LAKE TURKANA

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

VOLUME 3

EDITED BY A J HOPSON

LAKE TURKANA

A REPORT ON THE FINDINGS OF THE LAKE TURKANA PROJECT

1972 - 1975

GOVERNMENT OF KENYA AND
THE MINISTRY OF OVERSEAS DEVELOPMENT, LONDON.

EDITED BY A.J. HOPSON

Volume 3 of 6 Volumes

OVERSEAS DEVELOPMENT ADMINISTRATION
LONDON
1982

Published 1982

Institute of Aquaculture
University of Stirling
STIRLING FK9 4LA
Scotland

ISBN 0 - 901636 - 41 - X

Produced, Printed and Bound at the University of Stirling

CONTENTS

VOLUME 3

CHAPTER 9

THE BIOLOGY OF CYPRINIFORM FISHES

by
A. J. Hopson, J. Hopson, P.B. Bayley
A.A.Q.R. McLeod and H.R.S. Mraja

CONTENTS

THE BIOLOGY OF *Hydrocynus forskalii* Cuv. IN LAKE TURKANA

A J Hopson, P B Bayley and A A Q R McLeod

INTRODUCTION

Hydrocynus forskalii is a predatory characin of moderate size which is widely distributed in the soudanian region of Africa, occurring commonly in both riverine and lacustrine habitats. It is usually of only minor importance as a commercial species due to the poor keeping qualities of its flesh, and tends to occur as a by-catch in fisheries for the more valuable characins *Alestes baremose* and *A. dentex*.

In Lake Turkana *H. forskalii* is an important component of ecosystems in both inshore and offshore regions, where it preys on the small cypriniform fish which form a high proportion of the ichthyomass. During recent years the largest individuals have been caught increasingly in commercial gillnets and the annual catch rose from 233 tonnes wet weight in 1972 to 318 tonnes during 1974. Potential yields are probably much higher.

Previous work on the biology of *H. forskalii* has concentrated mainly on feeding habits. HOLDEN (1970) studied the food of this species in Lake Mobutu (formerly Lake Albert) and demonstrated marked changes in diet with habitat. LEWIS (1974) presented a detailed comparison of predation in the three species of *Hydrocynus*, including *H. forskalii*, which inhabit Lake Kainji.

The Lake Turkana population was previously investigated by WORTHINGTON and RICARDO (1936) who provided brief observations on food and gonadial condition. They also noted the occurrence in the lake of a second species of Hydrocynus, H. lineatus, which was not encounteredduring the present investigations. The status of the two species and their diagnostic characters are discussed in Chapter 5 (see page 295).

The present investigations were chiefly concerned with the distribution, breeding and food of H. forskalii. Attempts at ageing and the estimation of growth rates have proved unsuccessful. Field data were collected over a period of 3½ years from May 1972 to November 1975, but the most detailed information was obtained between August 1972 and February 1974 when regular monthly samples were taken in the vicinity of Longech Spit, from both onshore and openwater sites. During the course of the studies fork length was usually recorded (FL), but in a proportion of samples total length was measured (TL). Total length measurements were subsequently converted to fork lengths using the following expression

$$FL = 0.85\ TL - 0.78$$

DISTRIBUTION

Hydrocynus forskalii was caught regularly during the present investigations in most types of gear including bottom trawls, midwater trawls, gillnets and beach seines. The species proved to be widespread and at times abundant. Trawl samples provide the most detailed conspectus of distribution but for a correct interpretation of the results it is first necessary to consider vertical zonation and patterns of diel migration.

Frame trawl data (Chapter 8, Figs. 8.31-8.35) show that in the open waters of the lake, H. forskalii was a pelagic species, and was more concentrated in the surface layers during the hours of daylight. LEWIS (1974) noted a similar pattern of distribution in the offshore waters of Lake Kainji where H. forskalii was confined to the top 10 metres.

Studies of diel changes in distribution indicate that unlike most of the pelagic species in Lake Turkana, which tended to migrate nocturnally upwards, H. forskalii concentrated briefly on or near the surface at dusk and moved downwards into the midwater layers after dark. The evening shoaling of this species was a characteristic feature of Lake Turkana. Under calm conditions concentrations of fish, gently breaking the surface, were scattered at intervals of 200-300 m over much of the open lake. With the approach of darkness the shoals dispersed downwards.

Data from inshore samples indicate a similar diel migration pattern. Hydrocynus forskalii occurred commonly in beach seine catches during the day, but became rare with the onset of darkness and absent from samples in the middle of the night, suggesting an offshore movement into deeper water. A study of feeding habits (see below) proves that the species was a diurnal predator feeding on small cypriniform fish, and the nocturnal migration away from the surface layers coincided with a fall in feeding activity.

The distribution of H. forskalii in the open waters of the lake is illustrated by data from the Boris midwater trawl survey in Figure 8.21 (see Chapter 8) where catches from a layer extending downwards to a depth of 10 metres from the surface have been plotted. The species occurred ubiquitously in the Northern, Central and Turkwell Sectors, with the exception of Kerio Bay. Catches tended to be lower in mid-lake than closer inshore but varied comparatively little over the entire area. In contrast, no H. forskalii were recorded from the six hauls made in the southern basin.

A guide to openwater distribution is also provided by results from the bottom trawl survey (Figures 8.4-6 and 8.8). The overall pattern shown by these observations is confused by the failure of the gear to sample pelagic fish in deeper water. It is probable that all records of H. forskalii from offshore areas (Fig. 8.8) relate to fish captured in the midwater layers during the shooting or hauling of the net. For this reason, the differences in abundance between inshore and offshore areas suggested by bottom trawl catches are exaggerated. If the effects of lake depth on catch are disregarded, the results show no noticeable tendency for the species to concentrate in any particular region of the lake. Possible seasonal changes are suggested by the distribution charts (Fig. 8.8). In the southern basin, the absence of H. forskalii noted during early November in the Boris midwater trawl survey was also observed in bottom trawl catches for the same period (Fig. 8.8c). Results for March-June, however, show that the species then occurred sparingly at most of the stations in the southern basin (Fig. 8.8a), indicating that an influx of fish into the area had taken place.

The low densities of H. forskalii in the open waters of the southern basin were probably due to the extreme scarcity of Alestes minutus, the chief prey species in pelagic situations. Gillnet and beach seine results discussed below show that H. forskalii was relatively common at inshore sites in the south where Barilius niloticus and Alestes nurse provided an ample resource of potential food.

Data from bottom trawl catches for the Central Sector have been analysed to show changes in the inshore-offshore distribution of H. forskalii with size (Fig. 9.1). Mean values of catch per effort have been calculated for each 5 cm length class in each depth zone. Due to the failure of the trawl to sample this species effectively in deeper water, the changes of catch per effort with depth do not represent true density gradients. The results, however, enable the relative abundance of various size groups to be compared in each depth zone, and also provide a synopsis of the overall pattern of distribution. There was a clear tendency for H. forskalii to move offshore with increasing size, and whereas fish over 15 cm FL were recorded at all depths, smaller individuals were confined to inshore areas. Trawl catches from depths of less than 15 m were dominated by fish of 10-15 cm but due to escapement from the cod end of 19 mm stretched mesh, the 5-10 cm and particularly the 0-5 cm length classes were under-represented in the samples. Catch per effort for 20-30 cm fish in inshore waters increased markedly with depth to reach a peak in the 15-20 m zone. This increase probably represented an even greater proportional rise in actual population densities. The heaviest concentrations at depths of 15-20 m coincided with lake depths at which the midwater scattering layer tended to be most pronounced. Hydrocynus forskalii was probably attracted to this zone by the abundance of prey species Alestes minutus which was the principal component of the scattering layer. Peak catches of 30-45 cm fish were also recorded in the 15-20 m zone but catches of the largest fish tended to be highest in shallower water, indicating a distinct change in habitat preference, probably resulting from a change in feeding habits. These larger fish may in fact belong to a different population, the existence of which is discussed below.

Hydrocynus forskalii occurred regularly in gillnets, particularly surface set nets of 2½ to 3½ inches stretched mesh which caught chiefly fish of 25-40 cm FL. Data from all areas of the lake presented in Table 8.25 a-r and summarised in Figure 8.63 (see Chapter 8) show that Alestes baremose was generally the dominant species with H. forskalii filling an important subsidiary role. Catches of H. forskalii were generally highest in the central region of the east shore of the lake, and in Allia Bay the species formed nearly 50% of the 2½-3½ inch catch with a mean catch per effort of 33 kg/100 m headrope recorded for a total of 19 nights fishing with the 2½ inch nets.

Larger individuals of up to 75 cm FL were also regularly caught in surface set gillnets of 5 and 6 inch stretched mesh deployed at various sites on the east coast of the lake (Table 8.26) but the species was generally absent from the 7 to 10 inch experimental nets. Further records of the occurrence of H. forskalii at Longech in bottom and midwater gillnets appear in Tables 8.23 and 8.24.

The distribution of fish in marginal areas of the lake is illustrated by beach seine data (Table 7.1, see Chapter 7) collected during the lakewide shore survey. Hydrocynus forskalii was one of the most widespread species occurring at 66 out of a total of 82 sampling sites. Individuals ranged chiefly from ca 6-20 cm FL and in most instances formed a comparatively small proportion of the total catch, both by number and weight. However, on sandy shores on the west side of the lake, both in the mouth of Ferguson's Gulf and on the exposed sandy coast to the north, H. forskalii predominated in beach seine catches (Table 7.1 i-j).

Early juvenile H. forskalii of 1.8 cm FL and upwards were seasonally common in foot seine samples from sheltered bays near the tip of Longech Spit (Table 9.1). Fish of similar size were also recorded sparingly from the vicinity of Todenyang, but apart from a sample of 17 fish of 1.9-3.3 cm FL caught in the lee of Sandy Bay Spit on the east shore of the Turkwell Sector, none under 5 cm FL was observed in any of the widely distributed foot seine samples obtained during the course of the shore survey (see Chapter 7). The results suggest that the early juveniles of H. forskalii tended to avoid the actual margins of the lake but lived chiefly inshore between the 2 and 10 metre contours. Both the Longech and Sandy Bay sampling sites were unusual in that water shelved comparatively steeply from sand spits into water of 2-3 metres deep. Trawl data (Fig. 9.1) prove that H. forskalii of under 5 cm FL were present at depths of less than 10 metres and, as mentioned previously, due to escapement, small fish were considerably under-represented in the catch.

Post larval H. forskalii ranging from 0.6 to 1.9 cm in length were caught infrequently in metre townet catches between the months of July and November. The distribution charts summarising the observations appear in Chapter 8 (Fig. 8.49). Most of the post larvae were obtained in the shallow northern part of the Northern Sector, but 24 individuals of 0.7 to 1.2 cm were recorded in a sample from a mid-lake site in the Central Sector during October 1973. Since gonadial evidence (see below) suggests that H. forskalii regularly spawned in the lake, it would appear that the metre townet surveys have failed to locate the principal concentrations of post larvae which were probably located in comparatively shallow water inshore.

Data from co-operative catches (see Chapter 6) provide additional information on the distribution of H. forskalii. Monthly purchases of the species at the seven co-operative branches during the period May 1972 to December 1974 are included in Tables 6.5 - 6.13. From Kataboi southwards, H. forskalii formed a very low proportion of the catch and no seasonal fluctuations were discernable. At Todenyang, and to a lesser extent at Lowarangak and at Nachukui, a dramatic rise in catches was noted regularly each year in August, reaching a peak in October before decreasing in November and December (Table 6. 13).

The tendency for catches to rise in each succeeding annual peak during the period 1972-74 was due to the increasing use of 5 and 6 inch gillnets in the Todenyang area. These nets selected H. forskalii of 60-70 cm which formed the bulk of the catches under consideration. The results prove that an influx of large H. forskalii into the Northern Sector took place each year during the flood season. Gonadial data (see below) show that in this species the proportion of ripe fish rose to a seasonal peak in October, and it seems probable that the concentration of H. forskalii in the Todenyang area was associated with a spawning migration into the Omo Delta. No spawning concentrations of smaller size classes were noted in the Northern Sector although, as shown below, the species matures at a length of 30-32 cm. There is a possibility that two distinct populations of H. forskalii co-exist in the Turkana basin, a lacustrine population maturing at a length of 30-32 cm which formed the bulk of the material examined during the present study, and a riverine population breeding for the first time at a length of over 45 cm and confined almost entirely to the River Omo prior to the onset of sexual maturity. This hypothesis is discussed in the breeding section below.

BREEDING

MATURITY STAGES

The following maturity stages based on NIKOLSKY (1963) were recognised in H. forskalii:

Females

Stage 2 Resting: ovary narrow, flattened, gelatinous, no ova visible

Stage 3 Maturing: ovary larger, more rounded with ova often varying in size, clearly visible, embedded in gelatinous matrix

Stage 4 Ripe: ovary distended, filling body cavity, ova large, yolky

Stage 5 Running: as above but varying proportion of ova transparent, freely extruded from vent when pressure exerted

Recovering: gonads similar to Stage 2 but often pinkish red in colour and sometimes containing residual eggs were classified as Stage 2A.

Males

Stage 2 Early: testes slender, semi opaque, whitish

Stage 3 Maturing: larger, rounded, whitish but no milt emitted when cut

Stage 4 Ripe: large, rounded, white, with copious milt when cut

Stage 5 Running: milt extruded from vent when slight pressure exerted

SIZE AT MATURITY

Data relating to the length at maturity in male and female H. forskalii have been combined from all seasons in Tables 9.2 and 9.3. Maturation in the males commenced at a length of 26 cm FL and the proportion of ripe (Stage 4) fish fluctuated relatively little at lengths of 34 cm and above, suggesting that the population as a whole had now reached sexual maturity. The results indicate that the length at 50% maturity for males was ca 33 cm. Females started to mature at 28 cm and the percentage of ripe individuals rose to a peak in the 34 cm class, suggesting that the length at 50% maturity was similar to that of the males. The smallest recovering (Stage 2A) female was a fish of 29 cm FL, proving that in some instances spawning occurred at lengths below 30 cm. A marked fall in the proportion of ripe females in the 40-50 cm length classes is paradoxical. There is no evidence to suggest that this effect was due to seasonal bias although sample size was small. A suggestion that the larger fish may belong to a separate, predominantly riverine population maturing at a larger size is discussed below.

SEX RATIO

The sex ratio of H. forskalii in each 2 cm length class for trawl samples is shown in Table 9.4. With the exception of the 28 cm class, the numbers of males and females were not significantly different in size groups up to the length of sexual maturity. The marked preponderance of females at lengths over 36 cm suggests that during the spawning period the mortality rate is higher in males. Females of up to 60 cm were recorded during the present investigations but males reached a maximum size of only 50 cm FL as a result of a higher mortality rate.

SPAWNING SEASON

Seasonal changes in the sexual maturity of adult female H. forskalii are illustrated by Table 9.5 where monthly data for all localities collected over a 2½ year period have been combined. The results show that, with the exception of April, ripe fish were recorded in all months of the year. A pronounced seasonal cycle is evident with the proportion of ripe fish rising during August and September to reach an annual peak in October. Comparatively high percentages of ripe females were noted in samples up to January, and the presence of running (Stage 5) females in February and March proved that spawning was still in progress.

The gonadial data are in close agreement with observations on the seasonal occurrence of early juveniles in shore samples at Longech (Table 9.1). The juveniles were also present throughout most of the year but numbers were appreciably higher during the period September-March and reached a maximum in November.

Although the peak proportions of ripe fish coincided with the end of the flood season, there is no evidence to suggest that the main Hydrocynus forskalii population of Lake Turkana underwent a mass spawning migration into the River Omo or its Delta as was the case in other cypriniform fish such as Alestes baremose and Citharinus citharus. Ripe and running H. forskalii were recorded from all sectors of the lake and although early juveniles were generally uncommon, they were recorded from widely scattered localities in both northern and southern areas (see above). Post larval H. forskalii were chiefly restricted to metre townet samples from the extreme north of the lake (Fig. 8.49 a-c) but they occurred only rarely and one of the largest samples was from a mid-lake site in the Central Sector.

Although further proof is required, the results strongly suggest that the main population of H. forskalii spawned in the actual lake. The dearth of post larvae in metre townet samples from the open lake indicates that, as with Barilius niloticus, spawning sites were close inshore and the widespread occurrence of ripe and running females shows that breeding was probably not particularly localised.

The timing of the main breeding season in H. forskalii, from August to January, coincides with the annual period when turbid water spreads southwards from the River Omo to affect most areas of the lake. The influx of suspended material may have provided the principal environmental stimulus for spawning.

As mentioned previously, co-operative data showed that catches of H. forskalii ranging from ca 50-60 cm FL rose to a pronounced seasonal peak in the vicinity of the Omo Delta during October each year, suggesting a concentration of fish prior to an upriver spawning migration. Similar behaviour was not observed in the smaller mature H. forskalii of 30-40 cm FL which formed a high proportion of the catch in experimental nets. It is possible that the large fish formed part of a separate population which was chiefly confined to riverine habitats. No information is available on the distribution of H. forskalii within the Omo system, but the species is widely distributed in rivers of comparable size throughout the soudanian region.

GROWTH

The growth rate of H. forskalii was not satisfactorily estimated during the present investigations. Growth checks on scales and opercular bones were laid down irregularly and provided no clue to age determination. Length frequency histograms at times showed well-marked polymodal distributions but no clear pattern of progression in size cohorts has emerged from a series of monthly samples. Trawl data from the Longech area of the lake for the period June 1972 to February 1974 have been combined to produce the length frequency histograms shown in Figure 9.2. The results are typical of analyses carried out on data

data for other localities and serve to illustrate the problems of interpretation. Length frequency distributions revealed no apparent sexual differences in growth rate, and data for males and females have been combined.

An examination of Figure 9.2 shows that in some cases pronounced modes are apparently represented in samples for several successive months but the pattern always becomes disrupted and lacks continuity. Breeding data have shown that the main spawning season in H. forskalii extended from August to January, and as a consequence the size range of fish in a particular year class is likely to have been considerable. It seems probable that the pronounced modality observed in many of the samples was due to the propensity of fish of similar size to shoal together. Such behaviour would tend to divide a year class of disparately-sized individuals into separate shoals ranging in size structure and modal length. Under these circumstances random sampling would be difficult to achieve since length frequency distributions would be biased in favour of the dominant shoals encountered in a sampling area. This would lead to irregularities of the type noted in the present results. The situation may be complicated further by the admixture of two races as discussed above.

Length frequency data for all H. forskalii sampled by bottom and midwater trawls during the period May 1972-August 1973 have been combined in Figure 9.3. The frequencies reached a peak in the 20-24 cm length class and numbers fell steeply in larger size groups, suggesting that heavy mortality was occurring. The fall was particularly pronounced at lengths of between 32 and 36 cm, corresponding to the size at which H. forskalii spawned for the first time. The proportion of fish surviving at lengths of over 44 cm FL was extremely low although a few individuals up to a maximum length of 63 cm were recorded.

During the present investigations a total of 145 H. forskalii ranging from 21 to 57 cm FL were weighed and measured. The relationship between weight (w) in grammes and fork length (l) in centimetres is represented by the following expression

$$w = 0.0094\ l^{3.032}$$

FOOD

INTRODUCTION

Various aspects of feeding in H. forskalii were investigated during the present studies including:

(a) Changes in diet with increasing size

(b) Variations in food composition with habitat

(c) Seasonal changes in prey

(d) Diel variations in food intake and prey selectivity

Observations on a total of 1091 fish have been used in the analysis which appears below.

MATERIAL AND METHODS

Study material was obtained from four sources. Early juveniles of 1.6-6.9 cm FL were caught in a foot seine on the beach at Lodge Bay, Longech. An inshore bottom trawl sample from the Kakoi area provided larger juveniles of 4 to 14 cm FL. Further samples of inshore fish ranging from 8 to 54 cm FL were caught in beach seine hauls which were made regularly in Met Bay, Longech, during the period November 1972-November 1973 and provided data on seasonal changes in food. Observations on diel changes in the diet of inshore fish are based on further beach seine samples collected in the same area in October 1975. Diel changes in the feeding behaviour of offshore H. forskalii were investigated during October 1975 in a series of Boris midwater trawl samples made in the open lake off Longech. More extensive information on the food of offshore fish has been compiled from samples collected in all sectors of the lake during the Boris midwater trawl survey which was carried out between mid-September and mid-November 1975.

The stomach contents of larger individuals were usually recorded in the field, but fish of under 10 cm FL and all material collected during diel studies were preserved for subsequent examination in the laboratory. The analysis of food was based on a volumetric method described by HYNES (1950). Stomach fullness was estimated on a 16-point scale ranging from 0/16 (empty) to 16/16 (full). The number of points scored by the total volume of food present was then divided between the various prey categories. Summaries of the diet for each sample (Tables 9.6-12) were prepared by expressing the total points scored by each food item as a percentage of the total of points awarded to all food items. An estimate of percentage fullness was also made by expressing total points on the basis of 16 points per fish.

FOOD OF INSHORE FISH

Analyses of the food of two samples of early juveniles from the Longech area are shown in Table 9.6. Although differences between the two samples are evident, the diets were generally similar. Invertebrate prey predominated in all size categories with the exception of the largest size class in the December 1972 sample where fish formed half the food intake. The results show a tendency for the diet to change from mainly zooplankton in smaller size classes of H. forskalii to insects in the larger fish. In all cases the insects were forms which either habitually or periodically swam freely in the water column, and no strictly benthic forms were recorded.

Similar results were obtained for a sampling station situated at a depth of 5-8 m off Kakoi in the Northern Sector, where H. forskalii of 4-10 cm had preyed entirely on invertebrates (Table 9.7). In contrast, the food of 10-15 cm individuals in the same sample was composed wholly of fish. A changeover from an invertebrate diet to piscivorous food at a length of about 10 cm appears to be a general rule in the H. forskalii population of Lake Turkana. Supporting evidence is provided by analyses of the food of inshore H. forskalii from beach seine catches at Longech (Table 9.8). Corixids alone were found in the stomach of the single individual of less than 8 cm FL but fish formed 86 % of the food of H. forskalii of the 8-16 cm length group, and provided the entire food intake of larger individuals of 16-54 cm FL. Table 9.8 shows that three small cypriniform species, Alestes nurse, Micralestes acutidens and Engraulicypris stellae, ranging from ca 2 to 4 cm in length, formed the bulk of the food of adolescent and adult H. forskalii occurring inshore at Longech.

The data suggest a tendency for the proportion of E. stellae in the diet to increase with predator size but the rise in importance was in fact due to the combined effects of seasonal changes in the size composition of the catch and in the availability of the prey species. Pronounced seasonal changes are illustrated in Table 9.9. Micralestes acutidens was the predominant food of the inshore population of H. forskalii at Longech from March to September 1973. Foot seine catches from the same area indicated that M. acutidens occurred much more abundantly during this period than at other times of the year. Engraulicypris stellae showed no tendency for seasonal fluctuations in the foot seine samples and although H. forskalii preyed exclusively on it during December 1972 and January 1973, it would appear to have been avoided at times when the slightly larger species was available.

Diel changes in the feeding behaviour of inshore H. forskalii are illustrated in Table 9.10. The results show that the species is a diurnal feeder with a maximum volume of food recorded in the stomach during the afternoon period. Food intake decreased dramatically after dark, and the absence of fish from the 02.00 hrs sample indicates that H. forskalii migrated offshore into deeper water. The low proportion of food in the stomachs at dawn (06.00 hrs) when the fish reappeared in the sampling area suggests that heavy feeding had not occurred during the period of absence. The composition of the food was generally similar to that of H. forskalii of comparable length analysed previously (Tables 9.7-8). The occurrence of the prawn Macrobrachium niloticum in the dawn sample is of significance. Studies of diel migrations (Fig. 8.35, see Chapter 8) show that the crustacean dispersed from deep water throughout the water column after dark and thus overlaps in distribution with H. forskalii during the pre-dawn period.

FOOD OF OFFSHORE FISH

Investigations into the food of offshore fish are based chiefly on daytime samples collected during a lakewide survey with the Boris midwater trawl. Data have been analysed on the basis of lake sector (Table 9.11). In the case of the Southern Sector, the sample was small, including 20 fish only 5 of which contained food. Observations for this sector are thus of little significance with regard to the composition of the food. Results for remaining offshore areas of the lake show that the pattern of feeding varied relatively little, particularly in the Central Sector where very similar values were obtained for the two subdivisions (Table 9.11). Small pelagic Alestes particularly A. minutus formed a high proportion of the diet, with small Lates spp. and Engraulicypris stellae occurring more irregularly in small numbers. Prawns were uncommon in the food and made up only 1% of the total intake in each of the three areas. The study proves that H. forskalii fed predominantly on fish inhabiting the midwater scattering layer. The fish were presumably attacked during forays from the superficial layers of the lake where H. forskalii was normally located during the daylight hours. Such behaviour is unusual in pelagic predatory fish which are generally located in the water column below their potential prey.

The results of a diel study of the food of offshore H. forskalii are shown in Table 9.12. Feeding activity followed a similar pattern to that observed in the inshore fish (Table 9.10). Stomach fullness increased considerably from the level observed during the initial mid-morning level to reach a peak in the early afternoon. There was a marked fall in fullness between dusk and midnight, and stomachs remained nearly empty for the remaining samples with only a slight increase at dawn. As in the previous analysis of offshore food, A. minutus was the predominant food item throughout the sampling period and prawns were virtually absent from the diet.

The results prove that, as in the inshore population, H. forskalii occurring in the offshore waters of Lake Turkana were basically diurnal predators. The composition of the food differs strikingly from that of other predatory pelagic fish including Alestes ferox, Schilbe uranoscopus, Synodontis schall and Lates longispinis, each of which tends to feed heavily on prawns in addition to A. minutus. The virtually complete absence of prawns in the diet of H. forskalii is explained by the diurnal feeding behaviour and preference for the surface waters of the lake. Adults of both Caridina nilotica and Macrobrachium niloticum were confined to deeper waters of the lake below the scattering layer during the day time. The diurnal range of other predatory forms ranged from the lower fringes of the midwater scattering layer downwards into the depth zone occupied by prawns. They also continued to feed at night when the prawns dispersed upwards through the midwater layers. Prawns and H. forskalii overlapped in distribution after dark when the predator had ceased feeding.

The present results do not conflict with observtions made by WORTHINGTON and RICARDO (1936) on a small sample of H. forskalii from the Longech area of Lake Turkana. A comparison of data from Lake Turkana with studies of feeding habits in other lakes indicates that the tendency for adult H. forskalii to select prey of relatively small size is universal. Important lacustrine differences in diet are evident. HOLDEN (1970) working in Lake Mobutu (formerly Lake Albert) found that although H. forskalii from lagoons and inshore regions of the lake fed chiefly on fish, stomachs from offshore areas contained a high proportion of the prawn Caridinia nilotica. Prawns were also the chief food constituent of H. forskalii occurring in shallow marginal water in the eastern archipelago of Lake Chad (LAUZANNE, 1972). In the Lake Kainji population of H. forskalii small fish, principally clupeids, were eaten almost exclusively (LEWIS, 1974).

SUMMARY

Hydrocynus forskalii is a common predatory species occurring throughout the open waters of the lake. There is a tendency for the species to range further offshore with increasing size and fish under 10 cm are restricted chiefly to lake depths of less than 10 m. The species occurs principally in the surface waters during the hours of daylight when it is most active, and moves into the midwater layers after dark.

Commercial catches are made chiefly in the Todenyang area of the lake during the flood season and consists of large fish of 60-70 cm FL. It is possible that these large individuals represent a separate riverine population.

Both males and females mature at ca 33 cm FL. Relatively few fish over 40 cm FL were recorded and post-spawning mortality is probably high. The actual spawning grounds were not located but the evidence

suggests that the majority of fish spawn within the confines of the lake, probably in coastal waters. Ripe fish were present in nearly all months of the year but breeding activity reached a peak during the main flood season.

No satisfactory estimates of age and growth rates were made during the present studies.

Hydrocynus forskalii feeds during the hours of daylight. The diet changes from plankton and insects in the smallest groups of under 7 cm FL to fish, in individuals of 10-15 cm FL and above. Small characins and Engraulicypris stellae of 2-5 cm FL were the chief inshore prey species recorded. Offshore, H. forskalii preyed mainly on Alestes minutus in the midwater scattering layer.

REFERENCES

HOLDEN, M J (1970). The feeding habits of Alestes baremose and Hydrocynus forskalii (Pisces) in Lake Albert, East Africa. J. Zool. Lond. 161: 137-144

HYNES, H B N (1950). The food of fresh-water sticklebacks (Gasterosteus aculeatus and Pygosteus pungitius) with a review of methods used in studies of the food of fishes. J. Anim. Ecol. 19: 36-58

LAUZANNE, L (1972). Regimes alimentaires principales especes de possons de l'archipel oriental du Lac Tchad. Verh. int. Verein. Limnol. 18 : 636-646

LEWIS, D S C (1974). The effects of the formation of Lake Kainji (Nigeria) upon the indigenous fish population. Hydrobiologia 45 : 281-301.

NIKOLSKY, G V (1963). The ecology of fishes. London and New York, Academic Press. 352 pp

WORTHINGTON, E B and RICARDO, C K (1936). Scientific results of the Cambridge expedition to the East African lakes 1930-1. No. 15 The fish of Lake Rudolf and Lake Baringo. J. Linn. Soc. (Zool). 39: 353-389

THE BIOLOGY OF *Alestes baremose* (Joannis) IN LAKE TURKANA

Jane Hopson

INTRODUCTION

Alestes baremose is a shoaling, migratory fish belonging to the family Characidae. It is similar in appearance to a closely related species *A. dentex* which also occurs in Lake Turkana. Diagnostic features of the two forms are discussed in Chapter 5 (page 297). *A. baremose* is considerably more abundant and widespread in Lake Turkana than *A. dentex* and is consequently of greater potential commercial importance. It is widely distributed throughout the savannah region of Africa north of the equator, often in association with *A. dentex*, occurring in the Nile, Niger, Chad, Volta and Senegal basins. The species forms a basis for commercial fisheries in many parts of its range in both rivers and lakes, including Lake Mobutu (formerly Lake Albert), the major rivers of the Chad basin, Lake Kainji and Lake Debo in the Middle Niger. BLACHE (1964) estimated that the annual catch of *A. baremose* from the Lower Chari river totalled 10,000 tonnes. Up to the present time the species has not been commercially exploited in Lake Turkana.

Previous work on the biology of A. baremose has been carried out by DAGET (1952) as part of a study of growth, breeding and migrations of several species of Alestes from the Middle Niger (Mali Republic). HOLDEN (1963) investigated A. baremose populations during a survey of Lake Albert (now Lake Mobutu) and has published a description of feeding habits (HOLDEN, 1970). Detailed studies of all aspects of the biology of A. baremose in the southern basin of Lake Chad and the Lower Chari-Logone have been carried out by Durand and Loubens of the Centre O.R.S.T.O.M. de Fort Lamy in Tchad Republic (DURAND and LOUBENS, 1966, 1969). Concurrently with the work of Durand and Loubens, a study of breeding and growth in two populations of A. baremose from the northern basin of Lake Chad was made during 1967-69 by Hopson (HOPSON J, 1972).

Investigations into the biology of Alestes baremose in Lake Turkana covered the period February 1974 to February 1975. Previous to this, incidental data on A. baremose were acquired in the course of routine sampling for other species. Subjects to receive most attention were age determination and growth, breeding, length-weight relationship and feeding habits. The distribution and abundance of the species in the lake were also studied.

MATERIALS AND METHODS

Material used in the present study originated from the following sources:

(a) A standard fleet of surface gillnets with mesh sizes ranging from 2 to 4 inch stretched mesh, in 0.5 inch increments, set in the vicinity of Longech Spit at a lake depth of 8-10 m. It was considered that the combined fleet provided random samples of Alestes baremose from a length of 20 cm FL up to the maximum size of 46 cm FL. The size selectivity of the gillnet fleet with respect to the present species is summarised in Table 9.13. The gillnets were set overnight, once every month. Much data were also obtained from sites throughout the lake in the course of the gillnet survey (see Chapter 8, page 620).

(b) A beach seine 50 m in length with a mesh size of 19 mm, which was operated from the shores at least once a month in Ferguson's Gulf and at other localities whenever possible. A. baremose of about 6 cm FL and upwards were caught by this method.

(c) A small foot-seine of mosquito netting 4 metres long and 1 metre deep was used to collect juvenile fish of 2 cm and upwards in shallow waters along the shore.

Data were also obtained from routine samples using the metre townet and bottom, midwater and frame trawls (Chapter 8).

In the majority of fish examined, the fork length (FL) was measured to the nearest cm below. However, in fish of 5 cm and under, and where length-weight relationships were being studied, the fish were measured to the nearest mm below for greater accuracy. A sample of scales (for age and growth study) was removed from at least fifty fish each month, when possible. Scales were taken from the left side of the fish, from one of the three scale rows immediately above the lateral line, within the verticals of the dorsal fin. After cleaning by hand, in water, the scales were preserved in 50% alcohol. They were examined in water under a binocular microscope. Scale measurements, to the nearest 0.1 mm, were made along the longitudinal axis of the anterior field a-x (Fig. 9.4) using a micrometer eye-piece.

Regular examinations of gonads and mesenteric fat deposits were carried out, mainly in the field, and in certain cases counts were made of the branched anal fin-rays to determine whether more than one population existed in the lake. (The number of anal fin-rays in Alestes baremose is a morphometric character which may vary significantly between populations).

DISTRIBUTION

The distribution of juvenile and adult A. baremose ranging from 6 cm FL and upwards is considered in the present section. Post-larval and early juvenile stages are discussed in the breeding section, below.

Investigations of vertical zonation in open water using frame and midwater trawls indicate that A. baremose is principally restricted to the surface layers (Chapter 8, Figs. 8.31-35). Data indicate that unlike most other openwater fish the present species does not undergo diel vertical migrations. The distribution of A. baremose in midwater trawl catches, from the top 10 metres of the lake during October 1975, is illustrated by Fig. 8.22 in Chapter 8. Although the species was regularly caught at stations well offshore the results indicate a marked tendency for fish to concentrate near the east shore in the Central Sector of the lake. Hydrographic data (Chapter 1) show that turbidity was lower in this east coast area than elsewhere in the northern basin during the late flood season. Length frequencies of fish caught during the midwater trawl survey are shown in Figure 9.5. The size ranged from 14 cm to 41 cm FL but the majority were 1-group fish of 16 cm FL.

The distribution of Alestes baremose in bottom trawl catches is shown in Table 9.14. Relatively high catches were only recorded in the shallowest depth zone where the net effectively sampled the surface layers. It seems likely that in other depth zones fish were chiefly caught near the surface, during shooting and hauling. The tendency for the proportion of hauls containing A. baremose to decrease with depth may not be a true indication of relative abundance. Over the lake as a whole transparency tended to be greater in deeper areas and, where light penetration was greater, this species was almost certainly dispersed over a greater depth-range in the upper layers. During hauling, the bottom trawl spent more time on the surface, sampling a depth slice of 4-5 metres, than at intermediate depths. Results in Table 9.14 may thus have been biased.

Catch per effort of A. baremose in trawl catches was invariably low compared with other species of fish even at depths of less than 5 m where a maximum of only 84 kg/hr was recorded in the bottom trawl. Such results are in contrast to data from gillnet catches where, as shown below, A. baremose was a dominant species throughout the lake. It seems probable that the situation of the fish, close to the surface, rendered them particularly sensitive to the passage of the trawl and as a result of fright reaction a high proportion avoided the trawl.

