is provided in Chapter 1. Rainfall is considered to be particularly important in the breeding biology of the siluriform species under review. Additional data on monthly precipitation patterns at Kalokol, which is of special relevance to the present account, are presented in Table 10.2.

MATERIAL AND METHODS

A high proportion of the material on which the present study is based was caught by bottom trawling. Data from all areas of the lake have been incorporated but the most detailed information is derived from regular monthly samples made between May 1972 and July 1974 in the Longech area at depths ranging from 10 to 80 m. In the case of Siluriform fishes bottom trawl catch per effort has been expressed in terms of the catching power of the "Victoria" trawl and not the 3-bridled trawl as has been the practice elsewhere in the report. A factor of 1.43 may be employed to convert values in the present chapter to the 3-bridled trawl standard (see Chapter 8, page 587 , Fig. 8.1).

Details of the vertical zonation and diel migrations of siluriform fishes were investigated with various types of pelagic gear including metre townets, midwater trawls and particularly frame trawls (see Chapter 8). Bottom, midwater and surface-set gillnets also yielded valuable data (see Chapter 8, page 620 , Tables 8.23-8.25). Longlining, which was undertaken in the deeper waters of the lake, provided supplementary information on Bagrus bayad. Relatively large hooks (No 6) were used with the snoods attached to the line at intervals of 11 m.

Details of length, weight and gonad condition were recorded wherever possible on freshly caught fish. Fork lengths have been used throughout this study except for two species with rounded caudal fins, Clarias lazera and Malapterurus electricus. All stomachs, except those from larger Bagrus bayad were preserved in 5% formalin for subsequent examination in the laboratory. Juveniles were similarly treated.

SAMPLING SECTORS

To simplify the analysis of data collected in the field, Lake Turkana was divided into three sectors (Fig. 10.1) covering the following approximate areas (km^2):

North	3548
Central	1497
South	2515

The Central sector covered the smallest area but it was the most thoroughly investigated due to its close proximity to the research centre. Regular monthly bottom trawl samples were made in the Central sector enabling changes in gonad condition, fish numbers and diet to be monitored. The Northern sector included the Omo delta area where depths did not exceed 40 m and Allia Bay with extensive stretches of shallow water. The Southern sector comprised the Southern basin and the Kerio-Turkwell area. Much of the former consisted of water considerably deeper than 40 m, whilst the latter was generally shallower and lay within the influence of the Kerio and Turkwell rivers.

BAGRIDAE

BAGRUS BAYAD

Bagrus bayad is widely distributed across the soudanian region of Africa, occurring in the Niger, Senegal, Volta and Cha basins. It also extends through much of the Nile system from the delta to Lake Mobutu Sese Seico (formerly Lake Albert) (GREENWOOD, 1966). Observations on the biology of this fish prior to the present study were limited to notes on the Lake Turkana population made by WORTHINGTON and RICARDO (1936) and MANN (1964). Since B. bayad is primarily a deep-water fish in this particular lake, numbers examined by previous workers were small and few details could be given. The recent introduction of long-lines in Lake Turkana has brought about a sharp rise in the catch of B. bayad and an account of its biology is clearly needed to assist in fisheries management.

DISTRIBUTION

Bagrus bayad which grows to a maximum fork length of 105 cm is essentially a demersal fish. Bottom trawl catches prove that it is widely, though unevenly, distributed throughout Lake Turkana. Catches in mid-water were uniformly low, although results suggest that B. bayad moves off the bottom to feed at night.

Details of the distribution of B. bayad are based mainly on data obtained during the trawl survey of Lake Turkana. Catch per effort, expressed as kilograms per hour is considered to be an index of relative abundance. The pattern of distribution has been investigated in relation to both lake depth and season. Changes in habitat correlated with increasing size have also been studied. Gill net and frame trawl data have provided additional data.

Depth distribution

The most important factor governing B. bayad distribution is depth. Table 10.3 gives mean bottom trawl catch per effort in nine depth zones for the Northern, Central and Southern sectors of the lake (see also Fig. 10.2). Catches increased steadily from 7 kg/hr in water of less than 10 m depth to 102 kg/hr in the deepest areas of the lake. Data analysed separately for the various areas, however, show some divergence from this general pattern.

In the Northern sector low densities of B. bayad were recorded in the Allia Bay area with less than 5 kg/hr in over 50% of the hauls. Elsewhere in the Northern sector catches were similar to the lakewide means, although between North Island and the Omo delta exceptionally high catches were sometimes recorded.

The Central sector, for which most data is available, can be examined in greater detail. The mean catch rate (Table 10.3) shows the lakewide trend of increasing catches with depth. However, wide seasonal fluctuations in inshore areas were apparent and will be considered below.

In the Southern sector catches were generally lower than elsewhere. Above average catches were however recorded in the vicinity of the Kerio and Turkwell rivers. Also exceptional were the deeper waters of the Southern basin where catches below the 70 m contour were consistently high.

To examine depth distribution in fish of different sizes, catch rates (numbers per hour) were analysed for eight length groups (Table 10.4 and Fig. 10.3). With the exception of the smallest fish, catch increased with depth indicating that higher population densities occur in deeper water. The 0-9 cm length group does not follow the general pattern and peak numbers of these small fish occurred in water of between 30 and 40 m. Breeding in B. bayad is thought to occur in shallow water and the results in Figure 10.3 indicate that juvenile B. bayad tend to remain near the spawning sites. It was observed that juvenile B. bayad below 3 cm FL feed largely on copepods which are more common in shallow water.

Seasonal fluctuations in trawl catches

Seasonal fluctuations of catch in the Ferguson's Gulf area within the 40 m contour have been analysed in Figure 10.4. Above average catches were recorded between August and November, followed by a decline to a minimum in April. Peak catches coincide with the seasonal influx of turbid Omo flood water into the Central sector of the lake and the movement of B. bayad into shallower water is perhaps associated with this change in the water climate. One possible reason for the inshore migration is examined in detail in the section on feeding. Briefly the presence of turbid water may result in increased numbers of prawns inshore, either a result of their migration from deeper water or increased abundance in response to greater primary productivity. Since prawns form an important part of the diet of B. bayad the movement of this fish into shallower water is perhaps a feeding migration. An analysis of the stomach contents of B. bayad caught in shallower water has shown that from September to November the proportion of prawns in the diet is greater than at any other time of the year.

There is also the possibility that the minimum depth at which *B. bayad* occurs during daylight hours is determined by light intensity. Increased turbidity during the flood period would result in a decrease in light penetration and the point at which *B. bayad* tends to avoid critically high light intensities would shift nearer the surface and closer inshore. The result would be a movement of *B. bayad* into shallower water such as was observed.

Fluctuations in bottom trawl catches have also been noted in the Southern sector in the vicinity of the Kerio and Turkwell rivers, and in the Northern sector between the Omo river and North Island. Unfortunately regular sampling in these two areas was not possible but the higher catches appear also to be associated with the presence of turbid water. In the Kerio-Turkwell area catches equivalent to twice the annual mean were recorded in October 1973 in water of between 20 and 30 m when the two rivers were flowing and turbid water was present. Similarly in the north catches during the peak flood period were three times the annual mean in water between 10 and 20 m. There is no evidence that the concentration of *B. bayad* in the vicinity of flooding major rivers is associated with large scale breeding migrations.

Diurnal changes in distribution are considered below (page 1038) in the section on feeding.

Conclusions

Bagrus bayad is a demersal fish. Bottom trawl catches show that densities increase progressively from inshore areas to deep water. The densities of *B. bayad* in shallow water however appear to depend largely on water turbidity. High turbidity often results in increased catch rates. In areas such as Allia Bay, which has relatively long periods each year free from turbid water, low catches of *B. bayad* are recorded. The inshore movement of *B. bayad* during the flood season is probably a response to reduced light penetration, and to seasonally high densities of prawns in shallow water.

AGE AND GROWTH

In the tropics the ageing of fish poses many problems. Scales and skeletal structures may show rings similar to those laid down by temperate fish but they cannot be assumed to be annual until the seasonal timing of their formation has been demonstrated. Growth checks may be formed for a number of reasons. External factors include adverse conditions in the dry season (DAGET, 1952; JOHNELS, 1952; LOWE, 1964), fluctuations in food supply (BISHAL and GIDIERI, 1965a) and temperature change (HOPSON, 1965). Checks may also be associated with internal factors such as spawning (TWEDDLE, 1975) or loss in condition (HOLDEN, 1955; GARROD, 1959). In some species checks may be laid down twice a year as a result of both external and internal factors (HOPSON, J, 1972).

In many tropical species however no regular pattern or sequence of check formation occurs. Lake Turkana has a remarkably stable temperature regime with an annual variation of less than 2 C in deeper water, and temperature changes are unlikely to result in growth checks. Heavy flooding resulting in widespread hydrological changes is a regular seasonal event in Lake Turkana but there is no evidence to show that it results in an interruption of the growth pattern of *B. bayad*.

A second method of ageing fish which can sometimes be applied in the tropics is the interpretation of length frequency distributions (TESCH, 1968). Its application is limited to fish with breeding restricted to a short period of time each year. Such species are not uncommon in the tropics, especially in arid regions where spawning is frequently associated with seasonal rainfall. Because of the rapid growth of tropical fish, there is often little overlap in the size of individuals in adjacent year classes and this method of ageing may be particularly useful.

Vertebrae have been successfully used by other workers in ageing various African silurids. BISHAI and GIDEIRI (1965a) and WILLOUGHBY (1974) aged several species of Synodontis using this method and TWEDDLE (1975) was similarly successful with Bagrus meridionalis. In B. bayad however no correlations between check formation and fish age could be established. Fortunately breeding was found to be confined to approximately 4 months each year and an inspection of length frequency data revealed that Petersen's method for age and growth determination could be used.

Methods

Large samples of fish caught at regular intervals of time are essential for satisfactory estimates of growth to be made from length frequency data. All the B. bayad used in the present age analyses were caught by bottom trawling during the regular monthly programme. Data for length frequency analysis is ideally obtained by non-selective gear which samples the entire length range of the fish. Most fishing gear, however, is selective. The bottom trawl fitted with the standard cod end of 38 mm mesh did not catch fish less than approximately 10 cm. Smaller fish were obtained periodically by means of a bag of 19 mm mesh laced onto the cod end of the main net. Although fish of up to 85 cm were caught by the bottom trwl, the proportion of fish over 45 cm was low. It was not possible to determine whether this dearth of larger fish in the samples was the result of escapement.

Altogether more than 16,000 B. bayad were measured between May 1972 and July 1974 of which 11,000 were caught in the Central sector of the lake. Wherever possible fish were sexed so that variations in growth rate between males and females could be analysed.

Results

Length frequencies of all B. bayad caught in the Longech area during January, February and March 1973 are presented in Figure 10.5. In each month two peaks are prominent and the progression of the two modes from January to March gives a rough estimate of the monthly growth rates.

For a more accurate growth estimate it was necessary to examine all the length-frequency data collected between May 1972 and July 1974 and also to establish whether there was a significant difference in length distribution between the sexes. Figure 10.6 compares the length frequencies of males and females caught in March and July 1973 in the Ferguson's Gulf area. The histograms have been smoothed (moving average a = 3), using the method of TAYLOR (1965), and no great difference between the sexes is apparent. Means and variances were estimated for each of the size groups and females were compared with males using Student's t-test (see Table 10.5). There was no significant difference (P = < 0.05) between the sexes in either size groups and further analysis of other trawl samples showed that this was typical for the population. Data for the two sexes was therefore combined for growth analysis.

Percentage length-frequency histograms of all B. bayad caught at the monthly bottom trawl stations in the Longech area, between September 1972 and May 1974, are presented in Figure 10.7. The 1972 and 1973 year class peaks have been shaded and their progression can be traced from month to month. The 1972 year clss first appeared in the trawl catches in September 1972, and could be followed through subsequent months until the completion of sampling. Fish from the 1973 year class were first caught by the trawl in August 1973 and August to September is evidently the annual period when 0-group fish are recruited into the trawlable stock.

The 1971 year class was prominent in trawl catches until November 1973 when a mean length of approximately 39 cm was attained. At lengths above 40 cm the division of the population into definite length groups was no longer clear and age determination of fish exceeding 3 years old was not possible.

The extent of each year class on the monthly length frequency histograms (Fig. 10) was determined by careful comparison with results from adjacent months. Mean monthly fork lengths of each year class were then calculated (Table 10.6). They show a steady increment with time, and observed lengths in any month generally compare well with the corresponding lengths in other years. Before plotting the growth curve it was necessary to establish a 'birthdate' for B. bayad. The histograms in Figure 10.7 show that the length distributions of each year class were centred round a prominent mode, indicating that a spawning peak was reached each breeding season. The analysis of seasonal changes in gonad condition (page 1031) show that the main breeding period was between April and July and that peak spawning occurred in May. Mid-May therefore has been taken as the 'birthdate' for the Longech population of B. bayad.

Mean lengths of the four year classes in Table 10.6 have been plotted separately against age in Figure 10.8 and the combined data from Table 10.7 have been plotted in Figure 10.9 to demonstrate the observed pattern of growth over the first two and a half years of life. In both the 1972 and 1973 year classes growth appears to be almost linear over the first year and fish attain a length of approximately 17 cm at the end of the first year. Growth over the second year is apparently erratic with a sudden acceleration in October-November. However, this anomaly is probably a result of sampling error, since at this time medium sized B. bayad moved into shallower water where they were caught in large numbers. By the end of the second year the 1970 year class had an observed length of 31 cm and the 1971 and 1972 year classes had attained a length of 34 cm. Since few fish larger than 40 cm were caught, direct observtions of growth have been restricted to the first 30 months of life. Fish from the 1971 year class had an observed length of 39 cm at an age of two and a half years.

Mathematical expression of growth

Table 10.7 provides sufficient data to enable a von Bertalanffy growth model to be fitted to the observed values, using the equation

$$l_t = L_\infty \left(1 - e^{-K(t-t_0)}\right)$$

where L_∞ is the asymptotic length, K is the rate at which L_∞ is approached, l_t is the length at any age t and t_0 is a constant.

Growth parameters were estimated using the graphical method described by BEVERTON and HOLT (1957) and RICKER (1958). The Walford plot showing the relationship between l_t and l_{t+3} months is presented in Figure 10.10. The following values were obtained for the growth parameters of B. bayad.

$$L_\infty = 84 \text{ cm}$$

$$K = 0.2592$$

$$t_0 = 0.0672 \text{ years}$$

The estimate of L_∞ agrees well with field observations. Only 0.3% of B. bayad in the trawl catches exceeded 80 cm FL and the largest caught by trawling was a female of 85 cm FL. A value of $t_0 = 0.0672$ years indicates a birthdate in early June, a little later than would be suggested by the breeding data.

There is close agreement between the lengths estimated from the von Bertalanffy growth equation and observed lengths over the first two and a half years of life as shown in Table 10.8. By extrapolation it is possible to estimate theoretical lengths of older fish, assuming that the growth pattern of B. bayad does not change. Growth in fish does not always follow the von Bertalanffy model. VAN DER WAAL (1975) found that in Clarias gariepinus growth followed an arithmetic pattern for the first ten years. HOPSON, A J (1972) observed that in Lates niloticus (L) the growth pattern changed after the first five years from an exponential to an arithmetic form. Studies of Bagrus docmac (CHILVERS, 1968) and Bagrus meridionalis (TWEDDLE, 1975) indicate however that growth in Bagridae follows the same exponential pattern over the entire length range. It is reasonable therefore to estimate the lengths of older B. bayad by extrapolation.

Estimates of length at age have been plotted in Figure 10.11 together with the observed lengths from Table 10.8 (see also Table 10.11).

Length-weight relationship

Observations on the length-weight relationship are based on data obtained from B. bayad caught during the monthly trawl stations made in the Longech area. During the two years of sampling a total of 980 fish were weighed. Fish larger than 20 cm included 504 females and 374 males. The remaining fish were immature of between 10 and 20 cm FL.

The length-weight relationship of fish can usually be expressed by the equation

$$w = al^b$$

or logarithmically

$$\log_{10} w = \log_{10} a + b\,(\log_{10} l)$$

where a is the intercept of the regression line with the y axis and b is the regression coefficient. LE CREN (1951) showed that the length-weight relationship may vary with size, sex or maturity stage. To establish whether this occurred in B. bayd the length-weight relationships were calculated separately for a number of size groups of each sex (Table 10.9). The slopes were subsequently compared by applying d-tests. Results, given in Table 10.10, show that there was no significant difference (P = 0.05) between any of the regression coefficients. The length-weight data for all B. bayad can be combined therefore, giving the following regression equation

$$\log_{10} w = 3.032 (\log_{10} l) - 2.088$$

or

$$w = 0.00817\ l^{3.032}$$

where w = weight in g and l = length in cm.

A logarithmic plot of all fish caught in 1973 and 1974 during April and May is given in Figure 10.12 together with fitted regression line. Mean weights at one to ten years are presented in Table 10.11.

Discussion

Previous work on the ageing of catfish has been based mainly on the analysis of growth rings. In the present study however, although rings were found on the vertebrae of B. bayad no correlation between their formation and fish age could be established. Growth and age estimates up to two and a half years were possible however using length frequency data from trawl samples and growth was found to fit the von Bertalanffy growth method.

It is of interest to compare the growth rate of B. bayad with two other African Bagrids, B. docmac (CHILVERS, 1968) from Lake Victoria and B. meridionalis (TWEDDLE, 1975) from Lake Malawi. In Table 10.12 growth for the three species is given for the first five years.

Results show that the growth rate is higher in B. bayad than in the other species. More recent evidence, however, indicates that these species probably have a more rapid rate of growth than was first estimated. RINNE (pers. comm.) has reported that in Lake Victoria a single tagged B. docmac grew from 26 to 40 cm in a year, a growth rate equivalent to that of B. bayad. TWEDDLE (1975) assumed that two year classes of B. meridionalis were absent from the trawl catches. However observations (TWEDDLE, pers. comm.) of juveniles with fork lengths of 7 to 9 cm in nests with an attendant female early in the breeding season indicates that growth in the first year is perhaps much more rapid than was first estimated and only one year class was absent from the trawl catches. This would bring the growth rate more in line with that of B. bayad.

BREEDING

In the course of two years' fieldwork, 7,800 B. bayad were sexed in the Longech area. A further 600 were examined in the Northern sector and 1,100 in the Southern. A study of the changes in gonad condition has shown that in the Longech area an annual cycle of maturation occurred and a well defined breeding season, extending from April to July was apparent.

Maturity stages

The maturity stages of _B. bayad_ detailed below were assessed according to the classification by NIKOLSKY (1963). Sexing was possible at a fork length as small as 6 cm when the testes were already slightly villose in appearance.

Females

Stage 2 — Resting or recovering: found in all sizes of fish. Ovaries sac-shaped, translucent in maturing fish but pink in post-breeding fish due to greater vascularisation.

Stage 3 — Mature: ovary larger and well vascularised. Developing eggs whitish or yellow and less than 0.6 mm in diameter.

Stage 4 — Ripe: ovary greatly increased in size and weight. Ovary wall transparent, opaque eggs clearly visible varying in diameter from 1.0 to 1.4 mm. Eggs not free flowing when ovary wall cut.

Stage 5 — Ripe-running: ovary very turgid in appearance. Eggs translucent, varying in diameter from 1.3 to 1.6 mm. Slight pressure on belly causes extrusion of eggs.

Stage 6 — Spent: ovaries flabby in appearance and red in colour with residual eggs few in number.

Males

Stage 2 — Resting or recovering: testes a pair of thin transparent strands. In virgin males a very slight scalloped edge to testes visible. In recovering males larger flattened villiform protrusions on edge of testes.

Stage 3 — Maturing: villiform protrusions prominent, greyish white in colour.

Stage 4 — Ripe: testis white in colour, particularly the anterior villiform protrusions. Sperm released when cut and squeezed

Stage 5 — Ripe-running: testis white and villi turgid in appearance. Copious white milt extruded when cut.

Size and age at maturity

Changes in the proportion of _B. bayad_ at each maturity stage with increasing size are shown in Table 10.13 combining data collected during the breeding season April to July. The results show that males and females matured at approximately the same size. Fifty percent maturity in males was reached at a length of between 31 and 32 cm FL and in females at a length of between 33 and 34 cm FL. From the growth estimates presented above it would thus appear that B. bayad matures towards the end of the second year of life.

Seasonal changes in maturity

The regular appearance of O-group fish in trawl samples as demonstrated in length frequency histograms (Fig. 10.9) strongly suggests that B. bayad has a well defined breeding season. This was confirmed by the analysis of monthly changes in gonad condition, for although some ripe fish were present in most months, peak gonad activity was confined to approximately four months each year. Monthly changes in the gonad condition of fish in the 35 to 39 cm length group from the Longech area are presented in Tables 10.14 and 10.15 for the period July 1972 to June 1974. In Tables 10.16 and 10.17 (see also Figs. 10.13 and 10.14) data for the two years have been combined for three length groups. Most ripe males and females in the Longech area were caught between April and July, with peak numbers occurring in May and June. In the 35 to 39 cm length group, only 3% of all male fish examined in May had quiet gonads, while 56% were ripe. In females of the same size group 47% were ripe in May. After the breeding season the proportion of ripe fish declined considerably, with a minimum being recorded between September and January.

Fewer samples are available from the Northern and Southern sectors of the lake and the breeding pattern of fish from these two sectors is not so well known. The seasonal changes in gonad condition of fish caught outside the Central lake sector are given in Tables 10.18 and 10.19. In the Southern sector of the lake fish appear to follow a similar pattern of gonadial development to that found in the Ferguson's Gulf area, with most ripe fish occurring in the June sample and fewest in October and December.

The breeding season appears to be less well defined in the Northern sector of the lake (Table 10.19). All samples from the north included a greater percentage of ripe females than was recorded in the corresponding monthly samples from the Longech area. During November 1972 over 40% of the females larger than 35 cm were ripe (stage 4). In the Longech area November is a post-spawning time and over 70% of females larger than 35 cm were resting (stage 2). Regular monthly sampling in the Northern sector would be needed to confirm that the breeding pattern differs from more southerly sectors.

Sex ratio

The proportion of males to females was not constant, but change progressively with size. Table 10.20 presents the sex ratio of five length groups of fish examined in the Ferguson's Gulf area. In fish smaller than 40 cm the ratio of males to females was roughly 1:1 while in larger fish the proportion of males declined with increasing size.

Seasonal variations in sex ratio were observed in fish larger than 30 cm. The proportion of male fish increased during the breeding period reaching a peak in May and subsequently declined in the post-spawning months. This is shown graphically in Figure 10.15 where monthly sex ratios for three length groups have been plotted for a full year. From October onwards relative numbers of males increased and by May, the peak spawning month, in the Ferguson's Gulf area, males exceeded females in the 30 to 34 and 35 to 40 cm length groups. Peak numbers of males were recorded in the over 40 cm length group during the same period. Relative numbers of males declined during the period following the spawning season to a minimum in August and September.

Sex ratio data from the Northern and Southern sectors of the lake suggest that a similar decline in the proportion of males occurs throughout the entire lake during the post-spawning months. The lake-wide decline between June and September is probably therefore a result of the greater mortality of males during the early post-spawning phase, rather than a movement of males away from the sampling area.

Site of spawning grounds

Despite widespread sampling, the precise location of spawning grounds is still not known. Although occasional B. bayad have been reported in the Kerio river, there is no evidence that this species breeds in any of the rivers flowing into Lake Turkana. During the present investigations, few males or females were caught in the ripe-running state (stage 5) which suggests that the spawning beds are limited in extent. In an attempt to establish where breeding occurred a series of bottom trawls were made at a wide range of depths in the Longech area during May, the peak breeding time.

Table 10.21 summarises the results and shows that whereas ripe females (stage 4) were widespread in their distribution relatively high numbers of stage 5 females were found only in the sample from 15 m. The results suggest that the spawning grounds are located in water of moderate depth. This hypothesis is supported by the depth distribution of juvenile B. bayad (Fig. 10.3) which are concentrated in water of 30-40 m.

Stimulation of breeding

The breeding season, which extends from the beginning of April to the end of July, coincides with the time of year when rainfall is most likely to occur in the Lake Turkana area. Records of the monthly rainfall at Ferguson's Gulf over a 5 year period are given in Table 10.2. Although some variation occurs, heavy rain invariably falls between March and June, and in the five years nearly 60% fell during these months. It is possible that one or more factors associated with rainfall stimulates breeding activity. In the Ferguson's Gulf area rainfall is at times sufficient for the small rivers discharging into the lake to flow for a few hours or even days. Where these rivers enter the lake, turbidity increases and conductivity drops.

However, there is no evidence that B. bayad breeds close inshore and the lowered conductivity and increased turbidity are generally extremely localised and are unlikely to be factors directly stimulating breeding activity.

LAKE (1967a) examined possible environmental factors involved in the stimulation of breeding in the Australian catfish Tandanus tandanus which spawns after flooding has occurred. He concluded that a volatile oil called petrichor, which is released when dry ground is inundated by flood water, may induce this fish to breed. The chemical nature of petrichor and its formation has been investigated by BEAR and THOMAS (1964, 1965). It is composed of a complex mixture of organic compounds containing basic, neutral and acid fractions, and it represents an accumulation of these substances by adsorption onto materials such as silica. The oil possesses a characteristic odour and has been obtained by steam distillation of most silicate minerals and rocks. In nature it is formed particularly in dry arid regions after long periods of exposure. Following rainfall, petrichor is released and its presence in flood water may be an important factor in stimulating certain fish to breed.

VAN DER WAAL (1974) reported that *Clarias gariepinus* spawned the night after they had been placed in shallow ponds that had been dry and filled the day before. He suggested that the release of petrichor from the bottom of the ponds when water was introduced, may have been the chief factor triggering off breeding.

Petrichor may be responsible for the inception of spawning activity in other Claridae which breed during the flood season. *Clarias mossambicus* Peters reacted to flood waters flowing into Lake Victoria within eighteen hours (GREENWOOD, 1956) and *Clarias gariepinus* spawned in the early morning after heavy overnight rain in Rhodesia (HOLL, 1966 and 1968).

It is possible that although *B. bayad* in Lake Turkana do not actually breed in flood waters following rainfall, they are able to detect the presence of petrichor, and this may promote breeding. Fish are known to have a remarkable sense of odour perception (HASLER, 1966; KLEEREKOPER, 1969). After several dry months the fall of rain in the arid region surrounding Lake Turkana may release sufficient petrichor into the lake for it to be detected by *B. bayad* at some distance from the point of inflow. The other environmental changes that take place after flooding, higher turbidity and lower conductivity seem unlikely to stimulate spawning activity in this fish. During September a sediment plume from the River Omo extends southwards to include the Longech area of the lake. There is widespread, though slight reduction in conductivity and increase in suspended particles at this time in the Longech area, yet no surge of gonadial activity was observed. A high proportion of water entering Lake Turkana from the River Omo originated from the Ethiopian Highlands and may take several months to reach the lake. It seems likely that during this period the amount of petrichor is much diminished by dilution, vaporisation etc.

A second environmental factor which may be of importance in stimulating breeding is temperature. Records of temperature changes in water below the 80 m contour indicate that there is a slight fall in water temperature during March to a seasonal minimum of just below 25.5° C. This fall in temperature coincides with the onset of maturation in the gonads of *B. bayad*.

Condition

Values for the condition factor of all fish weighed during the course of routine data collection were estimated using the following equation

$$k = \frac{w_o}{\bar{w}} \times 100$$

where w_o is the observed weight and $\bar{w}$ is the corresponding mean weight derived from the equation

$$\bar{w} = 0.008171^{3.032}$$ (see page 1028)

The mean condition factors of all mature B. bayad weighed during the two years of sampling are given in Table 10.22 for four phases of the annual breeding cycle. The results show that there is a seasonal change in condition in both sexes. In males peak condition was recorded between October and January, the resting phase, possibly as a result of increased fat deposits. In females the value of k similarly increased at this time, but peak condition was recorded in the spawning phase between April and July as a result of increased gonad weight. With the shedding of gonadial products, a loss of condition was noted in both males and females in the post-spawning phase.

Fecundity

In this study fecundity is defined as the number of maturing eggs found in a female just prior to spawning. During May 1974, which is the peak breeding month, all female B. bayad with well developed gonads (stage 5) were measured to the nearest 0.1 cm. Pairs of ovaries were removed and a longitudinal slit made in each prior to preservation in Gilson's fluid. The preparation of preserved eggs for counting followed the method of BAGENAL (1968) and fecundity was estimated by the dry method, also described by BAGENAL (op. cit.). The results of the fecundity estimates are plotted logarithmically in Figure 10.16 and the points are distributed approximately on a straight line. A regression line has been fitted and the relationship between fork length and fecundity can be expressed as follows:

$$\log_{10} \text{egg number} = 2.373\ (\log_{10} \text{fork length cm}) + 0.0857$$

The estimated length of a three year old B. bayad is 45 cm and using the above equation a fish of this length would have a fecundity of 10,200 eggs. An 80 cm fish would have an estimated fecundity of 40,000 eggss.