The distribution of adult Alestes baremose, ranging from about 20 cm upwards, is well illustrated by data from surface gillnets (Chapter 8, Tables 8.25 a-r, summarised by Fig. 8.63). The species formed a high proportion of the catches throughout the lake with the exception of the somewhat specialized environment of Ferguson's Gulf. Particularly high rates were noted in the Northern Sector of the lake. Thus at Koobi Fora, North Island and Kakoi, mean values of over 75 kg/100 m headrope/night were recorded for the combined 2½, 3 and 3½ inch gillnets (Fig. 8.63) with A. baremose contributing over 80% of the catch.

Seasonal changes in gillnet catches were apparent particularly in the extreme north where ripe and ripening A. baremose tended to concentrate during the flood season prior to a spawning migration into the River Omo. At most stations catches were maintained at moderate levels throughout the year. Normally, gillnets were set in coastal areas within 2 km of the shore but data were also available from nets deployed up to 15 km offshore in the Central Island Sector (Table 8.25 m). Catches of between 10 and 15 kg/100 m headrope in the 2½-3½ inch nets proved that A. baremose was well distributed in the mid-lake surface waters.

Shore seine catches of Alestes baremose, made regularly in the Ferguson's Gulf area, consisted chiefly of 0-group and 1-group fish ranging from about 6-20 cm FL. Midwater trawl data (Fig. 9.5) indicate that fish of similar size also occurred commonly offshore. Larger individuals of up to 44 cm FL occurred only rarely in the shore seine samples at Ferguson's Gulf, suggesting that with increasing size Alestes baremose were inhibited from entering the sub-littoral region. However this does not appear to be a rigid rule since, at Koobi Fora in October 1973, specimens of 25-44 cm FL were caught abundantly with similar gear.

Mature fish were also caught at a number of widely scattered localities by spinning from the shore with rod and line using a small spoon. In this way, distribution records of A. baremose were obtained for several sites along the precipitous south west shore between Meriar Point and the Barrier region, where other fishing techniques were impracticable.

It has proved impossible to provide estimates of biomass in absolute terms for Alestes baremose since gillnets were the principal method of capture. An indication of relative biomass in the three main sectors of the lake is provided in Table 9.15 where 2½, 3 and 3½ inch gillnet data have been combined to produce a value of mean value of catch per effort for each sector. If these values are regarded as indices of abundance then A. baremose concentrations were considerably higher in the Northern Sector than in more southerly areas of the lake. Since it is known that A. baremose congregated in the Northern Sector prior to spawning, the relatively high value of catch per effort does not necessarily indicate higher rates of production in the Northern basin. Differences between the Central and Southern basins are not as great as might be expected from results for other pelagic fish such as Alestes minutus, A. ferox. Engraulicypris stellae and Lates longispinis where concentrations in the south of the lake were generally very low. It is probably significant that A. baremose catches in the Southern Sector were made close to the shore where algalogical evidence shows that productivity was locally high and where allochthonous food was relatively plentiful.

Catch rates for A. baremose in the Lake Turkana experimental gill-nets were high compared to yields from other parts of Africa where this fish forms the basis of important fisheries. The species would appear to be of potential commercial importance in Lake Turkana.

GROWTH

AGE DETERMINATION

It was found that age determination could be effectively carried out by a study of scale rings.

The scales are cycloid and during periods of normal growth a regular series of concentric circuli are laid down on the anterior field. If growth slows for any reason this is reflected in the circuli which are laid down closer together than when growth is more rapid. Serious checks or alterations in the regular pattern of growth produce breaks and irregularities in the circuli, resulting in the formation of annuli (or scale rings).

Two principal annuli are laid down on the scale in the course of one year, with a six-month interval between them. The most prominent of these is formed during the period July-August-September, and the second, somewhat fainter annulus, in January-February-March. August rings thus alternate with February rings. Table 9.16 shows the seasonal occurrence of scale rings.

August rings were used for age-determination, the age of a fish being designated by reference to the number of such rings present on the scales. Fish were accordingly classified as 0-group, 1-group, 2-group etc. It was found convenient to regard September 1st as the date on which age-designation changed. For example, fish spawned for the first time in or about August of their third year of life (see under Breeding) and were then forming the third August scale ring but they were not classed as 3-group fish until after September 1st.

In all cases six scales were measured from each fish and the mean radius taken. As mentioned previously radii were measured to the nearest 0.1 mm along the longitudinal axis of the anterior field a-x (Fig. 9.4).

The relationship between scale radius and fork length was calculated. Results for females were based on scale measurements from 241 females of 20-43 cm FL combined with 182 immature fish of 3-19 cm FL, and for males on measurements from 222 males of 20-40 cm FL combined with data from the same 182 immature fish of 3-19 cm FL. There was no significant difference between the regressions for scale radius on fork length in the two sexes, therefore all data from the 645 fish were combined to give the equation:

$$\text{Scale radius (mm)} = 0.145 \text{ fork length (cm)} - 0.374$$

It was found that the positions of the August and February rings on the scales did not vary very much between individuals of the same sex in a sample, or between samples of the same sex taken from different parts of the lake. This is demonstrated in Tables 9.17 and 9.18 where the mean radii of each sale ring are given for four separate samples of fish, together with the standard deviation and number of fish examined. The equivalent fork lengths at the times of ring-formation were obtained by back-calculation using the scale radius-fork length regression equation quoted above.

FACTORS INFLUENCING RING-FORMATION

The factors causing ring-formation on the scales of Alestes baremose in Lake Turkana are not fully understood but in the case of the August annulus this is almost certainly correlated with the influx of Omo flood water which stimulates the spawning migration in Alestes and other anadromous species. Evidence suggests that from June onwards, there is a general movement of adult fish towards the mouth of the river, followed by a rapid migration upriver culminating in mass spawning. Peak spawning (see under Breeding) coincides with the maximum flood period of the Omo in July, August and September. During the flood period brown, low-conductivity water from the Omo spreads over large areas of the lake, the sediment plume extending as far south as Ferguson's Gulf by early September. It was found that wherever this brown sediment-laden water was most turbid there was a very low occurrence of zooplankton (see Chapter 3). Various species of fish caught in these areas of high turbidity had empty stomachs or were sometimes found to be feeding on the scales of other fish. This suggests that during the period while the fish are congregating near the river mouth, and during the spawning migration, no feeding is possible and therefore growth stops temporarily, causing an annulus to be formed on the scales. The fact that August rings occur on the scales of immature fish as well as adults could be explained by the same conditions caused by the flood water affecting them to a certain extent during the course of the flood season, regardless of whether or not they were undergoing a migration. It is interesting to note that in over 90% of scales examined the first and second August rings were comparatively indistinct while the third and subsequent August rings were very conspicuous. This is plainly due to the changes in physiology and movements brought about by sexual maturity. The spawning migration is accompanied by profound physiological changes as the gonads pass through the late maturation stages and mesenteric fat is used up. These processes alone or combined with cessation of feeding could cause a significant growth check to appear on the scales. In Lake Chad a very well-marked 'spawning ring' was formed on the scales of adult Alestes baremose in the course of the spawning season (HOPSON J, 1972).

In the case of the February ring, the reason for its appearance is still obscure. Certainly changes in temperature are not considered to be an important factor influencing growth rates of A. baremose in Lake Turkana. Unlike the situation in Lake Chad, where a seasonal drop in temperature brought about a temporary cessation of growth and the formation of well marked 'winter rings' on the scales of A. baremose in January, Lake Turkana is remarkable for seasonal uniformity of temperature.

Plankton surveys indicate that there is no seasonal dearth of zooplankton during the period January to March which could cause the formation of scale rings.

Spawning in the great majority of A. baremose takes place between June and October each year but there is evidence that a small and insignificant section of the population spawn during February (see under Breeding). There appear to be no seasonal climatic factors operating at this time of year which would be likely to stimulate fish to spawn. The rains normally commence in late March or April and would therefore be too late to have an effect. This also applies to the influx of flood water from the Turkwell and Kerio rivers. However, whatever factors are involved they may also be correlated with February ring-formation in the population as a whole.

LENGTH-FREQUENCY ANALYSIS

Most of the growth data were obtained from the vicinity of Longech Spit where monthly samples were caught as regularly as possible during the period February 1974 to November 1975. Four sampling methods were employed:

(a) A graded fleet of surface gillnets consisting of nets of 2, 2½, 3, 3½ and 4 inch stretched mesh, set overnight about 1 km north east of Longech Spit at a lake depth of 10-15 m. It was considered that the fleet of nets provided random samples of fish of age-group 2 and above. The fact that large specimens of *Alestes baremose* were only rarely caught in the 4 inch net suggests that the gillnets effectively sampled all size groups, except individuals below 20 cm FL, which escaped from the 2 inch net.

(b) A shore seine of 19 mm stretched mesh used in Ferguson's Gulf, on beaches close to the Meteorological Station. This gear caught fish ranging from about 5 cm FL upwards. As noted previously, adolescent *A. baremose* tended to move offshore at a length of about 20 cm FL and the samples only occasionally contained individuals above this size. Additional seine-net data obtained in routine sampling during 1973 were included in the present study.

(c) 0-group juveniles of 1-6 cm FL were caught in a mosquito net seine at Todenyang, Ilaret and other localities on the north west and north east shores of the lake.

(d) A Boris midwater trawl provided a sample of 66 fish in October 1975.

Length-frequency histograms were prepared for monthly gillnet samples from the Longech Spit area, covering the period February 1974 to November 1975 (Figs. 9.6 and 9.7). Data for males and females have been treated separately but in each case length-frequency for fish of below 20 cm FL, caught by seine net, are appended. The proportions of fish caught in seine nets or in gillnets varied considerably from month to month and in several instances monthly samples from only one type of gear were collected. For this reason, percentage frequencies for seine net and gillnet data were calculated separately although they are juxtaposed in Figures 9.6 and 9.7.

The size ranges of seine net and gillnet catches did not usually overlap but where this occurred it is indicated on the histograms by double hatching.

Routine age-determination by scale reading was carried out on monthly samples and the age composition of the catches shown in Figures 9.6 and 9.7 was thus established.

The length-frequency histograms clearly indicate the size-progression of year classes from month to month. For example, the 1973 year class is readily followed through successive samples from April 1974 to November 1975 during which period the modal length increased from 12 to 25 cm FL. A regular annual pattern of recruitment is also evident and accordingly, during the latter half of 1975, the 1974 year class was situated in a similar position in the histograms to that occupied by the 1973 year class in the previous year. The effects of mortality are discernable, with representatives of older age-groups dwindling in importance during successive months and in the case of the 1969 and 1970 year class, disappearing altogether from later samples. However, such effects were partly due to an exodus of larger fish from the Longech area prior to spawning as shown by length-frequency histograms based on data from gillnet catches in the north and north-easterly areas of the lake (Fig. 9.8). From these results, it is evident that the 1970 year class, which was present in strength at Longech only during February 1974 (Figs. 9.6 and 9.7) was still represented by a high proportion of females in catches from the Northern Sector during October 1974 (Fig. 9.8). Males of the 1970 year class had largely disappeared by October 1974 presumably as a result of mortality following spawning. It seems likely that heavy mortality occurred also in the females during subsequent months since none reappeared in the Longech area and the 1970 year class was not present in samples from the Northern Sector during June and July 1975 (Fig. 9.8). The results show, however, that the 1971 year class which also largely migrated out of the Longech area during the 1974 spawning season (Figs. 9.6 and 9.7) and was common in the Northern Sector during June-October (Fig. 9.8), returned to Longech in relatively large numbers for a limited period between February and April 1975.

GROWTH CURVES

The length-frequencies on which Figures 9.6, 9.7 and 9.9 were based have been used to calculate mean monthly lengths for males, females and, where appropriate, immature fish of each year class (Tables 9.19, 9.20 and 9.21). Growth curves for each sex were prepared by plotting the mean lengths from Tables 9.19, 9.20 and 9.21 against time (Figs. 9.10 and 9.11). In small fish the sexes were not readily distinguishable and all data from size groups of under 20 cm FL were incorporated in the graphs for both males and females.

Von Bertalanffy growth curves were fitted to the plots shown in Figures 9.10 and 9.11, using the expression

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

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_o is a constant. In order to provide a series of values of length at equal time intervals the mean lengths (Tables 9.19, 9.20 and 9.21) on which Figures 9.10 and 9.11 are based were grouped consecutively into 3-monthly periods and averaged. Mean lengths for 0-group fish covering the period September-November formed the first group with an estimated age of 0.25 years. A total of 16 values for males and 17 values for females was so obtained. The 3-monthly means was then used in a Walford plot of L_t + 1 against L_t which provided the following values for L_∞ and for K adjusted to an annual basis:

	Males	Females
L_∞	48.0	54.9
K	0.398	0.333

The parameters were used in the von Bertalanffy equation to complete a series of values for L_t from which the fitted curves shown in Figures 9.10 and 9.11 were constructed. Values of t_o for males and females were 0.050 and 0.048 respectively. Since mid October was considered to be the time at which the age of 0.25 years was reached, the hypothetical origin of the fitted growth curve is thus approximately August 1st.

The fitted curves provide a satisfactory representation of growth in the Lake Turkana population of Alestes baremose although there is a tendency for the observed lengths in the range 15-20 cm to be less than the computed values. This discrepancy is probably due to a propensity for the largest 0-group and early 1-group fish to move away from the inshore areas sampled by the seine net, thus biasing catches in favour of smaller fish.

Values of L_∞ are somewhat higher than the observed maximum size of 43 cm FL for males and 46 cm FL for females. This suggests that the oldest fish were still growing steadily and that the relatively short life span of this species results from heavy mortality during spawning migrations.

A further opportunity for estimating the growth rate of A. baremose was provided by the back-calculated lengths estimated for the regular six-monthly intervals when ring-formation occurred (Tables 9.17 and 9.18). These data were combined to provide a series of overall mean values representing length at the formation of the first eight scale rings, for both males and females. Using the procedure described above, the following growth parameters were estimated from the overall back-calculated means:

	Males	Females
L_∞	51.0	69.7
K	0.353	0.227
t_o	- 0.053	- 0.080

Estimates of L_∞ are higher than those previously computed, particularly in the case of the females. Values of length for age calculated by means of the von Bertalanffy growth equation using the two sources of data are presented in Table 9.22 for comparison, together with back-calculated lengths.

The results are consistent, particularly for the smaller length-groups. Divergences in values for fish aged 4 years and over, probably result from the comparatively small sample size of fish used for back-calculations in the oldest fish. It is considered that values computed from the observed lengths in the first two columns provide the most satisfactory model for the pattern of growth in the Alestes baremose population of Lake Turkana. The resultant growth curves for males and females have been plotted together for comparison in Figure 9.12. It is evident that a similar pattern is followed in the two sexes for the first two years of life up to the onset of full sexual maturity in spite of the computed differences in growth rate. Sexual divergence in size becomes increasingly noticeable in fish above a length of 30 cm FL and by the age of 4 years, males have reached a fork length of only 38 cm compared with 42 cm in females. The number of females exceeding 42 cm was relatively low and a maximum size of 46 cm was recorded. The largest male was 43 cm in length and only few grew larger than 40 cm FL. As suggested previously, mortality is probably high during the breeding season and the porportion of the population which appears to have survived to spawn for a third time was low. Such fish were five years old, the maximum recorded age.

DISCUSSION

Detailed studies have been carried out on two populations of Alestes baremose in the northern basin of Lake Chad (HOPSON J, 1972). As in the Lake Turkana population females grew faster than males and a few individuals of both sexes survived into their sixth year as 5-group fish. The pattern of growth was, however, strikingly different in Lake Chad where the following values for the growth parameters were obtained:

Population	A		B	
	Males	Females	Males	Females
L_∞	27.6	33.0	28.0	33.3
K	0.94	0.66	0.81	0.62

Growth was thus extremely rapid during the first one to two years of life but increments in subsequent years were small and the maximum observed fork length of A. baremose in Lake Chad was approximately 10 cm less than the largest recorded in Lake Turkana. The contrast between the pattern of growth in Lake Chad (population A) and that of the Lake Turkana population is highlighed by the following estimates of length for age:

	Males		Females	
Age (years)	Lake Turkana	Lake Chad	Lake Turkana	Lake Chad
1	15.1	16.7	14.9	15.1
2	25.9	23.6	26.2	24.2
3	33.1	26.1	34.3	28.7
4	38.0	27.0	40.1	30.7
5	41.3	27.4	44.3	31.8

It is clear that although a similar length was achieved during the first year of life in both lakes, the subsequent growth patterns were very dissimilar. The differences between A. baremose in the two lakes may be the result of the greater variation in water temperature in Lake Chad where an annual range of 14 °C existed with temperatures falling to as low as 17 °C during December and January each year. Such low winter temperatures resulted in a winter growth check on the scales of A. baremose. This hypothesis is however thrown into doubt by the fact that growth increments during the first year of life were similar in the two lakes.

DAGET (1952) has shown that in the Middle Niger growth rates in A. baremose are lower than in Lake Chad with females attaining a mean fork length of about 25.8 cm and males a comparable length of 24 cm over a period of six years. The maximum length of 28.8 cm recorded in the Middle Niger was much lower than in either Lake Chad or Lake Turkana. Daget showed that a single annual scale ring was laid down during a prolonged dry season lasting from December-June each year. He believed that growth virtually ceased during this annual period as a result of rigorous environmental conditions.

HOLDEN (1963) studied Alestes baremose in Lake Mobutu (formerly Lake Albert). His results indicate that this population is very similar to that of Lake Turkana with a maximum recorded size of 46 cm FL obtained at an age of about 5 years. No apparent seasonal checks were noted on the scales but Holden was able to estimate growth rate by length-frequency analysis and he obtained the following values (combining data from both sexes) for the growth parameters

$$L_\infty = 50 \text{ cm FL}$$
$$K = 1.2$$

LENGTH-WEIGHT RELATIONSHIP

The relationship between length (l) and weight (w) in fish may be expressed by the equation

$$w = al^b$$

where the power b usually lies close to 3. Records of fork length in cm and weight in grams were obtained for a total of 1227 Alestes baremose ranging from 8 to 44 cm during the present investigations. By plotting log w against log l the following length-weight expression was obtained for the species:

$$w = 0.0085\ l^{3.07}$$

It was found that during the course of growth the relative weight of fish tended to alter with a slight increase in mature fish. Table 9.23 provides values of a and b calculated for various length groups of male, female and immature fish.

Length-weight data were also used to calculate the condition factor (K) for mature and maturing A. baremose where

$$K = \frac{100w}{l^3}$$

Table 9.24 shows that the condition factor increased markedly in both sexes from a value of below 1.05 in fish of less than 28 cm FL to over 1.10 in nearly all size groups above 30 cm FL. The increase corresponds to the length at which the gonads of A. baremose were maturing for the first time. A noticeable loss of condition was indicated by results for the largest size groups of both males and females (Table 9.24). This was due to the presence, during the post-spawning period, of emaciated 5-group fish with condition factors as low as 0.86.

Seasonal changes in condition factor are shown in Table 9.25. The males and the smallest females showed relatively little seasonal change. A marked fall in the value of K was however noted in the larger females during November, at the end of the annual spawning period. The fall was not as marked in females of 30-40 cm belonging to age groups 3 and 4 as it was in the 5-group fish of over 40 cm. The wasted appearance of such 5-group fish was symptomatic of physiological stresses which lead to high mortality during the post-spawning period each year.

Although no length-weight data are available for the period December-January, observations of mesenteric fat indicate that, in 3- and 4-group fish heavy reserves were laid down rapidly during the post-flood period. These reserves were gradually depleted during the maturation of the gonads prior to the succeeding spawning season. As a result of this inverse relationship between mesenteric fat and gonads the mean condition factor remained relatively constant in 30-40 cm fish from February-October (Table 9.25).

HOPSON J (1972) found a similar balance between gonadial state and fat reserves in Lake Chad populations of Alestes baremose. The condition factor of mature fish was generally lower in the Lake Chad population ranging from 1.03-1.09 in females, and from 0.96-1.14 in males. However, as mentioned previously, growth was slower in Lake Chad and A. baremose matured at 23-26 cm. The condition factors of mature fish were thus comparable to those of immature fish of similar size in Lake Turkana.

BREEDING

Observations on gonadial condition were made throughout the investigation to determine (a) seasonal changes in maturity of adults and (b) the size and age at first spawning.

Most observations were carried out in the field.

MATURITY STAGES

Females

In the classification of the ovaries eight maturity stages were recognised. These have been described in detail in a previous work on the Lake Chad populations (HOPSON J, 1972) and are merely summarised here:

Stage 0 — Immature: found in fish of up to 18 cm FL, gonads indistinguishable macroscopically; no mesenteric fat present.

Stage 1 Adolescent: found in fish of 18-25 cm FL; in practice these are grouped with Stage 0 as immature; gonads narrow transparent strands 2-5 mm wide, only distinguishable as ovaries or testes by examination under low-power microscope; no mesenteric fat present

Stage 2 Resting, recovering or virgin: found in fish of 28 cm FL and above; in recovering ovaries traces of previous spawning may be present in the form of 'brown bodies' and unresorbed ova; fat in body cavity moderate to heavy

Stage 3 Early maturation, onset of vitellogenesis: 33 cm FL and above; fat in body cavity medium to heavy

Stage 4 Late maturation: mesenteric fat reduced

Stage 5 Ripe: no mesenteric fat present

Stage 6 Running

Stage 7 Spent

Males

Seven stages are used in the classification of testes:

Stage 0 Immature: as in female

Stage 1 Adolescent: found in fish of 18-25 cm FL; testes can be distinguished under low-power microscope; these are usually classed with Stage 0 as immatures

Stage 2 Resting: occurs at 28 cm and over; includes virgin, resting and recovering stages

Stage 3 Developing: (equivalent to stage 3 in females)

Stage 4 Late maturation

Stage 5 Ripe and running

Stage 6 Spent

ONSET OF SEXUAL MATURITY; AGE AT FIRST SPAWNING

As in many characins, adult male Alestes baremose can be distinguished externally from females by the anal fin which assumes a markedly convex outline in the adult male. This is brought about by the elongation of the middle fin-rays.

In the Lake Turkana population sexual dimorphism begins to show at about 18 cm FL, when the fish are entering their second year of life, more than a year before they are ready to spawn for the first time. From 18 cm to about 28 cm FL they are in an adolescent state, but towards the end of their second year - at a length between 25 and 30 cm FL - changes take place which accompany the onset of full sexual maturity. Mesenteric fat reserves begin to accumulate in the body cavity; the ovaries and testes, hitherto difficult to distinguish apart, increase in size and become easily recognisable to the naked eye (as virgin Stage 2, male or female) and at the same time there is an increase in relative body weight.

Spawning takes place for the first time at the end of the third year of life, at about 33 cm FL in males and 35 cm FL in females. The first spawning season coincided with the formation of the third August scale annulus. Tables 9.26 and 9.27 illustrate the length at which sexual maturity commences in males and females. In the present study several hundred 0-group, 1-group and 2-group fish were examined during all months of the year and no males under 30 cm FL or females under 31 cm were found with gonads in an active state. All fish of 29 cm FL and below were in Stage 2 or immature.

In Lake Chad A. baremose also spawned for the first time in their third year but at a smaller size than the Lake Turkana population. The length at first spawning ranged from about 25 cm FL in males to 28 cm FL in females (HOPSON J, op. cit.). In both populations the first signs of sexual dimorphism appeared t 18-19 cm FL.

The spawning season in Lake Turkana extended from June to October and coincided with the annual flood period of the River Omo. Peak spawning, indicated in Tables 9.28 and 9.29 by the presence of relatively high percentages of ripe fish (Stage 5), occurred in August at the height of the flood season. The presence of a significant percentage of Stage 5 females was taken to be evidence of imminent spawning activity and the presence of spent fish (Stage 7) was evidence of recent spawning.

The proportion of fish with ripening gonads increased markedly towards the northern end of the lake. This is demonstrated in Figure 9.13 where percentages of each maturity stage are shown in samples of females taken at different localities during the months of June, July, August and September-October for 1974 and 1975 combined. Thus a higher proportion of advanced-developing fish were present in samples caught near North Island and Ilaret than in samples caught from Koobi Fora and Allia Bay. These latter contained a higher proportion of developing fish than samples from Longech Spit and Moite. South of Moite, apart from an insignificant number of Stage 3 females caught near South Island and at Sandy Bay, fish were in resting stage in all samples taken throughout the spawning season in 1974 and 1975. It is probable that adults which have moved into the southern half of the lake are generally beyond the influence of flood water from the Omo which is considered an important stimulus for the onset of vitellogenesis and northward migration.

It is believed that the majority of the population entered the River Omo and probably passed upstream for many miles (as in other African rivers) before actually spawning. Unfortunately it was not possible to verify this because of restrictions on entering Ethiopia. A few ripe adults were caught at Kaalom about ten miles upriver in Ethiopia in June 1974. Nevertheless, a proportion of the population may spawn at the mouth of the river - as suggested by evidence from three Stage 6 females caught in July 1973 near Todenyang. Stage 6 in females is a transitory stage which only occurs shortly preceding the act of spawning. The absence of Stage 6 females from any samples south of the Omo Delta suggested that spawning did not occur in the open lake.

The occurence and distribution of planktonic post-larvae of up to 3.0 cm FL and littoral fry of 2-6 cm FL provided supporting evidence that spawning took place in the River Omo. Post-larvae occurred in townet samples only in the northern parts of the lake (Fig. 8.50, Chapter 8) mainly within 20 km of the Omo Delta, during the months June-October 1974 and 1975.

A relationship between the mean length of post-larvae and their distance from land was noted (Table 9.30). Post-larvae ranging from 6 to 14 mm, with a mean length of 8 mm occurred further offshore in the 20-30 m depth zone. Mean length increased progressively in shallower water. This phenomenon was due to an active shoreward movement by post-larvae as they increased in size. Samples taken by townet close inshore from depths of 3-10 m contained post-larvae of 6 to 34 mm with a mean length of 16 mm. The transition from planktonic post-larval life to inshore shoaling behaviour took place between the lengths of 12 and 20 mm. Young Alestes baremose caught in beach samples ranged from 12 mm TL to 56 mm FL.

Fry occurred in shallow, protected inshore sites and were collected by means of the mosquito net foot seine. The highest concentrations of A. baremose fry were noted in the Todenyang and Ilaret areas where they were common in both October 1974 and 1975. Their distribution, as shown by the shore survey, (Fig. 7.1, Chapter 7), was limited to more northerly areas of the lake as far south as Allia Bay on the east coast and to a point just north of Ferguson's Gulf on the west. None were caught in Ferguson's Gulf itself nor were any found near the mouths of the Turkwell and Kerio rivers.

From about 6 cm FL upwards Alestes baremose juveniles moved further offshore in shoals and there was evidence to show that a mass movement of 0-group fish (average size about 8 cm FL) took place annually in March-April. The movement resulted in the southward dispersal of young fish from the northern end of the lake to all areas. During April of 1972, 1973 and 1974 shoals of 0-group A. baremose appeared in the Ferguson's Gulf area and were caught in large numbers in the beach seine. They also appeared in beach seine catches from the east shore. In Lake Chad, a similar migration of first-year fish took place, away from the river mouths to distant parts of the lake, ensuring their dispersal into feeding areas (HOPSON J, op. cit.).

SEASONAL CHANGES IN MATURITY

The data collected covered two spawning seasons and are shown in Tables 9.28 and 9.29. These deal only with gonadial data from the northern half of the lake, including the Longech Spit area and as far south as Moite. As previously mentioned, there was no indication that spawning took place in the southern part of the lake, almost all gonads being inactive.

During February, March and April the majority of fish examined were in a resting stage (Stage 2). Data for 1975 indicate that gonads began to ripen in May. By the end of June more than 60% of testes examined and over 30% of ovaries were either developing or ripe. The occurrence of post-larvea in townet hauls in June indicates that spawning had already started in early June, probably at the first influx of flood water from the Omo. Spawning was at a peak in August and continued well into October in 1974 and probably also in 1975 as indicated by a significant proportion of newly spent fish in the sample from November 1975. By November, spawning had ceased in the population as a whole and in December all fish were found to be recovered and resting.

In northern Lake Chad a similar situation was observed (HOPSON J, op. cit.) with a July-September spawning season coinciding with the beginning of the flood season in the River Yobe.

FEBRUARY SPAWNING

There is evidence that gonads ripened in a small section of the population during February in both 1974 and 1975 (Tables 9.28, 9.29). The gonadial evidence for this is scant, consisting of only two Stage 5 females in February 1974 and one spent fish in early March 1975, and inconclusive for males, there being no proof of actual spawning, merely the presence of a small number of developing fish. However, the evidence definitely points to there being a certain renewal of sexual activity during the period February-March. The only other supporting evidence for this came to light in the occurrence of a number of juveniles in shore samples collected in the vicinity of Ilaret in October 1975. When the various samples were combined it was found that the length-frequency distribution was distinctly bi-modal. Juveniles caught nearest to the mouth of the Omo River had a mean length of 2 cm and therefore belonged to the main batch of recruits produced by the 1975 August spawning, while those caught several miles to the south had a mean length of 8 cm. Assuming a normal rate of growth for Alestes baremose in Lake Turkana (see under Growth) it was concluded that these larger juveniles were spawned in February.

Altogether, it appears that February spawning, if it is an annual occurrence, is not very important in the population as a whole. It would, however, be interesting to discover what environmental factors are correlated with this activity, and also whether or not they are, as seems likely, connected with the formation of February scale rings which occur in the majority of the population.

FOOD

INTRODUCTION AND METHODS

The food of a total of 194 Alestes baremose ranging from 10 to 43 cm FL was analysed during the present investigations. The material was collected from four localities in the Central Sector of the lake, representing a wide variety of habitats:

(a) Meteorological Station, Ferguson's Gulf: sub-littoral conditions with minimal vegetation. Substrates generally sandy on the shore, merging into mud at a depth of 3 metres. Samples obtained with a shore seine

(b) Longech Spit: open water within 2 km of the shore and ranging from 10-25 m in depth. Samples obtained with pelagic trawls

(c) Crater Bay, Central Island: samples from surface gillnets set about 300 m from the precipitous shore, over the 40 m depth contour

(d) Allia Bay: open water about 1 km offshore with a depth of 6-8 m. Substrate muddy sand with a scattering of loose vegetation, particularly Potamogeton transported by wind from inshore area. Samples collected by bottom trawl.

Diel changes in the food of A. baremose were investigated at the Ferguson's Gulf station. Samples were collected at four-hourly intervals over a period of 24 hours.

Stomachs were removed from A. baremose in the field and preserved in formalin in individual vials for subsequent examination. In the laboratory the contents of each stomach were emptied into a Bogarov tray and scrutinised under a stereomicroscope. Sub-sampling was used to facilitate the handling of relatively large volumes of food. The composition of the food was analysed by means of a volumetric method based on HYNES (1950). Fullness was judged for each stomach on a percentage basis and the relative importance of constituent food items was assessed on a points system. The number of points was then multiplied by the percentage fullness and the resultant scores were summed for the whole sample.

A more accurate assessment of food intake was made for certain samples by drying total contents to constant weight in a vacuum oven and measuring the dry weight.

RESULTS

Summaries of the analysis of 10 samples from the 4 localities appear in Table 9.31. Data from 61 fish which were examined during the diel study (Table 9.32) have been combined in column 1. The results show that although in each series a particular food organism usually predominated, the chosen item varies considerably from sample to sample. Planktonic crustacea were first in overall importance but insects were common at all inshore sites and predominant in two samples. Thus in October 1975 corixids (62%) and chironomids (30%) formed the bulk of food in the Ferguson's Gulf sample (Table 9.31, col. 1). Chironomids were also important at Central Island during July 1975 where the diet included a significant proportion of insects of terrestrial origin, presumably blown off the adjacent island by strong overnight winds. No chironomids were recorded from Central Island in May 1974 where significant numbers of the Mayfly Povilla were, however, observed. Both Povilla and chironomids are known to show lunar periodicity in emergence patterns and their occurrence in the food of A. baremose in suitable sites probably fluctuates accordingly.

Local variation in the proportion of different crustacean forms in the diet is clearly linked with their distribution patterns. Tropodiaptomus banforanus, the dominant offshore zooplankter, was thus the most important crustacean in the food of A. baremose from Longech Spit and Central Island. The calanoid was replaced by Mesocyclops leuckarti in the plankton of Ferguson's Gulf and this change was reflected in the composition of food from samples collected in the gulf during April and September 1975 (Fig. 9.31, cols. 2 and 3). A similar relationship between diet and food availability is demonstrated by data from Allia Bay where M. leuckarti was again the predominant copepod. The Allia Bay results, however, indicate prey selectivity on the part of A. baremose since during September 1972 the smaller fish of 18-25 cm were feeding principally on M. leuckarti whereas larger individuals of 30-38 cm had preyed principally on the cladoceran Hyalodaphnia barbata. It is uncertain whether the two zooplankters were distributed at random within the sampling area or whether their distributions were segregated into clumps, with each prey species tending to attract different size groups of A. baremose.

Fish as prey were recorded chiefly from the open water samples caught in the Longech Spit area where Engraulicypris stellae post-larvae formed 63% of food in the September 1973 sample (Table 9.31, col. 5). The importance of fish is overemphasised by this relatively high percentage since the stomachs were almost empty.

Alestes baremose lives principally in the surface layers both in coastal areas and further offshore. The study shows that the food was mainly planktonic and that insect food was usually caught on the surface either as emerging adults or as terrestrial forms occurring fortuitously. The presence of a significant proportion of ostracods in the food of the March 1975 sample from Ferguson's Gulf indicates that in very shallow water feeding may occur on or near the bottom. This was confirmed by the presence of sand grains in most of the stomachs concerned.

Investigations into the zooplankton of Lake Turkana (Chapter 3) proves that in terms of production, Tropodiaptomus banforanus was the most important form. The copepod tended to concentrate in the surface layers during the afternoon and evening when, as shown below, A. baremose was feeding most actively. It is probable that on a lakewide basis T. banforanus was predominant in the diet of A. baremose. Supplementary data from field log books, collected on board the research vessel, indicate that small fish, particularly Alestes minutus and the prawns Macrobrachium niloticum and Caridina nilotica were noted regularly in the stomach contents of A. baremose trawled in the open waters of the lake.

A study of the diel pattern of feeding in A. baremose was carried out at an inshore site in Ferguson's Gulf on 16-17th October 1975. Samples of 10-19 cm fish were caught at 4-hourly intervals over a 24 hour period. Insect food formed the bulk of the intake but marked changes in the proportion of various food items with the passage of time are evident (Table 9.32). Feeding activity was highest during the hours of daylight, when small corixids were the major constituent of the diet. Peak fullness was reached at dusk. After dark the proportion of food in the stomachs fell, and at 22.00 hrs corixids were replaced by emerging chironomids as the dominant prey.

It is difficult to draw any conclusion for the single A. baremose caught at 02.00 hrs, but in the dawn sample stomachs were almost empty suggesting that during the early hours of the morning feeding activity had ceased. With daylight feeding recommenced and by 10.00 hrs the stomachs were more than half full with corixids again forming a high proportion of the intake.

The results indicate that A. baremose is a chiefly diurnal feeder, similar in this respect to Hydrocynus forskalii, the other major surface species.

LAUZANNE (1973) carried out a detailed study of the food of A. baremose in the Chad basin during various phases of the migratory cycle from the main lake, up the major rivers and onto the flood plains. There were considerable changes from a mainly zooplanktivorous regime in the lake to a herbivorous diet on the flood plains where grass shoots and seeds were eaten. Feeding activity was much reduced in the river during migrations. DAGET (1952) also noted that A. baremose subsisted on plant material in the flood plains of the Middle Niger. The present results from Lake Turkana agree closely with observations on the lacustrine phase of the Chad population.

Investigations made by LAUZANNE (1969) on the diel feeding cycle of A. baremose showed that feeding activity was restricted chiefly to the hours of daylight and that stomach fullness reached a peak during the afternoon. Similar results were obtained during the present study.

SUMMARY

Alestes baremose was a common and widespread species, mainly restricted to the surface waters of the lake where it formed a high proportion of the catch in surface-set gillnets of 2½-3½ inch stretched mesh.

The adult population tended to concentrate in the Northern Sector of the lake during the flood season, prior to migrating up the River Omo for spawning.

Post-larval stages were planktonic and were found chiefly within 20 km of the Omo Delta. Juveniles from 2 cm FL to about 5 cm FL were common in marginal areas of the Northern Sector, extending only as far south as the region of Ferguson's Gulf on the west coast and Koobi Fora on the east. Immature fish of 5-20 cm FL were distributed throughout the lake both inshore and offshore. Above a length of about 20 cm FL there was a tendency for fish to move away from the shore.

Since surface-set gillnets were the principal method of capture it was impossible to estimate biomass in absolute terms, but catch rates in Lake Turkana experimental gillnets were high compared to yields from other parts of Africa where A. baremose is fished commercially. It was therefore considered to be a potentially important commercial species in Lake Turkana.

Age determination was carried out by a study of scale rings. Two scale rings were laid down in the course of a year, at six-month intervals. The most prominent ring was formed in August, probably in response to the change in environmental conditions caused by the influx of flood water from the River Omo. The second, somewhat fainter scale ring was laid down in February, the reason for its formation not being understood. August rings thus alternate with February rings. Fish were aged according to the number of August rings present, and the age composition of seine and gillnet catches was therefore established. Recruitment to the gillnet catches occurred at age 1+; 2- and 3-group fish formed the bulk of the catches with smaller numbers of 4-group fish. Only a small proportion of the catches consisted of fish of age 5+, the maximum age observed.

Mean lengths at formation of each August ring were obtained both by direct observation and back-calculation. Growth parameters were estimated using the von Bertalanffy growth equation, and growth curves for males and females were plotted separately.

Growth rate was higher in females than in males but a similar pattern of growth was followed in the two sexes for the first two years of life up to the onset of full sexual maturity (25-30 cm FL). Sexual divergence in size became increasingly noticeable in fish above 30 cm FL and by the age of four years males had reached a length of only 38 cm FL compared to 42 cm in females. The number of females above 42 cm was relatively low and a maximum size of 46 cm was recorded. The largest male was 43 cm FL.

It was shown that the growth rate of *A. baremose* in Lake Turkana was similar to that of *A. baremose* in Lake Mobutu (formerly Lake Albert) but distinctly higher than growth rates of populations of *A. baremose* in Lake Chad and the Middle Niger, where seasonal climatic conditions are more variable than in Lake Turkana.

Secondary sexual characters (expanded anal fin in males) began to develop at about 18 cm FL when fish were entering their second year of life but full sexual maturity was not attained until the third year. First spawning took place at the time of formation of the third August scale ring, at a length of about 33 cm FL in males and 35 cm FL in females. Gonads began to ripen in May and the spawning season extended from June to October with a peak in August, coinciding with the flood season of the River Omo. Fish migrated to the Omo to spawn, probably passing upstream for many miles. From November to March the great majority of gonads were dormant but there was evidence of a slight renewal of spawning activity in February of both years under investigation. Post-spawning mortality was high and relatively few fish survived to spawn for a third time.

A. baremose is a zooplankton feeder and food studies showed that planktonic crustacea, particularly the copepods *Tropodiaptomus banforanus* and *Mesocyclops leuckarti* were first in overall importance in the diet, but insects were also common at inshore sites. Small fish such as *Alestes minutus*, and the prawn *Macrobrachium niloticum* and *Caridina nilotica* were noted regularly in the food of *A. baremose* from the openwaters of the lake.

A study of the diel pattern of feeding, carried out at an inshore site in Ferguson's Gulf, showed that *A. baremose* was a chiefly diurnal feeder.

REFERENCES

BLACHE, J (1964). Les poissons du bassin du Tchad et du bassin adjacent du Mayo Kebbi. Paris, O.R.S.T.O.M.

DAGET, J (1952). Memoires sur la biologie des poissons du Niger Moyen. I. Biologie et croissance des especes due genre Alestes. Bull. Inst. fr. Afr. noire. ser.A. 14: 191-225

DURAND, J R and LOUBENS, G (1967). Premieres observations sur la biologie d'Alestes baremoze dans le bas Chari et la partie est du lac Tchad. Paris, O.R.S.T.O.M.

DURAND, J R and LOUBENS, G (1969). La croissance en longeur d'Alestes baremoze (Joannis, 1835) dans le bas Chari et le lac Tchad. Cah. O.R.S.T.O.M. ser. Hydrobiol. 3: 59-105

LAUZANNE, L (1969). Etude quantitative de la nutrition des Alestes baremoze (Pisc.Charac.) Cah. O.R.S.T.O.M. ser. Hydriobiol. 3: 15-27

LAUZANNE, L (1973). Etude qualitative de la nutrition des Alestes baremoze (Pisces, Characidae). Cah. O.R.S.T.O.M. ser. Hydriobiol. 7: 3-15

HOLDEN, M J (1963). Report on the fisheries of Lake Albert. Fisheries Laboratory, Lowestoft, (mimeographed).

HOLDEN, M J (1970). The feeding habits of Alestes baremose and Hydrocynus forskalii (Pisces) in Lake Albert, East Africa. J. Zool. Lond. 161: 137-144

HOPSON, J (1972). Breeding and growth in two populations of Alestes baremose (Joannis) (Pisces: Chaaracidae) from the northern basin of Lake Chad. Overseas Res. Publ. 20: 50 pp. London HMSO

HYNES, H B N (1950). The food of fresh-water sticklebacks (Gasterosteus aculeatus and Pygosteus pungitius) with a review of methods used in studies of the food of fishes. J. Anim. Ecol. 19: 36-58

THE BIOLOGY OF Citharinus citharus Geoffr. IN LAKE TURKANA

P B Bayley

INTRODUCTION

The characoid genus *Citharinus* occurs in West Africa and in the river systems of the Zaire and Nile. *Citharinus* species are microphagous, feeding on the richer bottom deposits in shallow waters (BAKARE, 1970). The various species are potamodromous and appear to spawn at the onset of the flood season (DAGET, 1962).

The Lake Turkana environment is somewhat distinct from the more typical riverine-floodplain habitats of *Citharinus*. Studies have indicated that the *Citharinus citharus* population of this lake has not adapted significantly to the more lacustrine habitats, but is restricted inshore and retains the life cycle characteristics of the genus.

Analyses of the gut contents of a small sample of adult *C. citharus* from the Kalakol area (carried out by B J Harbott) show that the following species of benthic algae occurred in the diet in that part of the lake:

C. citharus formed the backbone of the fishery from 1966 to 1970 but has declined rapidly since 1971 due to recruitment failure. Possible reasons for this failure are discussed following an account of relevant biological information.

METHODS

Most of the fresh material examined during the present studies was caught in gillnets set principally in the Todenyang, Kalakol and Ilaret areas of the lake. Only one individual was caught in a total of 341 quantitative bottom trawl catches (see Chapter 8).

Total length (TL) was recorded in all cases and the gonadial condition was classified according to a scheme based on NIKOLSKY (1963):

Females

Stage II — Quiet: ovaries thin, flattened in cross-section, pale orange or yellow in colour, no eggs visible

Stage IIa — Recovering: ovaries flaccid, suffused with dark red. A few large residual eggs sometimes present

Stage III — Maturing: larger ovaries with eggs of variable size visible

Stage IV — Mature: ovaries large, eggs large yolky and of even size. Eggs do not flow freely when gonad cut

Stage V — Ripe: eggs flow freely from ovaries when cut. Ovaries of maximum size with mostly transparent eggs.

Males

Stage II — Quiet: testes thin, circular in cross-section, white or cream in colour

Stage III — Maturing: testes larger but no milt exuded when cut and squeezed

Stage IV — Mature: testes larger, milt exuded when cut and squeezed

Stage V — Ripe: testes of maximum size containing copious milt. Milt emitted from vent when belly of fish pressed.

MATURITY, REPRODUCTION, MIGRATIONS AND JUVENILES

MATURITY

A total of 246 specimens were sexed and graded. Most were caught in gillnets, principally in the Todenyang, Kalakol and Ilaret areas. Table 9.32 shows the length frequencies recorded for each gonadial stage. The minimum lengths at first maturity recorded during the present investigations were 54 cm for females and 48 cm for males. These are probably overestimates since few specimens of less than 50 cm were caught in experimental nets.

The gonadial data for mature C. citharus are presented by area, month and year in Table 9.33. To define a lower size limit for mature fish, a value of 43 cm was presumed for both sexes. Since few examples were encountered between 30 and 50 cm a large error in this estimate is unimportant in this comparison. In addition to these data, the gonads of 14 adult C. citharus caught in the Kerio area were reported to be quiet (Fr. J. O'CARROL, pers. comm.). It is clear that ripening females and males have only been encountered in the Todenyang and Ilaret areas in the extreme north.

Data from all years and localities have been combined to show the numbers of the various gonad stages observed on a monthly basis (Table 9.34). Mature females occurred only between June and October, and two ripe females were reported from Ilaret in August. Mature males were evident from April to October and from August to October only. Additional data are provided by WORTHINGTON and RICARDO (1936) who noted that 102 adult specimens caught between January and March 1930 in the Longech area were quiet.

In conclusion, despite the paucity of information in certain months, the data leave little doubt that ripening of both sexes occurred only in the north of the lake and was restricted to an annual period which corresponded in the case of the females to the Omo flood season.

REPRODUCTION AND MIGRATIONS

No larvae of C. citharus were found during extensive sampling in inshore and offshore areas and there was no other evidence of spawning occurring in the actual lake. During a visit to the lower Omo, the author interviewed the senior fisherman of the Merille tribe. He reported that Citharinus and Distichodus began moving upriver in January or February when the water was relatively clear. These fish were not "heavy with eggs". The migration increased in intensity until June or July. Fish caught between July and August were "heavy with eggs". After the ensuing period of maximum flooding the fish were no longer present in the river. These observations are corroborated by the weekly commercial catch per effort data (see Chapter 6, page 360) which indicate a general reduction in the abundance of C. citharus from February onwards, reaching a minimum between May and July. Maximum abundance was usually recorded between August and February, but during 1972 a few high values of catch per effort were recorded during May 1972 at Lowarengak and Todenyang, and in July 1972 at Kalokol.

Fishermen from the Kerio and Turkwell deltas stated categorically that C. citharus neither concentrated at the deltas nor entered the rivers. Commercial data from the intensive local fishery confirmed this (see Chapter 6, page 352).

The indirect evidence that spawning occurred in the River Omo between July and September is in agreement with observations on the genus in West Africa reviewed by DAGET (1962). The review indicates that spawning occurs in rivers at the onset of the major floods, with the larvae and adults subsequently moving downstream onto the flooded plains.

JUVENILES

Table 9.35 summarises five foot seine catches before 1970. Monthly samples using the foot seine between Todenyang and the Old Fort at Kalokol and at Kerio between April 1972 and February 1974 yielded no *C. citharus*. Only two specimens were caught during the extensive shore survey from October 1974 to October 1975 (Table 9.35, see also Chapter 7). None was caught during the extensive metre townet survey (see Chapter 8, page 614) and only occasional adult specimens appeared in beach seine catches made during the shore survey (see Chapter 7).

The growth rate estimates (see below) suggests that all the specimens in Table 9.35 are likely to be between one and three months old. Since they were all caught at the end of October, additional evidence that spawning occurs between July and September is provided.

The fact that hardly any young specimens were caught after 1970 provides collateral evidence for the recruitment failure discussed below.

GROWTH

GROWTH CHECKS: DESCRIPTION

Growth checks were apparent on scales and opercular bones. Other hard parts including otoliths which were lost during the splitting of the commercial product, were not examined. Scale checks appeared as incomplete circuli abutting upon complete successive circuli on the dorsal and ventral sides. This is typical of many tropical migratory species. The position of these scale checks corresponded with those of dark lines on the opercular from the same fish under plain transmitted light. However, the distance of the scale check from the centre was proportionately smaller than in the case of the opercular check, suggesting the loss of material from the outer edge of the scales during growth stoppages.

GROWTH CHECKS: INTERPRETATION AND METHOD

The number of checks per scale or operculum was plotted against fish length, but the former varied considerably and was obviously too large for the marks to correspond to annual growth checks. Such multiple growth checks are typical of many tropical migratory species (pers. observation). However, check radii from a sample of opercular bones were found to group towards certain values when plotted as a combined frequency distribution. This indirect method of estimating population growth has produced acceptable results for the South American characin *Prochilodus platensis* (BAYLEY, 1973). The requirements for the method are:

(a) a definite spawning season

(b) a regular annual event resulting in one of the growth checks being formed

(c) other growth checks occurring at irregular or random times during the year *or* close to the regular check defined in (b)

(d) a large sample of adult fish.

If growth checks described in (c) were not present, obviously direct ageing of individual fish would be possible.

In the case of the Lake Turkana population of C. citharus, (a) is fulfilled and requirement (b) is almost certainly satisfied by the sesonal migration of adult fish into the Omo delta and up the river. Direct evidence of (b) being satisfied by immature fish behaviour is not available, but the data discussed below indicate that regular checks occurred (although in some operculars the checks were faint or absent). Annual 'dummy runs' of immature Cypriniform fishes are known to occur in Africa (D HARDING, pers. comm.) and South America (pers. observation). Requirement (c) is apparent from the data. The possibility of a second annual event six months out of phase resulting in the growth rate being underestimated by a factor or two is considered unlikely in the light of comparative evidence (see below) and no bi-annual events are suspected. Finally, (d) was satisfied by a large supply of opercular bones from salted-dried fish which were sufficiently clear for reading.

Randomly selected left opercular bones were measured. The radii of checks along r_1 (see Chapter 6, Fig. 6.II.) were measured rather than along r_2, since the thick anterior edge made observations difficult.

RESULTS

Samples were taken from four Co-operative Branches. The check radii were converted to total length (calibrated from TL - r_1 measurements on fresh fish, see Chapter 6, page 358). The resulting frequency histograms were multimodal, with peaks at similar positions. Single mode distributions were separated graphically (by eye) and the mean values calculated. These are shown in Table 9.36 with the respective sample sizes, in terms of numbers of operculars, from each region. The close correspondence of the peaks shown by their mean values provides strong evidence that (i) this group of values could not have occurred from only randomly distributed checks, and (ii) that there is one homogeneous population of C. citharus in the lake.

The similarity of the distributions legitimized the unweighted pool of data, and the resulting distribution is shown in Figure 9.14. The smaller number of checks comprising the first two peaks is due to the fact that the earlier checks were not visible on some operculars. These peaks correspond to immature fish and the requirement (b) discussed in the previous sub-section may not apply to all members of this sub-population.

In order to reduce possible subjectivity in the growth assessments the pooled distribution was analysed into normal curves using an iterative, best-fit program devised for the Hewlett-Packard 9810A calculator. The results of the 30th iteration are shown in Table 9.36. A sixth curve could be fitted, and the χ^2 goodness-of-fit value for the composite multinormal distribution was 23.0 with 15 degrees of freedom (P 0.05).

Assuming (b) from the previous sub-section, and that the first peak corresponds to an age of one year, a growth curve was plotted as shown in Figure 9.15. Assuming the applicability of the von Bertalanffy growth model, the Gulland plot shown in upper Figure 9.14 was used to provide estimates of the growth parameters. The calculated regression line produced a K value of 0.22 yr^{-1}, an asymptotic length (L_∞) of 65.8 cm and a t_0 value of -1.6 yr. One cannot prove the applicability of the model statistically from the linearity of the plot because the variables are not independent, but the parameters estimated appear reasonable and the calculated mean lengths at age shown in Table 9.36 correspond closely with those of the fitted curves. Calculated weights corresponding to the mean lengths from the fitted curves are also shown in Table 9.36 along with the postulated annual weight increments.

The growth rate is within the range of estimates from other populations of the same genus. It is faster than that estimated for C. citharus at Diafarabe on the River Niger (DAGET, 1962), but slower than was observed in the Lake Kainji population of the same species during the first two years after impoundment (LELEK, 1973). These results were compared after converting standard lengths to total lengths using the calibrated factor of 1.3. The growth rate of the C. citharus from Lake Turkana is slightly faster than C. gibbosus from the River Zaire but indistinguishable from that of C. congicus from the same river during the first two years of life (HULOT, 1951).

POPULATION STRUCTURE AND MORTALITY

Experimental fishing yielded small samples of C. citharus and only a crude idea of population structure could be obtained. Conversely, large samples were available from the commercial fishery in the form of opercular bones from Co-operative Branches. This species is the most convenient to prepare in the 'split, salted and dried' form and is traded rather than consumed locally.

CALCULATIONS OF POPULATION SIZE DISTRIBUTIONS AND COMPARISONS WITH SIZES VULNERABLE TO CAPTURE

The length distributions derived from the Co-operative samples between December 1972 and February 1974 were corrected for the effects of relative selectivity of gillnets and current regional mesh size distributions (see Chapter 6, Table 6.30. Selectivity was discussed in Chapter 6 (see page 376), and a mean selection length of 7.8 cm TL per inch of stretched mesh with a standard deviation of 13 cm was assumed. When the local mesh size distributions were accounted for, the resulting compound selectivity curves were very flat, with modes varying between 58 cm (Todenyang) and 42 cm (Kerio). Recruitment to the fishery was thus a gradual process starting at an age of slightly under one year and not completed until an age of 4+ to 6+ years had been attained.

Because of the broad selectivity range for each mesh size and the range of mesh sizes used, inaccuracies in the selectivity parameters or moderate departures from the implied assumption of equal efficiencies between mesh sizes will produce small differences in the estimated population structures. These were weighted according to local catch per unit fishing intensity and combined for each month to provide estimates of the total population structure.

Biases due to selection ranges varying with locality are discounted because the minimum size captured was always well in excess of the theoretical minimum values susceptible to capture. Table 9.37 provides details of the size range of C. citharus caught in the

In 1963 all stretched mesh sizes down to 2" (5 cm) caught the species off Ferguson's Spit (MANN, 1964). In 1930, C. citharus down to 30 cm TL (calculated from standard length) were caught near Kalokol (WORTHINGTON and RICARDO, 1936).

MEAN WEIGHTS OF CATCHES

The regularity of length range and age distribution was also reflected in the mean weights of the catches for which data exist over a long time span (see Chapter 6, page 356). These were remarkably constant considering the temporal and spatial differences in mesh size distributions.

CONCLUSIONS

The lack of younger fish has resulted in the average age (or weight) being maintained at a high level. The population structure has been dominated by relatively old year classes dating from 1967 and earlier and more recent year classes have shown a sharp decline.

THE RECRUITMENT FAILURE: POSSIBLE REASONS AND DISCUSSION

It is evident from the foregoing information that the population of C. citharus has failed to recruit significantly since 1968. The cause or causes of the failure are not immediately apparent, but two possible reasons are discussed below.

RECRUITMENT OVERFISHING*

Commercial fishing for C. citharus began in 1966 with 7½ inch and 8 inch gillnets. The fishery reached its peak in 1970. As the fishery subsequently declined, increasing use of smaller mesh sizes and fishing in new areas maintainedthe yield by catching more of other species. This diversification helped to maintain the total catch per effort (see Chapter 6, Table 6.30) and prevented a decline in fishing effort. From 1972 to 1974 the effort was 1100-1237 equivalent full-time fishermen resulting in 1.40-1.24 fishermen per km^2 of regularly exploited area (see Chapter 6 Table 6.26). The latter only covered about half of the C. citharus habitat. It was shown in Chapter 6 that the density of gillnetting on the commercial fishing grounds was approxi-mately 47 m of net/km^2 . Unless local concentrations of fish weresubject to particularly high fishing pressure, exploitation does not appear to have been particularly heavy. The only case when the latter situation occurred was reported from the River Omo during 1973. For the first time, many gillnet fleets were spread across the river, and large catches of C. citharus resulted for a few months. However, later in the year sudden floods damaged or swept away the nets, and the practice was discouraged. In any case, the present symptoms of the C. citharus fishery were evident before that time. Fishing on the eastern shore did not begin until 1973. Catch per effort was a little higher than current values from the western shore except in the case of Todenyang, but were much lower than was recorded in the commercial fishery in previous years.

In contrast, very intensive gillnet fishing on the Zaire side of Lake Mobutu (previously Lake Albert) reduced the catch per effort

* defined by CUSHING (1973).

of C. citharus to less than half in about twelve months (WORTHINGTON, 1929). The fishery continued to decline and has not since recovered.

The catchability of this species is evidently high with respect to gillnets, and broad comparisons of fishing intensity with other species may be misleading. However, comparisons of mortality and exploitation rates are not dependent on relative catchability, and may be acceptable in some cases. An instantaneous total mortality rate, Z, or 0.5 for adult fishes does not appear symptomatic of a fishery overexploited in the growth or recruitment sense when compared with results for other fisheries covering a wide range of values for this parameter.

A comparison is made with other multi-age stocks notorious for collapses which have been ascribed by CUSHING (1973 and 1971) to recruitment overfishing. These comprise various clupeid fisheries whose species are noted for their limited fecundity and flat-domed stock/recruitment curves. CUSHING (1973) estimates that the limiting rate of exploitation for clupeid stocks is 0.40 to 0.52, above which they will decline to zero. It is considered unlikely that the instantaneous rate of natural mortality, M, for the Lake Turkana C. citharus population lies outside the range 0.1-0.3. Table 9.40 shows rates of exploitation $[= (Z-M)(1-e^{-Z})/Z]$ for the extreme values of M. The table also shows the two lowest values reported for clupeid stocks where symptoms of recruitment overfishing were postulated (CUSHING, 1973) along with the limiting values mentioned above.

Accepting these estimates, recruitment overfishing under constant environmental conditions for the C. citharus stock appears unlikely, unless:

(a) M is lower than the range estimated

(b) the estimate of Z = 0.51 for the study period is much lower than was the case during the earlier years of the fishery

(c) the stock/recruitment curve is even more 'primitive' than those for the clupeid stocks, and/or

(d) females have been much more heavily exploited than males.

Reason (a) is unlikely if one accepts the broad inter-group comparisons of M and K values in BEVERTON and HOLT (1959) from which it appears that M is unlikely to be less than 0.1.

Although there is no evidence that total fishing effort declined since 1970, the proportion of the more successful 7" and 8" nets decreased, making reason (b) a possibility. However, the evidence indicates a decline in recruitment since 1968 when effort was certainly lower. Assuming the applicability of Ricker's second recruitment curve (RICKER, 1973 and 1975) as used by Cushing, the limiting exploitation rate must have been exceeded consistently since 1968 to continually reduce absolute recruitment under fairly constant environmental conditions (cf. following sub-section).

Reason (c) cannot be evaluated due to lack of biological information. Time prevented sufficiently intensive study of fecundity being carried out, but casual observations of individuals indicated medium to high fecundity, which is typical of many large Cypriniforms. If various areas. The wider ranges from Lowarengak and Kataboi were due to two minor influxes of smaller fish (1+, 2+ and 3+ age groups, see Table 9.39) during December 1972 and February 1973 respectively. These were the only recorded instances of 1+ and 2+ age groups occurring in the commercial catches despite the comprehensive sampling program and the knowledge that all C. citharus were sold to the Co-operative during the study period. The dearth of smaller fish was also confirmed by the experimental gillnet data which proved that the larger mesh sizes, particularly 8 inches stretched mesh, were the most productive (see Chapter 6, Tables 6.43 and 6.44).

INSTANTANEOUS TOTAL MORTALITY COEFFICIENT

The theoretical population distributions all showed one dominant mode between 54.5 and 56.5 cm TL above which it was presumed that the recruitment of those age groups had been reasonably constant and the mortality rates did not differ between age groups. The relation $Z = K\ (L_\infty - \bar{l})/(\bar{l} - l')$, derived by BEVERTON and HOLT(1956) was used to estimate the total instantaneous mortality coefficient (Z) from the von Bertalanffy parameters (K and L_∞, see Growth above)and the mean length ($\bar{l}$) of the population above the modal length, l'. Table 9.38 shows the results for each month. No trend in Z is apparent over the period during which catch per effort (as running annual mean) fell by 63%. The mean value of 0.51 can be regarded as close to the maximum for age groups above 5+ years. Assuming no significant increase in natural mortality, the younger age groups would be expected to have lower total mortalities due to incomplete recruitment to the fishery. These could not be estimated because of the confounding influence of reduced absolute recruitment in recent years.

AGE DISTRIBUTIONS

Although individual fish could not be aged, the proportions of each age groups most likely to occur within calculated length limits could be estimated. Since the von Bertalanffy parameters fit the data well for the first six age groups (Table 9.36), these were used to calculate the length limits for each month, assuming the birth date to occur in August (see Breeding above). Growth was assumed to conform to the model from month to month, and the length limit dividing one age group from another was the mid-point between the current mean lengths of the age groups.

The results, using the calculated population distributions for the whole lake, are shown in Table 9.39. The larger 0+ fish are also susceptible to capture, but none was recorded. The consistent dominance of fish over four years old and no strong year classes since 1967 are the striking features of all the distributions. The 1970 year class was the last year class which contributed regularly (though to a minor degree) to the catch. The year 1970 was also the last one in which significant quantities of 0+ fish were recorded (Table 9.35).

These interpretations assume that the entire population, from an age of just under 1 year and upwards, was available for capture in the total area fished, since the effect of gradual recruitment to the fishery has been taken into account. The assumption appears reasonable because of the large extent of the fishery and the evidence of small fish present as far south as Kalokol in earlier years. Mr R R McConnel reports that in the middle 1960's large shoals of C. citharus from 20 to 30 cm long would be caught periodically in the gillnets at Kalokol.

the observed values of size at first maturity (Table 9.32) are close to the actual values and not overestimates as suggested previously, it would mean that population fecundity was low. However, the observed value for females is 82% of L_∞, which is considered an overestimate in the light of comparative evidence provided by BEVERTON and HOLT (1959). Also DAGET (1962) implies that C. citharus reaches maturity at two years of age in the River Niger.

Reason (d) appears the more likely among those discussed in this section. WORTHINGTON and RICARDO (1936) noted that there were twice as many females as males in their sample of 102 C. citharus from Lake Turkana. The data in Table 9.41 suggest that the relation has been reversed, resulting in the fecundity of the stock being halved if the population were similar in size and structure. There was no evidence to indicate a sexual difference in length frequency distribution in data provided by WORTHINGTON and RICARDO (op. cit.). Results in Table 9.41, however, indicate a difference : the null hypothesis that numbers of males and females in 10 cm groups above 50 cm were equally distributed was rejected by a highly significant χ^2 value of 41. The present difference may be due to changes in catchability or availability.

Relative catchability in gillnets could not be tested due to lack of another sampling method, but spatial distributions of the sexes could be investigated. The data in Table 9.41 were analysed as a 2 x 5 contingency table in which the expected values were based on the null hypothesis that the distribution of the sexes was independent of region. This was rejected by the highly significant χ^2 value of 27.2 (4 d.f., p <.005). Sex ratios for regional samples (Table 9.41) indicate a general tendency for the proportion of females to increase southwards along both western and eastern shores. It is interesting to note that Worthington and Ricardo's samples were from the Kalokol region. The C. citharus fishery reached its 1970 peak when effort was concentrated at Kalokol, but unfortunately no data on sex ratios for that period exist. There does, however, remain the possibility that the rate of exploitation of females was higher than that estimated above for the combined sexes, due to a larger proportion of females formerly migrating into the most heavily exploited area.

ECOLOGICAL AND HYDROLOGICAL CONSIDERATIONS

The distribution and ecology of genus Citharinus (DAGET, 1962) indicates that it is macrophagous and typically inhabits flooded plains, swamps, shallow lakes and lagoons associated with major rivers. The latter (for example the Rivers Niger and Zaire) seasonally flood large areas, maintaining a rich organic substrate and associated microfauna ideal for the specialised feeding of Citharinus (BAKARE, 1970). Although a detailed study of the feeding ecology of C. citharus in Lake Turkana could not be carried out, the general ecology of the lake in recent years does not appear to be ideal for this species, with the exception of the Omo delta. However, the lake underwent considerable flooding in 1961/62 due to a very large inflow from the River Omo. Extensive areas both in river valley and on the lake margin were inundated (R R McCONNEL, pers. comm.). High levels were maintained until 1966 but subsequently the level has steadily fallen (see Chapter 1, page 8) with only minor areas being flooded annually. This very unstable hydrological regime is not dissimilar to that of some newly flooded reservoirs. In Lake Kainji, C. citharus was very abundant due to a strong year class shortly after filling, but subsequently declined due to poor recruitment (LELEK, 1973, and pers. comm.). It was noted in Volta Lake (PETR and REYNOLDS, 1969) that *C. citharus* catches were much reduced following a poor flood the year before.

Unfortunately, detailed data on the major river fisheries do not appear to be available, but catch data and general comments (DAGET, 1962; BAKARE, 1970) do indicte that *Citharinus* fisheries continue to be of major importance in West Africa, which have been exploited for a long time. Certainly there are no reports of a major collapse such as in Lakes Turkana, Mobutu and Kainji.

The arguments presented above in the discussion on overfishing assume fairly constant environmental conditions. This has evidently not been the case which, whilst not invalidating the previous arguments, does provide an alternative or complementary explanation for the drop in recruitment since 1968.

CONCLUSIONS

The population of *C. citharus* in Lake Turkana consists of a stock of old fish declining through a combination of fishing and natural mortality which is not being maintained by sufficient recruitment. The drop in recruitment may be due to the following causes:

(1) recruitment overfishing

(2) reduction of food supply due to restriction of annually flooded areas

(3) increased predation on the young due to lack of vegetation, and/or

(4) isolation of fish in pools not being reconnected to the lotic system due to successively smaller floods.

The evidence suggests that for (1) to be solely responsible, it would require a very flat-domed stock/recruitment relationship combined with a consistently higher exploitation rate for females than the range estimated for the whole population.

Causes (2), (3) and (4) are all dependent on the reduction in the area flooded annually which is known to have occurred since 1966. Cause (3) may also be affected by shoreline grazing and local rainfall distribution as suggested for *Sarotherodon niloticus* (see Chapter 11, page 1348) and *Labeo horie* (see page 813), but the increase in young of these two species in 1974/75 was not paralleled by a similar increase in *C. citharus*. The evidence discussed above suggests that the increasingly lactustrine, less flood-plain environment of Lake Turkana since the middle 1960's has made conditions less suitable for the procreation of *C. citharus*, possibly through (2), (3) and/or (4).

The author suggests the following tentative explanation for the recruitment failure. Unexploited populations of *C. citharus* in marginal and hydrologically unstable environments such as Lake Turkana probably suffer large fluctuations in recruitment. Rapid recovery after prolonged lean periods is only possible when the breeding stock of older fish is maintained, because of the reduced number of younger adults normally constituting the bulk of the spawning biomass. When any new fishery develops, the biomass of the slower-growing and more vulnerable older fish is reduced rapidly. But when this occurs during a lean period of recruitment, the reduced number of younger more productive adults is not sufficient to maintain the future recruitment at some stable level. The situation has probably been exacerbated by a higher exploitation rate of females in the early years of the fishery. Therefore, the fishery 'collapses' at a level of fishing intensity lower than would be required under more ideal environmental conditions for procreation.

A combination of the above causes has probably occurred. In recent years a lean period which began in 1968 or before, combined with moderate fishing pressure since 1970, has continually reduced the chances of recovery when and if favourable conditions return.

REFERENCES

BAKARE, O (1970). Bottom deposits as food of inland freshwater fish. In Kainji Lake Studies, 1 Ecology, ed. S A Visser: 65-86

BAYLEY, P B (1973). Studies on the migratory characin Prochilodus plantensis Holmberg 1889, (Pisces, Characoidei) in the River Pilcomayo, South America. J. Fish Biol. 5: 25-40

BEVERTON, R J H and HOLT, S J (1956). A review of methods for estimating mortality rates in exploited fish populations. Rapp. P-V Reun. Cons. int. Explor. Mer. 140: 68-83

BEVERTON, R J H and HOLT S J (1959). A review of the life span and mortality rates of fish in nature and their relation to growth and other physiological characteristics, pp 142-189. In Ciba Foundation Colloquia on Ageing. 5. The life span of animals, eds. Wolstenholme, G E W and O'Connor, K J. Churchill Ltd., London.

CUSHING, D H (1971). The dependence of recruitment on parent stock in different groups of fishes. J. Cons. int. Explor. Mer. 33: 340-362

CUSHING, D H (1973). Recruitment and parent stock in fishes. Washington Sea Grant Publ. 73-1. 197 pp

DAGET, J (1962). Le genre Citharinus (Poissons, Characiformes). Rev. Zool. Bot. afr. 66: 81-106

HULOT, A (1951). Observations sur la biologie de Citharinus congicus et de C. gibbosus dans la region forestiere Congolaise aux environs de Yangambi. Cong. int. limnol. 11: 201-109

LELEK, A (1973). Sequence of changes in fish populations of the new tropical man-made lake, Kainji, Nigeria, W Africa. Arch. Hydrobiol. 71: 381-420

MANN, M J (1964). Report on a fisheries survey of Lake Rudolf, Kenya. In E. Afr. Freshwat. Fish. Res. Org. Ann. Rep. 1962/63. 53-62, Jinja, Uganda

NIKOLSKY, G V (1963). The ecology of fishes. Academic Press, London and New York

PETR, T and REYNOLDS, J D (1969). Fish population changes in the Volta Lake in 1968. Volta Basin Res. Proj. Univ. Ghana Tech. Rep. 32

RICKER, W E (1973). Critical statistics from two reproduction curves. Rapp. P. - V. Reun. Cons. int. Explor. Mer. 174: 333-340

RICKER, W E (1975). Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can. 191: 382 pp

WORTHINGTON, E B (1929). Report on fisheries survey of Lakes Albert and Kioga. Crown Agents, London.

WORTHINGTON, E B and RICARDO, C K (1936). Scientific results of the Cambridge Expedition to the East African lakes 1930-31. The fish of Lake Rudolf and Lake Baringo. J.Linn. Soc. (Zool). 39 : 353-389

YAMANAKA, I (1960). Comparative study of the population size of Japanese and Californian Sardines. FAO Proc. World. Sci. Meet., sardines and related species. 3: 1151-1191

THE BIOLOGY OF Labeo Horie Heckel IN LAKE TURKANA

P B Bayley

INTRODUCTION

The genus *Labeo* is widely distributed in rivers or in lakes and swamps associated with rivers of Africa and southern Asia. The constituent species are potamodromous and feed on mud, detritus and associated microflora. However, *Labóe coubie* has been observed to feed on aufwuchs in Volta Lake (KRAMER, 1973). In terms of trophic level, *Labeo horie* is probably similar to *Citharinus citharus*.

Although widely distributed in Lake Turkana at depths of less than 20m, *L. horie* was practically unexploited during the early years of the fishery due to the predominance of gillnets of 8 inch stretched mesh. Nets of finer mesh size were introduced into the Kalokol area in 1970 and the use of these had spread to other parts of the lake by 1972. As a result, the yield of *L. horie* rose steadily but the catch included an increasing proportion of immature fish due to further reductions in mesh sizes between 1973 and 1974.