Discussion

Prior to the present study there was little information available on the breeding of B. bayad. Worthington found that in Lake Turkana the ripest fish occurred close inshore (WORTHINGTON and RICARDO, 1936). MANN (1964) suggested that B. bayad may come into shallower water to breed since the only ripe fish examined was caught at the entrance of Ferguson's Gulf. Evidence from the present study does not support this view. Ripe fish were caught in all depths of water. The occurrence of large numbers of ripe-running females in 15 m of water and the presence of juveniles mainly in 30 to 40 m suggests that breeding occurred in water of moderate depth and not in very shallow water close inshore as was found to be the case in Synodontis schall (see page 1070).

It is interesting to compare the breeding of B. bayad with two other African Bagridae, B. meridionalis from Lake Malawi and B. docmac from Lake Victoria.

JACKSON et al (1963) reported that in B. meridionalis breeding coincided with the rainy season during the first quarter of each year. Spawning sites appeared to be in shallow, sheltered water where the sandy substrate was interspersed with rocks. A breeding migration occurred from the deeper water to these areas and circular or oval nests were built by male fish. Both JACKSON et al (op. cit.) and TWEDDLE (1975) caught a greater number of females than males. JACKSON et al (op. cit.) suggested that this was a result of males remaining on the breeding grounds for longer periods of time, and thus being caught in fewer numbers in the deeper sampling areas. Tweddle however considered that since males were proportionally fewer than females in the trawl catches at all times of the year, the difference in ratio was not due to any significant change in their behaviour. In Lake Turkana there was no evidence that males concentrated at any particular depth of the lake and the differences in sex ratio was probably the result of increased male mortality after spawning.

Evidence from Lake Victoria was thought by CORBET (1960) to support the view that B. docmac breeds in the main lake. The large numbers of juveniles caught on exposed rocky shores suggested that breeding occurred in the vicinity but the exact spawning site was not known. CORBET (op. cit.) considered a rocky shore to be ecologically similar to that of the turbulent reaches in rivers. ELDER (1960) reported that B. docmac takes part in upstream migrations, but only in relatively small numbers. In Lake Turkana, although fishermen reported that B. bayad were caught in the River Kerio during the flood period, it would seem from all other evidence that spawning occurs in the main lake. If there was a large scale migration up the Kerio and Turkwell rivers during flooding, numbers of B. bayad handled by the Kerio Co-operative would be expected to rise. Figure 10.26 shows that there was no apparent increase in numbers of B. bayad sold per fisherman per week at this Co-operative during the flood season. Similarly there is no evidence from Todenyang Co-operative that a massive spawning migration of B. bayad occurs up the River Omo.

FOOD

The diet of B. bayad consisted primarily of prawns and fish. Variation in the proportions of these two food categories in the diet depended on predator size and on depth. Insects and ostracods were only rarely eaten and were of little importance as food items except in the shallow water of Ferguson's Gulf. Few post-larval B. bayad were caught, but those that were examined had fed entirely on copepods.

Method

During the two years of sampling the stomachs of over 2,000 B. bayad were examined. Except where otherwise indicated, stomachs were from fish caught by bottom trawling and hence the times and depths at which samples were made are known. Stomachs taken from fish of less than 15 cm were usually preserved in 5% formalin and scrutinised later in the laboratory with the aid of a microscope. Larger fish were examined on board the research vessel.

Stomach fullness of fish larger than 10 cm FL was estimated using a points system. This method has been widely used by other workers (FROST, 1943; HYNES, 1950). Stomach contents are removed, sorted, identified and each food item is allotted points depending on size and abundance. Thus one large organism is considered equivalent to many small organisms and the method is essentially volumetric.

In the present study a stomach that was considered to be full was allocated sixteen points. The relative volume of each food item was reflected in the number of points. For example, if a stomach was half full and judged to contain 75% prawns and 25% fish, prawns would receive six points and fish two points. Using this method the percentage composition of the diet and frequency of occurrence of the various food items could be estimated. In fish smaller than 10 cm only the occurrence of a food item was noted.

Food of juvenile fish

A sample of 70 juvenile B. bayad ranging from 20 to 30 mm FL was caught in May 1973 at a depth of 26 m in the Longech area. An analysis of stomach contents showed they had fed entirely on copepods. Unfortunately further samples of similar sized fish were not caught and it is not known whether copepods are the only food of juveniles. It seems likely that other invertebrates, such as ostracods and cladocera are also eaten before the diet changes entirely to prawns.

Food of immature and adult fish

The diet of B. bayad larger than 3 cm FL consisted almost entirely of fish and prawns. The most common fish preyed on were Alestes spp., Haplochromis macconneli and B. bayad. The two prawns Caridina nilotica and Macrobrachium niloticum which occur widely in the lake formed the other major item in the diet. The relative proportion of fish and prawns eaten depended on two factors; predator size and the lake depth.

Diet and predator size

Figure 10.17 gives the change in diet with increasing predator size as illustrated by fish caught in the Longech area. The results show that there is a change in the diet of B. bayad with increasing length, from prawns to fish. Thus prawns which were the only food eaten by fish under 10 cm occurred as the sole stomach contents in only 2% of B. bayad larger than 70 cm. In all length groups few fish had fed on both prawns and fish, indicating that individual fish tend to prey exclusively on a particular type of food.

Figure 10.18 illustrates the change in diet that occurs in mature. bayad. The number of points scored by fish in the diet has been expressed as a percentage of the total points allotted in each 2 cm length group over the size range 30 to 74 cm. The results show that there is an abrupt change in the diet of B. bayad between 48 and 50 cm with the points attributable to fish increasing from 30% to 78% of the total.

Diet with relation to depth

The food of B. bayad also varies with depth. Fish tended to be more common in the diet of shallow water B. bayad of all sizes over 10 cm FL than was the case in deeper water. Table 10.23 presents a detailed analysis of the change in diet with predator size in relation to depth. The results have been combined on a lakewide basis for all bottom trawl stations.

In the 10-19 cm group, fish were the major food item only between the 10 and 29 m contour. At all other depths prawns were more common. With increasing size fish were eaten to a greater extent in all depth zones, although B. bayad of up to 50 cm still fed mainly on prawns in deep water. At lengths over 50 cm the feeding habits were principally piscivorous at all depths.

The variation in the percentage of prawns in the diet of B. bayad at different depths is probably a reflection of the distribution of prawns in the lake. Densities of prawns are generally lower in shallower water except under turbid conditions during the flood period (see Chapter 4). Consequently B. bayad inhabiting inshore areas depend to a greater extent on fish as a food item. Once B. bayad exceed a length of 50 cm changes in diet with depth are less apparent since fish are the preferred food, even when prawns are present.

Insects rarely occurred in the diet of adult B. bayad and were found only in offshore stomachs. Of the identifiable remains, locusts (Orthoptera) made up 70% of the total insect points, Anisopteran nymphs 19% and corixid nymphs and adults 11%. It was surprising to find locusts in the stomachs of fish caught in 80 m of water. These insects may alight on the water surface in error. They have a fairly thick exoskeleton, and once in water would quickly sink to the lake bottom where presumably they were scavenged by B. bayad.

Within the confines of Ferguson's Gulf where depths do not exceed 4m the diet differed markedly from the open lake. The stomach contents of fish caught in the Gulf by beach seines are presented in Table 10.24. Prawns were noticeably absent from the diet of these inshore fish. They were replaced by insects which formed more than 25% of food points in the 20-49 cm length groups. Ostracods which were not recorded elsewhere were also eaten by B. bayad in Ferguson's Gulf.

Mature B. bayad were found to feed on a variety of fish. The commonest prey species were Haplochromis macconneli, smaller Alestes spp. and B. bayad, and their relative importance varied with depth. In Figure 10.19 points allotted to prey species have been expressed as a percentage of the total number of fish points recorded at each depth interval. In water of less than 30 m Alestes spp. accounted for more than half the total intake of fish. Species of Alestes in the diet included A. nurse, an inshore form, and A. ferox and A. minutus which occur mainly in midwater. They are the principal species of pelagic fish occurring in the midwater scattering layer which is situated in the open waters of the lake at a depth of between 3 and 30 m (see page 599). These fish therefore would be readily available to B. bayad inhabiting shallower water, within the 30 metre contour.

In water deeper than 30 m Haplochromis macconneli become the dominant fish eaten. Trawling has shown that this species is restricted to water deeper than 20 m and becomes more abundant with depth. The importance of H. macconneli as a food item gradually increased offshore. Bagrus bayad is also cannibalistic, feeding to a significant degree on its own young in deeper water.

The remaining species are of less importance. Their occurrence in the diet reflects their distribution in the lake. Hydrocynus forskalii (Cuvier), a surface living predator, Tilapia spp. and several silurid fish (other than B. bayad) formed a minor proportion of the diet of B. bayad living in shallow water. Lates longispinis which is caught by trawling in the scattering layer was occasionally found in stomachs from depths of between 10 and 40 m. Engraulicypris stellae has a widespread distribution in the lake and occurred in the diet in most depth zones. The deep water Barbus cf anema was present in the diet of B. bayad caught at depths between 20 and 60 m.

Predator-prey size relationship

The relationship between predator and prey size is given in Figure 10.20 for the three principal prey forms. Total lengths of Haplochromis macconneli and Alestes spp. and fork length of B. bayad eaten have been plotted against predator fork length, and regression lines have been fitted. The results show that the mean lengths of Haplochromis and Alestes vary only slightly over the observed predator size range. Neither fish attain a size much greater than 10 cm in Lake Turkana. Mean length of Haplochromis in the diet was 5.34 ± 1.55 cm and of Alestes spp. 5.37 ± 1.46 cm.

Mean length of B. bayad occurring in the diet increased with predator size but the minimum prey size remained virtually unchanged in all size groups. Approximately one fifth of the B. bayad eaten were more than 40% of the predator length and in one instance the prey exceeded 60% of this length. The results show that B. bayad is capable of ingesting prey over a wide size range.

Diel feeding pattern

Catch rates with the bottom trawl varied considerably with the time of day. Results from a 24 hour trawling station maintained in 80 m of water off Central Island are given in Figure 10.21. Catch rates for B. bayad in kilograms per hour have been plotted against the times at which the trawls were made. The results show that between 17.00 and 18.00 hours catch rate fell by over 50%. The decline continued after nightfall and at 21.00 hours less than 1 kg of fish was caught per hour of trawling, equivalent to about 1% of the average daytime catch. With the approach of daylight the catch rate increased and at 10.00 hours it was similar to that of the previous day.

The results from a series of frame trawl samples made over a 24 hour period at a station in 25 m of water confirm that during the night B. bayad moves off the bottom into the midwater layer. Table 10.25 gives the numbers of fish caught per ten minute trawl in seven depth zones at five different times during a 24 hour period. The results show that at dusk B. bayad move off the lake floor and occupy the midwater layers, reaching a maximum distance above the lake bottom during the night. At dawn the fish return to their daytime position on or near the bottom. Results from stomach analyses are given in Figure 10.22 where mean percentage fullness of all fish caught is presented for each period during the 24 hour cycle. Peak fullness was recorded during the night and the vertical migration would appear to be an adaptation to maintain B. bayad in contact with its prey. Feeding is probably not confined to the hours of darkness since food was also present during the day.

The frame trawl results help to explain the marked decrease which occurred at night in bottom trawl catch rates in deep water shown in Figure 10.21. If fish behaviour follows the pattern demonstrated for shallower water, a vertical migration off the bottom at the approach of night would result in the low catches that were actually recorded.

Seasonal feeding pattern

Results from trawl catches have shown that in the Longech area there is a movement of B. bayad into shallower water between August and November. Table 10.26 examines the seasonal variation of catch rates and diet of 30 to 39 cm *B. bayad* in water of 10 to 20 m. Although samples from December and April are absent, the results show that there is an increase in the proportion of prawns in the diet from September onwards, with prawns providing the entire food intake during November. This coincides with the time when bottom trawl catches reach an annual peak in water of less than 40 m (see Fig. 10.4). From February to July fish form over 50% of the food and during these months catch rates with the trawl in water of less than 40 m are below the annual mean. The reason for the increase in prawns is not clear. From June to October the Omo river is in flood and sediment plumes spread south reaching the vicinity of Ferguson's Gulf in early September. Associated with the flood water is a reduction in light penetration. The depth at which 99% light extinction occurs decreases from 7.5 m in March, April and May to only 2 m in September and October. The reduction in light penetration results in the ascent of the scattering layer into surface waters and the movement of open water pelagic forms, including prawns, inshore. The movement of *B. bayad* inshore may be a direct result of increased prawn density and is possibly a feeding migration.

Discussion

Although immature *B. bayad* of between 3 and 30 cm feed on prawns, adults are mainly piscivorous and are important predators on fish in Lake Turkana. The other major piscivorous species in the lake are *Lates niloticus* and *Hydrocynus forskalii*. The role of these two species and other *Hydrocynus* spp. as predators in African lakes has been discussed at length by several workers (HAMBLYN, 1960; JACKSON, 1961; FRYER, 1965; LEWIS, 1974). In Lake Turkana *H. forskalii* occurs in surface waters while *Lates niloticus* mainly inhabits water of less than 30 m though it is occasionally caught down to a depth of 80 m.

Adult *Hydrocynus forskalii* feed chiefly on *Alestes minutus* and *Engraulicypris stellae* in Lake Turkana and therefore do not compete directly with *B. bayad* for food. *Lates niloticus* however preys on a wider variety of fish, including *B. bayad* and *Alestes* spp. It is therefore in competition with *B. bayad* in the shallower areas of the lake. *Schilbe uranoscopus*, *Lates longispinis* and *Synodontis schall* may also be regarded as competitors, since they are partly piscivorous, feeding particularly on *Alestes* spp. *Bagrus bayad* has no competitors in the deeper waters of the lake, where it is the only major predator on *Haplochromis macconneli*.

One group of fish rarely eaten by *B. bayad*, but which forms an important part of the diet of *Lates niloticus* is *Tilapia* spp. In Lake Victoria CHILVERS and GEE (1974) reported that few *Bagrus docmac* had fed on *Tilapia* spp. They suggested that the behaviour pattern, warning systems or some other factors made these cichlids inaccessible to *B. docmac*. *Tilapia* spp. in Lake Turkana similarly occurred only rarely in the diet of *B. bayad* but the reason would appear to be due to major ecological differences between the two forms. *Tilapia* spp. are restricted to a narrow inshore zone within the 4 m contour where *B. bayad* occur only infrequently.

A change in diet with increasing size was noted in *B. docmac* from Lake Victoria (CHILVERS and GEE, 1974) although this species became principally piscivorous at a fork length of 16 cm compared with 48 to 50 cm in *B. bayad*. The change in diet in both *B. bayad* and *B. docmac* is not a result of change of habitat. It is possible that larger bagrids have to switch to a diet of fish in order to obtain sufficient food.

It is concluded that B. bayad is most successful in the deeper waters of Lake Turkana where competition from other predatory species is minimal. In shallower water where interspecific competition from prawns and fish is greater, the species is relatively less abundant.

COMMERCIAL FISHERIES

Bagrus bayad is of very minor importance in the inshore gillnet fisheries. However since the introduction of longlines in 1972 this species has been caught in significant quantities and in 1974, 245 tonnes of B. bayad were exported from the lake. This represented 7% of the total commercial catch of 3,500 tonnes.

The commercial exploitation of B. bayad by gillnets and longlines will now be discussed in detail.

Gillnets

Trials to evaluate the commercial use of gillnets in a B. bayad fishery were carried out in the Longech area during the period January-July 1974. Details of gear used in the trials are presented in a previous section (see page 1022). The bottom-set gillnets were fished for periods of 24 hrs at various depths from 9 m to 73 m. Mean catch per effort for B. bayad (kg/24hrs/100 yds headrope) is given in Table 10.27, together with the percentage of weight of the total catch. It is clear from the few results in deeper water that gillnet catches of B. bayad were relatively poor in comparison with trawling or longlining. Figure 10.23 presents catch per effort data for trawling and gillnetting at various depths in the Longech area. Catch per effort for the gillnets is given as kilograms of B. bayad per 24 hrs per fleet of gillnets, and for trawling in kilograms per hour. Whereas the trawl catch gradually increased with depth, results from gillnetting showed a peak catch rate between 25 and 30 m, with a decline in the deeper water. The diurnal migration pattern of B. bayad may help to explain poor gillnet catches in deeper water. Bottom trawl and frame trawl catches over 24 hours (Fig. 10.21 and Table 10.25) have shown that at night B. bayad move off the bottom to feed. Although gillnets fished up to 4 m off the lake bed, it is possible that B. bayad were feeding above this depth. After feeding in midwater, fish return to the bottom at dawn, and probably remain relatively immobile during the day. Such behaviour could result in little horizontal movement in the vicinity of the deepwater nets, thus reducing the likelihood of capture. In shallower waters the probability is greater that the gillnets were set in part of the midwater zone where B. bayad were feeding, resulting in the higher observed inshore catches. Observations on the behaviour of Bagrus docmac (ELDER, 1962) have shown that this species is inactive in the daylight hours.

Work with gillnets is incomplete and more data is needed from the deeper areas of the lake. It would appear however at this stage that gillnetting is not a satisfactory method for catching B. bayad at depth.

The selectivity of the nine nets used in this survey is given in Appendix 10B and mean retention lengths in Appendix 10A.

Longlines

Longlines have been used for several years by Turkana fishermen but they were mainly set in shallower water to catch Lates niloticus. Only since 1972 has this method been used in the deeper parts of the lake through the encouragement of NORAD* master fishermen. Under their guidance an experimental scheme was started in January 1974 at Namudak, 10 km north of Ferguson's Gulf. A 7 m fibre glass dinghy powered by an inboard engine was used, enabling fishermen to operate up to 20 km offshore in the centre of the lake. Data from this scheme was collected and estimates of catch per effort are presented in Table 10.28 for the period January to September 1974. Lates niloticus was the only other fish caught by the longlines and catch per effort data is presented in Appendix 10E.

Figure 10.24 compares the length-frequency distribution of fish caught by longlining and by trawling during January 1974. The size of B. bayad was considerably greater in longlines, where a mean of 66 cm (sd = 12 cm) was recorded, than in the bottom trawl with a mean of only 27 cm (sd = 11 cm). The relatively large size of fish caught selectively by the longlines were of a size which was represented by only a small proportion of fish in the bottom trawl catches.

Catch per effort in the longlines varied during the experimental period (Table 10.28) with the mean monthly catch rate ranging from 20.7 kg/100 hooks/night in January to 8.7 kg/100 hooks/night in July. An analysis of the catch on a weekly basis, however, has revealed no tendency for catch per effort to decline over this initial period (Fig. 10.25). Catches tended to fall between January and March but there was a sharp rise in April. Similarly there was no tendency for a reduction in mean fork length during these preliminary investigations. However since the completion of this trial fishing period in September 1974 the Norwegian master fisherman has reported that during late 1974 and 1975 longline catches of B. bayad have fallen to uneconomical levels in offshore areas in the Central sector of the lake (E RØKKE, pers. comm.). The implications are that the present level of fishing intensity is already having a detrimental effect on stocks of B. bayad.

Longlining is probably the ideal method for catching B. bayad in Lake Turkana since only larger individuals are selected. Recruitment into the longline fishery is delayed until after B. bayad has bred at least once, and usually twice. The reason for the bias in favour of large size may be due to the feeding habits of fish smaller than 50 cm which as has been shown above, feed principally on small fish and prawns and are less likely therefore to take bait.

Trends in the commercial catch

A detailed account of the present day commercial fishery on Lake Turkana appears in Chapter 6. This information enables trends in catches of B. bayad between 1972 and 1974 to be examined. Table 10.29 gives the numbers of B. bayad handled, expressed as a percentage of the total fish bought, at each of seven collecting centres in the last three months of 1972, 1973 and 1974. During October-December 1972 the numbers of B. bayad exceeded 5% of the total catch only at Namudak and Kalokol co-operatives. These were the two centres where longlines were

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*Norwegian technical aid.

first introduced to the Turkana fishermen in early 1972. Bagrus bayad quickly became an important fish in the commercial catch, accounting for up to 27% of the total fish handled at Namadak during 1972. Elsewhere on the lake, gillnetting was still the main fishing method and few B. bayad were caught. Between 1972 and 1974 the numbers of B. bayad increased progressively at all co-operatives and by October-December 1974 lakewide catches were approximately three times greater than during the same months in 1972. Catches were still comparatively low to the north in the Todenyang and Lowarengak areas, and to the south in the Kerio area, where gillnetting remained the principal fishing method. The higher catches at the remaining co-operatives was largely due to the increased use of longlines. By the end of 1974 Kalokol co-operative had replaced Namadak as the main centre for B. bayad. This was primarily the result of an expansion of longlining into the central part of the lake from a base on Central Island. The island is close to deep water and to high concentrations of B. bayad. The establishment of bases on the island overcame the problem of travelling long distances to set and haul gear. Fish caught from Central Island were sold mainly through the Kalokol co-operative. In December 1974 nearly 70% of all fish handled by this co-operative was B. bayad, as compared with less than 5% in 1972. Much of the longline catch at these two co-operatives was caught in the vicinity of North Island where a fishing camp had been established during 1973.

By the end of 1974 B. bayad accounted for an appreciable proportion of the fish handled by most co-operatives. Values for catch per effort of the commercial fisheries, expressed as numbers of B. bayad sold per fisherman per week are given in Figure 10.26 for all co-operatives over a 30 month period, July 1972 to December 1974. At Kerio, Lowarengak and Todenyang where, as mentioned previously, longlines were not in use, less than one B. bayad was sold per fisherman per week. Catch per effort was appreciably higher than this mean value at all other co-operatives during 1974 and at Kalokol the commercial catch at times exceeded ten B. bayad per week.

Longlining was expanding continually during the period under consideration and pronounced seasonal trends may well have been masked. However at Lowarengak, Nachukui and Kataboi in 1973 an increase is noted in the middle of the year perhaps as a result of the inshore migration of B. bayad observed in the Longech area when turbid Omo flood water was present. An inshore migration would bring B. bayad into the shallow water gillnet areas.

Fishing pressure in the Central area

In the absence of reasonable estimates for either the small amount of B. bayad eaten locally or the negligible quantity caught by gillnets it is considered that co-operative data at Kalokol and Namadak provide a good approximation of the total longline catch in the area. The mean catch rate observed in experimental longlines in the same area was one B. bayad per 21 hooks per night. Since the weekly numbers of B. bayad purchased by the Namadak and Kalokol centres is available, an estimate of the numbers of hooks set per night during 1973 and 1974 in the Central lake area can be made as shown in Table 10.30.

By the end of 1974 an estimated 5,000 hooks were set nightly in the Central lake area, with a weekly catch of 1,500 B. bayad. This area of the lake has the highest longline fishing intensity and this method now accounts for between 50% and 70% of all fish handled by the Kalokol and Namadak co-operatives.

Future expansion

In other areas of the lake, particularly in the north, fishing effort with longlines is still low and the potential catch rate is likely to be much higher than was recorded in 1974. Results from trawl catches show that in the northern sector population densities of B. bayad are similar to those observed in the Central sector. This indicates that catch per effort in the north may increase to a level similar to that of the Central sector. Potential yield in the Southern sector is generally low. An exception is the small area of deep water in the south of South Island, where trawl catches were well above average.

After the initial expansion and high catches however, indications are that catch rate rapidly declines and falls below economical levels. Figure 10.24 shows that the majority of fish caught by longlines in January 1974 were larger than 50 cm. In Table 10.31 the percentage length distribution of the total catch by longlines between January and September 1974 has been compared with the entire trawl catch from the two years of sampling. Longline catches were composed of large fish 85%, of which exceeded 50 cm in length. In trawl catches only 7% exceed this upper size limit.

For the exercise which follows it is assumed that trawl catches provide a true estimate of population structure. The main longlining area of the lake encompasses an estimated 700 km to the north of Central Island. The depth of water is generally greater than 60 m and all the B. bayad caught here are sold through the Kalokol and Namadak collecting centres. Bottom trawl results in this area show that a mean of 12 B. bayad larger than 50 cm FL were caught per hour. Since the trawl covers an area of 0.11 km each hour (see page 586), the total number of B. bayad in the main longline area larger than 50 cm is 76,400. During 1974 a total of 58,660 B. bayad were sold at Namadak and Kalokol, and it may be assumed that the majority of these were caught by longlining and were larger than 50 cm. Thus in 1974 at least 75% of the estimated total standing stock of fish larger than 50 cm were removed. With fishing intensity as high as this it is not surprising that the catch rate has declined and is no longer economical in the Longech area. Since fish between 30 and 40 cm which make up approximately 80% of the breeding population, are not susceptible to longlining, recruitment would continue and no permanent damage to stocks is likely.

In other areas of the lake expansion of longlining will probably occur, with increased numbers of B. bayad entering the co-operatives. After the initial expansion however catch rates will certainly decline, eventually stabilising at a much lower level.

BAGRUS DOCMAC

Bagrus docmac is widely distributed throughout the soudanian region of Africa, occurring in the Chad, Niger and Volta systems. It extends through much of the Nile basin including Lake Victoria. The species has been studied in detail by a number of workers. ELDER (1960), CORBET (1961), CHILVER and GEE (1974) have investigated the population inhabiting Lake Victoria. Prior to the present survey B. docmac had not been recorded from the Lake Turkana basin and despite the extensive sampling programme carried out between May 1972 and July 1974, a total of only 33 specimens were caught by bottom trawling. Two further specimens were obtained from gillnets and two from beach seines. However an intensive programme of gillnetting carried out in the Loiengalani area of the Southern basin during early 1975 showed that B. docmac occurred frequently in rocky inshore areas.

The material was insufficient for a detailed analysis of distribution. The position of stations where B. docmac were recorded are given in Figure 10.27. No capture was noted in water deeper than 30 m and it was absent from samples north of North Island, though a very small number have been recorded at the Todenyang co-operative. An association between the occurrence of B. docmac and a hard substrate was noted, since the largest single catch coincided with extensive net damage, caused by large rocks entering the trawl. It is interesting to note that the only Malapterurus electricus (see page 1048) trawled during the present survey occurred in the same haul. At a second station where two B. docmac were caught the trawl was again damaged, presumably by rocks. Bagrus docmac inhabiting Lake Victoria also shows a preference for a coarse substrate (ELDER, 1960) and BLACHE (1964) noted that in the Lagone and Chari rivers this species was principally caught in the vicinity of rocks.

The majority of B. docmac examined had resting gonads and fish in a ripe or ripe/running condition were not caught (Table 10.32). ELDER (1960) reported that although some B. docmac in Lake Victoria migrate upstream to spawn, the majority probably breed within the confines of the lake. There was no evidence of anadromous breeding movements in the Lake Turkana population and spawning is probably fully lacustrine.

The food of B. docmac below 35 cm FL consisted chiefly of fish and prawns in equal proportions but insects were also frequently eaten (Table 10.33). The diet was thus more varied than was noted in B. bayad of similar size, where prawns formed over 70% of the diet (Fig. 10.17). The fish most commonly preyed on were Haplochromis macconneli and Chrysichthys auratus. Bagrus docmac larger than 35 cm FL were entirely piscivorous, feeding predominantly on Synodontis schall and Tilapia spp. CHILVERS and GEE (1974) reached similar conclusions in Lake Victoria where B. docmac larger than 27 cm FL were principally piscivorous.

The low incidence of B. docmac in the bottom trawl samples suggests that this species will be of little commercial importance. Nevertheless a small quantity of B. docmac passes through the co-operative each year and BAYLEY (1975) has estimated that a total of 5.9 tonnes (fresh weight) was exported in 1974. More than half of the catch came from the Kerio and Eliye co-operatives, probably from gillnets set on the more rocky east coast of the lake. Few B. docmac were recorded at Kalokol and Namadak, the main longlining centres indicating that in the Central sector no significant increase in the catch can be expected from the development of this method. However, as mentioned previously, trials with gillnets carried out by a group of Italian volunteers in the Loiengalani area of the Southern basin during the period February to April 15 show that in rocky inshore areas the proportion of this species in the catch is much greater than in the northern areas of the lake. For example in El Molo Bay during March 1975, two 6 inch gillnets set for a total of four nights caught 6 large *B. docmac* forming 18% by weight of the total catch.

CHRYSICHTHYS AURATUS

Chrysichthys auratus occurs in the Niger, Chad and Nile basins. There are no previous records of this species from the basin of Lake Turkana, although the present studies show that it is widespread and at times common. The maximum size recorded during the survey was 29 cm FL but the species matures at a length of only 7-8 cm, and the great majority of fish were smaller than 15 cm (Fig. 10.28). As a result of its small size *C. auratus* is not of potential commercial importance.

Distribution

Mean bottom trawl catches, in kilograms per hour, are presented in Table 10.34 for 12 depth zones. All data collected between May 1972 and July 1974 have been combined. *Chrysichthys auratus* is distributed over a wide depth range, peak numbers occurring within the 10 to 25 m contour. The mean catch rate was less than 2 kg/hour in all depth zones, but occasional hauls greatly exceeded this level. Thus during September 1973 a catch of 48 kg/hour was recorded at a depth of 12 m off Koobi Fora and in January 1974, 35 kg were trawled in one hour off Longech Spit in 16 m of water. Each of these samples included more than 2,000 fish suggesting that at times shoaling may occur.