From 1972 to 1974 the yield increased from 586 to 1034 tonnes which represented 21% and 29% respectively of the total yield for all species . Although originally marketed only in the salted-dried form, the more valuable smoked product increased to about 25% of the Labeo yield by 1974 and continued to increase during 1975. In that year the yield dropped to 565 tonnes due mainly to reduction in effort.

MATURITY, POST-LARVAL AND JUVENILE STAGES

MATURITY

A total of 487 L. horie ranging from 30 to 79 cm TL were sexed and graded according to the schedule laid down by NIKOLSKY (1963). The results are shown in Table 9.42. Sexual dimorphism is apparent both in the length at first maturity and in maximum size. Commercial samples indicated that few Labeo exceeded 80 cm TL.

Table 9.43 shows seasonal variations in sexual maturity and indicates that breeding could occur any time between March and November. Most of the females caught commercially in Kerio Bay during this period were ripe or ripening.

Migrations associated with reproduction are discussed below.

METRE TOWNET SAMPLES

Oblique metre townet samples produced sufficient quantities of Labeo in the northern part of the lake to indicate significant changes from year to year. The specimens ranged from 5 to 24 mm FL and were chiefly post-larvae. Nearly all were caught north of a line 10 km north of North Island, mostly within the 0-10 m depth range. Table 9.44 shows results of all hauls made in the Northern Sector in chronological order. The difference between the 1972/73 samples and those for 1974/75 is sufficiently striking for statistical tests to be unnecessary. Various transformations were tried in an attempt to anaylyse parametrically changes within and between the 1974 and 1975 samples. In order to stabilize the variance, logarithmic transforms are usually successful for this type of sampling (BARNES, 1952). Although the variance was homogenized ($p > .05$) within and between years (but not between the five months), tests for normality for the 1974 samples revealed significant departures ($p < .05$ and $p < .01$) from normality due to positive skewness. A further attempt to find a suitable transformation using Taylor's Power Law (TAYLOR, 1961) produced the inoperable power of zero, suggesting that the distributions were too far from normality for any appropriate transformation. Since the 1974 and 1975 samples covered approximately the same period, data were combined within each year and tested using Wilcoxon's Rank Test. The result ($Z = .71$ $p = .5$) shows no significant difference in abundances between the two years, despite the 9% increase in catch per haul.

It is apparent from Table 9.44 that within each year abundance may vary seasonally. When data for 1974 and 1975 were combined and the same rank test was used to compare pooled results for June-August with those for September-October it was evident that the latter period was significantly the more productive ($Z = 2.03$ $p < .05$). However, this result should not be interpreted as meaning a peak spawning period for L. horie in the lake as a whole, since significant spawning may take place in other affluents whose hydrological regimes are more variable. A post-larval specimen was caught in the River Turkwell by A J Hopson in October 1970 and two examples in the River Kerio in July 1972. Other data of relevance to the seasonality of spawning is discussed below.

FOOT SEINE SAMPLES

Samples of post larval and juvenile Labeo horie were collected regularly from stations on the west shore of the lake. The collections were augmented by material from shore survey sites throughout the lake (see Chapter 7). Results are summarized chronologically in Table 9.45. Where stations are relatively close together with a homogeneous area the results were combined. Number of hauls per station were not recorded in all instances during the shore survey, but a sample of 8 produced a mean of 3.5 ± 1.1 standard deviation. This mean was used to estimate the catch per effort in the combined stations whose geographic limits are indicated in Table 9.45.

The data indicate the lakewide presence of very young Labeo between June and December except for the region south of Kerio and Sandy Bay. Further interpretation of the lakewide data is not possible because of the impossibility of sampling all the areas on a regular basis.

Results from the Todenyang and Kerio areas are worthy of more detailed attention. Figure 9.16 illustrates trends in catch per effort in the two localities. Despite some large gaps in the time series, it is apparent that during 1974 and 1975, catches of young L. horie were higher than during the corresponding months in previous years. Such interannual variations parallel the year-to-year differences in post-larval abundance discussed above. However, seasonal changes do not accord closely if one compares the foot seine results for August and October 1975 from Todenyang with the metre townet records. This is probably due to sampling inadequacies.

BEACH SEINE SAMPLES

Table 9.46 summarizes the results in terms of catch, catch per effort, length range, mean and modal lengths.

Zero catches are not shown, but are included where results from a series of stations have been combined. The highest values of catch per effort were recorded on the east shore of the lake and in the Kerio area. Comparisons between various regions are difficult since the samples were often collected in different years. The results, however, agree with metre townet and foot seine data and indicate a general tendency for the youngest L. horie (with modal lengths of below 10 cm) to be commonest in September and October.

It is instructive to consider the sampling problems of the beach seine with respect to the areas in which large catches of L. horie were obtained. If it should prove possible to calibrate the efficiency of the net, a knowledge of the number of samples required for inshore abundance estimates would be valuable. This estimate is simplified by the fact that the standard deviations of the catches per effort shown in Table 9.46 have a strong linear relationship ($p = .02$) with the mean value indicating contagious distributions. Assuming the applicability of probability sampling theory, about 175 replicates would be required to provide an abundance estimate (within that stratum) to an accuracy of ±20% of the true value with 95% confidence.

GROWTH

The checks on scales from 71 *L. horie* from the western and eastern shores were measured and analysed, but no coherent pattern was evident from either the separate or the grouped results. There was a mixture of complete and indefinite checks which did not correspond to any consistent length groups. Although growth checks were present on the opercular bones, they were difficult to read and, as in the case of the scales provided no key to age determination. Estimates of population length frequencies derived from opercular bone samples and corrected for commercial mesh size distributions, revealed no peaks which could be traced from month to month. It was also difficult to trace a consistent pattern of modal progression from regular beach seine samples collected in Ferguson's Gulf (Table 9.46). Modal progression was evident in large beach seine samples collected on the east shore of the lake between October 1974 and January 1975, but the catch consisted of 0-group *L. horie* whose growth rate could not be reliably extrapolated to adult fish. Samples from the bottom trawl were too small and infrequent for growth interpretation.

A series of gillnet settings in the Longech area with a graded fleet of gillnets during the period February-June 1974 (see Chapter 8, page 620) caught *L. horie* in sufficient numbers for length frequency distributions to be estimated using the selectivity curve of the fleet (from data in Chapter 6, page 374). The length frequencies were summed for each of the four months and shown in Figure 9.17. Peak 'a', 'b' and 'c' in the distributions for February and April were not all present in the other months. The disappearance of size groups due to emigration was also indicated in the beach seine samples from Ferguson's Gulf. However, peak 'b' persisted throughout the sampling period and moved to the right. The growth rate indicated by this shift in modal length is equivalent to 280 gm/year, similar to the annual growth rate of 300 gm/year observed in *Citharinus citharus* (see page 793).

Peaks were separated from the February and April data using the Cassie method (CASSIE, 1950). Separation was more difficult, and therefore more subjective, after the first four peaks and separate analyses for the first four and first seven peaks were made. Assuming that growth conformed to a von Bertalanffy model, and that the peaks were annual peaks, Gulland plots ($l_{t+1}-l_t$) were made using a GM regression (RICKER, 1973) as shown in Table 9.47. The correlation coefficients merely show the linearity of the plots and cannot be tested. Nor do they provide any legitimacy as regards the applicability of the model.

Despite the linearity of the plots, the variability of the K and L_∞ estimates is considerable. This may be due to one or a combination of two or more of the following possibilities:

(a) growth not conforming to the model

(b) the presence of cohorts which represented brood classes formed at intervals of less than one year

(c) the sexual dimorphism evident in Table 9.42 being a result of widely-differing growth rates rather than longevity

(d) sampling error due to the chance encounter of homogeneous shoals of different mean lengths.

The selectivity curve for the fleet was based on data with sufficient overlap of lengths between successive mesh sizes (see Chapter 6, page 374 and Chapter 8, page 620) and a good linear relationship between mesh size and mean length was derived. It is therefore likely that the peaks are merely a reflection of gillnet selectivity, insufficiently accounted for by the selectivity curve, otherwise the peaks would be more evenly spaced and would fail to produce a negative slope on the Gulland Plot.

It seems probable that (b) combined with (d) have contributed mostly to the inconsistencies. As is clear from the preceeding section, the breeding season of L. horie is relatively prolonged and high sampling variance is evident even for the relatively efficient gillnets. There is a possibility that there is more than one breeding population of L. horie in Lake Turkana associated with different river systems. Individual populations may have relatively short breeding seasons, the timing of which may differ from river to river. Only the River Omo proved to have a regular seasonal hydrological regime, and the irregularity of breeding opportunities in other rivers could lead to the sporadic emergence of brood classes. The effects of river flow on local migrations of L. horie are discussed below.

ADULT FISH: STOCK, MIGRATIONS, POPULATION STRUCTURE, GILLNET SAMPLING

STOCK SIZE

Since it was not possible to calibrate the acoustic gear specifically for L. horie, the only possibility of directly estimating stock size was from the bottom trawl samples. The species was encountered in areas less than 40 m deep, but the largest catches were from 0-10 m on the eastern shore (Chapter 8, Fig. 8.9). Assuming 100% efficiency within the 10 m separating the wings, biomasses were estimated within 10 m depth strata from 142 hauls made between May 1972 and September 1973 in less than 40 m depth. Because of the commercial gillnets impeding trawling in what were probably the more productive areas on the western shore, the higher average catch (5 kg/hr) from the eastern shore was extrapolated for the total area corresponding to the 0-10 m stratum. The lakewide standing stock estimate of 132 tonnes is so small compared with the annual yields of 565-1034 tonnes that it cannot be accepted. The likelihood of sampling error on such a scale is small, but bias may result if larger concentrations existed in the commercial fishing areas on the west side of the lake which lay outside the region covered by the bottom trawl survey.

MIGRATIONS

Movements of adult and sub-adult L. horie were evident from the weekly catch per effort of commercial gillnets as illustrated in Chapter 6, Fig. 6.36. The results are re-examined below with particular reference to river flow and rainfall data. Marked increases in catch per effort of passive gear such as gillnets on a short time scale reflect increases in local migrations. Such behaviour was noted when local storms coloured the water inshore, or when discharge from previously-dry rivers stimulated movement.

Figure 9.18 shows the commercial catch per effort (as numbers of L. horie per commercially-active fisherman 'F' per week) over a period when the occurrence of rain was noted at Lowarengak in the absence of river flow in the area. Adjustment has been made to allow for an average drying time of five days for the catches recorded at the Co-operative. The correlation between rainfall and increased catch is clear.

The effect of river flow was more marked as shown by Figure 9.19 where seasonal trends in commercial catch per effort at Kerio are analysed. Weeks when the Rivers Kerio (pers. observation and Father J O'CARROL, pers. comm.) and Turkwell (from river flow data of J GRIMM) were known to be flowing into the lake are indicated and the results have been adjusted for fish drying time. The correlation of high catches with the inflow of one or both rivers is clear, as is also the seasonal nature of the fishery. Even when neither river was flowing, catch per effort was still higher during the period April-November than in other months. At times when the rivers were flowing, most nets in the Kerio area were hung from stakes at right-angles to the shore near the river mouths, but not within the rivers themselves. Lake depths in the vicinity of the stake nets were generally less than 1.5 m. The equivalent of 72 standard 50 yd gillnets was counted along a 2 km stretch of coastline on 13 August 1973. This was the most intensive fishing observed in Lake Turkana other than the Ferguson's Gulf Sarotherodon fishery. The mesh sizes of inshore nets ranged from 4" to 5.5". Since a large proportion of L. horie caught at Kerio during the season were immature (see following sub-section) it is suspected that the rivers attracted immature as well as the ripe or ripening fish.

POPULATION STRUCTURE

A detailed analysis of total population structure taking into account net selectivity was not made because of difficulties in estimating growth. However, gross changes in the size composition of the catches have resulted from changing mesh size distributions in the fishery and will affect the future population structure.

An instructive measure of the effects of modifications to the fishing effort is provided by the percentages of immature L. horie in the commercial catches. First maturity lengths of 51 cm TL (44 cm FL) for males, and 56 cm TL (48.4 cm FL) for females from Table 9.42 are assumed to be sufficiently close to 50% maturity lengths not to affect the trends analysed here. It is also assumed from the data in Table 9.42 that a sex ratio of unity exists between these sizes at first maturity. Thus the percentage number of immature L. horie of both sexes combined could be estimated from length frequency distributions of the total catch (Table 9.48). Sample size and the mean weights corresponding to the distributions are shown in Appendix 6.III. Some of the distributions were not available at the time of analysis, but appropriate transformations of the data at hand (108 monthly distributions, discounting samples less than 50 fish) produced a good linear relationship ($r = 0.963^{***}$, $p > .001$ and sy.x - 3.07) shown at the foot of Table 9.48. The estimates of immature fish derived from this reltionship are also shown.

Table 9.48 indicates that in areas where the proportions of immature L. horie was high, seasonal changes in the relative numbers are evident. This was the case at Kerio in all years, at Kalokol in 1974 and 1975, and at Kataboi in 1974. The highest proportion of immature fish occurred between April and July, especially at Kerio. This corresponds to the period of the inshore fishery in Kerio Bay discussed above. The biological significance of such changes in relative abundance is not clear, but food availability probably varies seasonally as a result of enrichment from flooding rivers and may be a causative factor.

Regional differences in the proportion of immature fish are an effect of variation in the stretched mesh size of commercial nets, particularly finer nets of 3½ to 5 inches. Annual trends within each region were estimated by interpolating mean weights for missing months taking into account seasonal trends, and estimating percentages using the relation shown in Table 9.48. These were weighted according to monthly catch and combined for each January-September period, and are shown in Table 9.49.

It is clear that the fishery is not in a state of equilibrium and this is due to the marked effects of mesh size reductions. In addition, if one assumes that the peak of the biomass curve is close to the sizes at first maturity, the large proportion of immature fish captured in 1974 and 1975 will lower maximum yields through the reduced surplus production.

SAMPLING WITH GILLNETS

It is evident from the foregoing discussions that the active fishing gear utilized was not satisfactory for estimating directly or indirectly stock sizes of L. horie.

Gillnets proved to be the only method which was capable of sampling large quantities of adult and sub-adult specimens. If it is accepted that mean catch per effort for gillnets provides an index of abundance for the size range vulnerable within the area sampled, one can estimate the approximate number of sets required for a desired accuracy assuming probability sampling theory. Table 9.50 shows estimates from experimental gillnets of 5 inches stretched mesh. The variances are considerable, but this is not surprising when one considers the dependence of catch on the movements of a migratory, shoaling species. Fleets of gillnets showed similar variances due to autocorrelation between meshes. Two examples are shown in Table 9.50.

As well as the problem presented by the very large samples required to obtain only modest precision, comparison from year to year was hindered by the nature of the distributions. No single transformation was found which normalized the distribution and homogenized the variance in all the samples, and consequently only simple tests using the less efficient non-parametric methods can be legitimately applied.

Experimental gillnetting has been essential for obtaining relative selectivity data and samples for biological information. However, it is clear that the cost of maintaining a gillnet programme in order to monitor the stock would be considerable, and it would be wiser to use resources to monitor catch, composition of catch, effort and mesh size distributions in the commercial fishery. An example of the use of these commercial statistics in conjunction with experimental data is presented in the following section.

POPULATION FECUNDITY AND ABUNDANCE OF YOUNG FISH

The marked changes in abundance of young L. horie from year to year, noted above, may reflect changes in population fecundity. The latter could not be estimated directly, but catch per effort of mature, female L. horie can be regarded as an unbiased index of spawning biomass. In turn, spawning biomass can be assumed to be directly proportional to population fecundity in the absence of short term changes in fecundity per unit weight.

Experimental gillnet catches of mature females were too sporadic and variable to provide reliable estimates, but ample commercial fishery data from 1973 to 1975 allowed regional and lakewide estimates to be made. Serious biases would be introduced if an overall catch of mature females was divided by an average effort value representing the relevant mesh sizes, because of regional and temporal differences in mesh size distribution. The method least subject to bias is described below.

The principle of the method is to calculate the size range of fish most vulnerable to capture in each of a series of gillnets at intervals of one inch stretched mesh size. The components of catch and effort corresponding to each interval are then summed after appropriate weighting to provide an index of population fecundity for a given time and area. Three steps are described below.

CATCH OF MATURE FEMALES

The gillnet selectivity curves derived for L. horie were used to estimate the length ranges most susceptible to capture in mesh sizes of successive one inch intervals. These ranges were further subdivided into 2 or 3 cm groups above the size of first maturity of females within which sex ratios were estimated using the data from Table 9.42. This information was used in conjunction with the length distribution data from the Co-operative Branches to calculate the weights of mature females most likely to be caught within each mesh size interval as percentages of the total catches. In a similar manner to that described above for immature L. horie, the percentage weight of mature females was estimated from known or interpolated mean weights using the following predictive equation:

$$\% \text{ by weight mature } ♀♀ = \sin^2 [54.03 \text{Ln (mean weight in kg)} + 7.58]$$

where corr. coeff., $r = .988^{***}$, $p < .001$

and s. dev. from regression, $s_{y.x} = 1.78$

Percentages by weight of mature females most susceptible to mesh sizes 3.5 to 4.5 inches, 5.5 to 6.5 inches and 6.5 to 7.5 inches were related linearly to the overall percentage ($r = -.922^{***}$, $p < .001$; $r = .906^{***}$, $p < .001$; and $r = .191$, $p \doteqdot .05$ respectively) and those for 4.5 to 5.5 inches were found by difference. The parameters derived from these regressions were not dependent on area or time, and all available data since January 1973, totalling 100 distributions (discounting sample sizes less than 50), were analysed. 1975 data were available until August or September. Values for the remaining months were estimated as a group within each area according to their relative proportions during the same periods for the previous two years. Estimates of total yields which take into account subsistence and extra-cooperative trade, were made for 1973 and 1974 (see Chapter 6) and together these exceeded the co-operative yields by 13% and 29% respectively. A value of 40% was assumed for 1975. Total extra-cooperative trade was much higher than this during 1975 due to the *S. niloticus* fishery in Ferguson's Gulf (see Chapter 11).

A summary of these data is provided in the form of percentages together with the total yields in Table 9.51.

EFFORT

Calculations of effort were conducted separately for each of the one inch mesh size intervals used above. The extensive mesh size distributions collected during 1973 and 1975 (see Chapter 6) were combined with the total effort 'E' (see Chapter 6) corresponding to each area and period. Owing to the lack of replications of mesh size samples in Nachukui and Kerio in 1975, effort was combined into two geographic areas: Todenyang-Lowarengak-Nachukui and Kerio-Kalokol (inc. E Shore)-Namudak-Kataboi with weighting according to 'E'. 1974 mesh size distributions were interpolated from those of 1973 and 1975. Effort is thus defined as the equivalent number of full-time fishermen using 80 m of gillnets of mesh sizes x inches to x+1 inches. During 1975 large numbers of fishermen concentrated in Ferguson's Gulf to exploit *S. niloticus*. It was estimated that 775 fishermen were involved (J OGARI, pers. comm.). Assuming this is equivalent to F_{max} (see Chapter 6) this would correspond to about 504 equivalent full-time fishermen or 40.7% of the 1974 total. If one can assume no overall increase in effort during 1975 then the effort exploiting *L. horie* would be about 40% less than in 1974. J OGARI (pers. comm.) also estimated that there were 50 boats connected with the *S. niloticus* fishery in 1975, which is 43% of the total in 1973 from the whole lake. The 40% reduction in effort with respect to *L. horie* in 1975 must be regarded as a maximum, since it is likely that the *S. niloticus* fishery attracted participants not previously engaged in the occupation. Also there was no evidence that effort was reduced in the Todenyang area (A McLEOD, pers. comm.) when the Co-operative Branch there was closed down in February 1975. Consequently, separate calculations were made for the Todenyang-Lowarengak area using 'E' values for 1974 in 1975. Other breakdowns of data on a geographic basis could not be made for 1975, because of the uncertain redistribution of effort nearer to the *S. niloticus* fishery.

CATCH PER EFFORT

The catch and effort values were combined for each mesh size interval and shown in Table 9.52 for years in which geographic areas could be compared. Very few mature females were most susceptible to capture in mesh sizes of less than 4.5 inches (i.e. those measuring 56 to 56.5 cm TL) but the consistency of their increase in biomass is notable. This is more than offset by the general reduction of older fish most susceptible to mesh sizes between 4.5 to 5.5 inches (from 56.5 to 69 cm TL) and 5.5 to 6.5 inches (from 69 to 82 cm TL). Catches of large individuals most susceptible to mesh sizes over 6.5 inches were sporadic and no trends were evident.

Differences between biomass trends are evident when one compares the northern and central areas of the lake. In 1973 the biomass of smaller females (less than 69 cmTL) was much higher in the northern area and yet the reverse was evident for the larger females. This difference may be attributed to a smaller proportion of 4.5 to 5.5 inch nets in the north (with a negligible number in previous years) and conversely a small proportion of 5.5 to 6.5 inch nets in the central area, in particular at Kerio (Table 6.22). Subsequent increases in smaller mesh sizes in the north probably contributed to the 50% reduction of young females there, whereas the biomass of similar sized fish in the central area was practically unchanged in 1974. If there was annual mixing due to extensive migrations, one would not expect these differences in trends unless some undetected changes in fishing strategy had occurred. It is therefore possible that at least two populations may exist in the lake.

In order to obtain an index of population fecundity for all mature females it was necessary to sum the component catches per effort taking into account estimates of relative efficiency. It is assumed that the efficiencies in terms of numbers of fish caught are similar over the range of mesh sizes (essentially 4 to 7 inches) which is indeed the assumption made in using the method described by HOLT (1963) for deriving the selectivity curves (see Chapter 6). Since catch per effort here is in terms of weight, the catch per effort components were adjusted according to the mean weights caught which corresponded to the fish most susceptible to the particular mesh size interval. Adopting the 4.5–5.5 inch mesh size interval as a standard, the weightings varied between 1.38 to 1.52 for 3.5–4.5 inch nets, 0.62 to 0.71 for 5.5–6.5 inch nets and 0.41 to 0.45 for 6.5–7.5 inch nets. The results are shown in Table 9.52 along with the percentage changes.

Between 1973 and 1974 the overall population fecundity dropped by 23% mainly as a result of the situation at the north end of the lake where a fall of nearly 50% is estimated. The fall in northerly areas continued in 1975. For reasons already stated the 1975 estimate for the whole stock is probably an overestimate. It is clear that despite moderate fishing intensity (see Chapter 6) spawning biomass or population fecundity has been reduced by nearly two thirds in three years, and is probably less than a third of the unexploited biomass at the beginning of the decade.

However, the evidence presented above strongly suggests sharp increases in population densities of young *L. horie* in 1974 and 1975 in the northern region where the spawning stock has decreased most rapidly. This inverse relationship between population fecundity and abundance of young fish suggests that natural mortality of very young fish and possibly spawning success are more instrumental in affecting the future recruitment to the fishery than the density of the parent stock. If one assumes that the variability in natural mortality suggested here for larval and post-larval stages is much higher than for later pre-recruitment stages, then one would expect recruitment to vary considerably. CUSHING (1973) shows that such a situation is widespread in marine species.

The reason for the observed phenomena is probably not dissimilar to that considered most responsible for the sudden and intensive fishery for *S. niloticus* (Chapter 11). The more evenly distributed rainfall during 1974 and 1975 increased the previously sparse shoreline vegetation considerably and provided both additional cover from predation and improved food resources for *Sarotherodon* fry. The fry of *L. horie* which similarly inhabit sublittoral regions of the lake probably also take advantage of these improved conditions for fry survival.

CONCLUSIONS

The biology of *Labeo horie* presented here deals with the life cycle, distribution, stock structure, and dynamic characteristics. Other aspects such as growth, feeding ecology and interactions with other species are still poorly understood, but despite the incomplete nature of the results, some general conclusions of use to the management of the fishery can be made.

Although yield and gross catch per effort (Table 6.30) increased from 1972 to 1974 this was due to reducing mesh sizes exploiting younger age groups, and to a lesser extent to the exploitation of new fishing grounds. The estimated 1975 yield was much lower due partly to reduced effort, but the gross catch per effort of ca 14 kg per fisherman per week was also lower despite reductions in mesh size. Over the period investigated, corrected catches per effort of mature females fell by more than half, and immature fish contributed increasingly to the yield. There are not many remaining areas legally open to exploitation in Lake Turkana which contain the present species, and those recently explored have not produced high catches (Tables 6.41-6.44, 6.5f and Table 9.49).

However, there is evidence that recruitment to the fishery may change significantly due to improved conditions for fry survival in 1974 and 1975. One would expect recruitment to vary in Lake Turkana with *L. horie* and other potamodromous species. Before 1968 the Kerio and Turkwell rivers used to flow continuously into the lake between about March and November (R R McCONNEL, pers. comm.). Since then river flow has been very erratic and this may well have affected breeding success and mortality of progeny in the Kerio, the Turkwell and similar rivers. In addition, effects of the successive lowering of the lake level may have reduced protection and feeding opportunities due to lack of vegetation in the unstable and overgrazed littoral regions prior to 1974.

Attempts to apply the concept of a maximum sustainable yield to a stock whose recruitment varies considerably from year to year may result in the reduction of the spawning biomass during an unfavourable period to a level from which recovery is slow or inhibited by competition from other species. Even under ideal conditions of management yields would fluctuate. The best practical solution to prevent a collapse during a critical period would be to control effort by enforcing a minimum stretched mesh size of 6 inches in the inshore gillnet fishery and by banning the use of nets in the mouths of active rivers. The well-documented collapses of *Labeo* fisheries elsewhere (CADWALLADR, 1965 and DE KIMPE, 1964) provides a warning of the consequences of allowing heavy exploitation of *Labeo* to continue unchecked.

Monitoring of the adult stocks by experimental gillnets is costly, but regular fishery statistics of yields, size distribution and mesh size distribution such as collected during this survey should be continued. If supplementary data is also obtained on the abundance of fry in marginal areas of the lake during July to November each year it may be possible to correlate recruitment with hydrological/meteorological conditions and associated habitat changes inshore. This could provide a basis for predicting yields with sufficient accuracy and time for market planning purposes.

REFERENCES

CADWALLADR, D A (1965). Notes on the breeding biology and ecology of *Labeo victorianus* Blgr (Cyprinidae) of L. Victoria. *Rev. Zool. Bot. afr.* *72* : 109-134

CASSIE, R M (1950). The analysis of polimodal frequency distributions by the probability paper method. *N. Z. Sci. Rev.* *8* : 89-91

CUSHING, D H (1973. *Recruitment and parent stock in fishes.* Washington Sea Grant Program, University of Washington, Seattle. 197p

HOLT, S J (1963). A method for determining gear selectivity and its application. *ICNAF Spc. Pub. No.5, Darmouth, Canada.* 106-115

KIMPE, P DE (1964). Contribution a l'etude hydrobiologique du Luapula-Moero. *Ann. Mus. r. Afr. Centr. 8 vol, Sci. zool.* *128* : 1-238

KRAMER, D L (1973). Preliminary investigations into the biology of *Labeo* in the Volta Lake. *Unpublished Tech. Rep. X38, Volta Basin Research Project, University of Ghana, July 1973.* 24pp

MANN, M N (1964). Report on a fisheries survey of Lake Rudolf, Kenya. *EAFFRO Annual Report 1963/63*, Jinja, Uganda, 53-62

NIKOLSKY, G V (1963). *The ecology of fishes.* London and New York Academic Press. 352pp

RICKER, W E (1973). Linear regressions in fishery research. *J.Fish. Res. Board Can.* *30* : 409-434

TAYLOR, L R (1961). Aggregation, variance and the mean. *Nature, Lond* *189* : 732-735

THE BIOLOGY OF Barbus Bynni (Forsk.) IN LAKE TURKANA

A H S Mraja

INTRODUCTION

Barbus bynni belongs to the group of large *Barbus* characterised by parallel striae on the scales. The species is essentially nilotic in distribution occurring commonly in the lower Nile and extending up the White Nile to Lake Mobutu (formerly Lake Albert). Populations of *Barbus bynni* also occur in Lake Turkana and in Lake Abaya, both of which once lay within the Nile basin. BANISTER (1973) has recently revised the taxonomy of the group of large *Barbus* to which *B. bynni* belongs. He regards the unique specimen of *Barbus meneliki*, also collected from Lake Turkana, as conspecific with *B. bynni*.

The species is of considerable commercial importance in Lake Turkana (see Chapter 6). Annual total commercial catch for recent years is shown in Table 9.53.

The size range of the commercial catch was approximately 40-60 cm FL and most *B. bynni* were caught in gillnets. A maximum size of

80.0 cm was observed during the present investigations on Lake Turkana.

Little work has been carried out previously on the biology of B. bynni. The present studies were made over a period of 3½ years, from May 1972 to November 1975.

MATERIAL

Information was obtained from the wide range of collecting gear in routine use during the present project, including various types of trawls, townets, gillnets and beach seines. The most comprehensive data, relating to a total of 5420 Barbus bynni ranging from 3.0 to 80.0 cm FL were derived from bottom trawl catches made in all parts of the lake. Regular monthly samples from the Central Sector near Longech Spit provided the bulk of material for biological studies. Further material was examined from the following gear:

	Number	Size Range
Midwater trawl	817	9 - 53
Frame trawl	42	2.5 - 34.5
Gillnets	2084	12 - 72
Shore seine		

Barbus bynni was also regularly caught angling from the shore with rod and line using a small spoon.

The size selectivity of gillnets in relation to B. bynni is illustrated by Figure 9.20. All available length frequency data for each mesh size has been combined for the calculation of mean retention lengths (see Chapter 6, page 374). The linear relationship between mean retention length and stretched mesh size is represented by the regression equation

Mean retention length (FL in cm) = 10.099 + 6.251 stretched mesh size (inches)

Length frequencies of all B. bynni studied during the present investigations, from all types of gear, have been combined in Figure 9.21.

The fork length of B. bynni was usually measured to the nearest centimetre below, exept where weight data was also collected. Under such circumstances lengths to the nearest millimetre below were recorded. Most observations were made in the field, but stomachs of B. bynni were preserved in formalin for subsequent examination in the laboratory.

DISTRIBUTION

INTRODUCTION

Barbus bynni proved to be the most widely distributed of the larger cypriniform fish in Lake Turkana occurring both in shallow inshore regions and in deeper water far offshore. Evidence (discussed more fully in the section on Breeding, below) strongly suggests that spawning is restricted to areas situated well upstream in the River Omo. No post-larval or juvenile B. bynni were observed in over 500 metre townet samples from all parts of the lake. Such early stages were also absent from frequent hauls made on the shore with a fine (2 mm mesh) seine net, including numerous samples from areas adjacent to the Omo Delta. The smallest B. bynni observed during the present investigations were caught by bottom trawls in the Northern and Central Sectors of the lake. Most of these immature fish exceeded 5 cm FL but a few individuals in the 3-4 cm length class were recorded.

DISTRIBUTION OF B. bynni IN BOTTOM TRAWL CATCHES

The occurence of B. bynni in bottom trawl catches is illustrated by the maps in Figure 8.10 (see Chapter 8). The species is well distributed throughout the lake, but it is evident that concentrations are generally highest in inshore areas. Consistently high catches were recorded in the vicinity of Allia Bay on the east shore of the Central Sector.

Records of B. bynni in the bottom trawl catches have been analysed on the basis of depth for 10 cm size groups in each of the three major lake sectors. Results are shown graphically in Figure 9.22 where catch per effort for each size group, expressed as numbers of fish per hour, has been logarithmically transformed. Data for the Central Sector is most comprehensive and indicate a progressive decrease in the mean size of B. bynni with increasing depth between the 0 m and 25 m depth zones. This resulted from a marked fall in the number of fish over 30 cm FL balanced by a steady increase in the proportion of individuals less than 20 cm FL. At depths greater than 30 m the trend was reversed and numbers of smaller fish declined rapidly. Below the 60 metre contour, catches of B. bynni were low and most fish were larger than 30 cm FL.

Results from the Southern Sector show a similar shift in size distribution as depth increases from 5 to 30 m. The proportion of fish below 10 cm FL was, however, very low in the Southern Sector compared with areas to the north (Fig. 9.22). The results may also indicate a tendency for B. bynni to concentrate at depths between 15 and 25 m in the south, but the observations are based on a low number of samples. In the Northern Sector, changes in size distribution with depth were less marked than in the Central Sector, and higher proportions of smaller fish were recorded in shallow water. Relatively large numbers of fish over 50 cm FL were also caught in the north, particularly in the 10 m depth zone. These larger individuals probably concentrate in the Northern Sector prior to spawning migrations up the River Omo.

The bottom trawl data discussed above have also been expressed in terms of kg/hr trawling (Fig. 9.23) to show the depth distribution of different size groups of fish in terms of biomass. The results indicate marked differences from region to region. In the Northern Sector a notable peak of 40-60 cm fish is evident in the 10 m depth zone. The highest concentrations of B. bynni in the Central Sector were observed in water shallower than 10 m where 30-40 cm fish predominated(Fig. 9.23). Comparatively high values for 20-40 cm fish recorded in the Southern Sector in water of 20-25 m.

Seasonal changes in depth distribution are illustrated by Figure 9.24 where mean catch per effort for B. bynni in each depth zone has been calculated separately for three seasons of the year. During the flood season, July-October, the population tends to concentrate inshore within the 10 metre contour. Under post-flood conditions fish move progressively further offshore and by the period March-June peak catches were recorded in the 10-15 m depth zone. Similar seasonal movements have been noted in other species, including Lates longispinis and Bagrus bayad during the present survey of Lake Turkana. The migration seems to be correlated with the influx of turbid water into the lake during the flood season, resulting in a reduction of light penetration. The B. bynni population probably tends to follow a particular level of illumination inshore during this period and moves offshore as the water clears during the post-flood period.

The evidence suggesting that B. bynni tend to concentrate at depths between 10 and 15 metres during the pre-flood season (Fig. 9.24) is supported by data from gillnets set on the bottom at depths from 4 to 24 metres off Longech Spit during the same period of the year (see Chapter 8, Table 8.62). Low catches of B. bynni were recorded at the shallowest and at the deepest of the four stations. Peak catches were recorded at station B situated at a depth of between 10 and 14 metres (Table 8.62).

DISTRIBUTION OF B. bynni IN THE MIDWATER LAYERS

The pregoing account has dealt with the occurence of Barbus bynni in a narrow layer sampled by the bottom trawl within ca 3 m of the lake bed. Data from Boris Midwater Trawl catches on a grid covering much of the open waters (see Chapter 8) indicate that the species was rare in the midwater layers with individuals recorded at only 3 out of a total of 81 stations. However, these hauls were restricted to the hours of daylight and evidence from a series of frame trawl hauls (Table 9.54) proves that B. bynni tends to move off the bottom at night. Further information has been obtained from a series of overnight catches made in open water off Longech Spit with nets set at various depths (see Chapter 8, Table 8.23). At each of the gillnet stations midwater catches were as high or higher than in bottom set nets and small numbers of B. bynni were caught in the surface layers (Table 9.54).

DISTRIBUTION OF B. bynni IN INSHORE WATERS

Much information on the distribution of B. bynni in inshore areas is provided by analyses of gillnet catches (see Chapter 6, Tables 6.42-6.45 and Chapter 8, Tables 8.61-8.63).

The data cover a wide range of mesh sizes. Results from the types of nets used most regularly have been combined in Figures 9.25 and 9.26. Fine mesh nets of 2½ to 3½ inches stretched mesh caught predominantly fish of between 30 and 35 cm FL. Figure 9.25 indicates that B. bynni of this size were well distributed in all sectors of the lake. Particularly high concentrations were recorded in the vicinity of Longech Spit and in the Ilaret area. Most of the sites in Figure 9.25, where no B. bynni were recorded, were fished on only a single occasion. Combined results from 5 and 6 inch nets, chiefly involving fish in the size range 45 to 55 cm, appear in Figure 9.26. The highest catches were recorded in the vicinity of the Omo Delta where B. bynni was the predominant species in the 5" gillnets

(Fig. 9.26). Relatively high catches were recorded at localities situated elsewhere in the Northern, Central and Southern Sectors. However, no B. bynni were observed in gillnets at Kerio where a total of 110 settings were made.

Barbus bynni occurred relatively uncommonly in beach seine catches which were made principally on shores with a fine substrate. A total of 78 hauls were made with the 19 mm and 50 m beach seines on shore in all regions of the lake, excluding the Ferguson's Gulf area, and the species was recorded at only 5 of these. Similarly, in Ferguson's Gulf, B. bynni was noted only once in a total of 36 sampling sessions at which the beach seines were in use. It seems reasonable to conclude that on muddy, sandy and shingly shorelines B. bynni does not occur regularly in the littoral region although large concentrations may be present at a depth of several metres offshore.

Direct observations on rocky coastlines show that B. bynni of ca 25-50 cm FL occur regularly in shallow water close inshore. In the clear waters of the Southern Sector B. bynni was often seen foraging over rocks close to the edge of the lake. Under such circumstances the species was caught by angling with rod and line using a small spoon for bait. Localities where B. bynni was caught by angling from the shore .

DISTRIBUTION OF B. bynni IN COMMERCIAL CATCHES

As mentioned previously commercial catches of B. bynni reached a peak in 1974 when a total of 422 tonnes was recorded. The catch was divided among the co-operative areas in the following way:

Co-operative area	Catch B. bynni in tonnes
Todenyang	254.4
Lowarangak	145.1
Nachukui	26.7
Kataboi	10.4
Namudak	0.9
Kalokol	0.8
East Coast	0.8
Eliye	0.3
Kerio	2.5

It is clear that a disproportionately large part of the catch was taken in the vicinity of Lowarangak and Todenyang near the Omo Delta. Experimental data from trawls and gillnets have not revealed such an overwhelming concentration of B. bynni at the northern end of the lake. It seems likely that the commercial fishery was based on an area through which B. bynni, from all parts of the lake, migrated in the course of movements to and from the River Omo. The comparative rarity of the species in commercial catches in the Kerio area suggests that unlike Labeo horie and Schilbe uranoscopus, Barbus bynni does not undergo spawning migrations into the Kerio River.

GROWTH

Preliminary examination of the scales of B. bynni from Lake Turkana showed that although frequent checks in the regular series of circuli were present, they were not laid down in a consistent pattern. In consequence, they provided no key to age determination. In a similar way opercular bones were found to be unsatisfactory.

Petersen's method of length frequency analysis proved to be more successful. Data from bottom, midwater and frame trawl samples were combined for each month from June 1972 to December 1974 to give the length frequency histograms shown in Figure 9.27. Mature fish of over 40 cm FL were usually poorly represented in the catches and since no sexual differences were discernable in the size distribution of sub-adult fish, length frequency data for males and females have been combined.

There is considerable irregularity in the length frequency histograms reflecting the varied gear in use, the wide geographical range from which the samples have been drawn, and in some cases the small sample size. Nevertheless, certain dominant size classes form marked peaks which it is possible to trace through successive months. In such cases, modal length tends to increase from month to month. Careful examination of the series of monthly histograms shows that in nearly all instances the dominant size groups represent year classes. Thus in May 1974 (Fig. 9.27) the two peaks at 12 and 23 cm represent the 1973 and 1972 year classes respectively. The 1973 year class also shows up very clearly in histograms from March, April and June 1974. In a similar way it is possible to follow the 1972 class backwards in time through a total of 12 months to June 1973 when the modal length was 13 cm. Comparable modal lengths were observed in the smallest size group of fish both in June 1974 and in June 1972 indicating that a regular annual pattern of recruitment occurs in this species. Reproductive data (see below) suggest that the spawning season is restricted to the annual period July to September when the River Omo is in flood. It seems probable that the 0-group fish remain in the river for an initial period and emerge into the open lake at an age of 6-8 months. The histograms suggest that the 0-group fish emerge on the offshore fishing grounds during the months of February and March each year at a modal length of 7-8 cm.

The position of identifiable year classes on the histograms is indicated in Figure 9.27. In the absence of absolute ageing techniques it was often impossible to separate overlapping year classes with accuracy and in such cases a subjective procedure was followed. Data for larger fish were generally sparse and for this reason no attempt was made to analyse the age of fish exceeding ca 35 cm FL. Estimated monthly mean lengths for each year class, derived from the histograms, are presented in Table 9.55. Growth curves for the 1971, 1972 and 1973 year classes have been plotted separately in Figure 9.28a, b, and c using the monthly mean lengths (Table 9.55). Results for the three years have been combined in Figure 9.2d. Supporting evidence suggests that spawning occurs in August and the combined curves thus cover the first 2½ years of life. The curves (Fig. 9.28) indicate that B. bynni attains approximately the following lengths for age:

Age (years)	Fork length (cm)
1	14
2	27
3	39

An attempt has been made to fit a von Bertalanffy growth curve to the data using the expression

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

where L_∞ is asymptotic length, K is the rate at which L_∞ is approached, l_t is the length at any age t, and t_o is a constant. The calculations were based on results for the 1972 year classes which include an unbroken series of mean lengths at three-monthly intervals commencing with April 1973 and ending in October 1974 (Table 9.55), a total of seven observations at equal time intervals. Values of L_∞ and K were calculated from the regression of l_t on $l_{t+1} - l_t$ with t expressed in units of 0.25 years. The following parameters were estimated for *B. bynni*:

L_∞ = 92 cm

K = 0.198 (corrected for units of 1 year)

t_o = -0.06 years

These estimates must be regarded with caution since they were based on a limited age and size range of fish. Values of length for age which have been computed from the values are as follows:

Age (years)	Fork length (cm)	Weight (gm)
1	15.8	56.5
2	29.5	383.2
3	40.6	1019.1
4	49.8	1904.8
5	57.4	2942.7
6	63.6	4028.6
7	69.7	5332.8
8	72.9	6118.7
9	76.3	7035.3

Weights have been obtained by means of the length-weight formula presented below.

LENGTH -WEIGHT RELATIONSHIP

A total of 677 *B. bynni* ranging from 9.5 cm to 69.0 cm were weighed and measured during the present investigations. The relationship between $\log_{10}$ weight and $\log_{10}$ length was found to be linear, as in most species of fish, and a regression equation was calculated. From this equation the following expression was obtained:

$$w = 0.01209\ l^{3.0623}$$

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

The condition factor of B. bynni was calculated from the expression

$$k = \frac{100w}{l^3}$$

Variations in the value of $\bar{k}$ were noted but the data were too sparse for an analysis to be made on a seasonal basis. An overall mean value of k = 1.49 was obtained for a total of 600 fish, the majority of which were immature. Higher mean values were noted in samples of mature fish and a maximum of $\bar{k}$ = 1.80 was recorded for a group of 30 individuals of over 40 cm FL caught during breeding.

BREEDING

INTRODUCTION

Gonadial stages for both males and females were classified according to the scheme of NIKOLSKY (1963):

Stage I	Immature
Stage II	Virgin-resting
Stage III	Ripening
Stage IV	Ripe
Stage V	Running
Stage VI	Spent

LENGTH AT FIRST MATURITY

Data from all sources relating to gonadial state have been combined in Table 9.56 for females and 9.57 for males to determine the length at which B. bynni reaches maturity. The results indicate that maturation of ovaries commences in fish with a minimum size of 30 cm. The smallest ripe (Stage IV) female measured 39.8 cm FL but the proportion of fish larger than 40 cm in the samples was low and it is thus difficult to make an accurate assessment of the mean length at first maturity for the population. The data in Table 9.56 suggest that the mean length at first maturity in females of B. bynni is approximately 48 cm FL. Data for males (Table 9.57) are more inconclusive. Males started to mature at a minimum length of between 28 and 30 cm but the smallest ripe individual observed measured 48 cm FL.

BREEDING SEASON

Data on seasonal changes in maturity are insufficient for a satisfactory analysis to be made. Ripe females were noted in most months between February and October and spent females were observed in September and October. These observations do not contradict indirect evidence which suggests that the breeding season coincides with the annual flooding of the River Omo and that spawning occurs only within the confines of this river. The indirect evidence is as follows:

(a) There was a total absence of larval and juvenile B. bynni of under 3 cm FL in samples made with suitable gear in all parts of the lake, both inshore and offshore. The situation is in marked contrast to Labeo horie (see page 805), larvae and juveniles of which were widespread. Spawning in B. bynni clearly occurred away from the lake.

(b) Only two major river systems, the Omo and the Turkwell/Kerio include areas with suitable breeding habitats. Co-operative catch data (see above) show that B. bynni is scarce in the Turkwell/Kerio area but occurs in peak numbers in the vicinity of the Omo Delta. From this information it is concluded that spawning is limited to the River Omo.

(c) Anadromous fish in tropical Africa, and elsewhere, typically migrate up rivers during the flood season for spawning. Several species were found to migrate seasonally in this way during the present study including Citharinus citharus (page 791), Distichodus niloticus (page 844) and Alestes baremose (page 780). It seems probable that peak spawning in B. bynni also occurs during the main flood period, July-October. The seasonal influx of 0-group fish of 3-4 cm FL into the open lake during February and March (see above) suggests that young fish spend their initial six months of life within the confines of the River Omo.

SEX RATIO

Data from all sources have been combined in Table 9.58 which indicates that males are generally outnumbered by females in the ratio of approximately 1:1.5.

FOOD

Stomachs of B. bynni were preserved in formalin and examined later in the laboratory. A volumetric method (HYNES, 1950) was used in the analysis of food. The fullness of a stomach was judged subjectively on a ten point scale: 0 - empty, to 10 - full. The contribution made by each item was then assessed as a percentage of the total food present. Finally a number of points was awarded to each food item by multiplying fullness by percentage contribution and dividing by ten. During the present investigations the food of a total of 335 B. bynni ranging from 6.4 cm to 61.5 cm FL was examined.

The results have been analysed on the basis of size and depth location (Table 9.59). In all categories ostracods were the most important food item forming approximately 40-50% of the diet of fish in shallower water and increasing to over 90% in B. bynni from deeper water. This increase reflects the tendency for benthic forms other than ostracods to become rare in the deeper waters of Lake Turkana. Sclerocypris clavularis, S. jenkinae, Megalocypris brevis, Cyprinotus kliei, Potamocypris producta, and Limnocythere africana were the most widespread ostracods in offshore waters.

In addition to ostracods the shallow water fish had fed extensively on insects and molluscs. Insects were rare in B. bynni of less than 20 cm FL but both corixids and chironomid larvae were frequently preyed on by larger size groups. Melanoides tuberculata and Cleopatra pirothi were each observed regularly in the stomachs and would certainly account for the relatively large quantities of broken mollusc shell noted in the smallest size group (Table 9.59). Possibly these small fish found it difficult to swallow molluscs whole and tended to crush such food with the aid of the pharygeal bones. Gabbiella rosei was not recorded in the present material, which was derived from trawl catches. This snail is frequent on rocky shores in the south of the lake and is probably an important food of B. bynni which were frequently observed foraging close inshore in the area.

Table 9.60 shows the percentage of stomachs in which each food category was observed. The results prove that in Lake Turkana B. bynni is a benthic feeder subsisting on a variety of invertebrate foods.

SUMMARY

A total of 5420 Barbus bynni were recorded during the present investigations but most were immature fish, under 45 cm FL. The species ranges widely both inshore and in deep water ofshore. Marked changes in depth distribution with size were observed. During the flood season the population tends to move closer inshore, probably as a result of increased turbidity. Although the food of B. bynni is chiefly benthic the species was often caught in daytime pelagic samples. The population as a whole tends to move into the midwater layers after dark. Barbus bynni was an important commercial species, caught mainly in the Northern Sector of the lake and a total of 422 tonnes was recorded in 1974.

The growth rate was estimated by Petersen's method. The species attains a length of 39 cm in 3 years. A von Bertalanffy curve was fitted to the observed lengths for age.

Limited reproductive data suggests that the length at first maturity is approximately 48 cm FL. The species is anadromous and spawns in the River Omo during the flood season. Juveniles migrate downriver at a length of 3 to 5 cm and appear in the open lake during February and March each year.

The food of B. bynni is mainly benthic with ostracods forming a high proportion of the intake. Chironomid larvae and molluscs are also eaten regularly.

REFERENCES

BANISTER, K E (1973). A revision of the large *Barbus* (Pisces, Cyprinidae) of East and Central Africa. Studies on African Cyprinidae part II. *Bull. Br. Mus. nat. Hist. (Zool.)* *26* : 4-48

HYNES, H B N (1950). The food of fresh-water sticklebacks (*Gasterosteus aculeatus* and *Pygosteus pungitius*) with a review of methods used in studies of the food of fishes. *J. Anim. Ecol.* *19* : 36-58

NIKOLSKY, G V (1963). *The ecology of fishes*. London and New York, Academic Press. 352 pp

THE BIOLOGY OF THREE SMALL CYPRINIFORM FISHES IN LAKE TURKANA

A J and J Hopson

INTRODUCTION

The endemic fish on which the present study is based proved to be widely distributed throughout the openwaters of Lake Turkana. *Alestes ferox* and *A. minutus* were confined to offshore localities but *Engraulicypris stellae* occurred ubiquitously from the margins to the deepest areas in mid-lake. In company with prawns and the post-larvae of *Lates* spp., the three species were the principal components of metre

metre townet samples in all sectors. Standing stock estimates (see Chapter 8, Table 8.22) indicate that A. minutus contributes nearly 190,000 tonnes to the ichthyomass of the lake which, particularly in view of the short life-span of this species, represents a high proportion of total fish production.

No detailed studies have been carried out previously on the small fish and, indeed, the two characins were unknown until the open waters of the lake were sampled systematically for the first time during the present survey. WORTHINGTON and RICARDO (1936) provided information on the feeding habits of E. stellae and noted that the species matured at a length of 22 mm.

The present investigations were planned with the object of providing a basic assessment of the life histories of A. ferox, A. minutus and E. stellae. It was hoped, in particular, that information on growth and reproductive cycles would be forthcoming. The study has utilized data and material collected during routine surveys, chiefly from metre townet, frame trawl and midwater trawl catches. In the case of A. ferox the gear failed to provide satisfactory samples since the size range of adolescent and adult fish lay below the 100% mesh selectivity point of the cod ends employed, resulting in a marked bias in favour of larger individuals.

Various aspects of the distribution of the three species, particularly vertical zonation and diel migration in the open waters of the lake, are dealt with in Chapter 8 and a brief synthesis of the results is provided below. Studies of diet and feeding behaviour are also considered separately in Chapter 12.

MATERIALS AND METHODS

Samples from offshore areas were obtained chiefly by metre townet, frame trawl and midwater trawl (see Chapter 8). Inshore collections of E. stellae were made with a fine foot seine (see Chapter 7). All material was preserved in 5% formalin for subsequent analysis in the laboratory.

Fork length was measured to the nearest millimetre below. The weights of smaller fish were estimated by weighing batches of similar sized individuals on an analytical balance to the nearest milligramme. Dry weights were obtained by desiccation of the same samples in a vacuum oven to constant weight at 70^{o}C.

Gonadial condition was classified according to the following schedule:

Stage 1 — immature: gonads thin, threadlike, not readily distinguishable as ovaries or testes

Stage 2 — virgin/resting: gonads easily recognisable as ovaries or testes, no sign of maturation

Stage 3 — early maturation

Stage 4 — late maturation

Stage 5 — ripe

Stage 6 running

Stage 7 spent

THE BIOLOGY OF *Alestes ferox*

INTRODUCTION

Observations on *A. ferox* are based chiefly on samples collected by midwater trawl and frame trawl from the Longech area during the period October 1972 to May 1974. Data on post-larval and juvenile fish have been combined from metre townet catches made throughout the lake over the entire survey period. Analyses of the food of *A. ferox* are presented in Chapter 12 (see page 1510).

DISTRIBUTION

Alestes ferox proved to be a pelagic species confined to the open waters of the lake and one of the most important components of the midwater scattering layer (see Chapter 8, page 637). The horizontal range of this species was probably very similar to that of the midwater scattering layer which is well illustrated by echo survey data in Figure 8.71. The results indicate that the scattering layer varied considerably in density and was most concentrated near the west shore between the 10 and 20 metre contours, from Kerio Bay to the vicinity of North Island. In the Northern Sector heavy concentrations were more widespread, and at times extended across the lake to the east coast. Very low acoustic densities were generally observed in the southern basin. A similar pattern was observed in *Alestes ferox* during the Boris midwater trawl survey (Fig. 8.23) with the highest catches occurring near the west coast. The tendency for *A. ferox* and other pelagic fish to concentrate in a zone near the west coast is thought to be due to north easterly drift of planktonic food in areas where aggregations of pelagic fish were generally observed. Catches of small *Alestes* spp. of up to 320 kg/hr were made with the Engels trawl during 1973 in locations where a dense midwater scattering layer was recorded.

The vertical zonation of *A. ferox* is well illustrated by frame trawl data (see Fig. 8.31-35) and discussed at length on pages
Light intensity was shown to be the most important factor controlling depth distribution in both this species and *A. minutus* with the populations tending to concentrate at depths where subsurface illumination was optimal (see page 637). Thus during the pre-flood season in the Central Sector of the lake, the two species of *Alestes* occurred in a narrow depth zone between ca 16 and 20 m. Seasonal changes in light penetration resulting from the spread of flood water from the major rivers led to wide temporal and spatial variations in the depth of the scattering layer which thus ranged from the top 5 m in the turbid waters of the north to deeper than 30 metres in the transparent waters of the extreme south.

Diel changes in light intensity effected a nightly migration towards the surface in both *A. ferox* and *A. minutus* followed by a dispersal throughout the top 10-15 metres during the hours of darkness (see Fig. 8.78). As a result of such nocturnal movements within the superficial layers of the lake *A. ferox* was occasionally caught in shore samples after dark. At dawn, both species re-established themselves in the midwater scattering layer.

BREEDING

Size at maturity

Data relating to length at maturity in female and male A. ferox are presented in Tables 9.61 and 9.62. Gonadial development was noted in females at a minimum length of 54 mm but no ripe Stage 5 fishes of less than 74 mm were recorded. The proportions of the various female maturity stages became relatively stable at lengths of over 94 mm (Table 9.61) indicating that all individuals had reached maturity, and the data suggest that the length at 50% maturity was approximately 86 mm. The mean length at which males matured is more difficult to estimate since the degree to which Stage 4-6 individuals reverted to Stage 2-3 after spawning is not known. Secondary sexual characters in the form of elongated central anal fin rays first appeared in males at a length of 54 mm FL. Mature testes were observed in fish with fully expanded anal fins from a length of 62 mm upwards, and the proportion increased in successive size classes up to maximum size (Table 9.62). It was found impossible in the formalin-fixed material to distinguish between mature and ripe-running fish.

Spawning seasons

Seasonal changes in sexual maturity for female A. ferox are analysed in Table 9.63. The results indicate that breeding continued for much of the year with ripe individuals present during most months. However, the high proportion of Stage 5 females during October 1972 suggested that, as in many species of fish in Lake Turkana, peak spawning coincided with the Omo flood season extending from August to October each year. Although no samples were obtained during October 1973, data for August and September indicate that the proportion of ripe fish was again increasing. Further evidence for heightened breeding activity during the flood season is provided by metre townet data (Fig. 9.29) which show that the largest proportion of young A. ferox ranging from 8 to 20 mm FL were caught during October and November. These probably represented broods which had originated during the main flood season in August and September.

Comparatively high proportions of ripe or ripening females were recorded during April 1973 and May 1974, suggesting that a subsidiary peak may have occurred during the period when the first major rains of the year had just fallen and the Rivers Kerio and Turkwell were in flood.

The spawning sites are unknown, but there is no evidence to imply that this species was anadromous in its reproductive habits. Early stages were more numerous in the Northern Sector of the lake and it may be inferred that the main breeding areas lay in comparatively shallow areas, probably within the limits of the main sediment plume.

GROWTH

Information on growth in Alestes ferox is limited to the length frequency histograms for males and females (Fig. 9.30) covering a period of thirteen months from December 1972 to December 1973. The gear failed to sample effectively fish below a minimum size of ca 50 mm and important evidence on the growth of smaller individuals is lacking. No clear cut pattern is immediately evident, but closer inspection reveals a number of important points.

(1) Although there is considerable variation in the form of the histogram from month to month, there is always close agreement in any particular month in results for the two sexes, whereas distributions for December 1972 and September 1973 were basically unimodal, distinctly bimodal distributions appeared in March, May and June 1973. Above ca 70 mm FL the modal lengths for females were distinctly higher than the corresponding lengths for males, indicating either selective male mortality, or a higher growth rate in females. It seems probable that the second alternative is correct since in other larger species of Alestes, both in Lake Turkana and elsewhere, females have been shown to grow at a fast rate (see for example A. baremose, page 776). The present results show that female A. ferox attained a maximum length of 120 mm compared with only 104 mm in the case of males.

(2) Even though there was not always a straightforward progression of size cohorts from month to month, certain dominant modes can be followed through a number of successive samples. For example, a conspicuous mode in males at 40 mm during May 1973 may be traced through June, August and September to the peak of 68 mm in December 1973.

(3) A decline in the proportion of females of over 90 mm and males over 80 mm between July and September 1973 suggests that high mortality was taking place in the larger fish. This is compatible with breeding data which indicate that peak spawning occurred during this period. Heavy mortality during the post-spawning epoch is widespread in characins. There is a suggestion of similar mortality in large females between March and April 1973 when, as noted previously, a subsidiary rise in spawning activity was observed.

It is considered that where bimodal distributions occurred, as in March 1973, the two modes represented age classes, a year apart, which originated during the spawning peaks in successive flood seasons (Fig. 9.30). Thus in March 1973 the mode at 48 mm was formed by 0-group fish of the 1972 year class, and the modes at 88 mm in the males and 92 mm in the females corresponded to 1-group fish of the 1971 year class.

Breeding data have showed that sexual maturity was achieved at a length of between 80 and 90 mm and the observations on growth suggest that the fish started to spawn during their second year of life at an age of from 18 months to 2 years. As a result of heavy mortality in post-spawners, it seems probable that most fish only spawned once and that the proportion of fish surviving into their third year was negligible.

LENGTH-WEIGHT RELATIONSHIP

The relationship between length (l) and weight (w) may be represented by the expression

$$w = al^b$$

During the present investigations, length/weight data were obtained for a total of 22 fish ranging from 36 to 77 mm, and the following relationship between fork length (in cm) and wet weight (in gm) was obtained:

$$w = 0.014l^{3.04}$$

Dry weights were also recorded for the same fish. The relationship between fork length (in mm) and dry weight (in gm) was found to be

$$w = 1.832 \times 10^{-7}\ l^{3.682}$$

THE BIOLOGY OF Alestes Minutus

INTRODUCTION

Data concerning the biology of *A. minutus* have been derived from metre townet catches made throughout the lake during the period August 1972 to November 1975. Distribution, breeding and growth are considered in the present account. Feeding habits are discussed in Chapter 12 (see page 1509).

DISTRIBUTION

Alestes minutus, a pelagic fish, was the most important component of the midwater scattering layer. The distribution proved to be almost identical with that of *A. ferox*, described previously. The present species, however, was much smaller in adult size and was always the predominant fish in terms of numbers. A high proportion of the echo traces which formed the characteristic midwater scattering layer in Lake Turkana was probably produced by *A. minutus*. As in the case of *A. ferox*, the lakewide pattern of distribution probably coincided with the disposition of the midwater scattering layer, as revealed by echo surveys (see Chapter 8, Fig. 8.78), with the highest concentrations in the western half of the lake from Kerio Bay northwards. The close similarity of distribution with *A. ferox* is well illustrated by results from the Boris midwater trawl survey (see Figs. 8.23 and 8.24).

Further information on the distribution of *A. minutus* is supplied by records from the frame trawl and metre townet surveys (see Chapter 8, Figs. 8.31-35, 8.37, 8.44-7 and 8.51 a-c). Relatively few samples were obtained with these types of gear from sites near the west coast where the scattering layer was heavy, but valuable supplementary information is provided on the shallow waters of the extreme north where the midwater trawl and the acoustic equipment could not be used. It is evident that high population densities occurred in the Northern Sector, particularly during the June-July sampling period (Fig. 8.51a, see also Table 8.22). These northern samples were actually obtained during late July 1974 during the early part of the flood season which also coincided with the onset of increased breeding activity in *A. minutus* (see below). It seems likely that the aggregations, which consisted of large mature adults, had concentrated prior to spawning.

The patterns of vertical distribution and diel migration in *A. minutus* were very similar to those described above for *A. ferox* and require no further elaboration. Light intensity was again the most important factor controlling depth distribution (for detailed discussion see Chapter 8, page 637).

BREEDING

Size at maturity

Alestes minutus reached sexual maturity at an unusually small size for the genus. Table 9.64 shows that ovaries began to mature at a minimum size of 24 mm FL and ripe individuals were recorded at a length of only 26 mm. Evidence from length frequency histograms suggests that post-spawning mortality was almost total and, with a dearth of recovering females, the proportion of Stage 2 fish declined steadily to a minimum of only 5% in the largest size class (Table 9.64). The length at 50% maturity was approximately 30 mm.

Comparable data for males (Table 9.65) show that the distal margin of the anal fin started to expand from a length of 24 mm onwards and that fish became ripe at a length of ca 30 mm. Males and females thus matured at approximately the same size. No marked sexual differences in length frequency distribution were noted and it would appear that, unlike large species of Alestes, growth rates in male and female A. minutus were similar.

Spawning season

Seasonal changes in the sexual maturity of A. minutus are illustrated in Table 9.66. The observations show that although a proportion of ripe females was noted during all sampling periods, seasonal fluctuations occurred. There is clear evidence to show that a spawning peak was reached between July and September, coinciding with the Omo flood season. Thus during June and August a high proportion of females were either maturing or ripe, whereas in September and October most were in a spent or resting condition. The results suggest that heightened spawning activity also occurred during the onset of the early rains, resulting in a marked fall in the proportion of ripe fish between March and May. The existence in A. minutus of two main spawning seasons at intervals of approximately six months is supported by length frequency data (see below).

The actual site of spawning in A. minutus is unknown but there is no evidence to suggest that this species migrates into rivers and none has been recorded from several hundred shore samples made with suitable gear at sites throughout the lake. The concentration of A. minutus in the Northern Sector during the flood season, in water of from 4 to 20 metres, suggests that breeding may occur within this depth zone. Although the Northern Sector was probably the most important breeding area for A. minutus, the distribution of early stages of this species (Fig. 9.31) shows that spawning was probably widespread. Individuals of less than 15 mm occurred regularly throughout the central areas of the lake as far south as the Turkwell Sector.

Breeding is probably stimulated by the spread of sediment plumes into the lake from flooding rivers.

GROWTH

A preliminary inspection of length frequency records revealed no sexual difference in the size structure of A. minutus populations, and data for males and females was subsequently combined. Length frequency histograms for a total of 23 months during the period August 1972-

November 1975 are presented in Figure 9.32. The data have been pooled from all metre townet stations.

Pronounced modes are present on the length frequency histograms in all months (Fig. 9.32) and critical examination proves that the various size cohorts represented brood classes. The fact that cohorts did not generally progress smoothly from month to month with a regular increment in modal length is probably due to bias caused by local variation in growth over the comparatively wide geographical area from which information was gathered. In spite of such irregularities, it is possible to trace a regular pattern of growth and recruitment which was repeated each year. For example, it is considered that during November 1972, the group of fish with a mode of 10 mm were recent recruits, originating from the peak spawning during the 1972 Omo flood season. The group may be traced through subsequent samples to the broad peak of 21-22 mm in May 1973 and to the dominant mode of 27 mm in October 1973.

Similar recruitment during the late flood season is evident in October 1974 and November 1975, when the polymodal pattern of length frequency distribution closely resembled that observed in November 1972.

Apart from the Omo flood season brood, originating chiefly in August-September, the length frequencies show that a second annual brood class was formed as a result of the earlier spawning peak in March-April. These early spawners are represented in the histograms by the mode at 14 mm in August 1972 (Fig. 9.32) and may be traced through subsequent months to the peak formed by mature fish in March 1973 at a length of 30 mm. The results suggest that, as in the case of the 'late spawners', heavy mortality occurred in the 'early spawners' during the post-breeding season, and although the 1972 brood class was represented by significant numbers of fish of 30 mm and above in May and June 1973, the largest length classes were absent from samples in subsequent months. Results from 1973, 1974 and 1975 show similar recruitment of a discrete group from the early spawning stock, with a prominent mode present at a length of between 12 and 14 mm during the period May-August.

It is concluded from the foregoing observations that A. minutus is an annual species which grows to maturity, spawns and dies within a single year. During the course of a normal life span the species usually attains a size of ca 30 mm FL but rare individuals, both males and females, of up to 37 mm FL were recorded. The two main breeding populations probably tended to form separate stocks, and thus individuals spawned during the main Omo flood season were late spawners themselves.

No attempt has been made to estimate von Bertalanffy growth parameters for A. minutus, but monthly growth increments in mature fish appear to have been comparatively large, indicating that L_∞ was well above the maximum observed size, the evidence suggests that A. minutus is a neotonic species with an inherent growth pattern similar to that of larger species curtailed by early maturity and death.

LENGTH-WEIGHT RELATIONSHIP

Length-weight data were recorded for a total of 62 A. minutus ranging from 24 to 33 mm FL and the following relationship between length (l) in cm and wet weight (w) in grammes was obtained:

$$w = 0.029\ l^{2.49}$$

Dry weights were recorded for the same fish. The relationship between fork length in mm and dry weight in gm was found to be:

$$w = 7.007 \times 10^{-6}\ l^{2.76}$$

THE BIOLOGY OF *Engraulicypris stellae*

INTRODUCTION

This species occurred in inshore and offshore areas of the lake and the present observations are based on both metre townet samples from the open waters of the lake, and foot seine samples from the shore. Although records from all areas of the lake have been utilized, seasonal changes in population structure have been elucidated from two main sources:

(1) metre townet data united on a monthly basis for all samples from the Central Sector of the lake during the period July 1972-November 1975, and

(2) monthly foot seine data combined from shore samples carried out on Longech Spit between December 1972 and November 1973. Studies of feeding behaviour and diet in *E. stellae* are considered in Chapter 12 (see page 1513).

DISTRIBUTON

The distribution of *E. stellae* at onshore sites is illustrated by shore survey results (see Chapter 7, Fig. 7.6). The species occurred in marginal areas throughout the lake on substrates ranging from mud to shingle and stones. Relatively low numbers were recorded in the Northern Sector, particularly on the eastern shore, and comparable results from metre townet samples during the flood season indicate that this species tended to avoid low conductivity water, rich in suspended solids. *Engraulicypris stellae* occurred sparingly on rocky shores in the southern basin, and the highest concentrations in shore samples were recorded from the Longech area southwards on both west and east shores, as far as the Loiengalani area. The species was unaffected by exposure and was often the only small fish collected on high energy beaches. A high proportion of *E. stellae* occurring in shore samples were adult fish ranging from 20-30 mm FL and appreciable numbers of smaller fish occurred only irregularly in foot seine catches. Length frequencies shown in Figure 9.35 for samples taken at Longech are characteristic of onshore sites in all areas of the lake.

Offshore distribution of *E. stellae* is summarised by metre townet survey data (see Chapter 8, Fig. 8.54) which prove that it ranged widely throughout the lake. The distribution chart for August-October (Fig. 8.5b) shows the marked fall in population densities in the Northern Sector towards the Omo delta, which was alluded to previously In most pelagic species, densities declined sharply in the extreme south of the lake, but although low *E. stellae* catches were recorded during the period June-October (Fig. 8.54 a and b), relatively high concentrations were noted in the southern basin between November and May (Fig. 8.54c).

Estimates of biomass (Table 8.22) based on metre townet samples indicate that three quarters of the offshore E. stellae population were concentrated in the Central Sector of the lake and that in this sector most fish occurred at lake depths of less than 50 metres. In the Southern Sector, the biomass was higher in deeper water.

Length frequency histograms for the three main sectors of the lake derived from metre townet samples collected during an extensive cruise in July 1974 are presented in Figure 9.33. The results show that E. stellae populations in the Central and Southern Sectors shared a similar polymodal structure with peaks at 9-10 mm, 22 mm and 26-27 mm, and a low incidence of fish between 15 and 19 mm FL. In the Northern Sector, the peak at 10 mm is also evident (Fig. 9.33) but the frequencies of larger individuals declined steadily, and although a moderate proportion of 15-19 mm fish were recorded, only few of over 20 mm were present. It might appear from these differences that whereas population cycles conformed to a common pattern in more southerly areas of the lake, an independent pattern was followed in the Northern Sector. However, further analysis of samples from the Central Sector showed that the observed differences between the north and elsewhere were probably an effect of depth. Length frequency data for the Central Sector (Fig. 9.34) prove that the size structure of E. stellae populations changed considerably with depth. Post-larvae with a modal length of 10 mm formed a conspicuous peak at all depths. In shallower water, length frequency distributions were basically unimodal, but below the 40 m contour the distributions became bimodal, with a second peak of adult fish at a length of 26-27 mm (Fig. 9.34). The size structure of the combined sample from the Northern Sector (Fig. 9.33), where depths only rarely exceeded 30 m, is obviously similar to that of depths of less than 30 m in the Central Sector (Fig. 9.34). Samples from the two remaining areas collected from depths as great as 90 m reflect the tendency of larger fish to concentrate in deeper water, as shown in Figure 8.76.

Further information on the distribution of E. stellae in the Central Sector of the lake is provided by monthly length frequency histograms (Fig. 9.35) in which both openwater and onshore samples are represented. The openwater data show that a pronounced mode at lengths ranging from 9 to 12 mm persisted, with but little seasonal change throughout the sampling period. In a similar way, onshore samples were always dominated by a group of mature fish with a modal length lying between 24 and 26 mm (Fig. 9.35). The same group of mature fish was often represented in offshore samples.

Unlike other species of fish investigated during the present studies, the size cohorts showed no tendency for seasonal changes in modal length which would indicate growth. It is considered that the observed pattern of distribution results from a regular sequence of migrations occurring during the life cycle of this species. As shown below, a high proportion of maturing fish were present throughout the year and spawning activity, although varying in intensity, was probably continuous. Post-larvae which formed the peak at 9-10 mm on the length frequency histograms for the openwater metre townet samples were thus constantly replenished. The small fish spread throughout the open waters of the lake but with increasing size they tended to move closer inshore. Individuals of 15-19 mm thus appear to have lived mainly in coastal waters within the 30 metre contour. The inshore movement continued with increasing size and E. stellae of 20 mm and over concentrated in the shallows of the lake where they were the predominant size group in the foot seine catches. The final phase in the migratory cycle appears to have been a movement from marginal areas to the deep offshore waters of the lake where, during certain months of the year, fish of over 20 mm FL formed a relatively high proportion of the catch. Evidence for such a migration is provided by data for the period December 1972-February 1973 when a progressive build-up of mature fish in offshore catches was accompanied by a marked fall in fish of over 23 mm FL in inshore catches (Fig. 9.35). It seems likely that the breeding grounds were situated in offshore areas of the lake and that the migration of mature fish into deep water was a spawning movement.