Evidence from frame trawling, carried out at a depth of 24 metres off Longech Spit over a 24 hour period shows that during the daytime *C. auratus* is confined to the region of the lake bed (Table 10.35). At dusk a vertical migration occurs, probably in response to falling light intensity, and fish swim into the midwater layers where they remain during the night. Peak stomach fullness was recorded at this time and the vertical migration thus coincided with an increase in feeding activity.

Close inshore *C. auratus* was only occasionally caught by beach seines during the day. However results obtained over a 24 hour period in Ferguson's Gulf in October 1975 show that *C. auratus* migrates inshore at night. Beach seine catches with a 45 m net of 19 mm mesh increased dramatically from 18.00 hours when no fish were caught, to approximately 500 per haul at 22.00 hours and 200 per haul at 02.00 hours. An analysis of stomach contents revealed that these fish had been feeding mainly on chironomid larvae and pupae. At dawn catch rate fell to only 3 per haul, and none were caught in the morning.

Chrysichthys auratus therefore has a markedly different distribution at night compared with the day. During the daylight hours it is principally demersal but at night it migrates into midwater areas and closer inshore to feed.

Breeding

A total of 444 males and 470 females were examined during the two years of sampling. The ratio of males to females over the length range 5 to 29 cm is presented in Table 10.36. Data has been grouped into 5 cm length classes and chi-square test revealed that the sex ratio was not significantly different from the hypothetical ratio of 1:1 (χ^2 = 4.08, with 4 degrees of freedom).

Size at maturity results (Tabe 10.37) show that males and females both matured at the same length. The smallest mature fish in both sexes measured 6 cm and 50% maturity was reached at between 7 and 8 cm. Only two ripe males were caught throughout the study period but ripe females were recorded in all months of the year. Seasonal changes in the proportion of ripe females, larger than 6 cm, are presented in Table 10.38. Insufficient data was available for all months but the results indicate that peak gonadial activity occurs between February and May. This coincides with the rainy season and breeding probably occurs in response to rainfall and flooding.

The fecundity-length relationship of C. auratus is presented in Figure 10.29 where egg number has been plotted against fork length. The diameter of preserved eggs ranged from 2.0 to 2.5 mm and in comparison with Synodontis schall and Bagrus bayad fecundity was low.

Feeding

The diet of Chrysichthys auratus was comprised almost entirely of insects and crustacea. The relative volume of each food item was estimated using the points system described previously for Bagrus bayad (see page 1036) and in Table 10.39 the stomach contents of all fish examined have been analysed. Chironomid larvae and pupae and ostracods are the most important food items and together contribute two thirds of the diet. Table 10.40 analyses diet composition in relation to depth. In water shallower than 20 m chironomids and ostracods were the dominant food items, but in deeper water prawns were of greater importance. The migration of C. auratus into midwaters and inshore for food has already been commented on.

Fisheries

Chrysichthys auratus has no commercial or subsistence value due to its small size and relative scarcity.

AUCHENOGLANIS OCCIDENTALIS

MANN (1964) was the first to record this species from Lake Turkana. Ten specimens, ranging from 26 to 31 cm FL were caught by gillnets during his visit, all from within Ferguson's Gulf. Despite extensive sampling during the present survey only one individual measuring 26.2 cm FL was caught, at Arika Lubwangole, an old river channel at the north end of the lake (see Fig. 10.27). It is curious that further specimens were not caught within Ferguson's Gulf or elsewhere in the lake, considering the relatively large number examined by Mann during his brief visit. It appears that A. occidentalis is now confined to the northern boundary of the lake and is perhaps fairly common in the River Omo and its delta.

CLARIIDAE AND MALAPTERURIDAE

CLARIAS LAZERA

This species has an extremely wide distribution in Africa, occurring in the Nile, Chad, Volta, Senegal and Lake Turkana basins (BOULENGER, 1911). Clarias lazera has also been recorded in Syria and Lake Galilee (GREENWOOD, 1966). In Lake Turkana C. lazera attains a maximum recorded length of 102 cm TL (Table 10.41).

The species is confined to shallow water close inshore and only one individual was caught in the course of several hundred trawl hauls. Clarias lazera was also rare in inshore gillnets and almost all specimens examined during the present survey were obtained by beach seining. Large samples were never obtained and data are insufficient for a detailed biological study. Small numbers occurred regularly in monthly seine net samples from Ferguson's Gulf and these, together with occasional specimens from seine net hauls in other parts of the lake, form the basis of the present account. Escapement from the shore seines was probably high since Clarias rarely became entangled and was frequently seen swimming through tears in the net or slipping under the foot rope. The habitat of this species ranged from soft mud in the Todenyang area to a stony substrate at Moite.

Information on the breeding biology of Clarias in Lake Turkana is incomplete. The species probably matures at a length of over 50 cm. The smallest ripe male observed measured 36 cm and the smallest female was 66 cm TL. Data on the seasonal occurrence of ripe individuals is inconclusive. Males in this condition were recorded during the months of September, October and January and the only ripe females were also recorded in January. Spawning however is thought to occur during the rains and under normal circumstances it is probably preceded by a migration into floodwater entering the lake. It seems likely that the River Omo is an important breeding area but spawning certainly occurs elsewhere as proved by a large sample of juvenile Clarias of 12-24 mm TL which were caught at the mouth of the River Kerio in July 1972. The species also migrates up smaller temporary rivers to breed and a juvenile of 35 mm was caught in a seasonal pool in the River Kalokol, approximately 12 km from the lake during July 1974.

Breeding however is not confined to rivers. During the 1930-31 Cambridge Expedition, several specimens were collected from Crater Lake A on Central Island (WORTHINGTON and RICARDO, 1936) and this isolated group of fish were clearly breeding in a lacustrine environment. Probable courtship behaviour between two large adult Clarias was noted in June 1975 on the grassy margin of Low Island in Allia Bay, suggesting that breeding might be occurring in this locality away from the influence of rivers.

In Lake Victoria Clarias mossambicus breeds in small temporary streams which flow into the lake during the rainy season (GREENWOOD, 1955). Breeding occurs over a limited period of time and ripe fish migrate upstream on one or two nights only, in response to flooding. In southern Africa Clarias gariepinus also breeds after flooding has occurred (VAN DER WAAL, 1974).

The analysis of stomach contents showed that copepods were the principal food with occasional ostracods, chironomid larvae and corixids (Table 10.42). The remains of a Tilapia were found in the stomach of a 36 cm Clarias. These results agree with the findings of WORTHINGTON and RICARDO (1936). POLL (1939) noted that in Lake Mobutu Sese Seico (formerly Lake Albert) C. lazera is omnivorous, but mainly a predator on small fish (Haplochromis and young Tilapia).

The small number of Clarias examined during the present survey gives an inaccurate picture of the importance of this fish in the present commercial catch. A total of 50 tonnes fresh weight (see Chapter 6) were exported in 1974, most of which came from the Todenyang and Kerio areas, and from the east shore between Allia Bay and Moite.

MALAPTERURUS ELECTRICUS

PELLEGIN (1935) recorded a single specimen of Malapterurus electricus, the electric catfish, from the Omo delta. During the present survey one fish, measuring 20 cm TL, was caught by the bottom trawl in 15 m of water, 1 mile off the west shore of Longech Spit (Fig. 10.27). This capture coincided with the largest sample of B. docmac obtained during the survey (see page 1044) and both these species appear to prefer a rocky substrate. For this reason Malpterurus electricus may be more plentiful in the Southern basin. A second specimen of 28 cm TL was caught in a shore seine on the east shore opposite the Kerio delta at Sandy Bay during January 1975. The substrate was muddy. It is reported to be fairly common in the River Omo in the vicinity of Kalom, just north of the delta, and has been noted in the permanent waters of the upper Turkwell river at Mamatte (J. RIENKS pers. comm.).

SCHILBEIDAE

SCHILBE URANOSCOPUS

Schilbe uranoscopus is a nilotic species restricted to the River Nile basin. WORTHINGTON and RICARDO (1936) recorded this fish frequently in the open waters of Lake Turkana but obtained only a single specimen from inshore waters within the confines of Ferguson's Gulf. In Lake Turkana Schilbe attains a maximum recorded fork length of 34 cm.

DISTRIBUTION

Results from the present survey show that although more plentiful in offshore waters Schilbe also occurs regularly inshore where it is caught in beach seines and gillnets. Although direct evidence is not available, larger numbers of mature fish probably migrate into the three main rivers flowing into Lake Turkana during the breeding season. A riverine population of Schilbe uranoscopus was discovered in 1974 in the upper reaches of the River Turkwell between Ketilo and Sigor.

Schilbe was present in roughly 50% of all the bottom trawl samples but catch per effort in terms of kilograms per hour was relatively low. Trawl catches exceeded 10 kg/hour in only 5% of the hauls and thus although Schilbe is widely distributed, the biomass is not high.

Trawl catches

Catch per effort in kilograms per hour of bottom trawling are presented in Table 10.43 for the three sectors of Lake Turkana.

In the Central sector Schilbe was most abundant at depths of between 20 and 25 m where the mean catch rate reached 10 kg per hour. Catches in this depth zone however varied considerably. During April 1973 catches fell to 6 kg per hour whereas in April of the following year 193 kg of Schilbe were trawled in one hour. In water shallower than 20 m and deeper than 30 m the mean catch rate did not exceed 3 kg/hour. Schilbe were rarely recorded at depths greater than 50 m and it is possible that fish from deep water stations may have been caught in midwater as the net was being shot or hauled.

Similar trends in distribution were noted in the Northern sector with catches very low at depths greater than 40 m. In the Southern sector no marked trend is evident and, although values varied, relatively low catch rates, not exceeding 2.5 kg/hour, were recorded from both shallow and deep water.

Frame trawling

Data from a series of daytime frame trawl hauls made at an inshore and an offshore station in the Longech area during September 1973 are presented in Table 10.44. Results from the inshore station show that Schilbe was restricted to a depth zone of between 4 and 20 m, and that peak numbers occurred within the midwater scattering layer (see page 605). A similar pattern of distribution was also observed at the offshore station where the relatively small numbers of Schilbe were confined to a narrow depth zone between 8 and 16 m. Frame trawl results thus indicate that in open water during the daylight hours Schilbe tended to concentrate in the vicinity of the midwater scattering layer. Further frame trawl observations to be discussed below in the section on feeding (see page 1058) show that Schilbe migrates towards the surface at night.

Gillnettting

Four bottom set gillnet stations were established off Longech Spit and were regularly fished between January and July 1974. The depth of the four stations, A, B, C and D and their relationship to the scattering layer are given in Figure 10.39 and Table 10.63. Catch data for Schilbe in the 2 inch and 3 inch nets are presented in Table 10.45. The highest catch rate with the 3 inch net was observed at station A in 9 m of water, where an average of 8.3 kg of Schilbe were caught per night. The lowest catch was recorded at station C in 19 m of water within the midwater scattering layer. In the 2 inch nets catches varied less but a minimum was again recorded at station C. These results at first suggest that Schilbe were least abundant within the scattering layer, and conflict with trawl results. However it is possible that Schilbe rest during the daytime in the vicinity of the scattering layer, but at night swim into shallower water to feed. If this were the case station A would be the best placed to catch fish involved in such a movement.

Results from bottom set gillnets in water deeper than 25 m support evidence from the bottom trawl which indicated that Schilbe was virtually absent from deep water. Catch rates of Schilbe in 2 inch and 3 inch nets at depths of 40, 60 and 70 m were less than 0.5 kg/night.

Gillnet catches were very variable within the sheltered waters of Ferguson's Gulf, and it appeared that Schilbe entered the Gulf in large shoals at certain times of the year. The highest catch was recorded in July 1974 when a 4 inch net caught a total of 17 kg of Schilbe in one night. An analysis of the gonads showed that over 40% of the females were ripe suggesting that these fish had moved into Ferguson's Gulf in the course of a spawning migration. At other times of the year the catch rate fell to below 1 kg/night, indicating that Schilbe were normally not abundant within the Gulf.

Beach seines

Although Schilbe were occasionally caught in large numbers within Ferguson's Gulf by gillnets, the species was generally uncommon in beach seine catches on all shorelines. Records of seine net catches in Ferguson's Gulf indicate that this fish was present only between March and July. This coincides with the period when, as noted above, the July gillnet catches included a high proportion of ripe females.

Discussion

It is suggested in the section on breeding (see page 1055) that Schilbe spawns principally in the River Omo during the flood period, July to September. Ripe Schilbe from the lake probably migrate into the Omo delta but unfortunately it was not possible to sample this area, which lay within the boundary of Ethiopia. Schilbe definitely migrates up the Kerio and Turkwell rivers and fishermen confirmed that large numbers were at times captured in these rivers during heavy floods.

The migratory behaviour of Schilbe would account for the wide variation observed in trawl catches in the Ferguson's Gulf area, and in gillnets set within Ferguson's Gulf. WHITEHEAD (1959) points out that some species of anadromous fish in Lake Victoria commence shoaling one or two months before the rivers flood. He suggested that pre-spawning assembly perhaps assists synchronisation of breeding in widely dispersed stocks. The indications are that shoaling also occurs in S. uranoscopus in Lake Turkana.

GROWTH

Most of the material for biological investigations was caught by bottom trawling but the sample number was generally low. It has proved possible, however, to estimate age and growth by reference to length frequency histograms. Schilbe of under 15 cm FL were rare in the bottom trawl but from August 1973 onwards frame trawl catches provided samples of juvenile fish.

Sexual differences in length frequency distribution

There was a marked difference in the length-frequency distribution of mature Schilbe, females attaining a maximum length of 34 cm, while males rarely grew to more than 21 cm. Figure 10.30 compares data for all males and females caught by bottom trawling during April 1973 in the Longech area. The difference between the means is highly significant ($P = < 0.001$) and growth of mature males and females therefore has been analysed separately.

The limited data available indicates that there is no sexual difference in the growth of immature fish. Length distributions of a sample of immature males and females caught by frame trawling in April 1974 are compared in Figure 10.31. Modal lengths are identical, and for growth analysis of immature fish the length data for both sexes have been combined.

Analysis of length frequency data

The length frequency distribution of Schilbe caught by bottom and frame trawling at a number of stations between July 1973 and June 1974 in the Central sector are presented in Figure 10.32. Males and females have been plotted separately and the length distribution of immature fish of both sexes combined is indicated by cross hatching. Histograms have been smoothed using Taylor's method (moving average, a = 3) (TAYLOR, 1965). In all months the distribution of fish in trawl samples was either unimodal or bimodal. A regular increment in modal length is clearly apparent in immature fish and females, though not in males. 0-group fish of the 1973 year class were first caught by the frame trawl in November 1973 when at a mean length of 5 cm, and were easily distinguishable as a separate size group ranging from 6 to 8 cm in the December 1973 trawl samples (Fig. 10.32). Fish from this year class were caught in increasing numbers in the following months (Fig. 10.32) and by June 1974 when the sampling programme was completed females of this year class had reached a modal length of 17 cm. Although the subsequent growth of these 0-group fish was not studied, results from the previous year provide data for the sequence of growth in late 0-group and 1-group fish. A modal length of 19 cm recorded in 0-group females of the 1972 year class during July 1973 (Fig. 10.32) corresponds closely with the value quoted above for 0-group to 1-group in this month. Females of the 1972 year class, which became 1-group fish in September 1973 dominated trawl catches from July 1973 until May 1974.

The histograms (Fig. 10.32) strongly suggest that late 1-group and 2-group fish are absent from the trawl samples. Evidence on breeding behaviour (see page 1055) suggests that Schilbe migrates away from the trawling grounds in the open lake at the end of the second year of life to breed in rivers. High mortality in the spawning areas would account for the dearth of the older fish.

Length-frequency histograms for males indicate that the course of growth is different to females. Definite year classes are distinguishable (Fig. 10.32) and these show the same pattern of recruitment in 0-group fish and migration in late 1-group fish. However the age classes of mature males show little progressive increase in size from month to month. This is probably a result of lower growth rate in males and they may also commence their spawning migration earlier than females.

Estimates of monthly mean lengths of all immature and female Schilbe in the 1972 and 1973 year classes caught by the bottom and frame trawls during the sampling period are presented in Table 10.46. The observed growth of females up to age 2 is shown in Figure 10.33 where mean lengths from Table 10.46 have been plotted against time. The points fall on a line which cuts the time axis in late August or early September. Since seasonal changes in gonad condition indicate that breeding probably coincides with the Omo flood season (i.e. June to October), early September has been taken as the 'birthdate' of Schilbe. Growth over the first year is rapid and a length of approximately 22 cm is reached at an age of 12 months. Over the second year growth increments decline but with the movement of mature individuals out of the population to spawn it was not possible to observe growth beyond 20 months of age. At an age of 24 months, however, the fork length of female Schilbe is estimated to be approximately 30 cm (see also mathematical expression of growth below).

The mean lengths of immature and male Schilbe were similarly estimated and are presented in Table 10.47. The observed growth of males up to an age of 24 months is shown in Figure 10.36 where mean lengths from Table 10.47 have been plotted against time. Growth in males is clearly slower than in females, with an increment of only 3 cm during the second year.

Mathematical expression of growth

Females

A von Bertalanffy growth curve has been fitted to the observed growth pattern given in Figure 10.33 using the following equation:

$$l_t = L_\infty \quad (1 - e^{-K(t-t_o)})$$

where l_t is the length of fish at age t, L_∞ is the asymptotic length, K is a constant and t_o is the theoretical time when the fish has zero length. In the Walford graph (Fig. 10.34) l_t + 3 months has been plotted against l_t months. The following values were obtained for the growth paramters of female Schilbe

L_∞ = 36 cm

K = 1.026

t_o = -0.0208 years

The largest female caught by trawling measured 34 cm FL and thus L_∞ agrees well with observed values. Likewise the value for t_o agrees with the observed time of peak spawning. Substituting the above parameters in the growth equation theoretical lengths at age can be estimated (Table 10.48) and a growth curve fitted to the data is given in Figure 10.33. Theoretical growth agrees well with observed values and in female Schilbe growth clearly follows the von Bertalanffy growth model.

Males

Values for L_∞ , K and t_o were similarly estimated for males. In the Walford graph (Fig. 10.35) length at 1 + 5 months has been plotted against l_t using data from Table 10.47. The following values were obtained for the growth parameters of male Schilbe

L_∞ = 19.5 cm

K = 2.1696

t_o = -0.0175 years

The estimate of L_∞ is rather less than that indicated by field observations and 5% of males caught by the bottom trawl exceeded 20 cm FL. The value for t_o agrees with the expected 'birthdate'. Substituting the above paramters in the growth equation, theoretical lengths at age can be estimated (Table 10.49) and a growth curve fitted to the data is given in Figure 10.36. Theoretical growth agrees well with observed values and in male Schilbe growth clearly follows the von Bertalanffy growth model.

Growth rates in the Northern and Southern Sectors

Insufficient data were available from areas outside the Central sector to enable direct growth estimates to be made. However by comparing the length frequencies of trawl samples from the Northern and Southern sectors with samples from the Central sector it was hoped to be able to establish whether growth rates were different. Length frequency histograms of samples from outside the Central sector were plotted and lengths were found to fall into definite groups as in the Central sector. Mean lengths of females from the Northern and Southern sectors have been compared with those of the equivalent monthly samples from the Central sector by applying t-tests and results are given in Table 10.50. In the Northern sector during all months when samples of sufficient size were available, there was no significant difference between the means ($P = 0.05$).

Only two samples of female Schilbe are available from the Southern sector for similar comparisons (Table 10.50). The December 1973 sample was not significantly different to the corresponding Central sector sample, but in May 1973 the mean length of Schilbe sampled from 2 km off the mouth of the River Kerio were significantly larger. The River Kerio was in flood at the time the latter sample was taken and it is possible that these females had recently left the main population in preparation for a spawning migration. Under such circumstances it is likely that they were among the largest individuals and thus unrepresentative of Schilbe in the Southern sector as a whole.

The similarity of the length-frequency distribution given in Table 10.50 suggest that there is a single population of Schilbe in Lake Turkana. However it is known that relatively small numbers of Schilbe do breed in the lower reaches of the River Kerio and it is possible that these form a breeding population distinct from the main population which spawns in the River Omo.

Length-weight relationship

A total of 95 Schilbe uranoscopus were weighed, and the length-weight relationship of males and females has been examined using the following equation:

$$\log_{10} \text{weight} = \log_{10} a + b (\log_{10} \text{length})$$

where a is the intercept of the regression line of log weight on log length, and b is the regression coefficient. The slopes of the regressions for males and femals were compared and found not to be significantly different ($d = 1.273$). Data for both sexes were therefore combined and the relationship between length and weight for all Schilbe may be represented by the following equation:

$$\log_{10} w = 2.9947 (\log_{10} l) - 2.0848$$

or

$$w = 0.00821\ l^{2.9947}$$

where w = weight in g and l = length in cm.

Estimated values of mean weight for age are given in Table 10.51 for the first 2 years growth in male and female Schilbe.

Conclusions

The analysis of length-frequency histograms has enabled estimates of growth rate to be made and observed values agree well with theoretical growth based on the von Bertalanffy equation. Schilbe is a migratory fish and the evidence suggests that during the breeding season, large numbers of mature individuals leave the population of the main lake to spawn in major rivers. As a consequence growth during the second year may be underestimated, especially in males. The length frequency histograms gave no indication of a return of post breeding fish into the trawlable population and it would appear that the majority of Schilbe do not live longer than 2 years.

BREEDING

Throughout the study period relatively few ripe Schilbe uranoscopus were caught and there is little direct evidence to indicate the location and time of breeding. The virtual absence of sexually active fish in trawl samples suggests that spawning does not occur in the lake. Previous workers on Lake Turkana (WORTHINGTON and RICARDO, 1936; MANN, 1964) also noted a dearth of ripe fish. In Lake Victoria Schilbe mystus ascends rivers to breed (WHITEHEAD, 1959; CORBET, 1961) and in the River Niger spawning occurs during the flood season (DAGET, 1954). Circumstantial evidence suggests that in the Turkana basin S. uranoscopus also migrates up rivers to spawn.

Maturity stages

The classification of NIKOLSKY (1963) was used to determine the maturity stages of Schilbe.

Females

Stage 2 Resting or recovering; gonads thin, sac-shaped, pale yellow in colour.

Stage 3 Mature: ovaries greatly increased in size, and opaque yellow eggs distinguishable with the naked eye.

Stage 4 Ripe: eggs of uniform size but do not separate when ovary wall cut.

Stage 5 Ripe-running: not observed.

Males

Stage 2 Resting or recovering: testes thin with a very slight scalloped edge, just visible to the naked eye.

Stage 3 Mature: scalloped edge clearly visible. Testes white or yellow.

Stage 4 Ripe: small quantity of sperm released when testes cut and squeezed.

Stage 5 Ripe-running: not observed.

Sex-ratio

Both WORTHINGTON and RICARDO (1936) and MANN (1964) noted that female Schilbe attained a much larger size than males. This was confirmed during the present study as is evident from Table 10.52 where the sex ratio of fish in the 10 to 31 cm length range from the Ferguson's Gulf area is given. Males and females smaller than 17 cm were caught in roughly the same numbers. In the size range 17 to 19 cm males outnumbered females by over 3 to 1, but in larger fish the proportion of males declined. The relatively greater abundance of males in the 17 to 19 cm length range is explained by the slower growth rate of males (see page 1050). The largest male measured in the Ferguson's Gulf area had a fork length of 24 cm, compared with a female of 34 cm.

Size and age at maturity

Data relating to length at maturity show that males matured at a slightly smaller size than females (Table 10.52). The smallest ripe male measured 16 cm compared with a minimum length of 19 cm in females. Males reach a length of approximately 17 cm and females 23 cm at an age of 12 months and therefore the majority of Schilbe mature in the second year of life.

Location and time of breeding

Between May 1972 and July 1974 less than 2% of the 1,300 females and 1% of the 500 males caught by trawling in the Longech area had ripe gonads and the analysis of seasonal changes in gonad condition of fish caught by trawling (Table 10.54) gave no clear indication of a peak of gonadial activity. Ripe females occurred in the open water of the Longech area between March and June and between September and November. In June 14% of females were ripe and it is possible that some breeding occurs in the Central sector at this time. In July 1974 nearly half of a sample of 88 females caught by gillnetting within Ferguson's Gulf were ripe and this sheltered area is perhaps a site of limited breeding activity.

Regular monthly samples were not available from the remainder of the lake. In the Southern sector the highest proportion of ripe females occurred in June 1974, when in a sample of 43 females 26% were ripe. In the Northern sector most ripe females were also caught in June, when 14% of a total of 37 females were ripe.

The small numbers of ripe Schilbe caught suggest that breeding probably does not occur in the main lake. Even if the major spawning sites were close inshore, where trawling was not possible for technical reasons, appreciably more Schilbe would have been caught. The major breeding sites are probably in the Omo, Kerio and Turkwell rivers, mature fish ascending these rivers to spawn.

As mentioned earlier there is ample evidence that Schilbe mystus inhabiting Lake Victoria migrates upstream to breed. CORBET (1955) noted that this fish was caught in an advanced state of maturity in affluent rivers of Lake Victoria at a time when river levels were falling after flooding. WHITEHEAD (1959) however, noted that in another part of Lake Victoria S. mystus asccended rivers at a time when flooding began. Migration was of a medium duration, fish ascending a few miles upstream and then passing laterally to spawn in floodwater pools.

During July 1972 the Kerio river was investigated as a possible spawning site. It proved impossible to obtain samples in the fast flowing river but basket net catches of the local fishermen confirmed that this species was present, though in small numbers, in the river 20 kilometres upstream from the lake. Three Schilbe were examined and all were mature females (Stage 3). Fishermen reported that large catches could be made at certain times of the year, and it is probable that the movement of Schilbe into this river is a spawning migration. Unfortunately samples were not obtained from the River Omo which is situated in Ethiopia. This river, on account of its large size, is probably the major spawning area of the Lake Turkana population.

Further evidence that Schilbe spawns in rivers was provided by the distribution of juveniles which were only observed in the vicinity of the Omo and Kerio rivers. A sample of 12 fish ranging in length from 27 to 31 mm were caught near the mouth of one of the main distributary channels of the River Kerio in October 1974. The river was not flowing at the time of sampling but it is highly probable that these small individuals had been swept down by river flow some time previously,and that the spawning sites were located upriver. Further samples of small Schilbe were obtained by fine shore seines in the Omo delta area. In August 1975 five individuals, ranging in length from 18 to 57 mm were caught at stations 2 to 8 km north of Todenyang and in October 1975 a further two Schilbe of 27 and 29 mm were caught in the same area. On the east shore only one juvenile was caught, at a station on the southern fringe of the Omo delta, during October 1974.

Despite extensive sampling with the metre townet in the open waters of the lake, a total of only 8 juvenile Schilbe were caught. Lengths of these individuals ranged from 30 to 44 mm and all were caught during October 1974 within 10 km of the Omo delta. The small numbers of juvenile fish caught in the open lake, and their occurrence in the vicinity of river mouths clearly indicates that breeding takes place in rivers and not in the actual lake. Their time of capture in the north shows that breeding coincides with the flood period, between July and October. Breeding in the two major rivers further south is probably less well defined since flooding in the Kerio and Turkwell may occur between March and October. Results from growth studies (page 1053) similarly indicate that the 'birthdate' of Schilbe is in late August - early September, coinciding with peak flooding of the River Omo.

FOOD

WORTHINGTON and RICARDO (1936) noted that Schilbe uranoscopus appeared to be primarily a predator feeding on Alestes spp, Tilapia spp. and Engraulicypris stellae. The present study shows that Schilbe also feeds on prawns, and that the proportion of fish and prawns in the diet depends on lake depth and on the size of the individual predator.

Schilbe has a well defined stomach. During the course of routine field data collection, stomachs were removed, preseved in 5% formalin, and examined later at the laboratory. The composition of the food was evaluated by means of a points system similar to that employed for B. bayad (see page 1036).

A total of 690 stomachs were examined, most of them from fish caught by bottom trawling. Gillnetting within Ferguson's Gulf provided information on the diet of fish from shallow water and data from frame trawling enabled the diurnal feeding pattern in the open lake to be examined. In Table 10.55 the number of points scored by each food type has been expressed as a percentage of the total points, combined for all samples during the two year period.

Fish and prawns contributed 98% of the food, and insects appear to be of little importance in the diet of Schilbe. Alestes spp. and Engraulicypris stellae provided over 90% of the total fish intake and other prey species including Barbus cf anema, Haplochromis macconneli and Bagrus bayad formed only a small part of the diet. The proportion of the two main food items, prawns and fish, was found to vary with depth and predator size.