The vertical zonation of E. stellae is discussed in Chapter 8 and illusted by Figure 8.45. Post-larvae were confined to the surface waters of the lake during the hours of daylight. Slightly larger fish of up to 20 mm FL penetrated into deeper water but were notably absent from the midwater scattering layer where they were dispersed throughout the water column extending into the deepest parts of the lake. The preference of offshore adults for deep water explains the dearth of large fish in oblique metre townet samples from depth zones shallower than 40 m, shown in Figure 9.34.

Diel vertical migration in offshore E. stellae is discussed in Chapter 8 (see page and Figs. 8.47 and 8.48). With the onset of darkness, adults tended to move upwards through the water column to reach the surface layers, but post-larvae dispersed downwards to a depth of 10-20 metres.

BREEDING

Observations on breeding in E. stellae are based on monthly samples from shore stations in the Longech area. Males and females started to mature at a size of 21 mm FL and a high proportion of females of 25 mm and above were in an advanced state of maturity (Stage 4). Seasonal changes in gonadial development are demonstrated in Table 9.67. Only two ripe (Stage 5) females were observed out of a total of 300 examined. However, the proportion of Stage 4 fish was high in nearly all months, indicating that the population was usually approaching a state of readiness for spawning. High percentages of maturing fish in July, August and September 1973, followed by a dearth of Stage 4 fish in October, suggests that, as in many other species of fish, spawning activity may have risen to a maximum during the main Omo flood season in August-September. This suggestion is supported by seasonal metre townet data from Station H1 (Fig. 9.36) which show that the numbers of early stages of E. stellae rose to a seasonal maximum in October 1973, and thus indicate that spawning had recently occurred. Similar maxima were observed in October 1972 and in May 1974.

The scarcity of ripe (Stage 5) fish in the inshore samples (Table 9.67) is in agreement with the hypothesis that adult E. stellae migrated into deep water for the purpose of spawning. Unfortunately, gonadial data are only available for the inshore fish. No information is available on either the site of spawning or the fertilised eggs of E. stellae. GRAHAM (1929) reported that Engraulicypris argenteus which occurs in Lake Victoria produced pelagic eggs with a large perivitelline space.

GROWTH

Although regular monthly length frequency data are available for *E. stellae* it has not proved possible to obtain estimates of growth using Petersen's method. Changes in habitat preference combined with the prolonged spawning season have resulted in a situation where, due to the passage of successive waves of the same growth stage through a sampling area, the mean size shows no tendency to increase with time.

LENGTH-WEIGHT RELATIONSHIP

Length-weight data were recorded for a total of 78 *E. stellae* ranging from 15 to 29 mm FL, and the following relationship between length (l) in cm and weight (w) in gm was obtained:

$$w = 0.010\ l^{2.74}$$

Dry weights were recorded for the same fish. The relationship between fork length (in mm) and weight (w in gm) was found to be:

$$w = 2.195 \times 10^{-7}\ l^{3.609}$$

SUMMARY

Details of the biology of three small pelagic fish, *Alestes ferox*, *A. minutus* and *Engraulicypris stellae* are provided.

Alestes ferox and *A. minutus* are confined to the offshore waters of the lake and are the principal components of the midwater scattering layer. They concentrate at a depth where subsurface illumination is optimal and migrate towards the surface at the onset of darkness. Population densities of both species tend to be highest near the west coast of the Central and Northern Sectors of the lake and lowest in the southern basin.

The breeding season of *A. ferox* is prolonged but peak activity was noted during the Omo flood season. Sexual maturity is reached in females at a length of ca 86 mm FL when the fish are ca 18-20 months old. Mature males are somewhat smaller. Mortality is high during the post-spawning period and only exceptional individuals survive.

Alestes minutus also has a prolonged breeding season with a major peak of activity during the Omo flood season preceded by an earlier peak during the first rains in March. Sexual maturity is attained at a size of 25-30 mm FL when the fish are 10-12 months old. Mortality is high following spawning and only a few fish survive into their second year. The spawning grounds are evidently situated within the lake.

Engraulicypris stellae probably spawns in the offshore waters of the lake. The post-larvae are pelagic and are widely distributed throughout the open lake in the surface layers. With increasing size, the young fish move inshore and individuals of ca 15-30 mm occur abundantly in the shallows, where they achieve sexual maturity. Larger size groups of ca 20 mm and above move offshore periodically, probably in order to spawn. They occupy the deeper regions of the lake below

the midwater scattering layer. The spawning season of E. stellae is prolonged but the data suggest peak activity during the Omo flood season. No information on age or growth rate was obtained for this species.

REFERENCES

GRAHAM, M (1929). The Victoria Nyanza and its fisheries - a report on the fishing survey of Lake Victoria 1927-1929. London, Crown Agents for the Colonies. 255 pp.

WORTHINGTON, E B and RICARDO, C K (1936). Scientific results of the Cambridge expedition to the East African lakes 1930-1. No. 15. The fish of Lake Rudolf and Lake Baringo. J. Lin.. Soc. (Zool). 39: 353-389

THE BIOLOGY OF Distichodus niloticus (L) IN LAKE TURKANA

P B Bayley

INTRODUCTION

Distichodus niloticus is a large charcoid fish inhabiting riverine flood plains over much of the soudanian region of Africa. In Lake Turkana it was second in overall importance to *Citharinus* during the period 1966-1970 when 8 inch gillnets were used almost exclusively in the inshore fisheries. Locally it was the most important species in commercial catches on the west coast between Namudak and Lowarengak (R R McCONNEL and Father RYAN, pers. comm.).

All stomach contents examined revealed that ostracods formed the main part of its diet, and five species were identified from the stomach of one specimen (J GREEN, pers. comm.). It was caught in most areas of the lake by bottom set gillnets or bottom trawl down to about 20 m depth. Bottom trawl results suggest that larger quantities exist in the extreme northeast of the lake.

Yield has declined markedly since about 1970, and fell from 480 tonnes in 1972 (17% of total yield) to 108 tonnes in 1974 (3% of total yield). The further decline to 65 tonnes in 1975 is at least partly attributable to a reduction in effort.

Scales and opercular bones provided no key to age determination, growth checks were indefinite and often incomplete on the scales examined, and the dried opercula could not be cleared evenly. The commercial length-frequency distributions, after correcting for respective mesh size selectivities, did not reveal consistant patterns of modes for age determination either.

Although experimental fishing provided biological data on relatively few fish, certain characteristics of the population have been elucidated, and are described below.

MATURITY, JUVENILES AND REPRODUCTION

MATURITY

Only 76 specimens were sexed and graded, and the results along with immature fish are shown in Table 2.68. It appears that females grow larger than males, and specimens between 80 cm and 110 cm TL recorded from the Co-operatives were probably all females. Table 2.68 suggests that females first mature at about 66 cm, and males at about 60 cm.

Adult D. niloticus were caught sporadically throughout the year in gillnets or bottom trawl between Todenyang and Kerio, but stage IV fish were restricted to the former region. Maturing fish in stage III or IV were only recorded between May and October.

JUVENILES

Despite the extensive and frequent sampling in all parts of the lake very few juvenile and no post-larval D. niloticus were encountered. The bottom trawl caught a few specimens between 19 cm and 40 cm in the vicinity of the Omo Delta and near Ilaret. Juveniles or sub-adults between about 30 cm and 60 cm were widespread but infrequent down to a depth of 20 m.

Early juveniles were even more scarce. A foot seine sample from north of Todenyang in October 1970 contained six specimens of 4 cm to 7 cm TL. Subsequent monthly samples from March 1972 to February 1974 produced one 4 cm specimen in September 1972 and one of 6 cm in November 1972, both north of Todenyang. No specimens were caught at other times or in other areas, including samples made during an extensive shore survey using the foot seine and beach seine (Chapter 7). The results suggest that either large numbers of post-larvae and juveniles were confined to the River Omo and its delta, or that a failure in recruitment to the youngest stages and in spawning success had occurred during the 1970's.

REPRODUCTION

No spawning was observed, but verbal evidence from a Merille chief suggests that D. niloticus regularly enters the Omo to spawn between July and August. This agrees with data on seasonal maturity and young fish distribution presented above. No evidence of concentration near the mouths of the Rivers Kerio or Turkwell was found and the species was not recorded from within these rivers. Seasonal concentrations of adults are further discussed in the following section.

ADULTS AND SUB-ADULTS: POPULATION STRUCTURE, DISTRIBUTION, SPAWNING BIOMASS AND RECRUITMENT

POPULATION STRUCTURE AND DISTRIBUTION

Detailed analysis of population structure was not undertaken becaue of the lack of growth estimates. However, an indirect measure of the effects exploitation may have on the population is provided by the percentages of immature fish caught.

By reference to the estimates of sizes at first maturity, the length distributions from Co-operative Branches were used to compute the percentages of immature fish by number. Between the postulated first maturity lengths of 60 cm and 66 cm it was presumed that numbers of males and females were equal, as indeed is suggested by the data in Table 9.68. The results are summarised in Table 9.69. The proportion of immature fish may be slightly underestimated, due to the lack of data, but this does not affect the trends discussed below. The sample sizes are those given under the respective Co-operative Branches and months in Appendix 6.III. Some of the distributions were not available at the time of the analysis and others contained too few samples for a direct percentage calculation. The following relationship was derived from the available data from samples containing more than 15 individuals.

$$\% \text{ immature } \underline{\textit{Distichodus}} \text{ (by no.)} = \sin^2 [95.83 - 43.70 \text{ Ln (mean wt in kg]}$$

where number of samples = 101
correlation coeff. = .932***
s. dev. about regression = 5.84

This relationship was used to estimate percentages for months in which mean weights had been estimated (see Table 9.69) and for interpolated mean weights.

Large quantities of immature Distichodus were noted, especially in Kataboi and Nachukui between February and August. This seasonal trend was also evident to a lesser extent in other areas.

These data were combined with percentage estimates from interpolated mean weights to provide estimates of annual percentages, after adjusting according to the monthly catch. Extrapolations for the latter part of 1975 took into account seasonal trends. The results for 1973 and 1975 are shown in Table 9.70. Considering the marked reduction in the mesh size of gillnets during this time (Fig. 6.4) and the usual decline in the proportion of larger adults during a developing fishery, the overall percentage did not greatly increase. Immature Distichodus are more vulnerable than adults to gillnets with stretched mesh sizes of less than 5 inches. Catch per effort expressed as kg per year per equivalent full-time fisherman using nets of less than 5.5 inches stretched mesh fell from 160 kg in 1973 to 49 kg in 1975. This is faster than the reduction for adults discussed in the following section, and explains the low increase in percentage by number of immature specimens.

When the monthly percentages are combined with the commercial catch per effort data from Figure 6.5b in such a way as to indicate catch per effort of adults, pronounced seasonal abundance of the latter are evident. Between Kerio and Nachukui adults were relatively abundant from September to February. However, in Todenyang and Lowarengak, peak abundances were somewhat irregular, but occurred during the period February to June.

A comparison of the size ranges caught and the minimum size vulnerable to the commercial nets allows one to assess some of the above results in a better perspective. Table 9.71 shows the length ranges caught during the period December 1972 to February 1974 from Co-operative Branch samples. These are fully representative samples since the species did not feature in extra-co-operative trade or subsistence. The ranges are compared with the approximate minimum vulnerable lengths estimated from the selectivity data and the current commercial mesh sizes (see Table 6.29) by subtracting the standard deviation from the mean selection length corresponding to the smallest mesh size in the region. The results indicate that between Kataboi and Todenyang all vulnerable sizes of D. niloticus have been exploited, whereas the smaller sub-adults did not penetrate the fishing zones serving Kalokol or Kerio, including parts of the eastern shore. As suggested by the data in Table 9.70, smaller fish were caught in the area serving Kalokol in 1975 (during which time fishing on the eastern shore was considerably reduced). The length range caught extended down to 35 cm TL, at a time when the minimum vulnerable size was reduced to about 21 cm. Three years earlier in 1972, immature D. niloticus had been relatively more abundant in the trawl catches off Kalokol, and specimens down to 32 cm were caught.

From the data available, the movements of adult and sub-adult D. niloticus may be traced. The overall picture is one of sparsely distributed shoals of adults concentrating seasonally at the north end of the lake at a time corresponding to the estimated period of reproduction and just prior to the maximum flooding of the River Omo. Sub-adults appear to concentrate further down the western shore, in particular from Nachukui to Kataboi during February to August.

SPAWNING BIOMASS AND RECRUITMENT

Spawning biomass and population fecundity are considered to be proportional to the catch per effort of mature females. Data for D. niloticus have been analysed using the method described for Labeo horie (see above) but employing a more approximate index of catch per effort by weight for all adults, with effort expressed in terms of equivalent full-time fishermen using nets of more than 5.5 inches stretched mesh. The annual catch per effort of adults in 1973, 1974 and 1975 was 248 kg, 111 kg and 127 kg respectively. Although the 1975 value may be overestimated, due to the assumption of a 40% reduction in effort, the rate of decline in catch per effort appears to have slowed down. However, as with Citharinus citharus the spawning biomass must be considerably smaller than that existing before 1970.

It is noteworthy that while catch per effort of sub-adults fell by over two thirds during the period under review, the adult value fell by only a half. At the same time the mean weight of sub-adults showed a 7% decrease compared with 31% for the adults. This suggests that a gradual reduction in recruitment has been taking place in D. niloticus as opposed to the more precipitous decline noted in C. citharus. The virtual absence of very young D. niloticus in the lake since 1972 supports this contention.

CONCLUSIONS

Distichodus niloticus is one of the largest species of fish in Lake Turkana and is restricted to depths less than about 20 m. It appears to be very vulnerable to gillnets, over a large size range for a given mesh size. These characteristics, together with the anadromous breeding habits, are similar to C. citharus. Although D. niloticus was originally second in overall importance to C. citharus in the gillnet fishery, catches have declined at a much lower rate. Large quantities of immature fish featured in the D. niloticus catches as opposed to negligible quantities in the case of C. citharus. There is however, evidence to show that recruitment may be declining in the D. niloticus population, although more gradually than in C. citharus.

Unless unforseen hydrological changes have a positive effect, D. niloticus yields will continue to decline until the species becomes "commercially extinct". This is the inevitable result of a multi-species fishery, since any mesh size control designed to protect this large species would prejudice optimal exploitation of more abundant but smaller species of higher total value such as Labeo horie and Barbus bynni.

TABLE 9.1

Showing the seasonal occurrence of early juvenile *Hydrocynus forskalii* in foot-seine samples from shore stations at Lodge Bay and Met Bay, Longech. Monthly data have been combined from the period June 1972 to October 1974

Month	No. of samples	Samples with *H.forskalii*	No. *H.forskalii* per sample	Size range cm FL
Jan.	4	1	6.0	2.6-6.3
Feb.	3	-	-	-
March	5	3	18.8	2.1-6.1
April	4	-	-	-
May	10	3	1.1	1.7-5.1
June	16	1	0.3	2.2-4.2
July	13	-	-	-
Aug.	6	1	0.6	3.6-3.7
Sep.	3	1	15.7	3.1-6.0
Oct.	4	2	9.3	2.1-4.1
Nov.	4	2	34.8	1.8-7.0
Dec.	5	4	21.0	2.4-7.0

TABLE 9.2

Changes in the maturity of male *Hydrocynus forskalii* with size. Showing the percentage of fish at various stages of maturity in each length group. All trawl data for the period August 1972-February 1974 have been combined

Length group FL in cm	Stage 2	Stage 3	Stage 4	Stage 5	Number of fish
16	100	-	-	-	21
18	100	-	-	-	52
20	100	-	-	-	80
22	100	-	-	-	126
24	100	-	-	-	113
26	98	1	1	-	96
28	92	7	2	-	67
30	77	17	6	-	65
32	57	31	6	2	79
34	32	35	30	4	119
36	38	28	27	7	73
38	33	31	30	6	30
40	55	21	24	-	10
42	56	18	25	-	6
44	33	33	33	-	3
46	-	100	-	-	1
48	100	-	-	-	1
50	33	-	33	33	3
52	50	-	50	-	2

TABLE 9.3

Changes in the maturity of female *Hydrocynus forskalii* with size. Showing the percentage of fish at various stages of maturity in each length group. All trawl data for the period August 1972-February 1974 have been combined

Length group FL in cm	Stage 2	Stage 3	Stage 4	Stage 5	Number of fish
16	100	-	-	-	32
18	100	-	-	-	45
20	100	-	-	-	95
22	100	-	-	-	115
24	100	-	-	-	135
26	100	-	-	-	118
28	98	1	1	-	100
30	92	3	4	-	71
32	66	8	25	2	80
34	52	10	37	1	122
36	57	8	33	2	109
38	71	8	21	-	53
40	80	10	7	3	28
42	89	11	-	-	19
44	96	4	-	-	8
46	96	-	4	-	9
48	93	-	7	-	9
50	91	8	-	-	14
52	56	36	8	-	13
54	50	34	17	-	16
56	63	25	8	5	21
58	55	31	13	-	18
60	50	40	10	-	10

TABLE 9.4

Changes in the sex ratio of *Hydrocynus forskalii* with size, combining all trawl data for the period August 1972-February 1974. Sex ratio is expressed as the number of females per 100 males

Fork length class (cm)	Total number	Sex ratio	Fork length class (cm)	Total number	Sex ratio
16	53	152	36	182	149*
18	97	87	38	83	177*
20	175	119	40	38	280*
22	241	91	42	25	317*
24	248	119	44	11	267
26	214	123	46	10	900*
28	167	149*	48	10	900*
30	136	109	50	17	467*
32	159	101	52	15	650*
34	241	103	54-60	65	∞ *

*indicates that sex ratio significantly different to 1:1

(chi-square $>$ 3.84 for P $<$ 0.05)

TABLE 9.5

Showing seasonal changes in the maturity of female *Hydrocynus forskalii* of 32 cm FL and over. The number of each maturity stage is expressed as a percentage of the total number for each month. All data for the period August 1972-March 1973 have been combined

Month	Stage 2 Virgin/ resting	Stage 3 Maturing	Stage 4 Ripe	Stage 5 Running	Total number
Jan.	77	-	23	-	35
Feb.	75	9	13	2	53
March	66	17	11	6	35
April	100	-	-	-	36
May	88	3	9	-	33
June	94	6	2	-	102
July	87	9	4	-	90
Aug.	62	26	12	-	84
Sep.	56	24	19	1	164
Oct.	26	31	40	2	137
Nov.	53	29	18	-	283
Dec.	70	9	19	2	43

TABLE 9.6

Food of juvenile *Hydrocynus forskalii* from foot seine hauls in Lodge Bay, Longech, analysed on the basis of size. Data are presented separated for two samples collected in December 1972 and November 1973. The number of points scored for each food item in each length group has been expressed as a percentage of the total points for each group.

	16th Nov. 1973					7th-9th Dec. 1972			
Length group (F.L. in cm)	1-2	2-3	3-4	4-5	5-7	2-3	3-4	4-5	5-6
Number of stomachs	9	12	12	6	4	25	25	11	3
Food items									
Crustacea :-									
Thermocyclops hyalinus	1	-	-	-	-	-	-	-	-
Mesocyclops leuckarti	51	44	7	15	13	3	2	+	-
Tropodiaptomus banforanus	8	6	9	2	3	2	4	+	-
Diaphanosoma excisum	-	-	-	-	-	9	8	1	-
Moina brachiata	-	-	-	-	-	12	6	+	-
Hyalodaphnia barbata	-	-	-	-	-	1	-	-	-
Leydigia sp	-	-	-	-	-	-	+	-	-
Ostracods	7	12	+	-	6	3	4	+	-
Insects :-									
Corixids	10	19	27	35	33	60	69	68	46
Chironomid larvae	24	12	16	18	5	5	1	5	+
Chironomid pupae	-	6	41	29	44	3	6	24	-
Hydracarina	-	+	-	1	+	1	-	-	-
Fish :-									
Lates spp.	-	-	-	-	-	-	-	-	34
Unidentified fish	-	-	-	-	-	-	-	-	19
All fish	-	-	-	-	-	-	-	-	53
% fullness	79	90	93	81	94	75	68	77	88

TABLE 9.7

Analysis of the food of two length groups of *Hydrocynus forskalii* from a bottom trawl station in the Kakoi area 2 km offshore, at a depth of 5-8 m. The number of points scored by each food category has been expressed as a percentage of the total points recorded for the length group

Length group (FL in cm)	4 - 10	10 - 15
Number of stomachs	32	12
Number empty	2	2
Crustacea:		
Hyalodaphnia barbata	3	-
Unidentified prawns	2	-
Macrobrachium niloticum	17	-
Insects:		
Ephemeropteran nymphs	10	-
Corixids	68	1
Chironomid larvae	+	-
Fish:		
Hydrocynus forskalii	-	12
Engraulicypris stellae	-	13
Lates spp.	-	23
Unidentified fish	-	50
All fish	-	98
% Fullness	79	57

TABLE 9.8

Hydrocynus forskalii : analysis of the food of inshore fish caught by beach seine in Met Bay, Longech in routine samples during the period November 1972 - November 1973. The number of points scored by each food item in a length class has been expressed as a percentage of the total points recorded for the length class.

Length class (cm F.L.)	8	8-16	16-25	25-33	33-42	54
Number of fish	1	23	160	150	19	1
% Empty stomachs	-	26	17	9	26	-
Food items						
Corixidae	100	14	-	-	-	-
Alestes nurse	-	5	13	6	20	-
Micralestes acutidens	-	43	46	41	31	-
Labeo horie	-	-	-	1	-	-
Engraulicypris stellae	-	19	18	32	44	-
Sarotherodon spp.	-	-	3	-	-	100
Unidentified fish remains	-	19	20	19	4	-
All fish	-	86	100	100	100	100
% fullness	13	23	31	33	30	50

TABLE 9.9

Food of *Hydrocynus forskalii* : showing seasonal changes in the species composition of the food of inshore fish ranging from 8-54cm F.L. caught in a beach seine at Met Bay, Longech, during the period November 1972 - November 1973. The number of monthly points scored by each prey species has been expressed as a percentage of the total points scored by identifiable fish.

Prey species	1972 Nov	Dec	1973 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Alestes nurse	81	-	-		19	8	15	29		20	1		-
Micralestes acutidens	-	-	-		65	92	85	61		40	88		-
Labeo horie	-	-	-		-	-	-	-		-	3		-
Engraulicypris stellae	19	100	100		16	-	-	10		40	-		90
Sarotherodon spp.	-	-	-		-	-	-	-		-	8		10
Total points scored by identifiable fish	62	86	206	NS	200	176	66	164	NS	70	321	NS	81

NS = No sample

TABLE 9.10

Diel study of the food of inshore Hydrocynus forskalii of 7-19cm F.L. caught during a 24hr cycle in Met Bay, Ferguson's Gulf, on 16-17/10/75. The number of points awarded to each food item has been expressed as a percentage of the total possible score and the same number, expressed as a percentage of the total actual score, is shown in brackets.

Time (hrs E.A.T.)	14.00	18.00	22.00	02.00	06.00	10.00	14.00
Number of stomachs	10	10	7		5	10	10
Size range (cm F.L.)	8-14	9-18	8-15		7-13	8-19	8-19
Food items							
Crustacea :-							
Ostracoda	0.4 (1)	0.2 (+)	0.1 (1)	none caught	-	-	0.3 (1)
Macrobrachium niloticum	-	-	-		1.0 (19)	-	-
Insects :-							
Ephemeropteran nymphs	0.4 (1)	-	-		1.0 (19)	-	-
Corixids	34.6 (56)	42.7 (77)	2.1 (45)		1.7 (33)	21.3 (50)	35.9 (78)
Chironomid larvae	1.1 (2)	-	-		-	-	0.7 (3)
Chironomid pupae	22.3 (36)	1.2 (2)	1.1 (23)		0.5 (10)	0.9 (2)	2.1 (5)
Hydracarina	+ (+)	-	-		-	+ (+)	0.1 (+)
Fish :-							
Alestes nurse	-	-	-		-	2.5 (6)	-
Barilius niloticus	-	-	-		-	17.0 (40)	5.3 (12)
Engraulicypris stellae	-	9.6 (17)	1.4 (30)		-	-	-
Unidentified fish	2.7 (4)	1.8 (3)	-		1.0 (19)	0.9 (2)	1.7 (4)
All fish	2.7 (4)	11.4 (20)	1.4 (30)		1.0 (19)	20.4 (48)	7.0 (16)
% fullness	61.5	55.5	4.7		5.2	42.7	46.1

TABLE 9.11

Analysis of the food of *Hydrocynus forskalii* of 10-62cm F.L. from the open waters of Lake Turkana. The data, collected during the Boris midwater trawl survey between mid-September and mid-November 1975, have been grouped according to lake sector. The number of points scored by each food item in each sector is expressed as a percentage of the total points recorded for the sector. The percentage fullness is an estimate of the volume of food observed in the stomachs expressed as a proportion of the total possible.

	North Sector	North Central Sector	South Central Sector	South Sector	All sectors
Total stomachs	113	208	151	20	492
% empty	45	28	25	75	
Food items					
Prawns	1	1	1	29	1
Insects :-					
Orthopterans	-	+	-	-	+
Notonectids	-	-	+	-	+
Fish :-					
Hydrocynus forskalii	-	2	-	-	1
Alestes minutus	50	54	72	36	60
Alestes ferox	17	14	10	-	13
Engraulicypris stellae	-	8	5	-	6
Chrysichthys auratus	-	-	1	-	+
Schilbe uranoscopus	-	+	-	-	+
Lates spp.	-	2	3	-	2
Unidentified fish	32	18	8	36	16
All fish	99	99	99	72	99
% fullness	14	18	25	4	

TABLE 9.12

Diel study of the food of offshore *Hydrocynus forskalii* of 10-37cm F.L. during a 24 hour cycle at a station 3km east of Longech Spit, at a lake depth of 27m, on 24-25th October 1975. The number of points awarded to each food item has been expressed as a percentage of the total possible score and the same number, expressed as a percentage of the total actual score, is shown in brackets.

Time (hrs E.A.T.)	11.09	15.05	19.05	23.12	03.05	07.15	10.39
Number of stomachs	10	10	19	12	13	10	12
Size range (cm F.L.)	12-23	14-26	10-37	12-31	10-28	12-26	11-32
Food items							
Crustacea :-							
Unidentified prawns	-	-	0.1 (+)	-	-	-	-
Caridina nilotica	-	-	-	-	-	-	0.2 (3)
All prawns	-	-	0.1 (+)	-	-	-	0.2 (3)
Fish :-							
Alestes minutus	9.4 (82)	19.2 (63)	18.5 (79)	5.7 (99)	4.4 (88)	8.0 (92)	1.7 (25)
Alestes ferox	-	7.0 (23)	-	-	-	-	-
Engraulicypris stellae	-	2.3 (8)	-	-	0.3 (6)	-	0.7 (11)
Lates spp.	2.1 (18)	2.0 (7)	0.1 (+)	0.1 (1)	0.3 (6)	0.2 (2)	-
Unidentified fish	-	-	4.6 (20)	-	-	0.5 (6)	4.1 (61)
All fish	11.5 (100)	30.5 (100)	23.2 (99)	5.8 (100)	5.0 (100)	8.7 (100)	6.5 (97)
% fullness	11.5	30.5	23.3	5.8	5.0	8.7	6.7

TABLE 9.13

Alestes baremose: mesh selectivity in surface-set gillnets combining all data from the period April 1974-April 1975. Frequencies are expressed as a percentage of the total number for a particular size

Fork length (cm)	Stretched mesh size (inches)				
	2	2½	3*	3½	4
18	+	-	-	-	nil
19	0.3	-	-	-	
20	0.9	-	-	-	
21	6.9	-	-	-	
22	14.6	-	-	-	
23	16.7	+	-	-	
24	15.9	-	-	-	
25	11.5	0.3	-	-	
26	7.8	1.5	+	-	
27	5.3	4.3	-	-	
28	3.3	8.0	0.1	-	
29	2.8	9.6	0.4	-	
30	2.6	10.1	1.6	-	
31	2.2	10.1	3.1	0.5	
32	2.1	9.4	7.6	0.3	
33	2.3	7.7	10.1	0.9	
34	2.1	9.0	5.7	2.1	
35	0.9	9.8	16.8	5.6	
36	0.6	7.0	15.1	8.6	
37	0.3	5.3	9.1	16.4	
38	0.3	2.9	6.9	17.0	
39	+	2.0	5.2	17.1	
40	-	1.4	3.6	15.8	
41	-	0.8	2.6	8.1	
42	-	0.2	1.1	4.5	
43	-	+	0.5	1.8	
44	-	+	0.2	0.7	
Total number	1540	3035	1884	833	
Mean length	25.15	32.38	35.39	38.35	
Standard deviation	3.62	3.47	2.66	2.19	

*'3 inch' gillnets actually $2\frac{2}{3}$ inch stretched mesh

TABLE 9.14

Occurrence of *Alestes baremose* in 341 quantitative bottom trawl samples analysed on the basis of depth zone. Catch per effort is expressed in kg/hr

Depth zone	No. of hauls	% with *A. baremose*	Mean catch per effort for *A. baremose* (kg)
0- 5	16	56	11.6
5-10	38	29	0.3
10-15	36	17	0.1
15-20	45	9	+
20-30	82	0	0.2
30-40	36	11	0.1
40-50	20	5	0.2
50+	68	4	+

TABLE 9.15

Alestes baremose: mean catch per effort (kg/100 m headrope/night) in surface-set gillnets for each of the three main Sectors of the lake. All data for 2½, 3 and 3½ inch gillnets have been combined

Sector	Total number of net nights	Mean catch kg/100 m headrope
North	92	52.4
Central	176	17.3
South	60	11.1

TABLE 9.16

Observed seasonal formation of scale rings in *Alestes baremose*. Data from both sexes combined

Month	No. of fish examined	Percentage with annulus forming on edge of scale
January	28	6
February	98	73
March	77	28
April	70	2
May	45	0
June	40	0
July	64	38
August	80	93
September	235	58
October	64	6
November	50	0
December	30	0

TABLE 9.17

Showing the position of annuli on the scales of female *Alestes baremose* together with the estimated fork length at the time of their formation, obtained by back calculation with corrections derived from the scale length fork length regression. Comparison of results from different samples

Ring	Mean radius ring (mm)	Standard deviation	No. of observtions	Equivalent fork length (cm)
Sample 1		Ferguson's Gulf area.	March-June 1974	
1st February ring	0.83	0.11	100	8.30
1st August ring	1.70	0.17	100	14.30
2nd February ring	2.56	0.12	36	20.23
2nd August ring	3.38	0.33	100	25.89
3rd February ring	4.19	0.19	30	31.48
3rd August ring	4.82	0.24	43	35.82
4th February ring	5.31	0.12	10	39.20
4th August ring	5.76	0.13	10	42.30
Sample 2		Allia Bay and Koobi Fora.	September 1974	
1st February ring	0.80	0.18	28	8.10
1st August ring	1.67	0.28	32	14.10
2nd February ring	2.62	0.28	24	20.65
2nd August ring	3.40	0.31	28	26.03
3rd February ring	4.12	0.18	26	31.00
3rd August ring	4.79	0.18	32	35.61
4th February ring	5.30	0.20	18	39.13
4th August ring	5.75	0.17	11	42.23
Sample 3		Koobi Fora.	6 August 1975	
1st February ring	0.82	0.07	10	8.23
1st August ring	1.77	0.17	24	14.79
2nd February ring	2.52	0.23	13	19.96
2nd August ring	3.38	0.24	25	25.89
3rd February ring	4.12	0.29	9	30.99
3 August ring	4.82	0.18	24	35.82

4th February ring	5.33	0.13	14	39.34
4th August ring	5.76	0.11	7	42.30
5th February ring	6.20	-	1	45.34
5th August ring	6.40	-	1	46.72

Sample 4		Kakoi	7 August 1975	
1st February ring	0.94	0.16	34	9.10
1st August ring	1.75	0.26	46	14.50
2nd February ring	2.67	0.28	37	20.99
2nd August ring	3.41	0.34	47	26.10
3rd February ring	4.13	0.31	24	31.06
3rd August ring	4.78	0.29	25	35.55
4th February ring	5.24	0.28	9	38.72
4th August ring	5.46	0.30	7	40.23
5th February ring	-	-	-	-
5th August ring	6.39	-	1	46.65

TABLE 9.18

Position of annuli on scales of male Alestes baremose with the estimated fork length at the time of their formation, obtained by back calculation with corrections derived from the scale length fork length regression. Comparison of results from different samples

Ring	Mean radius ring (mm)	Standard deviation	No. of observations	Equivalent fork length (cm)
Sample 1	Ferguson's Gulf area.		March-June 1974	
1st February ring	0.84	0.11	74	8.37
1st August ring	1.71	0.17	61	14.37
2nd February ring	2.57	0.18	23	20.30
2nd August ring	3.42	0.24	20	26.17
3rd February ring	4.07	0.16	13	30.64
3rd August ring	4.55	0.16	20	33.96
4th February ring	5.01	0.19	12	37.13
4th August ring	5.18	0.22	12	38.30
Sample 2	Allia Bay and Koobi Fora.		September 1974	
1st February ring	0.81	0.10	18	8.17
1st August ring	1.71	0.22	23	14.37
2nd February ring	2.75	0.20	23	21.55
2nd August ring	3.49	0.18	24	26.65
3rd February ring	4.16	0.15	19	31.26
3rd August ring	4.63	0.15	15	34.51
4th February ring	4.95	0.13	4	36.72
4th August ring	5.20	0.18	4	38.44
Sample 3	Koobi Fora		6 August 1975	
1st February ring	0.84	0.10	7	8.37
1st August ring	1.71	0.18	30	14.37
2nd February ring	2.61	0.18	18	20.57
2nd August ring	3.42	0.19	31	26.16
3rd February ring	4.06	0.22	24	30.58
3rd August ring	4.57	0.19	24	34.10
4th February ring	5.05	0.07	2	37.41
4th August ring	5.25	0.07	2	38.79

Sample 4		Kakoi	7 August 1975	
1st February ring	1.00	0.16	38	9.48
1st August ring	1.82	0.23	49	15.13
2nd February ring	2.72	0.23	41	21.34
2nd August ring	3.37	0.31	51	25.82
3rd February ring	4.12	0.22	17	30.99
3rd August ring	4.59	0.17	16	34.23
4th February ring	4.94	0.16	5	36.65
4th August ring	5.21	0.15	4	38.51

TABLE 9.19

Mean lengths of different age groups of female Alestes baremose in gillnet samples from February 1974 to November 1975, aged according to the number of August rings on the scales. Age designation changes from September 1st. Mean length in heavy type, standard deviation in brackets and number of observations in italics. LS = Longech Spit area; CI = Central Island; NI = North Island; IL = Ilaret; K = Koobi Fora; Kat = Kataboi; Kak = Kakoi.

Year class		1973	1972	1971	1970	1969
Age group		0	1	2	3	4
Date	Locality					
28 Feb 74	LS	-	-	-	**37.3** (1.88)	**42.1** (0.96)
					134	*36*
10-24 Apr 74	LS + CI	-	**23.9** (1.73)	**34.2** (1.50)	**39.5** (2.00)	-
			364	*10*	*57*	
4 May 74	LS	-	**25.4** (1.96)	**34.6** (2.39)	**39.0** (2.23)	-
			215	*133*	*23*	
17 May 74	CI	-	**24.6** (1.73)	**34.8** (2.26)	**40.0** (1.33)	-
			31	*51*	*38*	
6-14 Jun 74	NI + IL + K	-	-	**33.7** (2.19)	**39.7** (1.63)	-
				168	*161*	
20-28 Jun 74	South	-	-	**36.1** (1.69)	**39.0** (1.11)	**42.8** (1.05)
				185	*110*	*12*
2-5 Jul 74	Allia	-	**27.5** (1.59)	**34.4** (1.71)	**38.9** (1.38)	-
			22	*35*	*23*	

contd./

TABLE 9.19 (contd.) Sheet 2

19-20 Jul 74	IL + K	-	26.7 (2.45) 47	35.2 (3.44) 298	40.8 (1.21) 103	44.0 1
23 Jul 74	South	-	29.3 (2.17) 105	36.6 (2.10) 136	41.5	-
1 Aug 74	LS	-	24.2*(2.24) 39	34.4 (3.72) 9	-	-
14-18 Aug 74	IL + K	-	29.6 (1.64) 28	36.8 (1.78) 39	40.5 (1.48) 96	44.2 (0.58) 3
Age group (new designation)		1	2	3	4	
2-16 Sep 74	Allia + K	-	-	38.3 (1.73) 38	41.0 (1.34) 52	
20 Sep 74	LS	-	23.4* (1.81) 52	36.7 (0.75) 6	-	
28 Sep 74	South	-	29.9 (1.65) 35	37.2 (1.56 27	41.1 (1.72) 7	
3 Oct 74	LS	-	27.7 (3.87) 33	36.4 (2.45) 14	-	
10 Oct 74	Allia	-	29.3 (2.45) 47	36.8 (1.55) 45	41.4 (0.78) 9	
18-20 Oct 74	Omo	-	-	-	40.9 (1.75) 77	

contd./

TABLE 9.19 (contd.) Sheet 3

24-30 Nov 74	South	-	28.2 (2.73) 63	36.0 (1.84) 44	40.0 (1.64) 5
3 Dec 74	LS	-	-	37.7 (2.18) 11	-
4 Feb 75	LS	23.1 (1.26) 53	32.2 (2.59) 22	39.9 (2.33) 20	-
15 Mar 95	LS	22.8 (0.91) 40	34.7 (1.60) 42	39.7 (1.24) 46	-
22 Mar 75	LS	21.4 (1.81)	-	-	-
24-27 Mar 75	Kat	-	31.2 (1.51) 63	38.1 (2.17) 187	-
5-8 Apr 75	Kat	-	32.6 (1.85) 109	39.4 (1.95) 135	-
22 Apr 75	LS	22.8 (1.20) 158	32.4 (2.73) 19	39.0 (1.73) 4	-
8 May 75	LS	-	32.9 (1.51) 11	-	-
6 Jun 75	LS	23.9 (2.48 85	34.4 (2.06) 33	40.2 (1.57) 10	-
9-13 Jun 75	IL + K	25.8 (3.19) 88	34.7 (2.57) 44	40.0 (1.51) 79	

contd./

TABLE 9.19 (contd.) Sheet 4

25-29 Jun 75	Allia	-	34.3 (1.80)	39.6 (1.20)	-
			91	55	
2 Jul 75	LS	25.9 (2.43)	36.2 (2.21)	39.4 (1.52)	-
		34	70	10	
8 Aug 75	Kak	27.8 (2.29)	35.5 (2.93)	40.9 (0.74)	-
		78	48	8	
10 Aug 75	K	-	36.4 (1.85)	40.6 (0.90)	-
			24	7	

Age group (new designation)		2	3	4
15 Nov 75	LS	26.3 (3.02)	37.7 (2.67)	41.3 (0.98)
		100	15	6

TABLE 9.20

Mean lengths of different age groups of male *Alestes baremose* in gillnet samples from February 1974 to November 1975, aged according to the number of August rings on the scales. Age designation changes from September 1st. Mean length in heavy type, standard deviation in brackets and number of observations in italics. LS = Longech Spit; CI = Central Island; Kat = Katoboi; Kak = Kakoi; IL = Ilaret; K = Koobi Fora; NI = North Island.

Year class		1973	1972	1971	1970	1969	1968
Age group		0	1	2	3	4	5
Date	Locality						
28 Feb 74	LS	-	-	-	**35.3** (1.55) *67*	**39.5** (0.82) *4*	-
10-24 Apr 74	LS + CI	-	**24.2** (1.43) *62*	**32.2** (1.95) *37*	**35.0** (0.84) *6*	-	-
4 May 74	LS	-	**25.7** (1.93) *83*	**33.2** (1.31) *25*	-	-	-
17 May 74	CI	-	**25.0** (1.87) *69*	**34.2** (1.90) *61*	**37.5** (1.00) *3*	-	-
6-14 Jun 74	NI + IL + K	-	-	**33.7** (1.94) *342*	**36.6** (1.23) *115*	-	-
20-28 Jun 74	South	-	-	**33.7** (2.10) *130*	**38.3** (1.30) *24*	-	-
2-5 Jul 74	Allia	-	**28.5** (1.38) *32*	**34.5** (1.30) *29*	**36.9** (1.08) *14*	-	-

contd./

TABLE 9.20 (contd.) Sheet 2

19-20 Jul 74	IL + K	-	27.2 (2.47) 94	33.8 (2.12) 456	37.2 (1.28) 133	41.0 2	-
23 Jul 73	South	-	28.2 (1.54) 62	34.2 (1.77) 106	38.1 (0.55) 5	-	43.0 1
27 Jul 74	LS	-	24.5 (2.04) 42	-	-	-	-
1 Aug 74	LS	-	24.0 (2.74) 51	-	-	-	-
14-18 Aug 74	IL + K	-	-	35.7 (2.12) 237	-	-	-
Age group (new designation)		1	2	3	4	5	
2-16 Sep 74	Allia	-	28.1 (2.01) 10	35.3 (1.54) 101	-	-	
20 Sep 74	LS	-	25.8 (3.15) 13	-	-	-	
27-28 Sep 74	South	-	29.2 (0.47) 26	34.1 (1.76) 69	-	-	
3 Oct 74	LS	-	28.7 (3.11) 84	35.5 (0.71) 5	-	-	
3-10 Oct 74	Allia	-	28.0 (2.88) 82	35.6 (1.04) 34	-	-	

contd./

TABLE 9.20 (contd.) Sheet 3

24-30 Nov 74	South	-	30.1 (1.69) 64	35.5 (1.45) 46	-	-
4 Feb 75	LS	22.9 (1.15) 51	31.6 (2.31) 28	37.8 (0.58) 3	-	-
13 Mar 75	LS	22.8 (1.08) 74	32.2 (0.95) 13	36.3 (1.09) 17	-	-
22 Mar 75	LS	21.1 (1.98) 69	-	-	-	-
24-27 Mar 75	Kat	-	31.9 (1.68) 108	36.3 (1.14) 105	-	-
5-8 Apr 75	Kat	-	32.3 (1.43) 58	36.4 (1.72) 45	41.0 1	43.0 1
22 Apr 75	LS	22.8 (1.25) 159	32.3 (1.98) 8	-	-	-
8 May 75	LS	23.9 (1.38) 36	31.8 (1.59) 21	-	-	-
6 Jun 75	LS	24.5 (2.34) 123	33.9 (1.73) 15	-	-	-
9-13 Jun 75	IL + K	28.3 (0.91) 47	34.2 (1.87) 273	36.8 (1.01) 83	-	-
25-29 Jun 75	Allia	-	33.3 (1.75) 70	37.6 (0.90) 12	-	-

contd./

TABLE 9.20 (contd.) Sheet 4

2 Jul 75	LS + CI	26.5 (2.19)	33.7 (1.83)	38.5 (1.73)	-	-
8 Aug 75	Kak	28.3 (2.12)	34.7 (1.78)	38.1 (0.55)	-	-
		84	83	5		
10 Aug 75	K	-	33.8 (1.65)	-	-	-
			47			

Age group (new designation)		2	3	4	5
15 Nov 75	LS	27.9 (2.22)	34.9 (1.28)	-	-
		42	14		

TABLE 9.21

Mean lengths of different age groups, mainly 0-group and 1-group fish, in foot seine and beach seine catches from January 1973 to October 1975. FG = Ferguson's Gulf; TD = Todenyang; IL = Ilaret; K = Koobi Fora.

Year class		1975	1974	1973	1972	1971
Age group				-0	0	1
Date	Locality					
13 Jan 73	FG	-	-	-	-	22.2 (1.42) 69
28 Feb 73	TD	-	-	-	7.0 (1.30) 80	-
20 Feb 73	FG	-	-	-	-	21.8 (1.03) 101
15 May 73	TD	-	-	-	11.0 (1.20) 40	-
29 May 73	FG	-	-	-	11.1 (0.74) 73	-
25 Jun 73	FG	-	-	-	10.1 (1.41) 126	-
18 Aug 73	FG	-	-	-	12.7 (1.82) 132	-

contd./

TABLE 9.21 (contd.) Sheet 2

14 Aug 73	FG	-	-	1.7 (0.60) 28	-	-
Age group (new designation)				0	1	2
25 Sep 73	FG	-	-	2.7 (0.70) 38	13.9 (2.20) 132	-
19 Nov 73	FG	-	-	-	14.6 (1.20) 20	-
15 Dec 73	FG	-	-	-	18.5 (1.60) 55	-
14 Mar 74	FG	-	-	10.0 (1.00) 41	22.9 (1.31) 47	-
6 Apr 74	FG	-	-	9.6 (1.91) 91	-	-
21 May 74	FG	-	-	8.8 (1.30) 64	-	-
		-	-	12.5 (1.32) 38	-	-
21 Jun 74	FG	-	-	10.8 (1.50) 60	-	-
28 Jun 74	FG	-	-	10.6 (1.00) 339	-	-

contd./

TABLE 9.21 (contd.) Sheet 3

31 Jul 74	FG	-	-	10.6 (1.21) 156	-	-
26 Aug 74	FG	-	-	11.8 (1.70) 32	-	-
28 Aug 74	FG	-	-	13.6 (1.40) 91	-	-
24 Sep 74	FG	-	-	14.2 (1.60) 314	-	-
28 Oct 74	FG	-	-	16.9 (1.90) 99	-	-
20-26 Oct 74	N of IL	-	4.5 (1.70) 160	-	-	-
20-26 Oct 74	S of IL	-	8.6 (1.90) 160	-	-	-
28 Nov 74	K	-	1.6 (0.40) 35	-	-	-
14 Jan 75	FG	-	7.1 (1.70) 32	-	-	-
4 Feb 75	FG	-	-	20.0 (1.74) 41	-	-
22 Mar 75	FG (♂♂)	-	-	21.1 (2.10) 76	-	-
22 Mar 75	FG (♀♀)	-	-	20.4 (1.60) 83	-	-

contd./

TABLE 9.21 (contd.) Sheet 4

5 Jun 75	FG	-	15.7 (2.70) 91	-	-	-
12 Jul 75	FG	-	16.6 (2.24) 40	-	-	-
27 Aug 75	TD	-	14.8 (1.50) 122	25.0 (3.43) 508	-	-
Age group (new designation)		**0**	**1**	**2**	**3**	**4**
5 Sep 75	FG	-	17.0 (1.15) 171	-	-	-
4 Oct 75	FG	-	14.9 (2.44) 55	-	-	-
10 Oct 75	TD	2.8 (1.20) 168	-	-	-	-
17 Oct 75	FG	-	14.7 (2.60) 140	-	-	-
28 Oct 75	FG	-	15.6 (2.20) 127	-	-	-

TABLE 9.22

Showing estimates of length for age (FL in cm) for male and female *A. baremose* obtained by various procedures

Age (years)	Computed from observed lengths (Tables 9.19, 9.20, 9.21)		Computed from back-calculated lengths (Tables 9.17 and 9.18)		Back-calculated values (overall means)	
	Males	Females	Males	Females	Males	Females
1	15.1	14.9	15.8	15.1	14.6	14.4
2	25.9	26.2	26.2	26.2	26.1	26.0
3	33.1	34.3	33.6	35.0	34.2	35.7
4	38.0	40.1	38.7	42.0	38.4	41.8
5	41.3	44.3	42.4	47.6	-	-
6	43.5	47.3	44.9	52.1	-	-

TABLE 9.23

Showing the relationship between length (l) in cm and weight (w) in gm where $w = al^b$ for various size groups and combinations of male, female and immature *Alestes baremose*. The values were obtained by the regression of log w on log l and the regression coefficient r^2 for the computations appears in the final column

Category with FL in cm	No. of fish	a	b	r^2
Immature fish 23 cm	199	0.0139	2.88	0.99
Females 20-30 cm	190	0.0080	3.08	0.96
Females 30 cm	277	0.0186	2.85	0.84
All females 20 cm	467	0.0066	3.14	0.98
All females plus immature fish	666	0.0086	3.05	0.99
Males 20-30 cm	181	0.0086	3.07	0.92
Males 30 cm	181	0.0061	3.17	0.87
All males 20 cm	362	0.0043	3.27	0.98
All males plus immature fish	561	0.0082	3.08	0.99
All fish combined	1227	0.0085	3.07	0.99

TABLE 9.24

Showing changes in mean condition factor with size in male and female *Alestes baremose*

FL (cm)	Males $\overline{K}$	Males No.	Females $\overline{K}$	Females No
20	1.04	15	1.05	15
22	1.02	48	1.01	66
24	1.03	37	1.02	35
26	1.04	22	1.05	29
28	1.05	33	1.07	23
30	1.11	31	1.10	14
32	1.13	60	1.09	29
34	1.15	55	1.12	46
36	1.15	21	1.13	54
38	1.03	5	1.16	42
40			1.10	42
42			1.02	15

TABLE 9.25

Showing seasonal changes in condition factor for different size groups in *Alestes baremose*. Mean monthly values of K are shown together with the sample size in brackets.

F.L. in cm	February	March	April	May	June	August	October	November
Males :-								
20-28	-	0.99 (13)	1.02 (34)	1.05 (33)	1.02 (41)	0.98 (8)	-	1.05 (15)
30-40	1.14 (40)	-	-	1.13 (13)	1.16 (8)	1.13 (80)	1.21 (9)	1.11 (19)
Females :-								
20-28	-	0.98 (19)	1.04 (50)	1.02 (24)	1.05 (25)	-	-	1.02 (19)
30-40	1.14 (89)	-	-	1.09 (5)	1.13 (26)	1.15 (31)	1.14 (10)	1.03 (24)
40 +	1.07 (28)	-	-	-	1.12 (4)	1.20 (11)	1.03 (4)	0.97 (10)

TABLE 9.26

Showing the size at onset of sexual maturity in female *Alestes baremose* from a random sample of fish caught in gillnets during the months June-October. The number at each gonadial stage is expressed as a percentage of the total number of fish recorded in each length group

Fork length (cm)	Stage 2	Stage 3	Stage 4	Stage 5	Total
26	100	-	-	-	18
27	100	-	-	-	22
28	100	-	-	-	40
29	100	-	-	-	41
30	100	-	-	-	40
31	97	3	-	-	36
32	88	9	2	-	43
33	83	11	4	2	47
34	71	22	6	2	51
35	71	12	8	8	59
36	53	25	12	10	59
37	40	26	16	18	62
38	32	17	27	23	77
39	27	20	30	23	93
40	5	17	41	37	81
41	5	9	42	43	74
42	9	9	50	32	34
43	-	11	67	22	9
44	-	-	-	100	2

TABLE 9.27

Showing the size at onset of sexual maturity in male *Alestes baremose* from a random sample of fish caught in gillnets during the months June–October. The number at each gonadial stage is expressed as a percentage of the total number of fish recorded in each length group

Fork length (cm)	Stage 2	Stage 3	Stage 4	Stage 5	Total
26	100	-	-	-	6
27	100	-	-	-	14
28	100	-	-	-	25
29	100	-	-	-	24
30	95	5	-	-	41
31	70	28	2	-	43
32	57	36	6	2	53
33	39	41	18	2	56
34	31	47	16	6	108
35	27	38	30	5	138
36	25	47	21	7	109
37	30	45	17	8	53
38	37	30	15	19	27
39	33	33	17	17	6
40	20	40	20	20	5

TAABLE 9.28

Seasonal changes in maturity of adult male Alestes baremose (32 cm FL and over) in the northern half of Lake Turkana, showing the number of males in each maturity stage expressed as a percentage of the monthly total

Month	Maturity stages					Monthly Total
	2	3	4	5	6	
Nov. 73	66	25	8	-	-	24
Dec. 73			no sample			
Jan. 74			no sample			
Feb. 74	76	19	5	-	-	42
Mar. 74	100	-	-	-	-	1
Apr. 74	100	-	-	-	-	68
May 74	29	62	9	-	-	126
Jun. 74	24	38	21	16	-	247
Jul. 74	39	45	13	2	-	230
Aug. 74	29	36	29	4	1	311
Sep. 74	26	31	32	10	-	116
Oct. 74	90	8	1	-	-	72
Nov. 74			no sample			
Dec. 74	50	50	-	-	-	4
Jan. 75			no sample			
Feb. 75	80	15	4	-	-	26
Mar. 75	99	1	-	-	-	121
Apr. 75	100	-	-	-	-	117
May 75	100	-	-	-	-	18
Jun. 75	25	47	28	+	-	216
Jul. 75	63	30	7	-	-	30
Aug. 75	27	47	25	1	-	185
Sep. 75	31	60	5	5	-	42
Oct. 75			no sample			
Nov. 75	14	50	9	-	27	22

TABLE 9.29

Seasonal changes in maturity of adult female Alestes baremose (34 cm FL and over) in the northern half of Lake Turkana, showing the number of females in each maturity stage expressed as a percentage of the monthly total

Month	Maturity stages						Monthly total
	2	3	4	5	6	7	
Feb. 73	100	-	-	-	-	-	13
Jul. 73	-	-	-	-	100	-	3
Oct. 73	100	-	-	-	-	-	8
Nov. 73	100	-	-	-	-	-	9
Jan. 74	No sample						
Feb. 74	97	1	-	-	-	-	106
Mar. 74	100	-	-	-	-	-	7
Apr. 74	100	-	-	-	-	-	87
May 74	84	12	3	1	-	-	152
Jun. 74	63	3	10	23	-	+	251
Jul. 74	77	5	12	5	-	1	153
Aug. 74	25	15	12	28	-	19	128
Sep. 74	37	2	31	26	-	4	105
Oct. 74	26	1	1	71	-	-	76
Nov. 74	50	33	16	-	-	-	6
Dec. 74	100	-	-	-	-	-	14
Jan. 75	No sample						
Feb. 75	96	4	-	-	-	-	31
Mar. 75	98	-	-	-	-	2	40
Apr. 75	100	-	-	-	-	-	106
May 75	100	-	-	-	-	-	8
Jun. 75	59	19	7	14	-	-	280
Jul. 75	93	6	1	-	-	-	68
Aug. 75	59	13	17	9	-	1	69
Sep. 75	50	10	40	10	-	-	10
Oct. 75	No sample						
Nov. 75	76	-	-	-	-	24	34

TABLE 9.30

Planktonic post-larvae and littoral juveniles, comparison of lengths at different depth zones

Depth zones	20-30m	10-20m	3-10m	Shore
Length (mm)				
2	-	-	-	-
4	-	-	-	-
6	29	11	8	-
8	21	37	30	-
10	4	20	40	-
12	2	1	9	3
14	1	-	4	17
16	-	-	15	28
18	-	-	30	18
20	-	-	19	15
22	-	-	13	3
24	-	-	11	7
26	-	-	10	2
28	-	-	5	1
30	-	-	1	5
32	-	-	-	10
34	-	-	1	8
36	-	-	-	9
38	-	-	-	11
40	-	-	-	-
42	-	-	-	3
44	-	-	-	4
46	-	-	-	3
48	-	-	-	2
50	-	-	-	2
52	-	-	-	-
54	-	-	-	-
56	-	-	-	1
58	-	-	-	-
60	-	-	-	-
Totals	57	59	196	152
Mean	8.36	9.33	16.40	26.11
SD	1.73	1.33	6.42	10.82

TABLE 9.31

Analyses of the food of *Alestes baremose* from various localities in the Central Sector of Lake Turkana. The number of points awarded to each food item has been expressed as a percentage of the total points for each sample. F.G. = Ferguson's Gulf; L.S. = Longech Spit; C.I. = Central Island; A.B. = Allia Bay; S.S. = shore seine; M.W.T. = midwater trawl; F.T. = frame trawl; G.N. = gillnet; B.T. = bottom trawl.

Column No	1	2	3	4	5	6	7	8	9	10
Locality	F.G.	F.G.	F.G	L.S.	L.S.	C.I.	C.I.	A.B.	A.B.	A.B.
Month/year	10/75	9/75	3/75	10/75	9/73	5/74	7/75	9/73	9/73	11/73
Gear	S.S.	S.S.	S.S.	M.W.T.	F.T.	G.N.	G.N.	B.T.	B.T.	B.T.
Fork length (cm)	10-19	16-19	17-24	14-23	11-16	20-43	31-40	18-28	30-38	15-20
Microcystis	1	-	+	29	12	-	-	+	1	2
Potamogeton	-	-	-	-	-	-	-	2	1	7
Grass seeds	+	-	-	-	-	-	-	-	-	-
Macrophyte fragments	+	-	-	-	-	-	-	-	-	-
Crustacea :-										
Mesocyclops leuckarti	2	58	49	-	-	1	-	*	*	*
All cyclopoids	2	58	49	-	+	1	-	69	17	47
Tropodiaptomus banforanus	+	17	1	55	14	70	17	+	1	1
Diaphanosoma excisum	+	-	+	-	-	+	-	-	-	-
Ceriodaphnia rigaudi	+	-	+	-	+	+	-	-	+	-
Moina dubia	-	-	+	-	-	-	-	-	-	+

contd./

TABLE 9.31 (contd.) Sheet 2

Hyalodaphnia barbata	+	+	2	-	-	+	-	23	77	17
All cladocerans	+	+	2	-	+	-	-	23	77	17
Ostracoda	4	4	39	-	-	-	-	+	-	14
Argulidae	-	-	+	-	-	-	-	-	-	-
Macrobrachium niloticum	-	-	-	-	-	+	-	-	-	-
Caridina nilotica	-	-	-	-	1	+	-	-	-	9
All prawns	-	-	1	-	3	+	-	-	-	9
Insects :-										
Orthoptera	-	-	-	-	-	3	3	-	+	-
Povilla	-	-	-	-	-	22	-	-	-	-
Corixidae	62	15	8	-	-	-	-	1	4	1
Naucoridae	-	+	-	-	-	-	-	-	-	-
Terrestrial Hemiptera-Heteroptera	-	-	-	-	-	1	-	-	-	-
Coleoptera	-	-	-	-	-	1	-	-	-	-
Chironomid larvae	3	3	1	-	-	-	-	+	-	2
Chironomid pupae + adults	27	5	1	-	-	-	56	1	-	-
Lepidoptera	-	-	-	-	-	3	9	-	-	-
Hymenoptera	-	-	-	-	-	2	3	-	-	-
Unidentified insects	-	-	+	-	-	+	6	-	-	-
All insects	92	23	10	-	-	32	77	2	4	3

contd./

TABLE 9.31 (contd.) Sheet 3

Hydracarina	+	+	+	-	-	-	-	+	-	-
Fish :-										
Engraulicypris stellae	-	-	-	3	63	-	-	1	-	-
Lates post-larvae	-	-	-	12	5	-	-	-	-	-
Unidentified fish	-	-	1	1	-	-	-	2	-	-
All fish	-	-	1	16	68	-	-	3	-	-
Amorphous remains	1	-	-	-	-	-	3	2	-	-
% fullness	43	56	90	62	3	27	8	92	100	93
Number of stomachs	61	8	19	12	7	35	21	14	8	9

TABLE 9.32 (a)

Diel study of the food of *Alestes baremose* of 100-190mm F.L. caught by shore seine in Ferguson's Gulf at Meteorological Station at four hourly intervals on 16th-17th October 1975. The number of points awarded to each food item has been expressed as a percentage of the total points for each sampling period. The percentage fullness is the total points expressed as a percentage of the maximum possible points for each sampling period.

Time (hrs E.A.T.)	14.00	18.00	22.00	02.00	06.00	10.00	14.00
Microcystis	-	+	1	-	10	2	+
Grass seeds	-	+	-	-	1	-	-
Macrophyte fragments	-	-	-	-	-	-	+
Crustacea :-							
Mesocyclops leuckarti	1	2	2	1	16	2	1
Tropodiaptomus banforanus	-	-	1	-	7	1	-
Diaphanosoma excisum	-	+	+	-	-	+	+
Ceriodaphnia rigaudi	-	-	+	-	4	+	+
Hyalodaphnia barbata	-	-	-	-	-	-	+
All cladocerans	-	-	+	-	4	+	+
Ostracoda	4	10	3	-	+	3	-
Insects :-							
Corixidae	47	70	3	-	22	76	76
Chironomid larvae	-	-	-	-	-	10	4
Chironomid pupae + adults	48	13	90	99	36	6	16
All insects	95	83	93	99	58	92	96
Hydracarina	-	-	-	-	1	+	+
Amorphous remains	-	4	+	-	+	+	-
% fullness	55	72	24	(50)	2	52	56
Number of stomachs	10	10	10	1	10	10	10

TABLE 9.32 (b)

Showing the number of *Citharinus citharus* of each gonadial stage recorded in each length group

Total length 1 cm groups	Immature (not sexed)	Females					Males			
		II	IIa	III	IV	V	II	III	IV	V
30	1	-	-	-	-	-	-	-	-	-
31	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-
33	2	-	-	-	-	-	1	-	-	-
34	2	1	-	-	-	-	-	-	-	-
35	-	1	-	-	-	-	3	-	-	-
36	-	-	-	-	-	-	2	-	-	-
37	-	-	-	-	-	-	-	-	-	-
38	-	-	-	-	-	-	-	-	-	-
39	-	-	-	-	-	-	1	-	-	-
40	-	-	-	-	-	-	-	-	-	-
41	-	1	-	-	-	-	1	-	-	-
42	-	-	-	-	-	-	1	-	-	-
43	-	1	-	-	-	-	2	-	-	-
44	-	1	-	-	-	-	-	-	-	-
45	-	1	-	-	-	-	1	-	-	-
46	-	1	-	-	-	-	-	-	-	-
47	-	-	-	-	-	-	-	-	-	-
48	-	-	-	-	-	-	1	-	1	-
49	-	-	-	-	-	-	1	-	-	-
50	-	4	-	-	-	-	-	1	-	1
51	-	3	-	-	-	-	3	-	-	-
52	-	1	-	-	-	-	9	1	-	1
53	-	2	-	-	-	-	6	2	-	-
54	-	3	-	1	-	-	5	1	-	1
55	-	4	-	-	-	-	12	6	7	-
56	-	3	3	-	-	-	12	8	8	1
57	-	4	-	1	-	-	6	6	10	6
58	-	2	3	1	2	-	5	6	5	7
59	-	3	2	1	-	-	1	-	6	-
60	-	2	3	1	2	-	1	-	3	2
61	-	2	1	-	1	-	1	-	-	-
62	-	-	1	-	1	-	-	-	-	1
63	-	3	2	1	1	-	-	-	-	-
64	-	-	-	-	2	-	-	-	1	-
65	-	-	-	1	1	-	-	-	-	-
66	-	1	1	-	-	-	-	-	-	-
67	-	-	-	-	-	2	-	-	-	-
		Total females examined: 79					Total males examined: 67			

TABLE 9.33

Distribution of gonad stages of mature *C. citharus* by area, month and year.

Year	Month	Areas	Females						Males				
			II+IIa	(IIa only)	III	IV	V	All	II	III	IV	V	All
1972	Aug	Kalokol	-	(-)	-	-	-	-	2	-	-	-	2
	Nov	Kalokol	1	(1)	-	-	-	1	-	-	-	-	-
1973	Jan	Kalokol+Allia Bay	5	(3)	-	-	-	5	26	-	-	-	26
	Feb	Kalokol+Allia Bay	15	(4)	-	-	-	15	23	-	-	-	23
	Mar	Todenyang	3	(3)	-	-	-	3	2	-	-	-	2
	Apr	Todenyang	3	(1)	-	-	-	3	5	1	1	-	7
	May	Todenyang	2	(-)	-	-	-	2	1	1	-	-	2
	Jun	Todenyang	-		1	1	-	2	2	-	1	-	3
	Jul	Todenyang	-		-	-	-	-	-	4	-	-	4
	Aug	Todenyang	-		-	-	-	-	-	-	2	-	2
	Sep	Todenyang	1	(-)	-	3	-	4	3	1	15	6	25
	Oct	Todenyang	5	(4)	1	1	-	7	1	12	16	6	35
	Nov	Todenyang	-		-	-	-	-	-	2	3	-	5
1974	Apr	Kalokol	4	(-)	-	-	-	4	2	1	-	-	3
	Jun	Kalokol	1	(-)	1	-	-	2	-	1	-	-	1
	Jun	Ilaret	-		-	1	-	1	-	-	-	-	-
	Jul	Allia Bay	2	(-)	1	-	-	3	1	1	-	-	2
	Jul	Ilaret	5	(-)	1	3	-	9	-	-	-	-	-
	Aug	Ilaret	-		-	-	2	2	2	3	5	7	17
	Sep	Koobi Fora	-		-	-	-	-	-	-	1	-	1
	Sep	Sandy Bay	1	(-)	-	-	-	1	-	1	-	-	1
	Oct	Ilaret+Omo delta	-		-	1	-	1	-	4	-	-	4
	Nov	Allia+Koobi Fora	1	(-)	-	-	-	1	1	1	-	-	2
1975	Aug	Sandy Bay	-		1	-	-	1	-	-	-	-	-

TABLE 9.34

Distribution of gonad stages of mature *C. citharus* by month (all areas and years combined)

Month	Females						Males				
	II+IIa	(IIa only)	III	IV	V	All	II	III	IV	V	All
January	5	(3)	-	-	-	5	26	-	-	-	26
February	15	(4)	-	-	-	15	23	-	-	-	23
March	3	(3)	-	-	-	3	2	-	-	-	2
April	7	(1)	-	-	-	7	7	2	1	-	10
May	2	(-)	-	-	-	2	1	1	-	-	2
June	-		2	2	-	4	2	-	-	-	2
July	7	(-)	2	3	-	12	-	4	-	-	4
August	-		1	-	2	3	4	3	7	7	21
September	2	(-)	-	3	-	5	3	2	16	6	27
October	5	(4)	1	2	-	8	1	16	16	6	39
November	2	(1)	-	-	-	2	1	3	3	-	7
December	-		-	-	-	-	-	-	-	-	-

TABLE 9.35

Summary of all *Citharinus citharus* catches in foot seine samples during the period October 1970 to November 1975

Area	Date	No.	TL range (cm)
Typha-fringed lagoon near Old Fort, Todenyang	29.10.70	45	2.3 to 6.9
Typha-fringed shore at Todenyang	29.10.70	2	5.5 to 5.8
J23 : near Todenyang	30.10.75	1	4.8
J24 : near Old Fort, Todenyang	30.10.75	1	9.4

TABLE 9.36

Citharinus citharus : mean values of size cohorts separated from polymodal distributions of back-calculated total lengths corresponding to growth checks on operculars.

Source of data	Date	Number of operculars	Units	Mode number (=postulated age in years)					
				1	2	3	4	5	6
Todenyang	Mar 73	119	cm	29.5	36.5	42.6	47.4	50.9	-
Lowarengak	Feb 73	163	cm	29.5	36.3	42.6	47.3	51.2	-
Kalokol	Mar 73	109	cm	29.5	36.0	42.6	47.2	51.0	-
Kerio	Mar 73	131	cm	29.4	36.2	41.2	45.5	50.8	-
All areas (calculator programme)	-	522	cm	29.3	36.4	42.5	47.2	50.9	53.8
Calculated from von Bertalanffy parameters	-	522	cm	29.0	36.3	42.2	46.9	50.7	53.7
Calculated mean weights from all areas	-	522	gm	312	623	1013	1407	1795	2133
Postulated annual weight increments	-	522	gm	311	390	394	388	338	

TABLE 9.37

Size ranges of commercial catches of *C. citharus* and minimum sizes susceptible to capture between December 1972 and February 1974

Co-operative Branch	Sample size	Size range (TL in cm)	Approx. min. size susceptible to capture (TL in cm)
Todenyang	2617	44-70	22
Lowarengak	1889	33-69	22
Nachukui	362	44-69	22
Kataboi	533	34-69	19
Kalokol	1595	42-68	19
Kerio	1481	40-69	15

TABLE 9.38

Estimates of the instantaneous total mortality coefficient Z, from monthly length distributions of *C. citharus*

Month, Year	Sample size	Modal length l' (TL in cm)	Z
Dec. 1972	736	55.5	0.57
Jan. 1973	507	55.5	0.50
Feb. 1973	894	54.5	0.35
Mar. 1973	828	54.5	0.54
Apr. 1973	547	54.5	0.50
May 1973	440	54.5	0.75
Jun. 1973	301	56.5	0.40
Jul. 1973	403	54.5	0.47
Aug. 1973	627	56.5	0.61
Sep. 1973	561	56.5	0.42
Oct. 1973	693	56.5	0.54
Nov. 1973	519	56.5	0.54
Dec. 1973	447	54.5	0.44
Jan. 1974	577	56.5	0.61
Feb. 1974	397	55.5	0.48

Mean Z = 0.51

Standard deviation = 0.10

TABLE 9.39

Estimated percentage age distributions of C. citharus (assuming birth date in August)

Year class	1971	1970	1969	1968	1967	1966	1965	1964 and before
(Age group)	(1+)	(2+)	(3+)	(4+)	(5+)	(6+)	(7+)	(8+ and over)
Dec. 1972	0.1	1.5	1.1	6.3	18.7	31.1	19.1	22.2
Jan. 1973	0.0	0.0	0.3	6.7	17.9	34.1	15.2	25.9
Feb. 1973	2.2	7.3	8.0	9.1	13.2	19.8	10.0	30.6
Mar. 1973	0.0	0.1	0.9	5.9	21.3	31.2	16.1	24.5
Apr. 1973	0.0	0.1	3.7	7.8	26.6	26.4	14.1	21.3
May 1973	0.0	0.6	3.0	9.7	28.6	29.7	14.0	14.4
Jun. 1973	0.0	0.1	1.5	5.0	19.4	23.4	15.4	35.2
Jul. 1973	0.0	1.4	5.9	12.4	24.1	21.3	13.2	21.8
(Age group)*	(2+)	(3+)	(4+)	(5+)	(6+)	(7+)	(8+)	(9+ and over)
Aug. 1973	0.0	0.1	0.7	4.5	29.3	31.8	14.5	19.1
Sep. 1973	0.0	0.3	0.9	6.0	21.5	24.7	17.2	29.4
Oct. 1973	0.0	0.4	2.1	10.6	22.3	27.8	14.9	21.8
Nov. 1973	0.0	0.9	7.7	15.8	21.4	23.3	12.5	18.4
Dec. 1973	0.0	0.4	6.7	17.9	26.9	18.1	6.3	23.7
Jan. 1974	0.0	1.5	13.3	20.4	21.8	19.0	10.0	14.2
Feb. 1974	0.0	1.6	8.7	17.1	23.9	19.0	9.3	20.5

* No (1+) fish were recorded after August 1973

TABLE 9.40

Comparison of rates of exploitation, u

Stock and data source	u
C. citharus, Lake Turkana (M = 0.1)	0.32
C. citharus, Lake Turkana (M = 0.3)	0.16
Atlanto-Scandian herring (CUSHING, 1971)	0.35
Japanese sardine (YAMANAMA, 1960)	0.38
Estimated limiting rate of exploitation for clupeid stock (CUSHING, 1973)	0.40 - 0.52

TABLE 9.41

Sex ratios of *Citharinus citharus* expressed as numbers of females per 100 males observed in various regions of Lake Turkana. The chi-square test indicates where regional values depart significantly from the overall ratio of 88 females : 188 males

Region	Number of females	Number of males	Sex ratio	2
Todenyang	22	80	28	4.40
Ilaret-Omo	13	43	31	1.49*
Koobi-Allia-Sandy Bay	9	12	75	1.39*
Kalokol	25	52	48	0.19*
Kerio	12	2	600	15.6
All regions	81	188	47	

* = ^{2} 3.841

TABLE 9.42

Showing the numbers of immature, male and female Labeo horie recorded in each length class.