Composition of food in relation to depth

Prawns were most important in the diet of Schilbe in the 10 to 20 m depth zone, where they contributed 67% by volume of the total food intake (Table 10.56). Schilbe from water deeper than 20 m had fed almost equally on prawns and fish. The diet of inshore Schilbe both from Ferguson's Gulf and from shallow water within the 10 m contour was markedly different with fish constituting the dominant food, and prawns forming only a minor proportion of the diet. This was correlated with a general scarcity of prawns inshore.

Diet with relation to size

Individuals under 20 cm had a varied diet feeding mainly on prawns with a minor proportion of fish (Table 10.57). A few ostracods were also included in the diet of the under 15 cm length group. Higher proportions of fish were observed in the food of 20-24 cm Schilbe but prawns still formed three quarters of the total intake. The relative importance of fish and prawns was reversed in the largest Schilbe (over 25 cm) with fish now contributing three quarters of the food. A tendency for fish prey to change from Engraulicypris stellae in smaller Schilbe to Alestes spp. in larger specimens was also noted.

Diel feeding pattern

The diurnal feeding pattern of Schilbe was examined both in the shallow water of Ferguson's Gulf and in the open lake. Investigations in Ferguson's Gulf were carried out concurrently with studies on Synodontis schall and the methods used will be discussed below (see page 1078 Schilbe inhabiting the Gulf were mainly piscivorous and results from the 24 hour study showed that feeding occurred primarily during the hours of darkness. Changes in diet and stomach fullness, together with catch rate are given in Table 10.58. The number of points for each food type has been expressed as a percentage of the total number allotted during each time phase, and the catch rate is given as numbers of Schilbe caught per hour in the 4 inch gillnet. The results show that the diet varied little through the 24 hour period, with fish forming over 90% of the food intake throughout. However, Alestes spp. were more commonly eaten at night than during the day. The diurnal feeding pattern contrasted with Synodontis schall where there was a marked change in the diet from day to night (see page 1078).

Catch rate and stomach fullness, however, fluctuated considerably in Schilbe with peak catches, of 10 fish per hour, occurring at dusk and the lowest catches at dawn and during the morning. The results indicate that Schilbe was most active at sunset and during the early part of the night. Feeding followed a similar cycle with maximum stomach fullness being recorded at night. Schilbe inhabiting Ferguson's Gulf thus appear to have a definite feeding rhythm with peak activity between sunset and dawn. The increase in catches at dusk and during the night may also be partly due to the migration of Schilbe inshore.

It is of interest to compare catch rates of Schilbe with Hydrocynus forskalii, another common predator, over the same 24 hour period (Fig. 10.37). The observations show that the two species were caught at entirely different times. Hydrocynus forskalii is an active 'chasing' predator relying on sight for the capture of prey. The highest H. forskalii catches were made during the hours of daylight, indicating peak activity during the period when Schilbe was least active. Hydrocynus forskalii was virtually absent from gillnets during the night. Although temporarily separated and with different feeding methods, the two predators competed for the same food resources. Engraulicypris stellae and small Alestes spp. were the dominant prey species in each case.

To investigate the vertical migration and diurnal feeding pattern of Schilbe in the open lake frame trawl samples were made over a 24 hour period at a lake depth of approximately 25 m, 2 km east of Longech Spit in April 1974. A series of hauls was repeated at the following intervals during the 24 hour period; afternoon, dusk, night, dawn and morning. Each series consisted of seven 10 minute hauls covering seven depth zones from the surface to the bottom. The catch rates (Table 10.59) prove that Schilbe undertakes a vertical migration, leaving the lake floor at dusk and occurring mainly in the midwater layers during the night. At dawn Schilbe returns to the lake bottom remaining there during the daylight hours. The migration probably occurs in response to falling light intensity. Evidence from frame trawl hauls further offshore (see page 1049) suggests that at greater depths Schilbe remains in the midwater layers during daylight hours, where optimum light conditions prevail, and do not descend to the bottom.

The results of stomach analysis for the 24 hour study are given in Table 10.60. The composition of the food again showed little variation over the 24 hour period, but unlike the inshore Schilbe considered above, prawns formed the major part of the diet. Peak stomach fullness was recorded during the night and dawn phases, coinciding with the time when most Schilbe were in the midwater layers. The vertical movement that commenced at dusk thus coincided with an increase in feeding activity.

Conclusions

Results from the present study agree to some extent with the findings of earlier workers (WORTHINGTON and RICARDO, 1936; MANN, 1964). Larger individuals were found to prey on other fish, in particular Engraulicypris stellae and Alestes spp. However, prawns were of equal or greater importance in the diet of fish smaller than 25 cm, an observation not previously recorded. Diet was also found to be dependent on depth, fish being more commonly eaten in the shallow inshore water.

Schilbe appeared to feed primarily at night. In the open lake a vertical migration commenced at dusk, and fish occupied the midwater layers throughout the night. By dawn stomachs were relatively full and fish returned either to the bottom or in deeper water to the lower limits of the scattering layer, where they remained during the day. In Ferguson's Gulf gillnet catches showed that a similar pattern of feeding activity occurred with few Schilbe being caught during daylight hours.

The closely related Schilbe mystus, a widely distributed nilotic species feeds principally on small fish (Haplochromis spp) in the case of the Lake Victoria population, although insect larvae and prawns were also eaten (GRAHAM, 1929; WORTHINGTON, 1929; CORBET, 1961). Most insects were taken at the surface and consisted of terrestrial forms. In Lake Turkana there is no evidence to suggest that Schilbe uranoscopus fed regularly at the surface of the lake. Insects made up less than 2% of the diet and were mostly derived from on or near the lake bed.

COMMERCIAL FISHERY

Schilbe does not feature in the commercial catch and results from the present study show that this species is likely to be of only slight importance in any futute development of the Lake Turkana fisheries. Although Schilbe is a widespread species it is generally not abundant and catches in both bottom trawl and gillnet are generally low.

The present catch rate of Schilbe could be increased by fishing with gillnets of smaller mesh size. Experimental results have shown that with a graded fleet of 2 to 9 inch nets highest catches are generally made in 3 inch nets. Under the present conditions however the introduction of 3 inch nets would be most undesirable since the immature of numerous commercially valuable species would be destroyed. The mesh selectivity of nets from 2 to 4 inches, stretched mesh, and mean retention lengths, are given in Appendices 10A and 10D. Since males rarely grow larger than 24 cm, virtually the entire catch of Schilbe in the 2 and 3 inch nets would be females. Fifty percent maturation (Stage 3) in female Schilbe occurs at a length of 24 cm and the 3 inch net with a mean retention length of 30 cm would catch mainly mature fish.

MOCHOKIDAE

SYNODONTIS SCHALL

Over fifty species of Synodontis have been recorded from Africa but only two occur in Lake Turkana. One of these, Synodontis schall is very common and widespread throughout the lake whereas the second species, Synodontis frontosus was only rarely caught in the Omo Delta during the present study, and appears to be restricted to a riverine environment. Several species of Synodontis have been studied in detail in other parts of Africa. BISHAI and GIDEIRI (1965 a and b, 1968) investigated the biology of certain species, including S. schall, occurring in the River Nile at Khartoum, and WILLOUGHBY (1974) has studied the biology of several Synodontis spp, again including S. schall, from Lake Kainji. Both WORTHINGTON and RICARDO (1936) and MANN (1964) made valuable observations on the Lake Turkana population of S. schall. However, a more detailed study of the biology of this species was required because of its importance in subsistence fisheries. S. schall is probably the species most commonly eaten by the fisherman of Lake Turkana and their families. Moreover,since the latter half of 1974, increasing quantities have been smoked in the Longech area by Luo fish traders for export to markets elsewhere in Kenya.

DISTRIBUTION

Synodontis schall is an important species occurring in many of the major river systems in the soudanian region including the following river basins: Nile, Niger, Volta and Senegal (BOULENGER, 1911). The species attains a maximum fork length of 37 cm in Lake Turkanan where it is widely distributed, occurring in 85% of all bottom trawl samples made between May 1972 and July 1974. Greatest numbers were generally caught by bottom trawling and by gillnetting in inshore areas, where the midwater scattering layer was well marked and in close proximity to the lake bed. It was surprising to find that S. schall was not exclusively demersal in distribution, but was caught regularly in midwater trawls and in gillnets set at the surface even in the deepest areas of the lake, far offshore.

Bottom trawling

The mean bottom trawl catch per effort (corrected to the catching efficiency of the two-seam trawl, see page 587) in twelve depth zones was estimated for the Northern, Southern and Central sectors of the lake as shown in Table 10.61.

The Southern sector had relatively lower densities of S. schall than elsewhere. Only in the Kerio-Turkwell area, between 20 and 25 m, was the catch rate higher than the lake average of this depth. In the Northern sector catches in the shallow water of Allia Bay were high in comparison with the remainder of the sector, with peak catches in water of less than 10 m. The environment of Allia Bay, with extensive beds of Potamogeton spp. is atypical of shallow water elsewhere in the lake. Under these conditions S. schall were found to feed largely on aquatic insects and ostracods. Copepods, important food items in other shallow water areas, were absent from the diet of Allia Bay fish (see page 1077)

The distribution of S. schall in the remainder of the Northern sector and in the Central sector were basically similar. Catches declined from inshore areas to the deeper water and few fish were caught below the 40 m contour. Abnormally high concentrations of S. schall were occasionally found in the Omo delta area in the vicinity of the lake water-river water interface. For example, in February 1973 a catch of 240 kg/hr was recorded in 30 m of water at the interface, a value seven times the annual mean for this depth. Exceptionally large numbers of S. schall, with catches as high as 581 kg/hr were sometimes recorded in the Ferguson's Gulf area. Table 10.62 represents monthly data for the 15 to 20 m depth zone of the Ferguson's Gulf area over a period of two years. Peak catches were recorded between January and March in both 1973 and 1974.

Bottom trawling has shown that in all three sectors of the lake S. schall was most abundant in water shallower than 25 m. In the Northern sector (excluding Allia Bay) peak catch rate was recorded in water of 10 to 15 m. Further south, in the Central sector the fish was most abundant in water of 15 to 20 m whilst in the Southern sector maximum numbers were found between the 20 and 25 m contours.

The results show a correlation between the distribution of S. schall in relation to depth and the postion of the midwater scattering layer (see page 597 for details of this layer). In peripheral areas of the lake where the bottom rises above the 20 m contour the scattering layer lies in close proximity to the lake bed and catches of S. schall were generally high. The stomach contents of those fish caught in or just below the scattering layer show that feeding has occurred on copepods and ostracods. Results from plankton surveys(A J D FERGUSON, pers. comm.) however, show that zooplankters are not particularly concentrated in the scattering layer, although densities tend to increase in shallow water.

As mentioned previously (see page 597) the depth of the midwater scattering layer depends to a large extend on light penetration. In the north where water is generally turbid, the upper limit of the layer may be within 2 m of the surface. In the south, water is clearer and the layer may descend to a maximum of 30-35 m. Light penetration has been measured at several stations in the three sectors and the mean depth at which 99% light extinction occurs is given in Figure 10.38 for each of the sectors. The depth at which maximum catch rate occurred for S. schall in the bottom trawl is also included. Peak catch rates occurred at approximately 10 m below the 99% light extinction depth in all three sectors. These results indicate that the distribution of S. schall in inshore areas depends on the depth of light penetration, perhaps through the influence of light intensity on the depth at which the scattering layer occurs. Allia Bay, where S. schall were caught in large numbers above the scattering layer, was exceptional, possibly as a result of the abundance of food other than copepods in this area.

Gillnetting

To examine the association between the scattering layer and the distribution of S. schall, a programme of gillnetting was established in the open lake off Ferguson's Spit between January and June 1974. Fleets of bottom-set gillnets were fished at four stations, chosen for their position relative to the scattering layer. The layer was well marked in this area and its depth was determined by reference to the echo sounder on board R V HALCYON. The approximate position of the scattering layer and depths of the four stations are shown in Figure 10.39 (see also Table 10.63). Mean weights of fish caught in the 2, 3 and 4 inch nets per 24 hour period are given in Table 10.64. Since the gillnets were relatively unselective for the size range of S. schall occurring in the samples, the combined results for the three nets will be considered below.

Station C which sampled within the scattering layer had the highest catch rate of S. schall with a combined mean of 39.4 kg per night for the three nets. The catch was lowest at station A, above the scattering layer, with only slightly higher catches at station B. Below the scattering layer, at station D, catch rates were nearly as high as in station C. These results reinforce evidence suggesting that inshore, S. schall is found in greatest numbers in close association with the midwater scattering layer.

Bottom trawl results (Table 10.61) have shown that below the 20 m contour the catch rate of S. schall steadily declined in the Central sector of the lake. However, evidence from surface-set gillnets indicates that S. schall is not confined to the bottom. Table 10.65 compares the catch rate (kg S. schall/50 yards net/24 hours) of 4 inch (124 mm) gillnets set at the surface, in midwater and at a depth of 73 m on the bottom at an offshore station. The results show that in the deeper water of the lake, S. schall were more common at the surface than in midwater or on the bottom. Since the trawl data proves that S. schall were rare on the bottom in deep water these fish had either migrated away from the inshore areas on feeding forays or were permanent inhabitants of the midwater layer.

Frame trawling

Results from frame trawl catches were in general agreement with gillnet data and indicated that S. schall was not numerous in midwater, except in shallower water where the scattering layer approached the bottom. Data from a series of daytime frame trawl hauls carried out in September 1973 at an inshore and at an offshore station in the Ferguson's Gulf area are presented in Table 10.67. Inshore, S. schall was well distributed from a depth of about 4 m to the bottom. Peak numbers occurred within the midwater scattering layer. At the offshore station the species occurred only in small numbers and was restricted in vertical distribution to the region of the scattering layer at a depth of 8 to 16 m. Further results from frame trawling carried out over a 24 hour period at a station in 24 m of water are presented in Table 10.68. Catch rate is given as numbers of fish caught per 10 minute haul for each depth zone at 5 intervals of time. S. schall were caught in relatively small numbers and the results show that there are no marked trends. However, it may be significant that the only period when S. schall occurred in the top 12 m was during the night, suggesting that a vertical feeding migration may occur.

Beach seining

Larger numbers of S. schall were regularly caught by beach seining within the confines of Ferguson's Gulf. In other areas of the lake the species was caught over a variety of substrates by this method, including gravel and sand. No beach seining was possible on rocky shores but occasional S. schall were caught on rod and line in such areas. These data suggest that S. schall has no preference for a particular substrate although the species was not common in exposed situations on the western shore.

Conclusions

Synodontis schall has a fairly complex distribution in Lake Turkana and, although predominantly a demersal species during the hours of daylight, it also occurs regularly in the midwater scattering layer of the lake. It is found mainly in water less than 25 m deep, with particularly dense concentrations occurring where the midwater scattering layer meets the lake bottom. The depth at which maximum densities of S. schall occur thus varies with the position of the scattering layer which is in turn dependent on light penetration.

GROWTH

Growth studies on Synodontis spp in other areas of Africa have been based on the analysis of vertebral growth checks. BISHAI and GIDEIRI (1965a) found that growth rings in S. schall from the River Nile were laid down annually as a result of breeding and reduced feeding during the flood season. WILLOUGHBY (1974) working on Lake Kainji concluded that vertebral growth checks observed in several species of Synodontis were formed during the breeding season. In Lake Karibia, CHITRAVADIVELLI (1974) working on Synodontis zambezensis and FRANK (1974) working on Synodontis nebulosus, both estimated age with the aid of vertebral growth checks.

Attempts to age the Lake Turkana population of S. schall using vertebrae failed since, although checks were present, no correlation between their formation and age could be established. However, an inspection of length-frequency data revealed that the method of Petersen (TESCH, 1968) for age and growth estimation could be used. Large samples of mature S. schall were regularly obtained by the bottom trawl but unfortunately fish smaller than 15 cm were only rarely caught. As a result growth estimates of immature fish are less reliable than for adults.

Method

Material for age and growth studies was obtained over a 26 month period from regular monthly trawl samples made in the Ferguson's Gulf area at a depth of between 20 and 30 m. Although the bottom trawl caught few S. schall smaller than 15 cm FL it is considered that the gear was probably non-selective down to an appreciably smaller size. This was in fact proved by exceptional samples containing significant numbers of fish as small as 6 cm as demonstrated in Figure 10.40. Thus S. schall probably migrated into the trawl sampling areas on attaining a length of between 15 and 20 cm. It is unlikely that there was any size-dependant escapement of the largest S. schall from the trawl and random samples of the open lake population were probably obtained.

All fish were measured to the nearest cm below fork length and a considerable number were also sexed to enable possible differences in growth rate between males and females to be assessed. Fish caught outside the Longech area have not been included in the growth analysis since the time of peak spawning may have been slightly later in more northerly areas of the lake. Data from other sectors was too scanty to enable separate analysis of growth to be made.

Sexual differences in length frequency distribution

Monthly mean lengths of all males and females caught by bottom trawling in the Longech area between July 1972 and July 1973 have been compared by applying Students t-test, and the results are given in Table 10.74. In most months there was no significant difference, but during March, April and May 1973, and in November 1972 females were significantly larger than males.

The discrepancy noted in March, April and May coincided with the main breeding season. As shown later (page 1069) the proportion of males increased at inshore spawning sites during this time, indicating that they remained on the breeding grounds for longer periods than the females. It is reasonable to assume that the ripest fish were also the largest and their departure from the main population would result in the observed fall in relative size in the regular trawling area. The second discrepancy noted in November 1972 may also be a result of spawning movements since during this period further breeding activity was observed.

Seasonal changes in length-frequency distribution

Since mean lengths of males and females were not significantly different for most of the year, data for the two sexes, covering the period June 1972 to February 1974, have been combined for growth analysis. Length-frequency histograms were plotted for the monthly samples (Fig. 10.41) and examined in sequence. Histograms have been smoothed (moving average a = 3) using Taylor's method (TAYLOR, 1965). Pronounced modes were found to progress from month to month and a general pattern through the year was apparent:

1. From November to May, the length-frequency distribution of fish in the trawl samples was unimodal. Throughout this period the modal length increased regularly each month.

2. In June each year samples were augmented by the influx of smaller fish and the length-frequency distribution became bimodal. This was obviously the result of recruitment of fish smaller than 22 cm into the trawlable position. The length-frequencies of samples obtained between June and November exhibited one of the following distributional patterns:

   (a) Unimodal with the mean length usually greater than 25 cm

   (b) Unimodal with the mean length usually less than 22 cm

   (c) Bimodal in which both length groups of fish were present

   These features are highlighted in Figure 10.42 where length-frequency distributions from three separate samples made in the Ferguson's Gulf area during August 1973 are shown.

3. After September the larger fish became relatively fewer and by October-November the smaller length group was dominant in the trawl catches.

A similar sequence was repeated both in 1972 and 1973 indicating clearly that the recruitment of young fish into the adult population was a regular annual event. The pattern of recruitment suggested that breeding was restricted to a definite season each year. This was confirmed by an anlysis of seasonal changes in maturity to be discussed below (see page 1068). The main breeding season in the Ferguson's Gulf area extended from March to July with a peak in May and mid May is regarded as the 'birthdate' of the population under investigation.

Analyses of growth (see below) prove that the influx of small *S. schall* into the trawling areas during June occurs when the fish are approximately 13 months old. The bottom trawl catches are therefore composed chiefly of 1-group and 2-group fish. The length-frequency histograms suggest heavy mortality in 2-group fish during the period August-November each year which corresponds to the end of the breeding season.

The whereabouts of the main population of 0-group fish is at present unknown. Exceptionally, during October and November, they may occur in trawl samples. Figure 10.40 represents a sample taken in November 1973 from a depth of 16 m where in addition to the usual size group of fish over 20 cm in length, a group of smaller fish with a modal length of 10 cm appears. Small numbers of *S. schall* of 2-15 cm also occurred in shore seine catches particularly in more northerly areas of the lake. It is possible that 0-group *S. schall* live mainly inshore within the 5 m contour.

Estimates of growth rate

As a preliminary to the calculation of monthly growth increments, the mean lengths of fish in each year class were calculated for all stations of sufficient sample size. Since the majority of samples had a unimodal size distribution this presented no problem. In samples where the length distribution was bimodal the peaks of the two year classes were separated by eye and the means of each length group were then calculated. Table 10.70 provides additional information on the 1971 year class. Stations which provided the routine samples shown in the monthly histograms (Fig. 10.41) are marked with an asterisk. Each of the routine samples has been compared with samples from other trawl stations in the Longech area made during the same month. Results of t-tests showed that only at 4 out of 15 stations were mean lengths of the additional samples significantly different to the routine monthly samples ($P = < 0.05$). All monthly data from the 1971 year class was therefore combined to give the mean lengths presented in Table 10.71. Results for the 1970, 1972 and 1973 year classes were treated in a similar way and are aslo included in Table 10.71.

The mean lengths (Table 10.71) compare well with values obtained for the corresponding age group during the appropriate month in other years indicating that a regular seasonal pattern of spawning, recruitment and growth occurred. In Table 10.72 data for the four year classes has been combined to give mean observed lengths up to an age of 29 months.

Mathematical expression of growth

A von Bertalanffy growth curve has been fitted to the length for age data shown in Table 10.72 using the following expression:

$$l_t = L_\infty \ (1 - e^{-K(t-t_o)})$$

where L_∞ is the asymtotic length, K is a measure of the rate at which L_∞ is approached, l_t the length at any age t and t_o is a constant.

The Walford plot showing the relationship between l_t and $l_t + 2$ months is presented in Figure 10.43. The following values were obtained for the growth parameters of S. schall:

$$L_\infty = 32 \text{ cm}$$

$$K = 0.735$$

$$t_o = -0.175 \text{ years}$$

The estimate of L_∞ agrees well with field observations where the largest fish caught by trawling was a female of 35 cm and only 0.4% of all fish in the trawl samples exceeded 32 cm. The value of -0.175 years for t_o indicates a birthdate in mid-March, two months earlier than expected.

The growth parameters were used in conjunction with the von Bertalanffy growth equation to estimate length for age and observed lengths are compared with estimated lengths in Table 10.73 for the first three years (see also Fig. 10.44).

There is close agreement between the estimated and observed lengths indicating that the application of the von Bertalanffy growth equation is appropriate.

Age composition of trawl catches

The relative abundance of four year classes of *S. schall* in the monthly trawl samples between July 1971 and February 1974 are shown in Figure 10.45. 0-group fish were generally absent from the trawl catches. Recruitment into the trawlable population occurred at an age of approximately 13 months and fish of 1-group dominated the trawl catches. Relative numbers of 2-group fish declined, probably as a result of heavy mortality during the spawning and post spawning period. Individuals older than about 30 months were tco few in number to be distinguished in length frequency histograms. Older fish almost certainly occurred in trawl samples but it proved impossible to separate them from 2-group fish. Trawl catches between December and May each year consisted of a single year class, the 1-group fish.

Length-weight relationship

Observations on the length-weight relationship in *S. schall* are based on data from fish caught in routine monthly trawl samples from the Longech area. During the two years sampling period approximately 1,000 *S. schall* were weighed. The relationship between length and weight can be represented by the equation:

$$\log_{10} \text{weight} = \log_{10} a + b\ (\log_{10} \text{length})$$

where a is the intercept of the regression line of log weight on log length, and b is the regression coefficient. Using the above expression, the length-weight relationship for mature and immature fish were estimated and the slopes of the regression lines were compared (Table 10.74). The results show that in *S. schall* there is no significant sexual difference in length-weight relationship and no difference between mature and immature fish. Data was therefore combined and the relationship between length and weight for all *S. schall* may be represented by the following equation:

$$\log_{10} w = 3.001\ (\log_{10} l) - 1.679$$

or

$$w = 0.0209\ l^{3.001}$$

Estimated values of mean weight for age are given in Table 10.75 for the first three years of growth.

Discussion

Age determination during the present investigation was based on the analysis of length-frequency distributions in the absence of seasonal growth rings on skeletal structures. The Lake Turkana population appears to have a considerably higher rate of growth compared with *S. schall* studied elsewhere in Africa (Table 10.76). Thus in Lake Kainji WILLOUGHBY (1974) estimated that fish grew to a length of only 14.5 cm in 3 years, and matured at a length of only 12-14 cm (cf 22 cm in Lake Turkana).

BISHAI and GIDIERI (1965a) estimated different growth rates for males and females in the River Nile and found that growth was more rapid during the third than in the second year. WILLOUGHBY (1974) suggested that an incorrect interpretation of growth rings might explain this anomaly.

High, relatively uniform temperatures may explain the enhanced rate of growth in the Lake Turkana population compared with elsewhere.

BREEDING

Routine data on sex and gonad condition were collected at each trawl station. Additional information was obtained from gillnets and beach seines. Seasonal changes in maturity and sex-ratio have been studied and the time and place of breeding has been established.

Maturity stages

The sexes in *S. schall* are easily distinguishable since mature and maturing males have noticeably villose testes. The presence in males of a muscular protruberance or papilla anterior to the urinogenital opening enabled sexes to be separated externally. The papilla, generally less than 1 cm in length, becomes suffused with blood during spawning and on males caught at the spawning grounds it was well vascularised and pinkish in colour. WILLOUGHBY (1974) noted that the papilla on *Synodontis* spp. in Lake Kainji enlarged slightly during the breeding season.

Nikolsky's classification of gonad condition (NIKOLSKY, 1963) was used to describe maturity stages in *S. schall*.

Females

Stage 2 Resting or recovering: ovaries sac shaped, usually less than 5 cm in length. Translucent in maturing fish, but pink in post-breeding individuals.

Stage 3 Maturing: ovaries yellow in colour, extending more anteriorly and of greater cross-sectional area. Ovary wall semi-transparent and slightly vascularised with small blood vessels visible. Developing eggs 0.4 to 0.8 mm in diameter.

Stage 4 Ripe: ovaries up to 8 cm in length, filling most of body cavity. Eggs clearly visible through well vascularised ovary wall. Eggs opaque white or yellow, occasionally greenish, and up to 1.0 mm in diameter.

Stage 5 Ripe-running: eggs 1.2 to 1.4 mm in diameter, translucent grey in colour. Slight pressure on belly causes extrusion of eggs.

Stage 6 Spent: ovaries flaccid in appearance and pink in colour with residual eggs few in number.

Males

Stage 2 — Resting or recovering: testes a pair of thin strands, translucent grey in colour. In virgin males lateral edge of the testes slightly scalloped. In recovering males testes flattened, villose protrusions clearly visible. Anterior villi up to 2 mm in length, larger and more vascularised than posterior villi.

Stage 3 — Maturing: villi more prominent, up to 15 mm in length and 2 to 3 mm wide. Anterior villi translucent yellow, posterior opaque pink.

Stage 4 — Ripe: anterior villi whitish in colour, sperm released when cut and squeezed.

Stage 5 — Ripe-running: anterior villi turgid in appearance. When cut copious milt produced. Posterior villi pinkish grey in colour and less turgid.

Size at maturity

Data relating to size at maturity, based on material from trawl samples in the Longech area are presented in Table 10.77. Males started maturing at 16 cm and 50% had reached maturity at a length of 19 to 20 cm. The smallest observed ripe male (stage 4) had a fork length of 19 cm. Maturation in females commenced at 17 cm, slightly larger than was observed in males, and 50% had reached maturity (stage 3) at a length of between 20 and 21 cm. The smallest ripe female measured 19 cm.

The length for age estimates presented above indicate that 25% of males and 5% of females mature at the end of their first year and the remaining fish mature soon afterwards, early in their second year of life.

Table 10.78 compares the size at first maturity and breeding of S. schall in Lake Turkana with populations in the River Nile (BISHAI and GIDEIRI, 1968) and in Lake Kainji (WILLOUGHBY, 1974). Maturation and breeding clearly occurs at a much larger size in Lake Turkana, probably a result of their more rapid growth rate (see page 1065). Relatively larger size at maturity has been noted in other species inhabiting Lake Turkana. HOPSON, J (1975) showed that Alestes baremose grow more rapidly and matured at a larger size in Lake Turkana than in Lake Chad and HOPSON, A J (1975a) made similar observations on populations of Lates niloticus in the two lakes.

Seasonal changes in maturity

Central Sector

Seasonal changes in maturity were examined with the aim of establishing the time and duration of spawning. The majority of data came from the Central sector and results are presented in Tables 10.79 and 10.80. Ripe males and females were caught during all months of the year, and the proportion of ripe females over 20 cm did not fall below 10%. Fewer ripe males were caught and gonadial activity was confined mainly to two periods, May-June and September. A peak spawning season was not apparent in samples from the main lake.

However an investigation of the changes in maturity stages of fish caught inshore in the vicinity of the spawning grounds showed that S. schall had a definite breeding season. WORTHINGTON and RICARDO (1936) suggested that Ferguson's Gulf may have been one of the breeding sites of S. schall since the majority of ripe fish examined during the Cambridge Expedition came from here. The following evidence from the present study confirms that Ferguson's Gulf is a major spawning area:

(1) The occurrence of large numbers of ripe-running fish in each seine at certain times of the year.

(2) An increase in the proportion of males during this time.

(3) The occurrence of S. schall eggs on the floor of the Gulf.

(4) The capture of females in a spent condition.

Spawning grounds were located in water of less than 1 m depth, in areas where freshwater run-off entered the lake after heavy rain. Seasonal changes in conductivity and turbidity, associated with the flooding, were noted in these areas and both factors may be important in inducing S. schall to breed. Flooding brought about a fall in conductivity, from the usual level of 3,700 µS/cm to as low as 2,000 µS/cm at the mouths of temporary rivers entering the gulf. Turbidity resulting from the suspension of plant debris and soil particles derived from the land was also much greater.

Male and female S. schall with ripe-running gonads (stage 5) were caught in large numbers with beach seines under such conditions. Table 10.81 examines the seasonal changes in gonad condition of all males and females larger than 20 cm caught in Ferguson's Gulf. Peak maturity was reached in May, with 74% of females, and 66% of males in a ripe or ripe-running condition. In the main lake ripe and ripe-running fish never reached such high proportions. A second but less pronounced peak of spawning activity also occurred in October when 25% of females were ripe. Both these peaks of activity coincided approximately with the two periods of the year when rainfall and hence flooding was most likely. As discussed earlier (see page 31 and Table 10.2) 60% of the rain recorded at Ferguson's Gulf over a period of five years fell between March and June, with October and November accounting for a further 15%.

Results from the main lake do not conflict with the conclusions drawn from the spawning area in Ferguson's Gulf, although differences are evident. As noted above, in the Central lake sector an appreciable percentage of the population were ripe in all months of the year. It is perhaps an advantage in an area where rainfall is rather unpredictable that a certain percentage of the population should be ripe at all times so that spawning can take place whenever the necessary conditions arise. During the principal rainy season, March to June, ripening fish probably leave the main population and move onto the spawning grounds, thus accounting for the absence of enhanced gonadial activity between March and July in samples from the main lake.

Northern Sector

Results from the Northern and Southern sectors of the lake are incomplete since it was not possible to sample these areas every month. Limited data from the north (Table 10.82) indicate that spawning was more continuous over the period April to November than was noted in the Ferguson's Gulf area. In the large samples obtained in April 1973, over 80% of the females larger than 20 cm were ripe. The proportion of ripe male fish was low, probably due to their concentration on the actual spawning sites elsewhere. However data from metre townet samples taken in shallow open water within 10 km of the Omo delta (Table 10.83) showed that large numbers of S. schall post larvae were present during the period June to October. No ripe males and only a few ripe females were noted in September 1973 (Table 10.82) but over 50% of both males and females were ripe in catches made during November 1972, indicating that circumstances varied from year to year.

Southern Sector

Data from the south is presented in Table 10.84. The results indicate that as in the other sectors, spawning occurred in May and June. In June 1972 and May 1973 more than 40% of the fish examined had ripe gonads. Results from October 1973 however indicate that unlike more northerly areas, breeding activity was at a minimum in the Kerio-Turkwell area. The Kerio river flooded frequently between April and October and peak spawning in S. schall populations near the river mouth probably occurred during the earlier months of the flood season.

It is concluded from gonadial data that peak spawning in S. schall occurs between late March and June in the Longech area, during the main rainy season. In the Northern sector breeding activity is more prolonged and may continue until October and November.

Spawning sites

There is ample evidence to show that S. schall not only breeds in inshore areas of the lake near the mouths of rivers, but also enters rivers to spawn upstream. Post larvae of S. schall were caught at the mouth of the River Kerio in July 1972. The small fish ranged from 11 to 15 mm in length, and from laboratory observations on larval growth (see below) they were approximately two weeks old. After hatching some distance upstream, the larvae probably remained in the numerous channels of the delta, gradually drifting downstream in the current. R R McCONNEL (pers. comm.) of the Kenyan Fisheries Department has observed S. schall several kilometres up the River Kalokol, a minor river which usually flows into Ferguson's Gulf for a period of only two or three days after heavy rain. Small numbers of S. schall may therefore enter many of the similar small rivers feeding into the lake during temporary flooding and under favourable conditions, breeding probably occurs. Unfortunately it was not possible to obtain samples from the valley of the River Omo which is probably of major importance as a spawning area.

Synodontis schall is not entirely dependent on flood conditions for spawning as shown by the breeding population in Crater Lake A on Central Island. Nets set in this lake caught several S. schall, the smallest measuring 10.6 cm FL. Since this lake has been separated from the main lake for at least 70 to 80 years spawning must have occurred within the crater lake itself. Here conditions resembling flooding were unlikely, since rain water run-off would have come from a relatively small area. Changes in conductivity and turbidity would have been minimal and yet breeding had evidently occurred.

It is clear from the present study that S. schall has a wide range of tolerance to environmental conditions at the spawning site. Breeding may occur during the flood period either in the actual rivers or in shallow inshore areas influenced by flood water entering the lake. There is also evidence to show that isolated populations of S. schall may breed successfully in small lakes away from the influence of large-scale flooding.

Stimulation of breeding

Breeding in S. schall is clearly related to the influx of freshwater into the lake under flood conditions. The specific factor or combination of factors which stimulate breeding is uncertain, but it may include a fall in conductivity, an increase in turbidity or the inflow of petrichor (see page 50) into the lake. The commencement of spawning in the Ferguson's Gulf area coincided with rainfall and breeding sites were situated close inshore in the vicinity of fresh water run-off entering the lake after heavy rain. Elsewhere in Africa S. schall also breeds during the rainy or flood season. BISHAI and GIDEIRI (1968) reported that in the Nile S. schall bred between July and October while the river was flooding, and in Lake Kainji the initial appearance of maturing specimens of S. schall could be linked with the first local rainfall (WILLOUGHBY, 1974).

Sex-ratios

The ratio between numbers of male and female S. schall caught by bottom trawling in the Central sector is compared in Table 10.85. The sex-ratio, expressed as numbers of males per 100 fish is given for each cm group in the length range 15 to 34 cm. The results show that below 21 cm there was a slightly greater number of males than females. The proportion of males declined progressively at lengths over 21 cm. In Table 10.86 the ratio has been examined on a monthly basis in the 20-24 cm and 25-29 cm length groups. Variation was noted from month to month but no definite relationship between the peak spawning period (March to June) and relative numbers of males was observed.

Within Ferguson's Gulf the proportion of males was somewhat higher than in the main lake. This is demonstrated for mature fish in Table 10.87. Although there was no marked increase in the proportion of males in Ferguson's Gulf as a whole, during the breeding season the ratio was observed to rise to as high as 11:1 on the actual spawning sites. The higher proportion of females in samples from the main lake may indicate that males spend a greater period of time in the vicinity of the breeding grounds. However a higher male mortality is also likely since there was no apparent increase in the proportion of males in the main lake after the breeding season.

These results are in agreement with the observations of WILLOUGHBY (1974) and BISHAI and GIDEIRI (1968) who found significantly more females than males in Lake Kainji and the River Nile.

Condition

Values for the expected weight of all weighed fish were calculated using the regression equation for the length-weight relationship derived previously (see page 1066).

$$w = 0.029\ l^{3.001}$$

These results were subsequently used to obtain a condition factor (k) for each fish by substituting in the following equation:

$$k = \frac{w_o}{\bar{w}} \times 100$$

where w_o is the observed weight and $\bar{w}$ is the expected weight derived from the above length-weight regression equation. Mean monthly condition factors for all fish larger than 20 cm caught in the Longech area are given in Table 10.88 and presented graphically in Figure 10.46. Although the condition factor was almost always slightly higher in females than in males the seasonal pattern is similar in the two sexes with the exception of samples for May where a marked fall in condition was noted only in males. Condition was at a seasonal peak between September and November. The peak corresponded to the recovery period at the end of the breeding season. Relatively low values between December and March may be due to the replacement of 2-group fish in the trawl samples by 1-group fish which had not yet built up reserves of fat. The increase in the condition of females during the breeding season between April and June is probably the result of the additional weight of the ovaries.

WILLOUGHBY (1974) found that in the population of S. schall in Lake Kainji no significant variation occurred in the mean condition factors of two consecutive months or between the maximum and minimum levels of the condition factors. However, he did note that a reduction in fat content occurred in adult fish during the course of the breeding season.

Fecundity

Fecundity studies are based on data from fish caught in March 1974 by beach seining in Ferguson's Gulf. Gonads from ripe S. schall were collected and preserved in Gilson's fluid. Methods for the estimation of egg numbers were similar to those used for B. bayad (see page 1034) and described by BAGENAL (1968).

In Figure 10.47 egg number has been plotted against fork length. There is a wide scatter of points and considerable variability in fecundity between fish of the same length. A logarithmic transformation of the data was carried out and regression values estimated. However, the relationship between log length and log egg number showed very little correlation (correlation coefficient = 0.195) and regression values are not given. Assuming that the subsampling method used for estimating egg numbers was statistically sound, which is a reasonable assumption judging by results from Bagrus bayad (see above), the number of eggs appears to vary considerably at a given length. It was possible that since fish for this study were collected on or near the breeding grounds, partial release of eggs had already occurred. There was no evidence, however, to suggest that eggs were released in batches. Eggs in each fish appeared to reach roughly the same degree of ripeness at the same time and partially spent fish were never caught. On the contrary spent females caught near the spawning grounds had flaccid gonads with only few ripe eggs remaining in the ovary. Once the release of eggs commences it appears that all eggs are shed and gonads used for the present fecundity study probably had their full complement of eggs.

Synodontis schall is therefore moderately fecund, with fish larger than 24 cm FL producing more than 16,000 eggs. The highest number of eggs recorded in the present study was nearly 24,000 for a fish of 25.8 cm.

WILLOUGHBY (1974) also found a wide range in the fecundity at a given length in S. schall from Lake Kainji, and was unable to establish a fecundity-length relationship.

EMBRYOLOGICAL AND LARVAL DEVELOPMENT

Introduction

Although siluriform species are common throughout Africa, comparatively few details of the embryological and larval development of this important group of fish are known. GREENWOOD (1955) has briefly described the larval development of Clarias mossambicus Peters from Lake Victoria. More details are given by LAKE (1967b) on the larval development of the Australian freshwater catfish Tandus tandanus (Mitchell). Larval development in Synodontis schall proved to be quite similar to this fish, but there were some important differences which may be attributed to the adaptation in Synodontis of laying eggs in fast flowing but short lived rivers.

Artificial fertilisation of S. schall eggs was successfully accomplished during the present investigations and larval development was followed up to five days after hatching.

Methods

Live, ripe fish from the spawning areas in Ferguson's Gulf were taken to the laboratory and eggs were stripped from the females. The eggs were placed, in batches of 20, into 10 cm diameter petri dishes containing tap water. A portion of the anterior section of the testes of a ripe male was then agitated in the water. After one hour most of the water in the petri dishes was replaced with fresh tap water and any remaining pieces of testes removed. The tap water was pumped from the River Kalokol and contained no chlorine.

A variety of treatments for rearing were tried. Mortality was lowest in petri dishes where the embryos were covered with approximately 1 cm of water. The water was changed every 12 hours and any infertile or moribund eggs were removed. Temperatures varied from 25 to 28.5°C. Measurements of embryos and larvae have been made on living material removed with the aid of a pipette and anaesthetised in a dilute solution of MS 222 Sandoz.

Development was rapid and the eggs hatched within 24 hours of fertilisation. Larvae were actively swimming and feeding within 3 days of hatching.

Development of embryos and larvae

Table 10.89 gives the approximate time taken from fertilisation to attain each developmental stage. A selection of stages is illustrated in Plate 10.1.

Egg stage

The ripe eggs of *S. schall* vary in diameter from 1.2 to 1.4 mm and are translucent yellow in colour. Contact with water causes the outer gelatinous covering to swell and in 20 minutes the diameter of the eggs has increased to about 2.2 mm. The outer surface is initially smooth, but within 30 seconds of contact with water it assumes a sculptured appearance (Plate 10.1A). Eggs are slightly adhesive and cannot be dislodged from the bottom of the petri dish by gentle agitation. After approximately 2 hours the adhesive quality is lost but eggs are denser than water and remain in contact with the bottom of the dish. The yolk mass, 1.0 to 1.2 mm in diameter, fills most of the perivitelline space.

Development of the embryo

Within one and a half hours of fertilisation the first blastomere has formed, enclosing one third of the yolk, as shown in Plate 10.1B. The blastomere divides rapidly (Plates 10.1C and 10.1D) and a blastodermal cap is formed within four hours of fertilisation. During the blastula stage the chorion becomes elliptical in shape measuring 1.3 mm by 1.0 mm. Gastrulation commences an hour later and the head and tail folds are visible eight hours after fertilisation (Plate 10.1E). Over the next 12 hours head and tail folds become prominent and somites develop. Plate 10.1G shows an embryo 20 hours after fertilisation. The caudal region is free from the yolk sac and the auditory capsule, heart and somites are clearly visible. Occasional lateral movements of the tail occur. Immediately before hatching the embryo is 3.00 mm in length and lies with the caudal region curving ventrally below the body. In the late embryonic stages, two or three hours before hatching, the chorion increases in size to a mean diameter of 1.6 mm.

Larval development

Hatching takes place approximately 22 to 24 hours after fertilisation. Just before hatching the embryo becomes extremely active and appears to be pushing against the perivitelline membrane and outer sheath, through which it eventually breaks (Plate 10.1H). Newly hatched larvae have a yolk sac approximately 1 mm in diameter. Blood flow is visible in the caudal region and the heart beats approximately twice per second. There is at first no pigmentation (Plate 10.1I) but during the next 24 hours melanophores develop in the optic cup and both dorsally and ventrally on the fin fold (Plates 10.1J and K). Young larvae swim actively generally, with the yolk in contact with the bottom of the dish.

Two days after fertilisation the yolk sac is no longer rounded and the buds of developing barbels are visible (Plate 10.1L). In the following 24 hours the barbels develop rapidly, the anterior margin of the maxillary barbel becoming crenellated. Pigment forms in the head region and the blood supply to the gills is visible. Approximately 93 hours after fertilisation the yolk sac appears to be empty, and four and a half days after fertilisation the first signs of food are visible in the gut (Plate 10.1M).

The post larvae swim both in contact and away from the bottom. Six days after fertilisation the larvae measure approximately 6.8 mm in length (Plate 10.1N) and caudal and pectoral fin rays are present.

Discussion

Although S. schall breeds in Lake Turkana this is probably a relatively recent adaptation. The spawning runs observed in the Kerio river are perhaps more typical of the breeding behaviour of this fish. In Lake Turkana S. schall may take advantage of any river flow of sufficient volume to leave the lake and to migrate upstream for the purpose of breeding. With the exception of the River Omo, Lake Turkana is fed by temporary rivers which rarely flow for more than a week at a time and more typically for only days or hours. In most cases the current is strong and the substrate generally coarse with little or no vegetation. In such ephemeral rivers there is an obvious danger of eggs and larvae being trapped in pools upstream from the lake.

The adhesive quality of the eggs may help to overcome the problem of eggs being swept away before being fertilised. BISHAI and GIDEIRI (1958) have observed Synodontis schall spawning in aquaria. Just prior to egg release fish were seen to be digging the mud with their pectoral spines after which eggs and milt were released. The slight adhesiveness of the eggs might enable them to stick to the bottom thus delaying their flow downstream and give them a better chance of being fertilised. The urino-genital papilla on males may help with the more accurate placing of sperm onto the eggs rather than broadcasting them over a wide area.

With river flow usually restricted to a few days or hours it is clearly not an advantage for the eggs to remain in one place too long, because of the danger of stranding. This is probably why only light, temporary adhesion is present, so that a short time after fertilisation eggs are free to move downstream with the river flow.

Various features of the embryological and larval development of Synodontis schall enable the successful downstream movement of fertilised eggs and larvae possible. The swelling of the outer egg covering may have two functions. Firstly the larger size may prevent eggs from becoming trapped between sand grains, thus lowering the risk of stranding. Secondly the outer covering may offer physical protection as the egg is swept downstream.

The rapid development of the embryos and early hatching are further possible adaptations which enable successful downstream movement. Larvae were observed to swim actively in the laboratory and although movement was usually in contact with the bottom, the young fish occasionally rose towards the surface. In a fast flowing river such a vertical movement would bring larvae into stronger currents which would result in more rapid movement downstream and reduce the possibility of stranding.

Synodontis schall is therefore adapted to an early life spent in rapid flowing but short lived streams and rivers. The rate of development is different to that of Tandanus tandanus, an Australian catfish which also breeds in response to flood conditions (LAKE, 1967b) but in water of a less ephemeral nature. Parent fish build nests and a rapid rate of development is less important. Noticeably absent from the eggs of T. tandanus is the protective outer covering which is so prominent in S. schall. Larval development is slower and hatching occurs 151 hours after fertilisation. At this age larvae are at approximately the same stage of development as newly hatched S. schall only 24 hours old.

Features of the egg and larval behaviour of the cyprinid Labeo victorianus (Boulenger) are in some ways similar to those of S. schall. Labeo victorianus migrates up the affluent rivers and streams of Lake Victoria (FRYER and WHITEHEAD, 1959) and both fish have similar spawning habits. The developing cyprinid embryo is protected by the swelling of the vitelline membrane, not by a gelatinous sheath as in S. schall, but the adaptive value is probably the same. Larval behaviour in the two species is also similar, both swimming actively on the bottom with occasional sorties into the midwater layers.

In the Turkana basin, Synodontis schall has become more lacustrine, with breeding no longer confined to rivers (see page 1070). Early development which seems to be well adapted to ephemeral riverine conditions might not be so advantageous in the lake. However, S. schall is extremely abundant and the change to spawning in the lake has not apparently created any major problems for egg development. The inshore area where breeding now occurs is to some extent similar to a riverine environment since there is water movement, especially when onshore winds are strong.

FOOD

The food and feeding habits of Synodontis schall have been investigated in detail elsewhere in Africa. BISHAI and GIDEIRI (1965b) reported that the population inhabiting the Nile at Khartoum fed on a variety of food items ranging from insect larvae to diatoms. WILLOUGHBY (1974) provided information on the Lake Kainji population which also has an extremely varied diet. In Lake Turkana WORTHINGTON and RICARDO (1936) found that S. schall was omnivorous and results from the present survey confirm that the diet includes a large number of food categories.

Method

Observations on the feeding habits of S. schall are based on data collected from 1,200 fish caught in all areas of the lake. The majority were from bottom trawl samples, but gillnetting and beach seining provided data from inshore areas, such as Ferguson's Gulf, where trawling was not possible. All stomachs were preserved in 5% formalin and examined in the laboratory with the aid of a microscope. The relative volume of each food item was estimated using the points system described previously for B. bayad (see page 1035).

Food categories

Crustaceans formed the major part of the diet. Ostracods (including Megalocypris brevis Sars, Darwinula stevensoni (Brady and Robertson) and Limnocythere africana Klie) and copepods (Tropodiaptomus banforanus Kiefer, Mesocyclops leuckarti Claus and Thermocyclops hyalinus Rehberg) were the most common and occurred in the stomachs of fish from all depths of the lake. Less widespread were prawns (Caridina nilotica and Macrobrachium niloticum) recorded in deeper water and Cladocera (including Diaphanosoma excisum Sars and Hyalodaphnia barbata Weltner) confined to more inshore areas.

Insects were the second most common food category. Corixids (Micronecta ras Hugh), notonectids (including Anisops worthingtonia Jaczewiki) and Ephemeroptra (Povilla sp A and Caenis sp) occurred mainly in water of less than 20 m. Chironomids, of which 20 to 30 species have been identified in the lake, were recorded from all depths. Trichoptera and various terrestrial insects (including Coleoptera) were occasionally present in shallow water.

Gasteropoda were frequently found in the stomachs of fish inhabiting water deeper than 40 m. The most common was Cleopatra pnothi followed by Gabiella rosea and Melanoides tuberculata.

Fish, especially Alestes spp., were preyed on by larger S. schall. Barbus cf anema, Tilapia spp., Lates longispinis and Engraulicypris stellae were also included in the diet. Scales of Lates niloticus and Barbus bynni were common in the stomachs of fish from deep water.

Hydracarina, vegetable matter, algae and diatoms were only occasionally eaten.

Food in relation to depth

Diet was found to vary most markedly with depth. Results based on material obtained by bottom trwling in the main lake are analysed in Table 10.90 for six depth zones. Data collected in Ferguson's Gulf and Allia Bay by beach seining and gillnetting are also shown. From these results the following generalisations may be made concerning the food of S. schall in the main lake.

(a) Inshore, in water of less than 5 m, insects, particularly chironomid larvae and corixids, and crustacea (ostracods and copepods) were of roughly equal importance and together contributed over 75% of the food eaten. Alestes spp. made up most of the remainder of the diet.

(b) In water of moderate depth, between the 5 and 40 m contours, crustacea contributed between 60% and 83% of the food. Ostracods and copepods were still the principal crustaceans, but Cladocera and Caridea were also included. Few chironomids were eaten in this depth zone, and insects were of less importance than inshore. Alestes spp. continued to be a common food item.

(c) In water deeper than 40 m where relatively few S. schall were caught, gasteropods were the most important food, followed by Crustacea. The eating of fish scales was confined to water deeper than 60 m.

Whilst the diet of S. schall inhabiting the sheltered water of Ferguson's Gulf showed affinities with those caught in the inshore area of the lake, fish from Allia Bay had a markedly different diet with insects, principally corixids and chironomids, forming 51% of the food eaten. Allia Bay was the only area of the lake where copepods were not recorded in the diet.

Diet with relation to size

In all size groups of S. schall ostracods and copepods together contributed at least 60% of the food eaten. The proportion of chironomids and fish however was dependent on predator size and changes in diet with increasing size are examined in Figure 10.48. Results are based on data collected from fish caught by bottom trawling in the main lake. In the 15 to 19 cm length group fish were virtually absent from the diet whilst in the largest length group 25% of the points were allocated to this food category. Chironomids showed a reverse trend and were common in the smaller length group and absent from fish larger than 30 cm.

BISHAI and GIDEIRI (1965b) similarly found that food consumed by the Nile population to some extent depended on predator size and the larger S. schall ate a greater proportion of fish.

Diel feeding rhythms

Feeding and activity in S. schall was found to follow a well defined daily pattern. This is demonstrated in Table 10.91 where results from a 24 hour gillnet station maintained in Ferguson's Gulf are presented. Four inch gillnets, which fished the entire water column from surface to bottom, were lifted and fish removed at the end of six time phases; dusk, late evening, early morning, dawn and morning. Both stomach fullness and catch rate varied considerably during the 24 hour period (Fig. 10.49). Peak stomach fullness was observed in the dawn and morning sample when a mean of 6 points per fish were recorded. In the afternoon little feeding apparently took place and stomachs were more than three-quarters empty. Following a short burst of feeding at dusk, stomach fullness declined further to a minimum in the late evening. Catch rate followed an identical pattern and it is evident that increased feeding resulted in enhanced catches. Over 80 S. schall were caught per hour at dawn, coinciding with the time when stomach fullness also reached a peak. During the morning, although stomachs remained relatively full, catches declined dramatically which indicates that this was a rest period. Catch rates increased slightly at dusk, coinciding again with the rise in stomach fullness, but subsequently declined during the night.

Variation in the proportion of the three most common food items eaten during the six time phases are given in Figure 10.50. While the proportion of ostracods remained fairly constant, copepods and chironomids were clearly preyed on at different times during the 24 hour period. At night chironomids accounted for between 45% and 75% of all food, while copepods were preyed on mainly at dawn and during the morning. Changes in the diet during the 24 hours are probably associated both with the relative availability of food items and changes in the behaviour pattern of S. schall. During the night the high proportion of chironomid larvae in the food indicates that S. schall is feeding on the bottom. The marked change in diet to copepods which occurs at dawn suggests that at this time there is an increase in feeding activity in the midwater layers and at the surface.

Discussion

BISHAI and GIDEIRI (1965b) reported that in the River Nile S. schall feeds principally on bottom fauna including insect larvae and pupae, annelids, nematodes, crustaceans and lamellibranchs. Fish were also eaten, especially by the larger length groups, indicating that feeding was not solely confined to the bottom. WILLOUGHBY (1974) has examined the relative buoyancy of Synodontis spp. inhabiting Lake Kainji, and found that not all species were confined to bottom living, there being some better adapted to surface and midwater feeding. He found that Synodontis schall occurred mainly on the bottom and had a diet of humus, insect larvae and nymphs, and plant matter.

In Lake Turkana, where there is no competition from other Synodontis spp. which are more specialised in surface and midwater feeding, S. schall was not restricted to a diet of benthic forms. It fed actively on Alestes spp. and on copepods and it was also commonly caught in surface setgillnets. The Lake Turkana population is obviously very versatile with regard to feeding habits and is consequently able to live in a wide variety of habitats at all depths.

THE FISHERY FOR Synodontis schall

Prior to 1973, Synodontis schall was of no importance in the commercial fisheries of Lake Turkana, since on account of its small size it was unacceptable in a salted and sun dried form at the co-operatives. However the species has probably always been important in the subsistence fisheries of the lake. BAYLEY (1975) estimated that S. schall formed 25% of the fish eaten by the inhabitants of the Kalokol area.

In 1973 Luo fish traders started smoking fish including S. schall for sale in markets elsewhere in Kenya and the species is now of commercial value. No precise records are available for quantities of smoked fish, since this branch of the fishery is not controlled by the co-operatives. However, BAYLEY (1975) estimated that in 1974 approximately 122 tonnes (fresh weight equivalent) of smoked S. schall were exported. This constitutes 20% of the total weight of smoked fish and an increase from 8% in 1973. The steady increase in the importance of S. schall as part of the trade in smoked fish may be limited in the future by shortage of fuel for the smoking kilns.

The trawl survey (see page 590) has shown that S. schall occurs mainly inshore in areas easily reached by light fishing craft. Gillnets of a smaller size than are used at present have proved to be the ideal fishing method, and catch rate is highest at depths where the midwater scattering layer meets the lake floor (see page 590). In the Longech area this lies between the 15 and 25 m contour for much of the year, slightly deeper than the inshore gillnetting areas of the Turkana fishermen. Catches of S. schall could be increased, therefore, by setting nets of smaller mesh size slightly further offshore. Appendix 10C gives the gillnet selectivities of the fleet of nets used during the present survey. Since the majority of S. schall mature at sizes greater than 19 to 20 cm (see page 1068) it would be inadvisable to use nets of smaller than approximately 4 inch stretched mesh. In 4 inch nets 17% of S. schall were 20 cm or smaller, compared with 37% in 3 inch nets. However under present conditions the encouragement of a fine net fishery for S. schall would be contrary to conservation measures urgently required to protect other commercially important species such as Labeo horie and Barbus bynni. Nets of 4 inch mesh would catch juveniles of these species in considerable quantity. BAYLEY (1975) has recommended that regulations should limit the minimum mesh size for gillnets to 6 inches.

Experimental fishing has revealed that S. schall is also caught in large numbers in surface gillnets in water of 25 m depth (see page 623). Labeo horie and Barbus bynni were virtually absent from these nets, the catches being composed almost entirely of Alestes baremose, Hydrocynus forskalii and S. schall (see Chapter 8, page 621). Nets of 3½ inch mesh caught S. schall with a mean length of 25.2 ±2.3 cm and would be commercially successful for this species. Before fishing could commence in the surface waters of the lake with 3½ inch nets however legislation would have to be implemented to prevent them being set on the bottom in water shallower than 25 m. This would be a difficult law to enforce for a number of reasons, and at the present time the development of a surface fishery for *S. schall* should not be considered.

Thus although the trawl survey shows that *S. schall* is potentially one of the most important fish in the lake, a large scale expansion of the exploitation of this species would conflict with policies for the conservation of stocks of large fish.

SYNODONTIS FRONTOSUS

MANN (1964) reported that four specimens of *Synodontis frontosus* ranging from 18.5 to 29 cm FL were caught in small mesh gill nets at the mouth of Ferguson's Gulf. The only previous record of this fish in the lake was from the NE end at Galeba collected by ZAPHIRO and McMILLAN (BOULENGER, 1911). During the present survey all *S. frontosus* examined were caught in the River Omo. Thirteen specimens ranging from 18 to 27 cm FL were netted in a fine shore seine at Lochui in the River Omo, 3 km east of Namurupath on the Ethiopian frontier (Fig. 10.27). No examples were obtained from the main lake, and the earlier record by MANN (1964) from Ferguson's Gulf suggests that exceptional conditions may have prevailed at the time of his visit.

MOCHOCHUS NILOTICUS

BOULENGER (1911) recorded that *M. niloticus* had previously been collected from Lake Turkana though the specimen(s) had apparently been lost after collection. Neither the Cambridge Expedition (WORTHINGTON and RICARDO, 1936) nor MANN (1964) were successful in catching further examples of this fish. During the present survey a single specimen of 33 mm FL was caught in September 1972 in the Typha beds at Todenyang (see Fig. 10.27). This species is probably more common in the River Omo and perhaps only occasionally enters the lake after flooding has occurred.

SUMMARY

Siluriform catfish form an important part of the ichthyofauna of Lake Turkana (formerly Lake Rudolf) and the present investigations, which extended from May 1972 to July 1974, examine the biology and commercial potential of this group of fish. A total of ten species have been identified from the region of the lake, of which *Bagrus bayad*, *Synodontis schall* and *Schilbe uranoscopus* were most commonly caught, thus providing adequate material for detailed biological studies.

Each of the three species studied in detail have been aged by examining length-frequencies of samples caught by bottom trawling. Growth is relatively rapid in each species, and follows the von Bertalanffy growth model. No sexual differences in growth pattern were noted, except in *Schilbe uranoscopus* where females attain an appreciably greater maximum length than males.

The commencement of spawning activity in all three species is associated with rainfall and flooding. *Bagrus bayad* breeds within the

lake probably in coastal waters of moderate depth after local rainfall, while Synodontis schall spawns both close inshore and in seasonal rivers. Schilbe uranoscopus is an anadromous form and undergoes a major breeding migration up the River Omo. Artificial fertilisation of Synodontis schall was successfully carried out. Larval development proved to be rapid, and showed adaptations to an early life in temporary rivers.

The diet of Bagrus bayad changes with increasing size, from prawns to fish, and the species is an important predator on populations of small fish in Lake Turkanan. Synodontis schall feeds on a wide range of food items, and the species is widely distributed at all depths, though it is most common inshore. The diet of Schilbe uranoscopus is restricted mainly to prawns and fish.

Since the introduction of longlines, the Bagrus bayad fishery has increased in commercial value and in areas such as the East Shore where deep water fishing is important, the species may form up to 70% of the total number of fish sold to the co-operative. There are indications that stocks of catchable fish are being depleted rapidly. However fish smaller than 50 cm were rarely caught by longlining and since Bagrus bayad matures at a length of approximately 35 cm, a relatively high proportion of the breeding population is conserved. Synodontis schall is of major importance in the subsistence fisheries of the lake and was caught in larger numbers by gillnets. Yields of both Synodontis schall and Schilbe uranoscopus are potentially greater than at present, in gillnets of 2 to 4 inch stretched mesh. However the use of such fine mesh sizes would be detrimental to the juvenile populations of the larger commercially important fish.

The remaining seven species of silurids were less commonly caught and all available information has been included.

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TABLE 10.1

The ten species of catfish inhabiting Lake Turkana

SPECIES	FIRST COLLECTED BY:
Bagridae	
Bagrus bayad (Forsk.)	Cambridge Expedition, 1930-31 (Worthington and Ricardo, 1936)
Bagrus docmac (Forsk.)	Zaphiro and McMillan, 1908 (Boulenger, 1911)
Chrysichthys auratus (Geoffr.)	Present survey
Auchenoglanis occidentails (C. and V.)	Reported by Boulenger (1911)
Clariidae	
Clarias lazera (C. and V.)	Cambridge Expedition, 1930-31
Schilbeidae	
Schilbe uranoscopus Rupp.	Cambridge Expedition, 1930-31
Mochokidae	
Synodontis schall (Bl.-Schn)	Zaphiro and McMillan, 1908
Synodontis frontosus Vaill.	Zaphiro and McMillan, 1908
Mochocus niloticus Joannis	Reported by Boulenger (1911)
Malapteruridae	
Malapterurus electricus (Gmelin)	Mission Scientifique de L'Omo, 1932-33, (Pellegrin, 1935)

TABLE 10.2

Annual rainfall (mm) recorded at the Fisheries Department, Ferguson's Gulf, over 5 years. The number of days with rain is given in brackets

Month		Year				
		1968	1969	1970	1972	1973
January:	mm	-	25.7	30.2	-	0.5
	days		(2)	(4)		(1)
February:	mm	23.9	1.8	-	45.0	-
	days	(4)	(1)		(1)	
March:	mm	82.1	20.5	5.1	-	-
	days	(5)	(1)	(1)		
April:	mm	137.4	-	92.2	-	46.4
	days	(6)		(2)		(3)
May:	mm	-	42.0	11.6	8.9	36.7
	days		(4)	(4)	(2)	(2)
June:	mm	18.0	-	-	70.3	-
	days	(1)			(2)	
July:	mm	-	-	-	-	10.6
	days					(2)
August:	mm	-	-	16.6	-	-
	days			(1)		
September:	mm	-	-	-	-	41.2
	days					(2)
October:	mm	3.9	6.9	-	92.0	10.2
	days	(2)	(1)		(2)	(1)
November:	mm	0.2	9.6	-	0.5	24.5
	days	(2)	(1)		(1)	(2)
December:	mm	42.3	-	-	17.0	-
	days	(4)			(1)	

TABLE 10.3

Bagrus bayad: mean bottom trawl catch per effort, in kilograms per hour in the Northern, Southern and Central sectors of Lake Turkana for the period May 1972 to July 1974.

	Depth zones in metres								
	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80+
Northern sector.									
Allia Bay	3.5	14.5	3.5	-	-	n/a	n/a	n/a	n/a
other areas	8.3	33.4	23.9	62.9	39.8	30.0	50.0	92.0	n/a
Combined	4.7	31.4	21.4	62.9	39.8	30.0	50.0	92.0	n/a
Central sector	18.5	33.2	33.2	30.4	53.2	43.8	64.7	80.5	99.3
Southern sector	2.6	5.1	35.1	21.7	6.0	31.0	21.2	152.0	113.0
Overall mean	7.1	29.5	30.0	40.3	47.7	41.6	50.2	86.4	102.0

n/s - no sample

n/a - not applicable

TABLE 10.4

Bagrus bayad: catch per effort (mean numbers of fish caught per hour of trawling) in eight length groups. All data from the Longech area collected between May 1972 and July 1974 has been combined, and is given for nine depth zones.

Depth zones (metres)	length groups (cm)							
	0-9	10-19	20-29	30-39	40-49	50-59	60-69	over 70
0 - 10	0	0	4	7	4	+	0	0
10 - 20	1	5	14	35	9	1	1	+
20 - 30	3	11	16	25	8	3	3	+
30 - 40	25	5	12	18	8	4	2	+
40 - 50	10	38	24	25	9	5	3	1
50 - 60	9	46	18	18	6	3	2	2
60 - 70	2	44	44	42	8	6	5	3
70 - 80	3	71	34	70	6	7	4	2
Over 80	1	55	34	109	5	5	3	2

(+ = less than 1 fish/hour)

TABLE 10.5

Bagrus bayad: Comparison of mean lengths of males and females for each of the two main size groups caught by bottom trawling in the Longech area in March and July 1973 (see Fig. 9). Results of t-tests are given

		Mean fork length (cm)	Variance	Sample Size	Degrees of freedom	t value
March:	Females	13.05	8.36	20	48	0.72
	Males	12.37	12.61	30		
	Females	34.11	17.99	186	323	0.86
	Males	33.70	19.20	139		
July:	Females	15.61	9.52	72	130	0.13
	Males	15.53	15.86	60		
	Females	35.27	30.25	113	216	0.51
	Males	35.65	31.10	105		

TABLE 10.6

Observed mean monthly lengths of four year classes of *Bagus bayad* caught by bottom trawling between May 1972 and July 1974 in the Longech area. Sample sizes are given in brackets

Sample date		Year class			
		1970	1971	1972	1973
1972:	May	31.1 (57)	18.8 (167)		
	Jun	33.4 (26)	22.9 (26)		
	Jul	34.2 (197)			
	Aug	36.6 (137)			
	Sep	35.1 (67)		5.0 (222)	
	Oct	36.5 (25)	23.8 (174)	7.3 (36)	
	Nov	39.3 (17)	27.4 (20)	8.0 (64)	
	Dec			9.3 (24)	
1973:	Jan		31.4 (87)	10.9 (139)	
	Feb		32.9 (165)	13.3 (101)	
	Mar		33.3 (180)	14.4 (338)	
	Apr		32.8 (83)	14.1 (174)	
	May		34.2 (288)	15.1 (252)	
	Jun		34.5 (40)	17.5 (18)	
	Jul			15.5 (332)	
	Aug		35.8 (39)	19.6 (62)	5.1 (28)
	Sep		36.6 (162)	21.0 (17)	
	Oct		33.2 (65)	24.1 (86)	8.9 (125)
	Nov			28.9 (176)	10.4 (90)
	Dec				11.7 (389)
1974:	Jan			31.0 (197)	11.3 (64)
	Feb			29.7 (52)	13.6 (88)
	Mar			33.5 (283)	14.2 (268)
	Apr			32.0 (258)	14.9 (241)
	May			34.4 (289)	17.2 (107)
	Jun			32.3 (53)	18.6 (25)
	Jul			33.7 (267)	19.4 (17)

TABLE 10.7

Growth of Bagrus bayad: Data from four year classes (Table 6) have been combined to give the observed monthly increment in length up to 2½ years of age.

	Approx age (months)	Mean length cm.	Sample size
May		-	-
Jun	1		
Jul	2	-	-
Aug	3	5.1	28
Sep	4	5.0	222
Oct	5	8.5	161
Nov	6	9.4	154
Dec	7	11.6	413
Jan	8	11.0	203
Feb	9	13.4	182
Mar	10	14.3	606
Apr	11	14.6	415
May	12	16.7	526
Jun	13	19.9	69
Jul	14	15.7	349
Aug	15	19.6	62
Sep	16	21.0	17
Oct	17	23.9	260
Nov	18	28.7	196
Dec	19	-	-
Jan	20	31.1	284
Feb	21	32.6	214
Mar	22	33.4	463
Apr	23	32.2	341
May	24	34.0	634
Jun	25	33.3	119
Jul	26	33.9	464
Aug	27	36.4	176
Sep	28	36.2	229
Oct	29	34.1	90
Nov	30	39.3	17

TABLE 10.8

Comparison between observed and theoretical lengths in *Bagrus bayad*

Age (months)	Observed fork length cm	Theoretical fork length cm
3	5.1	3.9
6	9.4	9.0
9	13.4	13.7
12	16.7	18.2
15	19.6	22.4
18	28.7	26.3
21	32.6	29.9
24	34.0	33.3
27	36.4	36.5
30	39.3	39.5

TABLE 10.9

Bagrus bayad. Length:weight regression coefficients, calculated from $\log_{10}$ weight (g) = $\log_{10}a + b \log_{10}$ length (cm) for a number of size groups of each sex.

	correlation coefficient	b	$\log_{10}a$	No. of fish
Females larger than 20cm.				
Gonad stage				
2	0.899	3.066	-2.149	421
3	0.992	2.815	-1.703	39
4	0.991	2.995	-2.006	44
All	0.905	3.053	-2.122	504
Males larger than 20cm.				
Gonad stage				
2	0.993	3.067	-2.159	128
3	0.993	2.998	-1.908	215
4	0.994	2.945	-1.917	31
All	0.994	3.023	-2.073	374
Females less than 20cm.	0.980	2.749	-1.751	36
Males less than 20cm.	0.974	2.826	-1.846	66
All less than 20cm.	0.975	2.801	-1.815	102
All *B. bayad*	0.968	3.032	-2.088	980

TABLE 10.10

Bagrus bayad : comparing the length-weight relationship of grouped data (Table 10.9). The slopes of the regressions have been compared by applying d-tests.

Comparison between :	Degrees of freedom	d value
Stage 2F cf stage 3F	458	1.505
Stage 2F cf stage 4F	463	1.434
Stage 2M cf stage 3M	341	1.253
Stage 2M cf stage 4M	167	0.604
Stage 2M cf stage 2F	547	0.005
Stage 3M cf stage 3F	252	0.653
Stage 4F cf stage 4M	73	0.123
M of F under 20 cmFL.	100	0.395
F < 20cm cf F > 20cm.	538	1.019
M < 20cm cf M > 20cm.	438	1.598
All fish <20cm cf all> 20cm.	978	1.580

F : females

M : males

TABLE 10.11

Bagrus bayad : showing estimated mean lengths and weights at ages 1 to 10 years.

Age (years)	Mean fork length (cm)	Mean weight (g)
1	18.2	54
2	33.3	337
3	44.7	824
4	53.7	1436
5	60.6	2072
6	66.0	2684
7	70.1	3223
8	73.3	3689
9	75.7	4068
10	77.6	4385

TABLE 10.13

Changes in the maturity of male and female *Bagrus bayad* with size during the spawning season, April to July, in the Longech area. Data from 1972, 1973 and 1974 have been combined, and numbers of fish at each stage are expressed as a percentage of the total in each 1cm length group.

	Fork length cm.	Number of fish	Maturity stage %			
			2	3	4	5
Males	25	16	100	-	-	-
	6	18	89	11	-	-
	7	13	85	15	-	-
	8	22	95	5	-	-
	9	42	69	27	2	-
	30	41	68	32	-	-
	1	36	56	36	8	-
	2	36	28	50	22	-
	3	54	20	59	20	-
	4	59	17	47	36	-
	5	59	22	47	31	-
	6	62	14	44	40	2
	7	56	14	41	45	-
	8	40	7	38	55	-
	9	17	6	65	29	-
	40	15	20	40	40	-
Females	25	22	100	-	-	-
	6	15	93	7	-	-
	7	17	94	6	-	-
	8	30	90	7	3	-
	9	31	94	3	3	-
	30	37	81	16	3	-
	1	38	68	16	16	-
	2	43	72	23	5	-
	3	51	51	31	14	4
	4	68	44	18	35	3
	5	60	47	28	23	2
	6	48	31	44	23	2
	7	47	40	30	28	2
	8	26	50	27	19	4
	9	29	69	21	7	3
	40	25	48	16	32	4

TABLE 10.14

Changes in the gonad condition of male *Bagrus bayad* in the 35 to 39 cm length group in the Longech area between July 1972 and June 1974. Numbers of fish at each maturity stage have been expressed as a percentage of the monthly total.

	Month	Total number	Gonad stage %			
			2	3	4	5
1972	Jul	23	35	48	17	-
	Aug	40	20	60	20	-
	Sep	17	71	29	-	-
	Oct	24	42	58	-	-
	Nov	37	22	73	5	-
	Dec	11	64	36	-	-
1973	Jan	18	11	89	-	-
	Feb	27	52	33	15	-
	Mar	37	35	49	16	-
	Apr	30	57	33	10	-
	May	113	2	35	62	1
	Jun	12	75	25	-	-
	Jul	61	10	85	5	-
	Aug	64	31	63	6	-
	Sep	54	24	76	-	-
	Oct	27	22	78	-	-
	Nov	27	30	67	3	-
	Dec	21	24	76	-	-
1974	Jan	20	25	75	-	-
	Feb	50	16	76	8	-
	Mar	59	-	86	14	-
	Apr	33	3	88	9	-
	May	47	6	51	40	-
	Jun	12	17	75	8	-

TABLE 10.15

Changes in the gonad condition of female *Bagrus bayad* in the 35 to 39cm length group in the Longech area between July 1972 and June 1974. Numbers of fish at each maturity stage have been expressed as a percentage of the monthly total.

	Month	Total number	Gonad stage %				
			2	3	4	5	6
1972	Jul	33	30	70	-	-	-
	Aug	27	41	29	30	-	-
	Sep	22	100	-	-	-	-
	Oct	61	84	8	6	-	2
	Nov	56	70	20	9	1	-
	Dec	7	100	-	-	-	-
1973	Jan	27	78	18	4	-	-
	Feb	26	69	23	8	-	-
	Mar	81	61	5	34	-	-
	Apr	56	86	5	9	-	-
	May	29	17	17	66	-	-
	Jun	15	80	20	-	-	-
	Jul	55	2	29	64	4	1
	Aug	85	75	18	5	2	-
	Sep	98	63	31	6	-	-
	Oct	49	74	25	1	-	-
	Nov	38	87	13	-	-	-
	Dec	35	80	20	-	-	-
1974	Jan	24	67	29	4	-	-
	Feb	30	73	23	4	-	-
	Mar	20	70	20	10	-	-
	Apr	40	18	80	2	-	-
	May	56	28	34	25	13	-
	Jun	10	40	10	50	-	-

TABLE 10.16

Seasonal changes in the maturity stages of three length groups of male *Bagrus bayad* from the Longech area. Data for the two years have been combined and numbers of fish at each maturity stage have been expressed as a percentage of the monthly total.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
30-34cm												
Number	78	72	93	84	121	15	86	62	65	72	66	35
% Stage 2	42	54	47	51	14	47	39	58	57	33	59	63
3	58	46	44	49	50	40	57	36	43	66	41	37
4	-	-	9	-	36	13	4	6	-	1	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-
35-39cm												
Number	38	77	96	63	160	12	84	104	71	51	64	32
% Stage 2	18	29	13	29	3	17	17	27	35	31	25	38
3	82	61	72	62	39	75	75	62	65	69	70	62
4	-	10	15	9	56	8	8	11	-	-	5	-
5	-	-	-	-	2	-	-	-	-	-	-	-
Over 40cm												
Number	42	50	67	46	42	17	32	75	32	48	42	38
% Stage 2	24	48	19	13	7	41	47	36	38	10	24	34
3	76	48	67	80	55	41	40	49	50	90	69	63
4	-	4	14	7	26	18	13	15	12	-	7	3
5	-	-	-	-	12	-	-	-	-	-	-	-

TABLE 10.17

Seasonal changes in the maturity stages of three length groups of female *Bagrus bayad* from the Longech area. Data for the two years have been combined and numbers of fish at each maturity stage have been expressed as a percentage of the monthly total.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
30-40cm												
Number	78	60	77	101	107	22	97	99	80	94	84	36
% Stage 2	77	77	86	70	42	59	39	83	85	92	86	97
3	23	18	8	28	20	18	28	13	11	5	13	3
4	-	5	6	2	34	23	32	3	4	3	1	-
5	-	-	-	-	4	-	-	-	-	-	-	-
6	-	-	-	-	-	-	1	1	-	-	-	-
35-39cm												
Number	51	56	101	96	85	25	88	112	120	110	94	42
% Stage 2	72	71	62	57	25	40	13	67	70	79	77	83
3	24	23	8	37	28	10	44	20	25	16	17	17
4	4	6	30	6	39	50	40	11	5	4	5	-
5	-	-	-	-	8	-	2	-	-	-	1	-
6	-	-	-	-	-	-	1	2	-	1	-	-
Over 40cm												
Number	64	73	70	65	50	31	45	171	102	117	108	71
% Stage 2	88	69	87	66	52	84	76	74	75	76	73	93
3	8	16	4	19	12	10	7	17	16	9	16	6
4	4	11	9	15	26	3	11	5	9	7	10	1
5	-	4	-	-	8	3	-	1	-	-	1	-
6	-	-	-	-	2	-	6	3	-	8	-	-

TABLE 10.18

Maturity stages of female and male *Bagrus bayad* from the Southern sector. Numbers of fish at each maturity stage have been expressed as a percentage of the total examined in two length groups.

		Sample size	Gonad stage %				
			2	3	4	5	6
Females	35-39cm						
	1972 Jun	8	75	25	-	-	-
	Dec	45	78	22	-	-	-
	1973 Oct	42	67	31	2	-	-
	1974 Jun	19	68	16	15	-	-
	Over 40cm						
	1972 Jun	29	41	28	14	14	3
	Dec	48	75	12	12	-	-
	1973 Oct	49	78	18	4	-	-
	1974 Jun	32	56	22	22	-	-
Males	35-39cm						
	1972 Jun	8	50	25	25	-	
	Dec	46	11	89	-	-	
	1973 Oct	27	44	56	-	-	
	1974 Jun	8	50	25	25	-	
	Over 40cm						
	1972 Jun	24	29	38	29	4	
	Dec	35	6	88	3	3	
	1973 Oct	35	34	63	3	-	
	1974 Jun	19	89	11	-	-	

TABLE 10.19

Maturity stages of female and male *Bagrus bayad* from the Northern sector. Numbers of fish at each maturity stage have been expressed as a percentage of the total examined in two length groups.

		Sample size	Gonad stage %				
			2	3	4	5	6
Females	35-39cm						
	1972 Nov	39	21	33	46	-	-
	1973 Feb	42	86	7	7	-	-
	Apr	73	78	6	16	-	-
	Jul	48	77	13	10	-	-
	1974 Jun	24	50	33	17	-	-
	Over 40cm						
	1972 Nov	20	30	20	40	-	10
	1973 Feb	55	64	18	16	2	-
	Apr	43	70	5	23	-	2
	Jul	29	90	7	3	-	-
	1974 Jun	27	22	33	22	22	-
Males	35-39cm						
	1972 Nov	35	14	66	20	-	
	1973 Feb	19	53	47	-	-	
	Apr	49	31	69	-	-	
	Jul	24	58	42	-	-	
	1974 Jun	13	62	23	-	-	
	Over 40cm						
	1972 Nov	8	25	50	25	-	
	1973 Feb	28	18	75	4	3	
	Apr	25	4	88	8	-	
	Jul	21	38	62	-	-	
	1974 Jun	15	60	7	26	7	

TABLE 10.20

Changes in the sex-ratio of *Bagus bayad* from the Longech area, with size. The sex-ratio is expressed as numbers of males per 100 fish in each length group. All data collected between May 1972 and July 1974 has been included.

Length group	Number of males	Number of females	Sex-ratio
under 19cm	464	466	50
20-29cm	918	868	51
30-34cm	864	944	48
35-39cm	864	980	47
over 40cm	531	972	35

TABLE 10.21

Bagrus bayad : changes in the proportion of ripe-running (stage 5) females, larger than 30cm with depth in the Longech area during May 1974. Numbers of fish at each maturity stage have been expressed as a percentage of the total caught at each depth.

Sample depth	Number of females	Gonad stage %				
		2	3	4	5	6
15m	38	39	10	16	35	-
20m	25	36	28	28	8	-
30m	12	50	25	25	-	-
50m	7	86	-	14	-	-
60m	33	33	49	18	-	-
80m	36	42	19	36	3	-

TABLE 10.22

Bagrus bayad : seasonal changes in mean condition factor ($\bar{k}$) of fish larger than 30cm. $\bar{k}$ is given for four breeding phases and all data from the Longech area has been included.

Months	Feb Mar	Apr to Jul	Aug Sept	Oct to Jan
Breeding phase	Pre-spawning	Spawning	Post-spawning	Resting
Males > 30cmFL				
$\bar{k}$	101.9	101.6	98.3	104.3
Sample size	(82)	(95)	(46)	(102)
Females > 30cmFL				
$\bar{k}$	99.2	103.9	99.1	102.1
Sample size	(107)	(119)	(82)	(163)

TABLE 10.23

Bagrus bayad : variation in diet composition with depth and length. The number of points scored by each food category has been expressed as a percentage of the total points allotted in each length group and depth zone. All B. bayad caught during the two years sampling by the bottom trawl have been included.

		Depth zone (m)								
Length groups	Food items %	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	Over 80
10-19 cm										
	Prawns	100	33	50	81	98	95	100	99	93
	Fish	-	67	50	14	2	5	-	1	7
	Insects	-	-	-	5	-	-	-	-	-
20-29 cm										
	Prawns	83	73	88	67	92	77	92	73	94
	Fish	13	27	12	33	7	23	8	27	6
	Insects	4	-	-	-	1	-	-	-	-
30-39 cm										
	Prawns	31	62	71	80	86	75	77	84	80
	Fish	69	36	28	19	13	25	23	16	20
	Insects	-	2	1	1	1	-	-	-	-
40-49 cm										
	Prawns	8	41	59	61	67	67	64	65	83
	Fish	87	56	40	38	28	33	35	34	17
	Insects	5	3	1	1	5	-	1	1	-
50-59 cm										
	Prawns	3	8	19	28	26	30	13	32	10
	Fish	97	92	79	71	22	60	86	66	77
	Insects	-	-	2	1	2	10	1	2	13
60-69 cm										
	Prawns	9	2	8	7	21	-	17	4	-
	Fish	88	96	91	90	76	96	80	94	100
	Insects	3	2	1	3	3	4	3	2	-
70-79 cm										
	Prawns			3	8	9		2		
	Fish	n/s	100	97	88	91	97	92	98	100
	Insects				4		3	6	2	
Over 80 cm	Prawns	n/s	100	n/s	100	100	n/s	n/s	100	100

n/s = no sample

TABLE 10.24

The food of *Bagrus bayad* inhabiting Ferguson's Gulf. The total number of points for each food type have been expressed as a percentage of the overall total awarded in each length group. All fish caught by beach seines within the Gulf have been included.

	Length group cm				
	10-19	20-29	30-39	40-49	50-59
Food categories %					
Alestes spp.	25	27	30	-	-
Engraulicypris stellae	-	-	15	-	-
Fish remains	75	23	17	63	100
Total fish	100	50	62	63	100
Chironomid larvae	-	10	9	13	-
Corixids	-	13	7	-	-
Other Insects	-	15	13	12	-
Total insects	-	38	29	25	-
Ostracods	-	12	-	12	-
Prawns	-	-	8	-	-
Total crustacea	-	12	8	12	-
Hydracarina	-	-	1	-	-

TABLE 10.25

Frame trawl catches of *Bagrus bayad* over a twenty-four hour period at a station in 25m of water in the Longech area, during April 1974. Catch/effort is given as numbers of fish/10 minute haul.

	Day p.m.	Dusk	Night	Dusk	Day a.m.
Surface	-	-	-	-	-
4m	-	-	-	-	-
8m	-	-	-	-	-
12m	-	-	1	-	-
16m	-	-	9	-	-
20m	1	12	4	-	3
25m (bottom)	13	3	7	4	4

TABLE 10.26

Seasonal variation of bottom trawl catch rates and diet of 30 to 39cm *Bagrus bayad* in water of 10 - 20m depth in the Longech area. Changes in the depth of light penetration in the sampling area are also given. All data for the two years has been combined.

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Number of *B. bayad* caught per hour of trawling	30	34	56	79	94	n/s	38	30	45	n/s	54	14
Diet %												
Prawns	-	21	79	97	100		47	17	34		42	20
Fish	100	79	21	3	-		53	83	66		57	80
Water state	G	G	B	BB	GB	G	G	G	G	G	G	G
Light compensation point (metres)	6.0	4.5	2.0	2.0	3.0	4.0	5.0	5.5	7.5	7.5	7.5	7.0

G = green

B = brown

BB = very brown

GB = green brown

n/s = no sample

TABLE 10.27

Mean catch per effort of *Bagrus bayad* (kg/100 yard net/night) in a fleet of experimental gillnets fished at various depths in the Longech area of Lake Turkana. The percentage *B. bayad* by weight of the total catch is shown in brackets.

	Depth m.	No. of nights	Mesh size (inches)								
			2	3	4	5	6	7	8	9	10
Mean catch/effort	9	4	-	-	+	-	-	-	-	-	-
% of total catch					(1)						
Mean catch/effort	14	6	1	1	+	-	-	-	-	-	1
% of total catch			(2)	(1)	(1)						(19)
Mean catch/effort	19	5	-	1	4	2	4	-	-	-	-
% of total catch				(2)	(13)	(11)	(63)				
Mean catch/effort	25	5	15	2	3	1	2	4	+	4	1
% of total catch			(36)	(2)	(6)	(9)	(56)	(31)	(8)	(100)	(8)
Mean catch/effort	40	1	-	-	-	8	-	10	-	-	-
% of total catch						(40)		(100)			
Mean catch/effort	60	1	-	-	-	12	12	-	-	-	-
% of total catch						(46)	(60)				
Mean catch/effort	73	3	-	3	2	1	5	4	-	-	-
% of total catch				(33)	(29)	(29)	(78)	(52)			

TABLE 10.28

Results from an experimental longline fishery in the Central lake sector. Catches of *Bagrus bayad* are given for the period January to September 1974.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
No. nights recorded	4	19	25	12	6	18	12	14	8
No. *Bagrus* caught	366	1623	1544	1069	344	1078	417	869	412
Mean No./Night	92	85	62	89	57	60	35	62	52
Mean No. Hooks/Night	1400	1400	1400	1400	1400	1400	1400	1400	1323
Mean No. *Bagrus*/100 hooks	6.5	6.1	4.4	6.4	4.1	4.3	2.3	4.4	3.9
Mean Fork length of *Bagrus* (cms)	66.4	66.0	66.2	70.0	65.5	70.6	69.2	62.4	64.8
Mean fresh weight/100 hooks (kgs)	20.8	18.8	14.4	23.0	13.1	17.1	8.7	12.4	12.0
Mean fresh weight of each *Bagrus* (kgs)	3.2	3.1	3.3	3.6	3.2	4.0		2.8	3.1

TABLE 10.29

Numbers of *Bagrus bayad* handled at seven co-operatives expressed as a percentage of the total number of fish bought in October, November and December 1972, 1973 and 1974. Actual number of *B. bayad* is given in brackets.

	Todenyang	Lowarengak	Nachukui	Kataboi	Namadak	Kalokol	Kerio	Totals
1972								
Oct	.03 (6)	.06 (2)	.04 (1)	0.95 (29)	27.50 (1660)	9.12 (490)	0.24 (72)	3.19 (2260)
Nov		.03 (2)	.93 (37)	2.00 (100)	11.67 (390)	1.52 (160)	0.81 (140)	1.23 (829)
Dec		.01 (1)		1.64 (65)	20.91 (500)	4.78 (190)	1.81 (180)	3.84 (1765)
1973								
Oct	.81 (290)	1.25 (170)	2.68 (190)	8.00 (780)	14.82 (840)	15.77 (1980)	1.80 (370)	4.39 (4620)
Nov	1.28 (320)	.24 (56)	1.21 (180)	7.02 (610)	12.14 (600)	12.47 (1651)	2.47 (360)	3.58 (3777)
Dec	.61 (250)	.13 (38)	0.35 (55)	2.66 (180)	31.37 (960)	23.03 (2280)	3.14 (270)	3.52 (4033)
1974								
Oct	4.41 (1000)	3.22 (250)	12.01 (140)	20.97 (1110)	42.58 (620)	61.03 (5200)	3.44 (410)	14.23 (8730)
Nov	3.38 (779)	1.97 (390)	28.26 (400)	21.42 (1640)	45.02 (990)	54.12 (3600)	3.63 (150)	10.73 (7949)
Dec	1.18 (280)	1.97 (330)	21.83 (390)	23.79 (1810)	57.35 (1240)	68.59 (5740)	3.49 (220)	13.82 (10,010)

TABLE 10.30

Estimate of mean number of hooks set per night in the principle longlining area of the Central lake sector between January 1973 and December 1974

		Total number of Bagrus	Estimated mean nightly number of hooks
1973	Jan	620	423
	Feb	440	332
	Mar	540	368
	Apr	320	226
	May	620	423
	Jun	510	359
	Jul	490	334
	Aug	1120	764
	Sep	2064	1454
	Oct	2820	1924
	Nov	2250	1586
	Dec	3240	2210
1974	Jan	3460	2360
	Feb	3520	2658
	Mar	3000	2040
	Apr	3340	2354
	May	4750	3240
	Jun	6100	3348
	Jul	4530	4160
	Aug	4860	3090
	Sep	7550	5399
	Oct	5830	3976
	Nov	4590	3235
	Dec	6980	4761

TABLE 10.31

Comparison between length distribution of *Bagrus bayad* catches by trawling and longlining in the Longech area. All trawl data collected between May 1972 and July 1974 and longline data from January to July 1974 have been included.

Length groups cm	30	30-39	40-49	50-59	60-69	70-79	80-89	90
Trawl catch % distribution	55.8	30.5	6.6	3.6	2.4		1.1	
Longline catch % distribution	0.4	4.9	9.4	12.5	21.5	29.7	16.2	5.3

TABLE 10.32

Bagrus docmac : Length, sex and gonad condition of all fish caught by bottom trawling between May 1972 and July 1974.

	Depth metres	Length range cm.	Number			Gonad condition	
			Immature	Male	Female	Male	Female
1972 Jun	20-30m	64,56		1	1	resting	resting
"	5	48			1		maturing
"	14-18	91			1		resting
"	10	74			1		resting
Aug	4-8	80			1		resting
Sep	4	81			1		maturing
1973 Jan	4	27			1		resting
Oct	16	82,89		1	1	maturing	resting
"	15	14-75	2	10	13	resting & maturing	resting

TABLE 10.33

Diet of *Bagrus docmac*. Points for each food item are expressed as percentages of the total points in two size groups. All data from May 1972 to July 1974 are included.

	Length group	
	under 35cm FL.	over 35cm FL.
Number of fish	10	7
Number empty	1	2
Food items %		
Fish		
Lates longispinis	1	-
Alestes spp.	7	-
Hydrocynus forskalii	-	13
Haplochromis macconneli	18	-
Tilapia spp.	-	24
Synodontis schall	-	50
Chrysichthys auratus	16	-
Fish remains	-	13
All fish	42	100
Insects		
Hemiptera	7	-
Ephemeroptera	6	-
Insect remains	1	-
All insects	14	-
Crustacea		
Prawns	43	-
Ostracods	1	-
All crustacea	44	-
Total points	77	32

TABLE 10.34

Chrysichthys auratus : mean bottom trawl catch per effort, in kilograms per hour. Results are based on all trawl samples made throughout the lake between May 1972 and July 1974.

Depth zone metres	% samples with *C. auratus*	Mean catch kg.
0-5	8	+
5-10	17	+
10-15	32	1.8
15-20	46	1.6
20-25	47	0.8
25-30	50	+
30-40	41	0.3
40-50	17	+
50-60	19	0.3
60-70	15	+
70-80	6	+
over 80	0	0

+ : less than 0,1 kg/hour

TABLE 10.35

Vertical migration and diel feeding pattern of *Chrysichthys auratus* over a twenty-four hour period as shown by frame trawling results at a station in 25 metres of water off Longech Spit. Catch rates, in number of *Chrysichthys* per 10 minute trawl, are given for six depth zones and five time phases. Percentage stomach fullness is also presented for each time phase.

	Time phase				
	Day a.m.	Dusk	Night	Dawn	Day p.m.
Surface	-	-	-	-	-
4m	-	-	-	-	-
8m	-	-	1	-	-
12m	-	-	1	-	-
16m	1	-	7	-	-
below 20m	1	1	1	1	-
% fullness	12	0	19	0	0

TABLE 10.36

Ratio of males to females in *Chrysichthys auratus*. The sex ratio is expressed as numbers of males per 100 fish in five length groups. All data collected between May 1972 and July 1974 have been included.

Length group	Number of males	Number of females	Sex-ratio
under 9cm	152	211	42
10-14cm	147	145	50
15-19cm	63	35	64
20-24cm	76	75	50
25-29cm	6	4	60
TOTAL	472	446	

TABLE 10.37

Changes in maturity of *Chrysichthys auratus* over the size range 5 to 15 cm. Data obtained between May 1972 and July 1974 have been combined and numbers of resting, mature and ripe fish are expressed as a percentage of the total in each 1cm length group.

		Gonad condition			
		Number of fish	Resting	Mature	Ripe
	Fork length cm				
Males	5	1	100	-	-
	6	13	92	8	-
	7	22	73	27	-
	8	52	31	69	-
	9	64	52	48	-
	10	63	52	48	-
	11	42	74	26	-
	12	22	59	41	-
	13	15	53	47	-
	14	6	50	50	-
	15	12	58	42	-
Females					
	5	6	100	-	-
	6	9	89	11	-
	7	37	46	32	22
	8	80	39	41	20
	9	75	40	31	29
	10	56	38	41	21
	11	51	39	35	26
	12	17	59	18	23
	13	17	59	18	23
	14	2	100	-	-
	15	7	40	-	-

TABLE 10.38

Seasonal changes in the proportion of ripe female *Chrysichthys auratus*. All females larger than 6cm examined between May 1972 and July 1974 have been combined and the percentage of ripe females is given for each month.

	Number of fish	% ripe
Jan	49	20
Feb	34	47
Mar	13	31
Apr	7	57
May	2	50
Jun	7	29
Jul	68	9
Aug	72	16
Sep	36	11
Oct	45	38
Nov	42	24
Dec	72	32

TABLE 10.39

Diet of *Chrysichthys auratus*. The number of points for each food item has been expressed as a percentage of the total allotted. Results are based on all fish examined throughout the study period.

Number of stomachs with food		247
Total points allotted		1596
Food items		**%**
Insects :	Chironomid larvae and pupae	34
	Corixids	5
	Other Insects	2
	Total Insects	41
Crustacea :	Ostracods	31
	Copepods	4
	Prawns	22
	Total Crustacea	57
Hydracarina		1
Fish		1

TABLE 10.40

Variation in the diet of *Chrysichthys auratus* with depth. Number of points scored for each food item have been expressed as a % of the total allotted in each depth zone.

	Ferguson's Gulf	0-10 metres	10-20 metres	Over 20 metres
Total points	130	308	384	774
Food Items %				
Insects : Chironomid larvae and pupae	62	41	44	21
Corixids	2	11	8	1
Other insects	8	4	3	+
Total insects	72	56	55	22
Crustacea : Ostracods	27	37	36	28
Copepods	-	6	5	4
Prawns	-	1	1	44
Total Crustacea	27	43	42	76
Hydracarina	1	1	1	+
Fish	-	-	2	1

+ : less than 1%

TABLE 10.41

Combined length frequency distribution of all *Clarias lazera* caught by shore seines between May 1972 and July 1974.

Total length	Number
30 - 39	3
40 - 49	-
50 - 59	9
60 - 69	15
70 - 79	7
80 - 89	5
90 - 99	3
over 100	2

TABLE 10.42

Diet of *Clarias lazera*. Points for each food item are expressed as a percentage of the total allotted. All data collected between May 1972 and July 1974 are included.

	Number of stomachs with food	13
	Total points allotted	132
Food items		
%	Copepods	73
	Ostracods	4
	Cladocera	3
	Corixid	6
	Chironomid	3
	Tilapia spp	11

TABLE 10.43

Schilbe uranoscopus : mean bottom trawl catch per effort, in kilograms per hour, in the Northern, Central and Southern sectors of Lake Turkana for the period May 1972 to July 1974.

	Depth zones in metres											
	0-5	5-10	10-15	15-20	20-25	25-30	30-40	40-50	50-60	60-70	70-80	80+
Northern sector												
Allia Bay	-	-	3.3	-	-	-	-	-	n/a	n/a	n/a	n/a
Remainder	-	3.3	2.1	3.3	2.9	3.8	1.5	0.3	-	+	-	n/s
Combined	-	2.0	2.3	3.3	2.6	3.8	1.3	0.3	-	+	-	n/s
Central sector	n/s	0.6	0.6	1.6	10.0	0.7	0.8	2.2	0.4	0.6	0.5	0.2
Southern sector	-	2.5	0.6	-	2.2	2.5	1.7	-	1.0	2.3	-	2.0
Overall mean	-	1.7	1.4	1.6	7.5	1.9	1.0	1.8	0.4	1.1	0.5	0.5

n/s = no sample

n/a = not applicable

TABLE 10.44

Frame trawl catches of Schilbe uranoscopus at two stations in the Longech area in September 1973. Catches are expressed as mean number of fish per 15 minute haul.

	Inshore station Depth 30m		Offshore station Depth 82m	
	Number of Schilbe per 15 mins.	Number of hauls	Number of Schilbe per 15 mins.	Number of hauls
Sampling depth metres				
0-4	0	3	0	1
4-8	1	3	0	2
8-12*	3	2	2	3
12-16*	11	1	2	3
16-20	3	2	0	1
20-24	0	1	0	1
24-30	0	1	0	1
30-40		n/a	0	1
40-60		n/a	0	2
60-80		n/a	0	1

* : appropriate depth of midwater scattering layer

n/a : not applicable

TABLE 10.45

Mean catch rate of *Schilbe uranoscopus* in kg/50 yard net/night in two inch and three inch nets at four stations off Longech Spit. The percentage of *Schilbe uranoscopus* by weight of the total catch is shown in brackets.

Station	A	B	C	D
Depth (metres)	9	14	19	25
No. of nights	4	7	6	4
2" Gill net				
Mean catch rate kg/night	2.5	2.5	0.1	2.4
% of total catch	(32)	(14)	(3)	(14)
3" Gill net				
Mean catch rate kg/night	8.3	3.2	0.6	3.7
% of total catch	(22)	(8)	(2)	(14)

TABLE 10.46

Mean length of female *Schilbe uranoscopus* caught by bottom and frame trawls in the Longech area between July 1973 and June 1974. Immature O-group fish (*) are also included.

	Jul 1973	Aug	Sep	Oct	Nov	Dec	Jan 1974	Feb	Mar	Apr	May	Jun
1973 year class												
Mean length (cm)					5.4*			12.2*	13.4*	14.1*	17.3	17.1
Number					(26)			(5)	(19)	(68)	(21)	(134)
1972 year class												
Mean length (cm)	20.0	23.8	24.3		25.2	26.9			28.1	26.6	25.9	29.8
Number	(20)	(24)	(76)		(78)	(46)			(16)	(195)	(34)	(27)

TABLE 10.47

Mean lengths of male *Schilbe uranoscopus* caught by bottom and frame trawls in the Longech area between July 1973 and June 1974. Immature O-group fish (*) are also included.

	Jul 1973	Aug	Sep	Oct	Nov	Dec	Jan 1974	Feb	Mar	Apr	May	Jun
1973 year class												
Mean length (cm)					5.4*			12.2*	13.4*	14.1*		
Number					(26)			(5)	(19)	(68)		
1972 year class												
Mean length (cm)	17.1		17.7	18.0	19.4			18.7	19.4	19.2	19.1	19.1
Number	(36)		(35)	(40)	(13)			(13)	(55)	(26)	(19)	(12)

TABLE 10.48

Comparison between observed and theoretical lengths in female *Schilbe uranoscopus*

Age (months)	Observed fork length (cm)	Estimated fork length (cm)
3	n/s	8.7
6	13.4	14.9
9	17.1	19.7
12	24.3	23.4
15	26.9	26.2
18	28.1	28.4
21	29.8	30.1
24	n/s	31.5

n/s = no sample

TABLE 10.49

Comparison between observed and theoretical lengths in male *Schilbe uranoscopus*.

Age (months)	Observed fork length (cm)	Estimated fork length (cm)
2	5.4	6.4
7	14.1	14.2
12	17.7	17.4
17	18.7	18.6
22	n/s	19.1
24	n/s	19.3

n/s = no sample

TABLE 10.50

Schilbe uranoscopus : results of t-tests comparing mean lengths of females in the Central sector with Northern and Southern populations.

			Mean length (cm)	Numbers	variance	t value
Comparison between Northern and Central populations						
1972	Nov	N	22.31	91	11.44	-1.5056
		C	23.13	55	7.30	
1973	Feb	N	23.91	33	4.59	0.0391
		C	23.89	36	4.67	
	Apr	N	24.81	417	5.74	1.7397
		C	25.44	48	4.29	
	May	N	25.09	47	4.86	0.7229
		C	25.76	87	6.95	
Comparison between Southern and Central populations						
1972	Dec	S	24.50	52	7.22	1.5806
		C	23.61	41	7.34	
1973	May	S	27.14	99	2.22	7.6999
		C	24.76	87	6.95	

N: Northern population
C: Central population
S: Southern population

TABLE 10.51

Mean length and weight in male and female *Schilbe uranoscopus* at ages 1 and 2 years.

	Age (years)	Mean fork length (cm)	Mean weight (g)
Males	1	17.4	42.7
	2	19.3	58.2
Females	1	23.4	103.7
	2	31.5	252.5

TABLE 10.52

Schilbe uranoscopus : ratio of males to females in the Longech area. The sex-ratio is expressed as number of males per 100 fish. All data from May 1972 to July 1974 are included.

Fork length cm.	Number of females	Number of males	Sex-ratio
10	1	1	50
1	4	5	56
2	7	8	53
3	16	13	45
4	13	8	38
5	14	13	48
6	29	31	52
7	24	60	71
8	34	87	72
9	42	111	73
20	69	79	53
1	82	41	33
2	114	14	11
3	154	8	5
4	140	2	1
5	147	-	0
6	115	-	0
7	140	-	0
8	85	-	0
9	61	-	0
30	28	-	0
1	8	-	0

TABLE 10.53

Schilbe uranoscopus : size at maturity results for all females and males caught between May 1972 and July 1974 in the Longech area. Numbers of fish at each gonad stage are given as a percentage of the total numbers in each cm length group.

Fork length cm	Number of fish	Gonad stage (%) 2	3	4	5
Females					
10	1	100	-	-	-
11	4	100	-	-	-
12	7	100	-	-	-
13	16	100	-	-	-
4	13	100	-	-	-
5	14	100	-	-	-
6	29	100	-	-	-
7	24	100	-	-	-
8	34	88	12	-	-
9	42	90	7	3	-
20	69	87	13	-	-
1	82	89	11	-	-
2	114	69	30	1	-
3	154	53	47	-	-
4	140	48	51	1	-
5	147	37	61	2	-
6	115	31	66	3	-
7	140	21	76	3	-
8	85	25	72	3	-
9	61	18	80	2	-
30	28	7	85	8	-
1	8	-	100	-	-
		2	3	4	5
Males					
10	1	100	-	-	-
1	5	100	-	-	-
2	8	100	-	-	-
3	13	100	-	-	-
4	8	100	-	-	-
5	13	100	-	-	-
6	31	87	10	3	-
7	60	77	23	-	-
8	87	71	28	1	-
9	111	75	25	-	-
20	79	72	26	2	-
1	41	54	46	-	-
2	14	43	57	-	-
3	8	13	87	-	-
4	2	-	100	-	-

TABLE 10.54

Seasonal changes in the maturity stages of *Schilbe uranoscopus* from trawl catches in the Longech area. Data collected between May 1972 and July 1974 have been combined and numbers of a) females larger than 18cmFL. and b) males larger than 16cmFL. at each maturity stage have been expressed as a percentage of the monthly total.

	Month	Number of fish	Gonad stage (%)			
			2	3	4	5
Females	Jan	22	36	64	-	-
	Feb	49	76	24	-	-
	Mar	132	42	56	2	-
	Apr	249	26	72	2	-
	May	131	38	61	1	-
	Jun	28	57	29	14	-
	Jul	36	97	3	-	-
	Aug	28	50	50	-	-
	Sep	181	72	26	2	-
	Oct	151	67	32	1	-
	Nov	131	34	66	1	-
	Dec	89	38	15	-	-
Males	Jan	13	85	15	-	-
	Feb	8	100	-	-	-
	Mar	60	88	12	-	-
	Apr	59	69	31	-	-
	May	57	81	19	-	-
	Jun	30	73	27	-	-
	Jul	21	86	14	-	-
	Aug	9	67	33	-	-
	Sep	74	57	41	3	-
	Oct	60	70	28	2	-
	Nov	41	61	39	-	-
	Dec	25	76	24	-	-

TABLE 10.55

Food of *Schilbe uranoscopus*. Data collected throughout the lake from May 1972 to July 1974 have been combined and points for each food item are expressed as a percentage of the total points recorded.

Stomachs with food	520
Empty stomachs	160
Total points	2148
Food items %	
Fish	
Alestes sp	20.0
Engraulicypris stellae	13.1
Haplochromis macconneli	1.4
Barbus cf. *anema*	0.7
Bagrus bayad	0.7
Fish remains	21.4
Total fish	57.3
Crustacea	
Prawns	40.6
Copepods	0.1
Ostracods	0.3
Total Crustacea	41.0
Insects	
Corixids	0.4
Locusts	1.2
Chironomid larvae	0.1
Total Insects	1.7

TABLE 10.56

Schilbe uranoscopus : diet with relation to depth. The number of points scored by each food type has been expressed as a percentage of the total points allotted in each depth zone. Results are based on all data collected throughout the lake between May 1972 and July 1974.

	Ferguson's Gulf	0 - 10 m	10 - 20 m	Over 20 m
Stomachs with food	110	65	58	207
Empty stomachs	27	15	13	49
Total points	484	190	328	812
Food items %				
Fish				
Alestes spp.	50.2	72.2	11.6	2.0
Engraulicypris stellae	15.5	1.1	2.4	22.1
Haplochromis macconneli	-	-	-	3.6
Barbus cf *anema*	-	-	-	1.7
Fish remains	26.9	23.2	18.6	21.3
Total fish	92.6	96.5	32.6	50.7
Crustacea				
Prawns	6.0	3.1	67.1	49.1
Copepods	0.2	-	-	-
Ostracods	-	0.4	-	0.2
Total Crustacea	6.2	3.5	67.1	49.3
Insects				
Total Insects	1.2	-	0.3	-

TABLE 10.57

Schilbe uranoscopus : diet with relation to size. The number of points scored by each food item has been expressed as a percentage of the total points allotted in each of four length groups. Results are based on all data collected throughout the lake between May 1972 and July 1974.

	Length groups cm.			
	Under 15	15 to 19	20 to 24	25 to 29
Stomachs with food	22	26	40	33
Empty stomachs	5	7	11	8
Total points	42	69	153	174
Food items %				
Fish				
Alestes spp	-	-	1.3	25.3
Engraulicypris stellae	4.8	-	7.8	11.5
Barbus cf *anema*	-	-	2.6	1.2
Fish remains	-	2.9	13.1	40.2
Total fish	4.8	2.9	24.8	78.2
Crustacea				
Prawns	85.7	97.1	75.2	21.8
Ostracods	4.8	-	-	-
Total Crustacea	90.5	97.1	75.2	21.8
Insects	4.7	-	-	-

TABLE 10.58

Changes in the diet of *Schilbe uranoscopus* over a twenty-four hour period at a gillnet station within Ferguson's Gulf in July 1974. Points gained by each food item are expressed as a percentage of the total points recorded in each of six time phases. Catch rate (numbers of fish caught per 50 yard net) is also given.

	Afternoon 12.00 to 18.00 hrs.	Dusk 18.00 to 24.00 hrs.	Late evening 20.00 to 24.00 hrs.	Early morning 24.00 to 06.00 hrs.	Dawn 06.00 to 08.00 hrs.	Morning 08.00 to 12.00 hrs.
Total number of fish caught/ 50 yard net	15	21	21	23	2	0
Mean number/hour	2.50	10.50	5.25	3.83	1.00	-
Number of stomachs with food	3	8	19	20	2	-
Number of empty stomachs	12	13	3	0	0	-
Total number examined	15	21	22	20	2	-
Total number of points	4	68	126	182	8	-
Mean number of points/fish	0.27	3.24	5.73	9.10	4.00	-
Food items %						
Alestes sp.	-	94	45	57	25	-
Engraulicypris stellae	-	6	21	26	50	-
Fish remains	75	-	27	25	25	-
Prawns	25	-	-	-	-	-
Insects	-	-	7	2	-	-

TABLE 10.59

Frame trawl catches of *Schilbe uranoscopus* over a twenty-four hour period at a station in 25m of water in the Longech area during April 1974. Catch/effort is given as numbers of fish/10 minute haul.

	Afternoon	Dusk	Night	Dawn	Morning
Surface	-	-	-	-	-
4m	-	-	-	-	-
8m	-	-	5	-	-
12m	-	-	10	-	-
16m	-	1	1	1	-
20m	2	16	2	5	14
25m (bottom)	10	4	2	8	13

TABLE 10.60

Changes in stomach fullness and diet of *Schilbe uranoscopus* over a twenty-four hour period at a frame trawl station in 25m of water in the Longech area during April 1974. Points gained by each food item are expressed as a percentage of the total points recorded during each of five time phases.

	Day p.m.	Dusk	Night	Dawn	Day a.m.
Total number of fish caught	12	21	20	14	27
Stomachs with food	6	10	18	12	14
Empty stomachs	6	10	2	2	13
Number of points allotted	16	33	62	62	69
% fullness	8.3	13.1	19.4	27.7	16.0
Food items %					
Fish					
Alestes sp	-	5.7	-	-	-
Engraulicypris stellae	12.5	-	-	-	-
Fish remains	-	28.6	19.4	23.0	29.0
Total fish	12.5	34.3	19.4	23.0	29.0
Crustacea					
Prawns	81.3	62.9	79.0	77.0	68.1
Copepods	6.2	-	-	-	-
Ostracods	-	2.8	-	-	1.4
Total crustacea	87.5	65.7	79.0	77.0	69.5
Insects					
Chironomid larvae and pupae	-	-	1.6	-	-
Corixid	-	-	-	-	1.5
Total insect	-	-	1.6	-	1.5

TABLE 10.61

Synodontis schall : mean bottom trawl catch per effort, in kilograms per hour in the Northern, Central and Southern sectors of Lake Turkana for the period May 1972 to July 1974.

	Depth zones in metres											
	0-5	5-10	10-15	15-20	20-25	25-30	30-40	40-50	50-60	60-70	70-80	80+
Northern Sector												
Allia Bay	98	78	2	-	2	-	2	+	n/a	n/a	n/a	n/a
Remainder	28	21	46	15	6	6	37	-	7	-	-	n/s
Combined	82	50	40	15	5	6	32	+	7	-	-	n/s
Central Sector	n/s	113	106	129	44	32	17	2	2	+	1	+
Southern Sector												
Kerio - Turkwell	1	4	1	2	37	-	5	n/a	n/a	n/a	n/a	n/a
Southern Basin	-	2	2	-	2	10	3	-	+	2	-	-
Combined	1	3	1	2	22	10	4	-	+	2	-	-
Overall mean	67	52	61	101	32	20	20	2	2	1	1	+

\+ = less than 1 Kg/hour of trawling

n/a = not applicable

n/s = not sampled

TABLE 10.62

Syndontis schall mean catch rate, in kilograms per hour of trawling in the Longech area, in water between the 15 and 20 metre contour, over the period July 1972 to May 1974.

	1972/3		1973/4	
	Mean catch rate kg/hour	Number of hauls	Mean catch rate kg/hour	Number of hauls
Jul	99	1	71	1
Aug	62	1	88	3
Sep		n/s	184	4
Oct		n/s	6	1
Nov	19	2	27	1
Dec		n/s		n/s
Jan	312	1	87	1
Feb	73	1	148	1
Mar	272	1	581	1
Apr		n/s		n/s
May		n/s	85	2
Jun	26	1		n/s

n/s = no sample

TABLE 10.63

Position of four gillnet stations relative to the midwater scattering layer, fished between January and June 1974 off Longech Spit.

Station	Depth metres	Position relative to scattering layer
A	9	Entirely above
B	14	Uppermost fringe only
C	19	Within
D	25	Below

TABLE 10.64

Mean catch rate (kilograms of *Synodontis schall* per 50 yard net per night) recorded at four stations off Longech Spit between January and July 1974.

Station	Number of nights	Mesh size		
		2"	3"	4"
A	4	1.5kg.	4.1kg.	1.3kg.
B	6	1.3	4.4	2.9
C	6	10.5	19.3	9.7
D	4	10.1	15.9	8.0

TABLE 10.65

Comparison between surface, midwater and bottom set gillnets at an offshore station in the Longech area during May 1974. Catch of *Synodontis schall* is expressed as numbers and kilograms per 24 hours per 50 yard net of 4" stretched mesh.

Net position	No. of fish	Catch Kg/50 yd. net
Surface Set	74	36
Midwater 15m depth	2	1
30m depth	0	0
Bottom 73m.	10	4.5

TABLE 10.66

Catch data from three and four inch gillnets surface set at three stations in the Longech area during May 1973. Catch per effort is in numbers and kilograms of *Synodontis schall* per 50 yard net per 24 hours and is from a single setting at each station.

	3" net		4" net	
	No.	Weight kg.	No.	Weight kg.
Depth of water				
25m	98	30	80	28
40m	11	4	6	2
50m	12	4	4	1

TABLE 10.67

Frame trawl catches of *Synodontis schall* at two stations in the Longech area during September 1973. Catches are expressed as mean number of fish per 15 minute haul.

	Inshore Station. Depth 30m.		Offshore Station. Depth 80m.	
	Mean No./15 min.	No. of hauls	Mean No./15 min.	No. of hauls
Sampling depth metres				
0-4	-	3	-	1
4-8	4	3	-	2
8-12 *	+	2	2	3
12-16 *	9	1	1	3
16-20	5	2	-	1
20-24	6	1	-	1
24-30	2	1	-	1
30-40	n/a	n/a	-	1
40-60	n/a	n/a	-	2
60-80	n/a	n/a	-	1

n/a = not applicable

\+ = less than 1 fish

* : approximate depth of midwater scattering layer

TABLE 10.68

Vertical distribution of *Synodontis schall* over a 24 hour period, as shown by frame trawl catches at a station in 25m of water. Catch rates, in numbers of fish per 10 minute haul, are given for six depth zones and five time phases.

	Time phase				
	Day p.m.	Dusk	Night	Dawn	Day a.m.
Surface	-	-	1	-	-
4m.	-	-	-	-	-
8m.	-	-	1	-	-
12m.	2	-	-	1	1
16m.	-	-	4	-	-
below 20m.	4	2	1	2	1

TABLE 10.69

Comparison by t-tests of monthly length frequency distributions of male and female *Synodontis schall* caught by bottom trawling between July 1972 and July 1973 in the Longech area.

	Month	Mean L	Variance	n	t.val	D.F.	Significance at 95% confidence limits
1972	Jul	F 22.3167	11.4068	60	0.1395	99	n/s
		M 22.2195	12.4236	40			
	Aug	F 24.5909	10.2008	44	1.3172	69	n/s
		M 23.5926	8.6353	27			
	Sep	F 25.4718	4.6340	142	0.8677	186	n/s
		M 25.1739	2.4065	46			
	Oct	F 21.3962	21.3977	53	0.9059	91	n/s
		M 20.5750	15.1737	40			
	Nov	F 23.8235	8.0110	119	2.8298	234	s
		M 22.9060	4.3618	117			
	Dec	F 24.3476	10.1913	164	1.8487	290	n/s
		M 23.6797	8.3454	128			
1973	Jan	F 24.4865	8.0615	74	1.3163	148	n/s
		M 23.8553	9.1654	76			
	Feb	F 26.0722	8.5052	97	1.2490	146	n/s
		M 25.4510	7.8125	51			
	Mar	F 25.5894	8.5287	246	4.6073	389	s
		M 24.1655	9.0282	145			
	Apr	F 25.9605	4.4257	228	5.4466	353	s
		M 24.6772	4.7124	127			
	May	F 22.1503	10.4773	173	4.1248	285	s
		M 20.5526	10.0547	114			
	Jun	F 22.3171	9.4720	41	0.4257	75	n/s
		M 22.000	11.3333	34			
	Jul	F 23.9237	12.1736	118	1.6736	200	n/s
		M 23.1071	10.9884	84			

s : significant

n/s : not significant

TABLE 10.70

Mean fork length of the 1971 *Synodontis schall* year class in trawl catches from July 1972 to October 1973.

	Month		Station Depth	Mean fork length cm	Standard deviation	Sample size
1972	Jul	*	12/1	19.16	1.66	138
			13/1	19.42	2.37	79
			16/3	20.87	2.54	71
	Aug		20/1	20.81	1.40	31
		*	22/1	20.19	1.49	26
			22/2	19.51	1.79	39
	Sep		no sample			
	Oct		44/2	22.40	3.19	79
	Nov		52/1	22.4	1.74	9
		*	52/2	24.30	3.03	23
			52/3	24.37	2.63	30
	Dec		59/2	23.65	2.61	138
		*	59/7	22.95	3.24	150
			59/8	23.58	3.38	229
1973	Jan		62/6	25.00	2.10	41
		*	65/2	23.92	2.94	482
	Feb	*	75/1	25.65	2.61	361
	Mar		84/1	24.80	3.44	176
		*	84/2	25.34	2.22	402
	Apr	*	89/1	25.40	2.13	255
			89/2	25.25	2.76	248
	May	*	97/3	25.68	1.90	136
	Jun		no sample			
	Jul	*	105/2	26.68	1.48	101
	Aug	*	114/5	26.20	1.67	117
			116/1	27.18	1.40	45
	Sep		128/1	25.67	1.58	191
		*	135/2	26.07	2.00	45
			135/3	25.77	2.58	43
	Oct		140/1	26.63	1.04	11
		*	140/2	27.28	2.23	29

(* : sample from routine monthly trawl station)

TABLE 10.71

Observed mean monthly lengths of four year classes of *Synodontis schall* caught by bottom trawling between June 1972 and July 1974 in the Longech area. Sample sizes are given in brackets.

		Year classes			
		1970	1971	1972	1973
1972	J	26.08 (102)			
	J	25.61 (305)	19.65 (288)		
	A	25.75 (160)	20.11 (96)		
	S	26.44 (64)			
	O		22.40 (79)	11.05 (18)	
	N		24.06 (62)	11.87 (22)	
	D		23.42 (517)		
1973	J		24.03 (523)		
	F		25.65 (361)		
	M		25.18 (578)		
	A		25.33 (503)		
	M		25.68 (136)		
	J				
	J		26.68 (101)		
	A		26.47 (162)	19.99 (293)	
	S		25.75 (279)	20.27 (157)	
	O		27.10 (40)	20.85 (57)	
	N			23.41 (236)	11.27 (82)
	D				
1974	J			22.85 (328)	
	F			24.01 (164)	
	M			24.01 (937)	
	A				
	M				
	J				
	J			26.68 (111)	

TABLE 10.72

Growth of *Synodontis schall*. Data from four year classes (Table 10.71) has been combined to give the observed monthly increment in length up to 2½ years of age.

	Approx. age months	Mean length cm.	Sample size
May			
Jun	1		
Jul	2		
Aug	3		
Sep	4		
Oct	5	11.05	18
Nov	6	11.39	104
Dec	7		
Jan	8		
Feb	9		
Mar	10		
Apr	11		
May	12		
Jun	13		
Jul	14	19.65	288
Aug	15	20.01	389
Sep	16	20.27	157
Oct	17	21.75	136
Nov	18	23.54	298
Dec	19	23.42	517
Jan	20	23.57	851
Feb	21	25.13	528
Mar	22	24.45	1515
Apr	23	25.33	503
May	24	25.68	136
Jun	25	26.08	102
Jul	26	26.04	517
Aug	27	26.20	322
Sep	28	25.87	343
Oct	29	27.10	40

TABLE 10.73

Comparison between observed and estimated lengths in *Synodontis schall*.

Age (months)	Estimated fork length (cm)	Observed fork length (cm)
6	12.5	11.4
12	18.5	n/a
18	22.7	23.5
24	25.5	25.7
30	27.5	n/a (27.1 at age 29)
36	28.9	n/a

n/a = not available

TABLE 10.74

Synodontis schall : comparing the length-weight relationship of grouped data. The slopes of the regressions have been compared by applying d-tests.

Comparison between	Degrees of freedom	d
Females 20cm cf females 20cm	532	0.888
Males 20cm cf males 20cm	464	1.216
All males cf all females	998	0.036

TABLE 10.75

Synodontis schall : mean length and weight at ages 1 to 3 years.

Age (years)	Mean fork length (cm)	Mean weight (g)
1	18.5	133
2	25.5	250
3	30.0	507

TABLE 10.76

Comparison of the growth of *Synodontis schall* from Lake Turkana with two other African populations.

Author	Present study	Willoughby (1974)	Bishai and Gideiri (1965a)	
Locality	Lake Turkana	Lake Kainji	River Nile	
	Both sexes	Both sexes	Male	Female
Fork length (cm) at age				
1	18.5	8.7	9.5	10.3
2	25.5	11.7	12.2	14.7
3	30.0	14.5	22.0	23.5

TABLE 10.77

An analysis of size at maturity in *Synodontis schall* combining all data obtained between May 1972 and July 1974 from bottom trawl samples in the Longech area for a) females and b) males. Numbers at each maturity stage are expressed as a percentage of the total in each cm length group.

			Gonad Stage				
a) FEMALES	Fork length (cm)	Number	2	3	4	5	6
	15	22	100	-	-	-	-
	16	30	100	-	-	-	-
	17	38	97	3	-	-	-
	18	65	95	5	-	-	-
	19	126	84	10	6	-	-
	20	189	61	29	8	1	1
	21	263	44	34	20	+	1
	22	317	44	31	24	+	+
	23	319	42	35	21	1	1
	24	323	45	32	21	1	1
	25	355	45	28	27	+	1

			Gonad Stage			
b) MALES	Fork length (cm)	Number	2	3	4	5
	15	22	100	-	-	-
	16	35	97	3	-	-
	17	47	94	6	-	-
	18	66	76	24	-	-
	19	142	59	39	1	-
	20	211	36	61	3	-
	21	281	15	80	6	-
	22	302	14	82	4	+
	23	277	6	87	7	-
	24	241	10	80	10	+
	25	236	5	80	14	1

+ : less than 1%

TABLE 10.78

Comparison of the size at first maturity and first breeding of the Lake Turkana population of *Synodontis schall* with populations from two other localities.

	L. Turkana	R. Nile	L.Kainji
Author	Present study	Bishai and Gideiri (1965a)	Willoughby (1974)
Size at first maturity (fork length cm)			
Males	16	10.7(15.6cmTL.)	-
Females	17	13.2(18.4cmTL.)	-
Size at first breeding (fork length cm)			
Males	19	-	12.5(10.4cmSL.)
Females	19	-	14.0(11.8cmSL.)

TABLE 10.79

Seasonal changes in maturity of three length groups of male *Synodontis schall*. Numbers of fish at each maturity stage are expressed as a percentage of the total number examined each month. Data is based on all fish caught between May 1972 and July 1974 in the Central lake sector.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15-19cm Stage	2	67	72	52	44	81	71	83	74	96	75	80	92
	3	33	28	48	56	16	14	17	22	4	25	20	8
	4	-	-	-	-	2	14	-	4	-	-	-	-
	5	-	-	-	-	-	-	-	-	-	-	-	-
Number		27	36	21	34	43	7	30	27	23	16	15	37
20-24cm Stage	2	13	15	7	3	16	26	42	20	18	20	4	26
	3	83	83	87	94	71	57	53	71	59	70	94	72
	4	3	2	5	3	13	17	5	8	23	10	2	2
	5	1	-	-	-	-	-	-	1	-	-	-	-
Number		129	143	148	199	87	23	60	120	91	44	102	173
25-29cm Stage	2	19	11	2	3	1	11	13	4	-	7	9	2
	3	57	83	89	83	69	67	80	72	71	93	75	93
	4	24	6	8	14	28	22	7	24	26	-	13	5
	5	-	-	-	-	1	-	-	-	3	-	3	-
Number		58	94	121	76	81	9	45	89	70	15	32	56

TABLE 10.80

Seasonal changes in maturity of three length groups of female *Synodontis schall*. Numbers of fish at each maturity stage are expressed as a percentage of the total number examined each month. Data is based on all fish caught between May 1972 and July 1974 in the Central lake sector.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
15-19cm Stage	2	89	88	100	88	91	100	90	88	89	100	93	97
	3	7	8	-	12	9	-	3	12	11	-	-	3
	4	4	4	-	-	-	-	7	-	-	-	7	-
	5	-	-	-	-	-	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-	-	-	-	-
Number		27	24	11	17	46	7	30	25	28	16	14	37
20-24cm Stage	2	49	51	40	37	43	15	28	32	35	46	43	65
	3	30	29	23	45	29	62	31	39	31	33	33	19
	4	30	19	10	17	26	23	36	24	33	19	21	15
	5	1	-	-	-	2	-	-	4	2	-	-	-
	6	-	1	-	1	-	-	4	1	2	2	3	1
Number		131	146	163	176	126	26	89	104	129	43	103	190
25-29cm Stage	2	35	54	70	61	51	25	32	40	27	37	40	57
	3	25	23	17	16	13	50	19	27	30	20	21	15
	4	38	17	13	23	34	25	41	23	38	43	21	23
	5	1	2	-	-	-	-	-	1	+	-	-	-
	6	1	4	-	-	2	-	7	8	4	-	2	5
Number		115	196	253	180	136	8	68	132	201	30	62	111

TABLE 10.81

Seasonal changes in gonad condition of *Synodontis schall* caught by beach seines in Ferguson's Gulf between May 1972 and July 1974. Percentage numbers of males and females larger than 20cm at each maturity stage are given for each month.

Females	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Stage 2	87	83	49	48	15	47	58	26	89	49	49	84
3	6	17	17	7	7	16	23	45	11	26	27	5
4	1	-	33	44	36	18	9	-	-	25	1	-
5	-	-	1	-	38	16	-	-	-	-	1	-
6	6	-	-	-	4	3	11	-	-	-	21	11
Number	137	12	76	27	55	38	93	29	9	73	95	19
Males												
Stage 2	5	42	28	-	8	21	48	29	17	32	19	14
3	94	58	60	100	25	54	45	47	50	66	80	86
4	1	-	12	-	56	17	4	24	33	2	1	-
5	-	-	-	-	10	8	1	-	-	-	-	-
Number	127	12	82	33	48	24	69	62	6	44	93	14

TABLE 10.82

Seasonal changes in maturity of male (M) and female (F) *Synodontis schall* larger than 20cm in the northern sector. Numbers of fish at each maturity stage are expressed as a percentage of the total number examined each month.

			Number	Gonad stage				
				2	3	4	5	6
1972								
	Nov	F	121	4	22	66	2	5
		M	131	5	36	54	5	
1973								
	Feb	F	41	46	24	-	-	-
		M	28	-	100	-	-	
	Apr	F	188	10	3	86	1	-
		M	142	-	77	23	-	
	Jul	F	27	33	19	48	-	-
		M	22	18	82	-	-	
	Sep	F	164	84	10	6	-	-
		M	133	71	29	-	-	
	Nov	F	99	87	10	3	-	-
		M	49	37	65	-	-	
1974								
	Jun	F	28	7	18	39	36	-
		M	12	17	17	67	-	

TABLE 10.83

Occurrence of post-larval *Synodontis schall* in meter townet catches within 10 kilometres of the Omo delta. Catch rate (mean number of post larvae/haul) has been combined for the period November 1972 to September 1975.

Month	Number of hauls	Mean number of post-larvae per haul
Jan	n/s	
Feb	2	0
Mar	n/s	
Apr	n/s	
May	n/s	
Jun	6	60
Jul	4	7
Aug	10	14
Sept	4	134
Oct	25	7
Nov	5	1
Dec	n/s	

n/s = no sample

TABLE 10.84

Seasonal changes in maturity of male (M) and female (F) *Synodontis schall* larger than 20cm in the Southern sector. Numbers of fish at each maturity stage are expressed as a percentage of the total number examined each month.

			Number	Gonad stage 2	3	4	5	6
1972	Jun	F	39	10	21	40	8	-
		M	25	16	32	48	-	
	Dec	F	12	92	8	-	-	-
		M	9	-	78	12	-	
1973	May	F	31	6	16	68	10	-
		M	31	-	29	68	3	
	Oct	F	112	39	48	10	-	1
		M	84	18	82	-	-	
1974	Jun	F	58	36	19	43	2	-
		M	31	23	67	10	-	

TABLE 10.85

Ratio of male to female *Synodontis schall* in the Central lake area. The sex-ratio is expressed as number of males per 100 fish, and all fish caught by the bottom trawl between May 1972 and July 1974 have been included.

Length cm	Number of males	Number of females	Sex ratio
15	22	22	50
6	35	30	54
7	47	38	55
8	66	65	50
9	142	126	53
20	211	189	53
1	281	263	52
2	302	317	49
3	277	319	46
4	241	323	43
5	236	355	40
6	242	394	38
7	145	339	30
8	83	236	26
9	42	145	22
30	12	60	17
1	3	23	12
2	4	8	33
3	1	5	17
4	0	4	0

TABLE 10.86

Ratio of male to female *Synodontis schall* in the Central lake area. Sex-ratio is expressed as numbers of males per 100 fish for two length groups in each month and includes all fish caught by the bottom trawl between May 1972 and July 1974.

	20-24cm		25-29cm	
	Sample size	Sex ratio	Sample size	Sex ratio
Jan	260	50	173	34
Feb	289	49	290	32
Mar	311	48	374	32
Apr	375	53	256	30
May	213	41	217	37
Jun	49	47	17	53
Jul	149	40	113	40
Aug	224	54	221	40
Sep	220	41	271	26
Oct	87	51	45	33
Nov	205	50	94	34
Dec	363	48	167	34

TABLE 10.87

Ratio of male to female *Synodontis schall* within Ferguson's Gulf. The sex-ratio is expressed as numbers of males per 100 fish in two length groups for each month. All data collected between May 1972 and July 1974 has been included.

	20-24cm		25-29cm	
	Sample size	Sex ratio	Sample size	Sex ratio
Jan	44	50	194	49
Feb	6	67	18	44
Mar	82	50	73	55
Apr	28	57	32	53
May	107	59	49	49
Jun	34	68	29	38
Jul	111	46	51	33
Aug	65	71	32	41
Sep	10	40	4	25
Oct	74	30	40	53
Nov	66	52	118	47
Dec	10	40	19	42

TABLE 10.88

Synodontis schall : seasonal changes in mean condition factor ($\bar{k}$) of males and females larger than 20cmFL.in the Longech area. Data from the two years fieldwork has been combined and $\bar{k}$ is given for each month.

	Month	Number	$\bar{k}$	Standard Deviation
a) Females	Jan	60	101	11.7
	Feb	29	97	9.8
	Mar	32	97	9.0
	Apr	82	105	9.3
	May	74	103	11.3
	Jun	72	100	10.5
	Jul	8	93	10.4
	Aug	42	99	10.2
	Sept	66	108	9.8
	Oct	59	107	9.9
	Nov	13	106	11.7
	Dec	15	101	10.0
b) Males	Jan	16	100	6.9
	Feb	60	95	9.0
	Mar	40	97	9.6
	Apr	67	99	9.4
	May	79	92	8.9
	Jun	34	95	9.7
	Jul	5	89	7.6
	Aug	47	96	10.8
	Sep	40	103	7.8
	Oct	30	103	11.2
	Nov	17	107	8.9
	Dec	12	94	7.7

TABLE 10.89

Embryological and larval development of *Synodontis schall*

Approximate time after fertilisation	Plate	Stage of development
00 mins		Egg diameter 1.2 to 1.4mm. Translucent yellow colour.
20 mins.	1A	Outer covering swollen with a sculptured surface. Egg diameter 2.2mm. Yolk diameter 1.0 to 1.2mm.
1 hr. 30 mins.	1B	First blastomere formed. Approximately 0.5mm in length.
2 hrs.	1C and ID	Division proceeding rapidly. 16-32 blastula.
4 hrs.		Blastodermal cap 1.0mm in length covers $\frac{1}{3}$ of yolk. Maximum cell diameter 0.15mm.
5 hrs.		Gastrulation commences. Marginal ridge visible.
5 hrs. 30 mins.		Blastopore closes.
8 hrs.	1E	Head and tail folds of embryo just visible. Embryo encircles approximately half of yolk.
10 hrs.		First somites visible.
18 hrs.		20 somites present. Posterior end of embryo lifted slightly from yolk.
20 hrs.		Head fold well developed, caudal region free from yolk sac. Auditory capsule visible. Somites extending to caudal region. Slight lateral movement.
23 hrs.		Embryo 3.0mm in length. Fin fold forming, more developed ventrally than dorsally. Two pairs of otiliths now visible.
24 hrs.	1H	Hatching after vigorous movement of embryo. Optic vesicle present but not pigmented.

Contd./........

27 hrs.	1I	Larvae 3.8 to 4.0mm in length, swimming with elliptical yolk sac in contact with dish.
33 hrs.	1J and 1K	Eye pigmented and slight pigmentation, both dorsally and ventrally, in caudal region at base of fin fold. Fore and mid-brain prominent.
45 hrs.	1L	Approximately 30 somites present. Three pairs of barbel buds developing in buccal region. Occasional flicks of body enables larva to move into midwater.
47 hrs.		Larval length 4.5mm. Pectoral fin bud visible.
48 hrs.		Nostril forming.
56 hrs.		Larvae 4.7 to 5.0mm in length. Lens forming in eye. Gill rudiments present.
68 hrs.		Anterior margin of maxillary barbel crenelated. Pectoral fin bud well formed. Larvae swim vigorously.
74 hrs.		Mouth opens and closes. Peristalsis visible in gut. A few melanophores present in head region. Blood supply to gills.
93 hrs.		Yolk sac empty. Maxillary and mandibular barbels lengthened and crenelated on anterior margin. Three pairs of otoliths visible.
102 hrs.	1M	Food in gut. During feeding barbels splayed out and mouth closely applied to food.
116 hrs.		Larvae 6.4mm in length. Increased head pigmentation. Gut folded.
129 hrs.		Mandibular teeth visible.
141 hrs.	1N	Larvae 6.8mm in length. Caudal and pectoral fin rays present.

TABLE 10.90

Synodontis schall : Food in relation to depth. Points for each food item are expressed as a percentage of the total allotted in each depth zone. All stomachs examined between May 1972 and July 1974 have been included.

Depth zones, metres.

	0-5	5-10	10-20	20-40	40-60	Over 60	Ferguson's Gulf	Allia Bay
Number of stomachs with food	39	108	270	390	32	40	383	43
Total points	337	730	1505	2321	120	151	2792	275
Food items %								
Crustacea								
Ostracods	8	27	23	31	20	10	28	23
Copepods	28	10	48	37	7	5	49	-
Caridea	1	+	6	13	11	7	+	-
Cladocera	-	23	+	2	-	-	-	-
All Crustacea	37	60	77	83	37	22	77	23
Insects								
Corixids	23	5	+	1	-	-	4	20
Chironomids	15	2	1	2	11	5	13	24
Notonectids	+	-	+	-	-	-	-	-
Ephemeroptera	-	2	1	-	-	-	-	3
Trichoptera	-	1	1	-	-	-	-	4
Terrestrial insects	4	-	+	-	2	-	+	-
All Insects	42	10	4	3	13	5	17	51
Gasteropods								
Cleopatra pnothi	-	-	1	-	33	21	-	-
Gabiella rosea	-	+	1	-	-	-	-	-
Melanoides tubuculata	-	+	-	+	-	-	-	-
Unidentified	-	+	1	1	17	19	-	2
All Gasteropods	-		3	1	50	40	-	2
Fish								
Engraulicypris stellae	-	-	-	+	-	1	2	-
Lates longispinus	-	-	+	+	-	-	-	+
Tilapia spp.	-	-	-	+	-	-	-	3
Barbus ofanema	-	-	-	+	-	-	-	-
Alestes spp.	14	22	11	+	-	-	-	-
Scales (B.bynni L.niloticus)	-	-	-	-	-	32	-	-
Unidentified	2	3	3	2	-	-	2	6
All Fish	16	25	14	12	-	33	4	9
Vegetable matter	5	2	-	-	-	-	-	4
Algae	-	3	1	-	-	-	+	4
Diatoms	-	-	-	+	-	-	+	7

+ = less than 1%

TABLE 10.91

Changes in the diet of *Synodontis schall* through a twenty four hour period at a gillnet station in Ferguson's Gulf in July 1974. Points gained by each food type are expressed as a percentage of the total points recorded during six time phases. Catch rate (numbers of fish caught per hour per 50 yard net) is also given.

	Afternoon 12.00 - 18.00hrs.	Dusk 18.00 - 20.00hrs.	Late evening 20.00-24.00 hrs.	Early morning 24.00-05.00 hrs.	Dawn 06.00-08.00 hrs.	Morning 08.00-12.00 hrs.
Total number of fish caught/ 50yd net	69	40	17	61	157	10
Mean number/ hour	11.5	20.0	4.25	10.25	78.25	2.5
Number of stomachs with food	17	21	14	14	19	10
Number of empty stomachs	4	1	3	1	1	-
Total number examined	21	22	17	15	20	10
Total number of points	76	86	52	34	138	67
Mean number of points/ fish	3.6	3.9	3.1	2.3	6.9	6.7
Food items %						
Chironomid	28	72	77	44	24	4
Corixid	3	3	8	-	2	2
Ostracod	35	19	15	44	9	16
Copepod	33	6	-	3	49	72
Hydracarina	1	-	-	3	1	-
Fish remains	-	-	-	6	5	-
Diatoms and Algae	-	-	-	-	10	6

Appendix 10.A

Mean retention lengths in cm ($\bar{l}$) of *Bagrus bayad*, *Synodontis schall* and *Schilbe uranoscopus* for nine mesh sizes of gillnets. All data collected between May 1972 and July 1974 have been included. Standard deviations (sd) and sample sizes (n) are also given.

Species		2	3	4	5	6	7	8	9	10
Bagrus bayad	$\bar{l}$	25.3	40.4	52.8	48.1	63.3	62.8	51.5	33.5	66.5
	sd	±3.2	±7.7	±10.6	±13.9	±12.1	±14.7	±15.9		
	n	(9)	(24)	(61)	(44)	(23)	(20)	(23)	(1)	(2)
Synodontis schall	$\bar{l}$	22.0	23.88	26.93	24.86	25.01	25.41	25.70	24.3	21.0
	sd	±3.47	±2.86	±2.57	±3.53	±4.05	±3.74	±2.84	±2.6	
	n	(509)	(1117)	(647)	(639)	(51)	(32)	(20)	(4)	(2)
Schilbe uranoscopus	$\bar{l}$	25.61	30.11	28.00	27.5	27.0	25.5	-	-	-
	sd	±3.16	±1.83	±2.88		±3.6				
	n	(270)	(278)	(10)	(1)	(6)	(1)			

Appendix 10.B

Bagrus bayad : gillnet selection. Length frequencies of fish caught between May 1972 and July 1974 have been accumulated for each net size.

Fork length (cm)	Stretched mesh inches 2	3	4	5	6	7	8	9	10
20	1	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-
22	2	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	-
24	1	-	-	-	-	-	-	-	-
25	1	-	-	-	-	-	-	-	-
26	2	-	-	-	-	-	-	-	-
27	-	-	-	1	-	-	-	-	-
28	1	-	1	-	-	-	-	-	-
29	-	-	-	-	-	-	-	-	-
30	1	1	-	1	-	-	-	-	-
31	-	1	-	-	-	-	-	-	-
32	-	1	-	1	-	1	1	-	-
33	-	1	2	1	1	-	1	1	-
34	-	1	-	-	-	-	-	-	-
35	-	2	-	1	-	-	2	-	-
36	-	1	-	1	-	-	2	-	-
37	-	3	-	1	-	1	2	-	-
38	-	-	-	-	-	1	2	-	-
39	-	1	-	-	1	-	-	-	-
40	-	3	3	2	-	-	-	-	-
41	-	-	-	1	-	-	2	-	-
42	-	2	1	2	-	-	-	-	-
43	-	-	1	1	1	1	-	-	-
44	-	2	-	1	-	-	-	-	-
45	-	2	6	2	-	-	-	-	-
46	-	2	2	1	-	-	-	-	-
47	-	-	3	2	-	-	-	-	-
48	-	-	6	1	-	-	2	-	-
49	-	-	3	3	-	-	-	-	-
50	-	-	4	2	-	-	-	-	-
51	-	-	6	4	-	-	-	-	-
52	-	-	3	1	-	-	-	-	-
53	-	-	-	-	-	-	-	-	-
54	-	-	-	1	-	1	-	-	-
55	-	-	-	2	-	-	1	-	-
56	-	-	-	-	-	-	-	-	-
57	-	-	3	3	-	-	-	-	-
58	-	-	2	1	2	1	-	-	-
59	-	-	1	-	1	1	1	-	-
60	-	-	1	-	1	-	-	-	-
61	-	-	3	-	2	-	-	-	-
62	-	-	1	-	1	1	-	-	-
63	-	-	-	-	-	-	-	-	-
64	-	-	1	-	5	-	-	-	-
65	-	-	2	-	-	1	-	-	-
66	-	-	-	1	-	-	1	-	2
67	-	-	-	1	2	2	1	-	-
68	-	1	-	1	1	1	-	-	-
69	-	-	-	-	-	2	2	-	-
70	-	-	1	-	-	1	2	-	-
71	-	-	1	-	-	-	-	-	-
72	-	-	-	-	1	-	1	-	-
73	-	-	1	-	1	-	-	-	-
74	-	-	-	-	-	1	-	-	-
75	-	-	-	-	-	1	-	-	-
76	-	-	1	1	1	1	-	-	-
77	-	-	-	-	-	-	-	-	-
78	-	-	1	-	-	-	-	-	-
79	-	-	1	-	-	-	1	-	-
80	-	-	-	-	1	-	-	-	-

Appendix 10.C

Synodontis schall : gillnet selection. Length frequencies of fish caught between February and June 1974 at four stations off Longech Spit have been accumulated for each net size.

Fork length (cm)	Stretched mesh (inches) 2	3	4	5	6	7
10	-	-	-	-	-	-
1	-	-	-	-	-	-
2	2	-	-	-	-	-
3	-	-	-	-	-	-
4	9	-	-	-	-	-
5	9	-	-	1	-	-
6	4	2	-	-	-	-
7	13	5	-	-	-	-
8	24	15	-	-	1	-
9	39	50	2	1	2	-
20	37	103	7	2	-	1
1	46	121	5	2	1	2
2	51	87	6	3	1	1
3	52	73	6	3	-	1
4	44	65	18	3	2	-
5	32	39	22	2	1	-
6	13	55	38	4	1	-
7	13	29	39	1	-	-
8	12	15	41	2	-	-
9	3	9	24	1	-	-
30	3	4	10	2	-	-
1	2	1	4	2	-	-
2	-	2	3	3	-	-
3	-	-	3	-	-	-
4	-	-	-	-	-	-
5	-	-	-	2	-	-
6	-	-	-	-	-	-

Appendix 10.D

Schilbe *uranoscopus* : gillnet selection. Length frequencies of fish caught between February and June 1974 at four stations off Longech Spit have been accumulated for each net size.

Fork length (cm)	Stretched mesh (inches)		
	2	3	4
15	-	-	-
6	1	-	-
7	-	-	-
8	-	-	-
9	2	-	-
20	13	-	-
1	17	2	-
2	18	2	-
3	11	1	-
4	12	3	-
5	23	-	1
6	39	6	-
7	36	10	-
8	33	34	-
9	21	83	-
30	10	83	-
1	6	57	-
2	1	16	1
3	-	8	-
4	-	-	-
5	-	1	-
6	-	-	-
7	-	-	-

Appendix 10.E

Results from an experimental longline fishery in the Central lake sector. Catches of *Lates niloticus* are given for the period January to June 1974.

	Jan.	Feb.	Mar.	Apr.	May.	Jun.
No. of nights recorded	40	19	25	12	6	18
No. *Lates* caught	12	69	41	13	7	37
Mean No./night	3	3.63	1.64	1.08	1.16	2.05
Mean No. hooks/ night.	1400	1400	1400	1400	1400	1400
Mean No. *Lates*/ 100 hooks	0.21	0.26	0.12	0.08	0.08	0.15
Mean length *Lates*	122.3	120.9	121.13	111.31	117.29	121.76
Total fresh-weight of *Lates*/month	303	1560	1208	254	145	846
Mean fresh weight/100 hooks	5.41	5.86	3.45	1.51	1.73	3.36