Total length	Immature (not sexed)	Females						Males				
		♀II	♀IIA	♀III	♀IV	♀V	all ♀♀	♂II	♂III	♂IV	♂V	all ♂♂
30	2	1	-	-	-	-	1	-	-	-	-	-
31	2	-	-	-	-	-	-	-	-	-	-	-
32	1	1	-	-	-	-	1	1	-	-	-	1
33	3	2	-	-	-	-	2	2	-	-	-	2
34	7	-	-	-	-	-	-	1	-	-	-	1
35	2	1	-	-	-	-	1	-	-	-	-	-
36	3	2	-	-	-	-	2	-	-	-	-	-
37	9	3	-	-	-	-	3	1	-	-	-	1
38	4	2	-	-	-	-	2	2	-	-	-	2
39	5	2	-	-	-	-	2	1	-	-	-	1
40	5	3	-	-	-	-	3	3	-	-	-	3
41	7	9	-	-	-	-	9	6	-	-	-	6
42	1	2	-	-	-	-	2	5	-	-	-	5
43	6	3	-	-	-	-	3	4	-	-	-	4
44	1	2	-	-	-	-	2	3	-	-	-	3
45	4	1	-	-	-	-	1	3	-	-	-	3
46	3	2	-	-	-	-	2	3	-	-	-	3
47	2	2	-	-	-	-	2	3	-	-	-	3
48	2	6	-	-	-	-	6	-	-	-	-	-
49	-	2	-	-	-	-	2	3	-	-	-	3
50	-	8	-	-	-	8	8	3	-	-	-	3
51	-	3	-	-	-	-	3	3	-	1	2	6
52	-	3	-	-	-	-	3	4	1	-	1	6
53	-	3	-	-	-	-	3	4	1	1	-	6
54	-	1	-	-	-	-	1	6	2	-	3	11
55	-	3	-	-	-	-	3	3	7	2	3	14
56	-	5	-	-	2	-	7	4	3	2	2	11
57	-	5	-	-	1	-	6	3	3	2	-	8
58	-	5	1	-	2	2	10	5	4	-	2	10
59	-	4	-	-	1	-	5	3	6	2	-	11
60	-	3	1	1	2	-	7	1	3	-	-	3
61	-	5	4	1	1	-	11	3	6	3	-	12
62	-	4	2	1	3	-	10	2	4	3	1	10
63	-	7	1	-	6	-	14	1	1	1	-	3
64	-	5	1	1	4	-	11	1	3	-	-	3
65	-	5	2	-	5	-	12	1	2	-	-	3
66	-	2	1	1	4	-	7	-	1	1	-	2
67	-	10	3	2	6	-	21	-	-	-	-	-
68	-	7	1	-	6	1	15	-	-	-	-	-
69	-	4	2	-	4	3	13	1	-	-	-	1
70	-	4	1	-	4	-	9	-	-	-	-	-
71	-	1	-	-	4	-	5	-	-	-	-	-
72	-	1	1	-	2	-	4	-	-	-	-	-
73	-	1	-	-	1	2	4	-	-	-	-	-
74	-	2	1	-	1	-	4	-	-	1	-	1
75	-	-	1	-	-	-	1	-	-	-	-	-
76	-	-	-	-	1	-	1	-	-	-	-	-
77	-	-	-	-	2	-	1	-	-	-	-	-
78	-	-	1	-	1	-	2	-	-	-	-	-
79	-	-	-	-	-	-	-	-	-	-	-	-

Total females = 249 Total males = 169

TABLE 9.43

Showing seasonal changes in the maturity of *Labeo horie*

Month	Year	Nos of females over 56 cm TL: all ♀II's (♀IIA+ only)	♀III	♀IV	♀V	all ♀♀	Nos of males over 51cm TL: ♂II	♂III	♂IV	♂V	all ♂♂
May	1972	6 (4)	1	2	-	9	-	-	-	-	-
Jun		2 (-)	-	-	-	2	2	-	-	-	2
Jul		2 (-)	1	-	-	3	1	-	-	-	1
Aug		2 (1)	-	-	-	2	2	-	-	-	2
Sep		4 (-)	1	2	-	7	4	1	-	-	5
Oct		2 (-)	1	-	-	3	4	2	-	-	6
Nov		1 (-)	1	-	-	2	-	1	1	1	3
Dec		-	-	-	-	-	-	-	-	-	-
Jan	1973	4 (-)	1	-	-	5	2	-	-	-	2
Feb		8 (2)	-	-	-	8	5	1	1	-	7
Mar		5 (1)	-	-	-	5	1	-	-	-	1
Apr		1 (-)	-	6	-	7	-	4	1	-	5
May		14 (8)	-	5	3	22	1	6	1	-	8
Jun		3 (3)	-	4	1	8	2	8	6	-	16
Jul		2 (-)	-	1	-	3	5	4	-	-	9
Aug		-	-	8	1	9	-	-	1	12	13
Sep		6 (1)	-	13	-	20	2	1	4	-	7
Oct		7 (-)	-	4	-	11	4	-	1	-	5
Nov		7 (1)	-	1	-	8	4	1	-	-	5
Dec		3 (1)	-	-	-	3	2	1	1	-	4
Jan	1974	-	-	-	-	-	-	-	-	-	-
Feb		5 (1)	-	1	-	6	1	4	1	-	6
Mar		17 (-)	-	6	2	25	-	6	1	-	7
Apr		4 (-)	-	2	-	6	1	1	-	-	2
May		-	-	-	-	-	-	-	-	-	-
Jun		2 (1)	2	6	-	11	1	3	1	-	5
Jul		-	-	-	1	1	-	-	-	-	-
Aug		-	-	-	-	-	-	-	-	-	-
Sep		-	-	-	-	-	-	-	-	-	-
Oct		-	-	2	-	2	1	3	-	-	-

TABLE 9.44

Summarising catches of post-larval *Labeo horie* made in metre townet hauls north of a line 10 km north of North Island

Month/Year	No. caught	No. hauls	No. caught/ haul	Variance
Nov. 1972	1	7	0.14	0.14
Mar. 1973	-	4	-	-
Jun. 1973	-	4	-	-
Oct. 1973	-	4	-	-
Jul. 1974	9	9	1.0	4.0
Oct. 1974	198	27	7.3	887
Jun. 1975	4	3	1.3	5.3
Aug. 1975	25	7	3.6	56.0
Sep. 1975	127	8	15.9	603

TABLE 9.45

Summarising catches of *Labeo horie* made in foot seine hauls (FL in mm)

Month/Yr	W. Shore north of Todenyang			Ferguson's Gulf			Kerio Bay			Other Areas			(Source)
	No caught	No/ Haul	FL range	No caught	No/ Haul	FL range	No caught	No/ Haul	FL range	No caught	No/ Haul	FL range	
Oct 70	40	20	14-65	-	-	-	-	-	-	-	-	-	
Mar 72	0	0	-	-	-	-	-	-	-	-	-	-	
Apr 72	0	0	-	-	-	-	0	0	-	-	-	-	
May 72	0	0	-	-	-	-	0	0	-	-	-	-	
Jun 72	0	0	-	-	-	-	13	2.6	19-43	-	-	-	
Jul 72	27	4.5	19-31	-	-	-	4	0.8	13-19	-	-	-	
Aug 72	0	0	-	-	-	-	0	0	-	-	-	-	
Sep 72	34	4.9	19-29	-	-	-	6	1.2	21 24	-	-	-	
Oct 72	9	1.5	30-59	-	-	-	0	0	-	-	-	-	
Nov 72	26	4.3	15-30	-	-	-	0	0	-	2	0.3	54-60	(Allia Bay)
Dec 72	0	0	-	10	-	37-60	47	5.2	16-42	0	0	-	(Loiengalani & Kalomongin)
Jan 73	0	0	-	7	-	38-66	7	1.4	39-66	-	-	-	
Feb 73	6	2.0	35-64	0	0	-	0	0	-	-	-	-	
Mar 73	0	0	-	2	0.5	43-60	0	0	-	-	-	-	
Apr 73	0	0	-	0	0	-	0	0	-	-	-	-	
May 73	0	0	-	0	0	-	0	0	-	-	-	-	
Jun 73	8	2.7	19-24	0	0	-	0	0	-	-	-	-	
Jul 73	0	0	-	9	4.5	39-48	0	0	-	-	-	-	
Aug 73	5	2.5	25-32	0	0	-	0	0	-	-	-	-	
Sep 73	51	17.3	21-52	8	1.6	41-66	2	0.4	19-27	-	-	-	
Oct 73	0	0	-	0	0	-	0	0	-	-	-	-	
Nov 73	7	1.8	26-72	0	0	-	0	0	-	-	-	-	
Dec 73	0	0	-	0	0	-	0	0	-	-	-	-	

contd./

TABLE 9.45 (contd.) Sheet 2)

Jan	74	0	0	-	0	0	-	2	0.5	-	-	-	-	
Feb	74	0	0	-	0	0	-	0	0	-	-	-	-	
Aug	74	82	23*	15-120	-	-	-	-	-	-	-	-	-	
Oct	74	105	30*	15-52	-	-	-	48	14*	14-34	903	14*	12-116	(Kakoi Horst-Arika)
Nov	74	-	-	-	-	-	-	-	-	-	11	0.2*	30-91	(Oryx Pt. - Kakoi Horst)
Jan	75	-	-	-	-	-	-	-	-	-	1	+	60	(Loiengalani-Moite)
Mar	75	-	-	-	-	-	-	1	+	147	0	0	-	(Loelia-Meriar)
Jun	75	-	-	-	0[1]	0	-	-	-	-	0	0	-	(Nabuyatom, S.Is. & El Molo Is.)
Jul	75	-	-	-	-	-	-	-	-	-	0	0	-	(Central Is.)
Aug	75	4341	138*	14-49	-	-	-	-	-	-	2	+	61-69	(Moite - Oryx Pt.)
Oct	75	-	-	-	-	-	-	-	-	-	143	4*	17-135	(Nachukui - Todenyang)
Oct	75	-	-	-	-	-	-	-	-	-	30	0.5*	31-92	(R. Kalokol - Nachukui)
Nov	75	-	-	-	-	-	-	-	-	-	5	0.4*	27-44	(Eliye)

* estimated from a mean of 3.5 (± 1.1s.) hauls per station

[1] from samples between Ferguson's Spit and Audache

Under 'No caught' zero denotes no *Labeo* in catch and a dash indicates no sample taken

TABLE 9.46

Summarising beach seine catches of *Labeo horie* from various localities. Zero catches are not shown.

Month/Yr		Area (No of stations)*	No caught	No/ Haul (s.d.)	FL range	Mean Length FL	Mean Length TL	Modal Length[1] FL	Modal Length[1] TL
Apr	73	F. Gulf (1)	17	8.5	9-19	13.0	14.9	11	12
Apr	73	Moite Spit (1)	27	27	12-40	16.7	19.2	14	16
May	73	Sibiloth Bay (2)	5	1.3	25-60	34.7	40.1	29	34
May	73	Moite Spit (1)	13	13	14-38	20.9	24.0	16	18
May	73	F. Gulf (1)	122	31	12-27	19.9	22.9	18	21
Jun	73	F. Gulf (1)	7	1.8	18-24	20.8	23.9	22	25
Jul	73	F. Gulf (1)	1	1	19		-		-
Sep	73	F. Gulf (1)	66	17	6-32	12.1	13.8	7	8
Oct	73	Sandy Bay (1)	2	1	-		-		-
Oct	73	F. Gulf (1)	13	4.3	10-26	17.7	20.3		-
Nov	73	F. Gulf (1)	8	2.7	10-29	22.0	25.4	22	25
Oct	74	Arika - Kakoi (7)	83	11.9 (11.9)	3-23	9.0	10.3	6	7
Nov	74	Kakoi - Oryx Pt. (11)	112	10.2 (17.9)	6-53	11.8	13.5	10	12
Jan	75	Moite - El Molo (16)	258	16.2 (39.4)	6-25	13.7	15.7	11	13
Mar	75	Kerio (5)	207	41.4 (50.2)	11-34	18.5	21.3	16	18
Jun	75	Longech Spit	1	0.5	33		-		-
Aug	75	Oryx Pt. - Moite (7)	14	2.0 (2.9)	34-39	38.4	44.3	36	42

* total number of hauls can exceed number of stations.

[1] the length group corresponding to the highest mode in the distribution when this is unequivocal.

All lengths are in cm.

TABLE 9.47

Estimates of von Bertalanffy growth parameters from corrected distributions of *Labeo horie* caught in gillnet fleets.

Month	Total Sample size	No of peaks analysed	K	L_∞ (TL)	Correlation coeff. from Gulland plot
Feb	145	first 4	0.24	74	.997
Apr	118	first 4	0.36	60	.999
Feb	145	first 7	0.12	112	.862
Apr	118	first 7	0.16	92	.750

TABLE 9.48

Percentages by number of immature *Labeo horie* at Cooperative Branches

Month/Yr		Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang[1]
Oct	72	-	1.0	-	-	-	-
Nov	72	-	0.5	-	-	-	-
Dec	72	13.5	0.5	0.2	0.9	1.0	0.8
Jan	73	13.4	1.5	2.0	0	1.6	3.2
Feb	73	7.8	2.3	1.5	0.8	2.3	0.6
Mar	73	8.6	2.1	3.5	1.0	0.5	1.7
Apr	73	14.1	0.8	2.0	1.3	0.8	1.8
May	73	10.5	0.3	0.8	0.7	0.4	0.4
Jun	73	21.8	0.3	1.8	0	0	0.3
Jul	73	22.3	0.8	2.9	1.3	0.8	0.5
Aug	73	17.9	0.3	2.5	0.3	2.3	0.5
Sep	73	17.8	2.4	2.8	0.8	1.6	0.3
Oct	73	15.4	0	0.8	0.3	0	1.3
Nov	73	9.8	0.9	1.5	0.9	2.7	0.8
Dec	73	17.3	3.3	2.0	0.5	0	1.5
Jan	74	10.9	1.9	3.9	2.1	5.8	1.3
Feb	74	8.0	0.5	1.8	1.5	2.6	0.5
Mar	74	29.0	15*	-	-	-	-
Apr	74	-	-	12*	-	7*	-
May	74	48.2	33*	-	-	-	-
Jun	74	-	-	13*	-	16*	-
Jul	74	42.3	16*	-	-	-	-
Aug	74	-	-	10*	-	0.6*	-
Sep	74	26.8	10*	8*	-	-	-
Oct	74	-	12*	8*	6*	2*	-
Nov	74	27*	-	-	-	-	-
Dec	74	-	-	-	20.8	9*	-
Jan	75	35.1	17.8	-	-	-	-
Feb	75	-	-	-	11.0	5*	-
Mar	75	34.0	33.8	-	16.9	10*	-
Apr	75	41.5	-	-	-	-	-
May	75	31.8	42.5	-	-	9*	-
Jun	75	30.2	-	-	-	-	-
Jul	75	25.4	34.6	-	-	3*	-
Aug	75	16.1	-	-	-	-	-
Sep	75	-	17.0	-	-	4*	-

[1] all Todenyang catch sold in Lowarengak after February 1975

*estimated from: % immature Labeo = $\sin^2$ (63.42 - 52.59Ln (mean weight)

TABLE 9.49

Weighted percentages by number of immature *Labeo horie* from January to September, 1973-75, at Cooperative Branches.

Year	Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang
1973	17.8	1.3	2.3	0.6	1.0	0.8
1974	37.5	14.4	10.0	7.3	5.8	2.6
1975	31.5	27.0	22.4	11.7	7.3*	

*combined value for Lowarengak and Todenyang

TABLE 9.50

Approximate number of sets per standard net (or fleet) required per annum for the mean catch per effort of *Labeo horie* to be within certain tolerance limits (expressed as percentage of the mean) with 95% confidence.

Area (Year)	Depth	Mesh Size (inches)	Number of sets made	Mean C/E (in kg/st. net or fleet/set)	Variance of C/E	Approx. number of sets for tolerance of: ±50%	±20%
Kalokol (1963)[1]	-	5"	2	14.1	48.7	4	24
Todenyang (1973)	3-4m	5"	56	0.7	1.9	56	350
Todenyang (1973)	5-8m	5"	3	5.4	20.2	11	67
Koobi Foora (1973)	10m	5"	8	1.3	3.9	35	215
Koobi Foora (1973)	10m	4, 5, 6"	8	1.7	7.1	38	236
Kerio (1973)	4m	5"	18	4.3	18.2	16	97
Kalokol (1973)	4-10m	5"	24	1.2	1.1	12	70
Kalokol (1974)[2]	10-16m	5"	10	13.0	97.8	9	56
Kalokol (1974)	10-15m	2, 3, 4, 5, 6"	10	46.9	1031	8	46

[1]from (1964), Table 1

[2]see Table 8.24

TABLE 9.51

Percentages by weight of mature females caught and total yields of *Labeo horie* from 1973 to 1975.

Year	Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang	Overall %	Total Yield (mt)
1973	54.5	84.2	82.0	86.4	83.8	85.5	74.7	794
1974	35.0	62.7	62.5	70.7	69.0	79.8	60.6	1034
1975	33.4	47.9	50.1	60.4	70.5[1]		58.7	565

[1] combined value for Lowarengak and Todenyang

TABLE 9.52

Catch per effort of mature, female *Labeo horie* (in kg per equivalent full-time fisherman per annum) using stated mesh sizes (in inches)

Year	Area	Catch/Effort in mesh size interval 3.5-4.5	4.5-5.5	5.5-6.5	6.5-7.5	Total Catch/ Effort*	% change from 1973
1973	Tod.-Low.-Nach.	27	2551	871	10	3210	
1974	Tod.-Low.-Nach.	121	1257	532	20	1820	-43
1973	Kerio-Kal.-Kat.	31	1180	1703	10	2350	
1974	Kerio-Kal.-Kat.	59	1217	1094	0.4	2000	-15
1973	Tod.-Low.	25	2324	750	9	2890	
1974	Tod.-Low.	97	1156	507	21	1670	-42
1975	Tod.-Low.	149	474	208	6	850	-73
1973	L. Turkana	31	1491	1132	10	2310	
1974	L. Turkana	64	1234	662	15	1770	-23
1975	L. Turkana	57	824	413	10	1190	-49

*weighted total of component catches/effort, used as an index of population fecundity (see text for further explanation).

TABLE 9.53

Estimates of the total weight of *Barbus bynni* caught in the Lake Turkana fishery for the years 1972-75 inclusive.

Year	Total catch *B. bynni* in tonnes	Percentage by weight of total commercial catch
1972	87	3.1
1973	315	10.2
1974	442	12.4
1975	237	6.6

TABLE 9.54

Numbers of *Barbus bynni* caught in a series of 10 minute frame trawl hauls made at a station 2.5 km east of Longech Spit at a depth of 26 metres on 9th-10th April 1974. The hauls were made at depth intervals of 4 metres from top to bottom and the series was repeated 5 times during a 24 hour period.

	Day	Dusk	Night	Dawn	Day
Surface	-	-	-	-	-
4 m	-	-	-	-	-
8 m	-	-	-	-	-
12 m	-	-	-	-	-
16 m	-	-	13	-	-
20 m	-	5	1	2	-
Bottom	7	2	1	4	1

TABLE 9.55

Barbus bynni showing mean lengths (in cm) for three year classes estimated from the monthly histograms (Fig. 9.27). The number of fish sampled is shown in brackets.

Month		Year class		
		1971	1972	1973
1972	Jun	11.5 (4)	-	-
	Jul	12.4 (52)	-	-
	Aug	-	-	-
	Sep	13.8 (44)	-	-
	Oct	-	-	-
	Nov	15.5 (309)	-	-
	Dec	-	-	-
1973	Jan	-	-	-
	Feb	17.4 (35)	7.5 (1)	-
	Mar	-	-	-
	Apr	22.0 (21)	8.9 (26)	-
	May	-	-	-
	Jun	22.4 (9)	13.8 (157)	-
	Jul	23.6 (258)	14.9 (693)	-
	Aug	-	14.7 (292)	-
	Sep	-	14.2 (124)	-
	Oct	27.9 (295)	17.8 (153)	-
	Nov	29.4 (45)	19.5 (150)	-
	Dec	29.9	19.0 (65)	-
1974	Jan	-	18.6 (122)	-
	Feb	-	22.4 (63)	-
	Mar	-	22.9 (105)	9.7 (109)
	Apr	-	23.4 (100)	10.0 (75)
	May	-	23.7 (244)	11.7 (131)
	Jun	-	-	11.5 (117)
	Jul	-	28.9 (213)	11.7 (13)
	Aug	-	-	-
	Sep	-	30.5 (210)	11.5 (46)
	Oct	-	31.2 (60)	-
	Nov	-	-	13.9 (17)
	Dec	-	31.3 (71)	-

TABLE 9.56

Changes in the maturity of female Barbus bynni with size. The number of each maturity stage in each length class is expressed as a percentage of the total recorded at that size.

Length (cm)	Maturity Stage				Total No
	2	3	4	5	
20	100	-	-	-	1
22	100	-	-	-	6
24	100	-	-	-	11
26	100	-	-	-	35
28	98.0	2.0	-	-	99
30	99.2	0.8	-	-	127
32	97.1	2.9	-	-	102
34	94.7	5.3	-	-	75
36	87.3	12.7	-	-	63
38	91.3	8.7	-	-	69
40	79.6	20.4	-	-	49
42	81.9	17.1	-	-	41
44	79.3	20.7	-	-	29
46	91.7	8.3	-	-	12
48	86.6	6.7	6.7	-	15
50	83.3	16.7	-	-	12
52	75.0	25.0	-	-	12
54	45.4	36.4	9.1	9.1	11
56	63.6	27.3	9.1	-	11
58	20.0	60.0	20.0	-	5
60	-	100.0	-	-	1
62	-	-	100.0	-	1
64	-	-	-	-	-
66	-	-	100.0	-	1
68					
70					

TABLE 9.5 7

Changes in the maturity of male Barbus bynni with size. The number of each maturity stage in each length class is expressed as a percentage of the total recorded at that size.

Length (cm)	Maturity Stage				Total No
	2	3	4	5	
20	-	-	-	-	-
22	100	-	-	-	8
24	100	-	-	-	35
26	100	-	-	-	54
28	100	-	-	-	104
30	98.6	1.4	-	-	146
32	97.6	2.4	-	-	167
34	94.8	5.2	-	-	155
36	95.7	4.3	-	-	116
38	87.9	10.1	2.0	-	99
40	73.8	23.0	3.2	-	61
42	64.9	35.1	-	-	37
44	69.8	30.2	-	-	43
46	72.0	28.0	-	-	25
48	56.2	43.8	-	-	16
50	76.0	20.0	4.0	-	25
52	71.4	21.4	7.2	-	14
54	80.0	6.7	13.3	-	15
56	79.0	10.5	10.5	-	19
58	50.0	37.4	6.3	6.3	16
60	100.0	-	-	-	5
62	66.7	33.3	-	-	3
64	20.0	20.0	40.0	20.0	5
66	50.0	-	50.0	-	2
68	100.0	-	-	-	1
70					

TABLE 9.58

Sex ratios in two size groups of *B. bynni* combining data from all samples

Size group (F.L. in cm)	Sex ratio females/100 males	Total number
30 - 44.9	152	1351
Over 45	164	243

TABLE 9.59

Showing the food of *Barbus bynni* analysed on the basis of size class and depth zone. The number of points scored by each food category has been expressed as a percentage of the total points awarded to the size group.

Depth zone	Water shallower than 30m				Water deeper than 30m				All depths combined			
Size group (F.L. in cm)	20	20-30	30-40	40	20	20-30	30-40	40	20	20-30	30-40	40
Total fish examined	47	58	107	29	74	13	1	6	121	71	108	35
Number empty	5	3	2	1	5	-	-	-	10	3	2	1
Number with food	42	55	105	28	69	13	1	6	111	68	106	34
Food items :-												
Ostracoda	47	37	52	40	94	90	100	85	79	44	52	47
Chironomid larvae	2	6	16	19	2	-	-	2	2	5	16	16
Corixidae	2	25	20	10	-	-	-	-	1	22	20	8
Total insects	4	31	36	29	2	-	-	2	3	27	36	24
Melanoides tuberculata	1	5	7	8	1	1	-	2	1	4	7	7
Cleopatra pirothi	1	10	6	13	-	-	-	-	+	8	6	11
Fragments snail shell	39	11	5	3	2	8	-	11	16	10	5	4
Total gastropoda	41	26	19	25	4	10	-	-	18	23	19	23
Vegetable fragments	1	+	2	1	-	-	-	-	+	1	1	+
Mud and sand	5	4	2	5	-	-	-	-	2	4	2	4
Total points	2325	4220	8130	2680	3690	690	80	510	6085	4910	8210	3190
Points per fish	49	72	85	92	53	53	80	85	50	69	76	91

TABLE 9.60

Showing the percentage occurrence of various food categories in the stomachs of four size groups of *Barbus bynni* combining results from all source.

Size group (F.L. in cm)	20	20-30	30-40	40
Total stomachs	121	71	108	35
Number empty	10	3	2	1
Number with food	111	68	106	34
Food items :-				
Ostracoda	84	76	68	83
Chiromonid larvae	8	21	33	57
Corixidae	2	31	31	17
Total insects	9	42	44	63
Melanoides tuberculata	7	20	22	40
Cleopatra pirothi	2	20	14	40
Fragments snail shell	32	35	14	9
Total gastropoda	37	54	24	71
Vegetable remains	3	4	10	
Mud and sand	3	14	3	

TABLE 9.61

Changes in the sexual maturity of female *Alestes ferox* with size. Showing the percentage of fish at various stages in each length group. All data for the period December 1972-May 1974 have been combined.

Fork length (mm)	Stage 2	Stage 3	Stage 4	Stage 5	Total number
50	100	-	-	-	145
54	99	1	-	-	140
58	98	2	-	-	121
62	99	1	-	-	171
66	98	2	-	-	139
70	92	6	2	-	145
74	86	8	4	2	139
78	83	12	5	1	175
82	85	9	5	1	168
86	73	11	11	4	150
90	64	11	15	9	182
94	55	16	14	14	146
98	59	10	18	13	100
102	56	13	11	20	54
106	41	22	19	19	27
110	56	11	11	22	18
114	50	50	-	-	2
118	100	-	-	-	1

TABLE 9.62

Changes in sexual maturity and in the development of the anal fin in male *Alestes ferox*. Showing the percentage of fish in various stages of development in each length group. All data for the period December 1972 - May 1974 have been combined.

Fork length (mm)	Stages 2-3 unexpanded anal fin	Stages 2-3 slightly expanded anal fin	Stages 2-3 greatly expanded anal fin	Stages 4-6 greatly expanded anal fin	Total number
50	100	-	-	-	120
54	96	4	-	-	166
58	80	20	+	-	182
62	43	53	3	+	153
66	13	75	9	4	162
70	4	75	15	6	152
74	-	66	21	12	121
78	-	39	38	23	77
82	-	30	37	33	57
86	-	20	38	43	40
90	-	5	36	59	22
94	-	-	14	86	7
98	-	-	-	100	2

TABLE 9.63

Showing seasonal changes in the maturity of female *Alestes ferox* of 8mm F.L. and over. The number of each maturity stage is expressed as a percentage of the total number for each month.

Month	Stage 2	Stage 3	Stage 4	Stage 5	Total
Oct 72	20	25	10	45	20
Nov 72					no sample
Dec 72	52	14	16	17	63
Jan 73	78	7	7	7	27
Feb 73	86	51	5	3	80
Mar 73	87	8	5	-	75
Apr 73	42	11	33	15	55
May 73	71	12	6	-	30
Jun 73	51	23	23	4	168
Jul 73	68	14	13	5	130
Aug 73	83	5	4	15	139
Sep 73	50	21	18	12	34
Oct 73					no sample
Nov 73					no sample
Dec 73	69	24	6	1	67
Jan 74					no sample
Feb 74					no sample
Mar 74	75	6	16	3	32
Apr 74					no sample
May 74	69	2	-	29	98

TABLE 9.64

Changes in the sexual maturity of female *Alestes minutus* with size. Showing the percentage of fish at various stages in each length group. All data collected during the present survey have been combined.

Fork length (mm)	Stage 2	Stage 3	Stage 4	Stage 5	Total number
21	100	-	-	-	3
22	100	-	-	-	3
23	100	-	-	-	5
24	93	-	7	-	14
25	84	8	8	-	25
26	76	14	8	3	37
27	86	6	9	-	35
28	34	39	22	5	41
29	21	32	38	9	47
30	26	17	52	4	46
31	18	24	31	27	45
32	16	21	53	11	19
33-35	5	26	42	21	19

TABLE 9.65

Data from a sample of 77 male *Alestes minutus* caught in the Longech area on 15/5/73, analysed to show the onset of maturation with increasing length and the development of the expanded anal fin. The number of fish in each category are shown for each length class.

Fork length (mm)	Stages 2-3 unexpanded anal fin	Stages 2-3 slightly expanded anal fin	Stages 2-3 greatly expanded anal fin	Stages 4-6 greatly expanded anal fin
22	1	-	-	
23	1	-	-	
24	4	1	-	
25	6	-	-	
26	5	1	1	
27	8	1	-	
28	3	6	-	
29	-	4	2	
30	-	5	3	1
31	2	3	1	3
32	-	2	2	4
33	-	-	-	3
34	-	-	-	3
35	-	-	-	1
36	-	-	-	1

TABLE 9.66

Showing seasonal changes in the maturity of female *Alestes minutus* of 26mm and over. The number of each maturity stage is expressed as a percentage of the total specimens examined each month. Data for the period September 1972 - November 1975 have been combined.

Month	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6	Stage 7	Total number
Jan	23	23	32	23	-	-	22
Feb							no sample
Mar	4	26	43	26	-	-	23
Apr							no sample
May	41	14	39	6	-	-	80
Jun	-	11	67	22	-	-	9
Jul							no sample
Aug	5	35	45	15	-	-	
Sep	40	12	28	4	-	16	25
Oct	55	25	9	6	1	3	67
Nov	13	31	44	13	-	-	16
Dec	3	39	52	6	-	-	31

TABLE 9.67

Showing seasonal changes in the maturity of female *Engraulicypris stellae* of 25mm and over from the Longech Spit area. The number of each maturity stage is expressed as a percentage of the total number for each month.

Month	Stage 2	Stage 3	Stage 4	Stage 5	Total
Dec 72	32	24	45	-	38
Jan 73	46	13	42	-	24
Feb 73					no sample
Mar 73	-	21	75	4	24
Apr 73	-	14	86	-	28
May 73	12	24	64	-	33
Jun 73	27	27	45	-	22
Jul 73	6	16	78	-	32
Aug 73	13	25	63	-	24
Sep 73	4	22	70	4	27
Oct 73	69	31	-	-	13
Nov 73	20	31	49	-	35

TABLE 9.68

Showing changes in the maturity of *Distichodus niloticus* with size.

Total length (2cm groups)	Immature (not sexed)	Females					Males			
		II	IIA	III	IV	V	II	III	IV	V
20-21.9	3	-	-	-	-	-	-	-	-	-
22-etc	-	-	-	-	-	-	-	-	-	-
24	2	-	-	-	-	-	-	-	-	-
26	1	-	-	-	-	-	-	-	-	-
28	1	-	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	-
32	-	-	-	-	-	-	-	-	-	-
34	-	-	-	-	-	-	-	-	-	-
36	3	1	-	-	-	-	1	-	-	-
38	2	5	-	-	-	-	5	-	-	-
40	1	3	-	-	-	-	2	-	-	-
42	3	3	-	-	-	-	4	-	-	-
44	2	5	-	-	-	-	8	-	-	-
46	3	9	-	-	-	-	8	-	-	-
48	1	5	-	-	-	-	4	-	-	-
50	5	2	-	-	-	-	5	-	-	-
52	-	4	-	-	-	-	7	-	-	-
54	3	5	-	-	-	-	7	-	-	-
56	3	5	-	-	-	-	4	1	-	-
58	-	2	-	-	-	-	-	-	-	-
60	1	4	-	-	-	-	2	-	1	-
62	1	4	-	-	-	-	1	-	-	-
64	-	3	-	-	-	-	5	-	-	-
66	-	1	-	2	-	-	6	-	-	-
68	-	3	-	2	-	-	2	-	-	-
70	-	1	-	-	-	-	2	-	1	-
72	-	-	-	-	-	-	4	-	1	-
74	-	-	1	-	-	-	4	-	-	-
76	-	1	-	1	-	-	1	1	1	-
78	-	2	-	-	-	-	-	-	-	-
80	-	1	-	-	-	-	-	-	-	-
82	-	2	-	1	-	-	-	-	-	-
84	-	-	1	1	1	-	-	-	-	-
86	-	1	-	-	-	-	-	-	-	-
88	-	-	-	-	1	-	-	-	-	-

TABLE 9.69

Percentages by number of immature *Distichodus niloticus* at Cooperative Branches.

Month/Yr	Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang[1]
Oct 72	-	27	-	-	-	-
Nov 72	-	21	-	-	-	-
Dec 72	13	27	60	18	26	11
Jan 73	18	21	62	22	54	13
Feb 73	21	26	90	63	0	12
Mar 73	28	53	91	65	19	32
Apr 73	22	67	88	59	79	49
May 73	14	61	79	72	46	31
Jun 73	35*	50	82	74	60	23
Jul 73	18	53	88	74	42	24
Aug 73	27	51	85	70	36	15
Sep 73	17	63	67	48	14	10
Oct 73	24	61	56	38	14	13
Nov 73	17	49	64	42	28	16
Dec 73	23	39*	60	41	25	13
Jan 74	27	36	69	34	32*	21
Feb 74	12	35	77	59	69	22
Mar 74	-	72*	78*	-	65*	-
Apr 74	-	-	-	-	-	-
May 74	-	-	90*	-	75*	-
Jun 74	-	83*	-	-	-	-
Jul 74	-	-	64*	-	31*	-
Aug 74	-	-	-	-	-	-
Sep 74	-	75*	83*	46*	37*	-
Oct 74	-	54*	-	-	-	-
Nov 74	-	-	89*	54*	24*	-
Dec 74	-	90	-	-	-	-
Jan 75	-	-	-	56	42	-
Feb 75	-	-	-	-	-	-
Mar 75	-	89	-	-	34	
Apr 75	75	-	-	-	25	
May 75	-	95	-	-	-	
Jun 75	24*	-	-	-	42	
Jul 75	-	90	-	-	-	
Aug 75	52	-	-	-	27	

[1]all Todenyang catch sold in Lowarengak after February 1975

*estimated from mean weight, see formula in Section 2.3(a)

TABLE 9.70

Weighted percentages by number of immature *Distichodus niloticus* in 1973 and 1975 for separate Cooperative Branches and for total catch.

Year	Kerio	Kalokol	Kataboi	Nachukui	Lowarengak	Todenyang	Total Catch
1973	26	45	70	41	27	18	33
1975	55	88	86	60	43*		49

*combined value for Lowarengak and Todenyang

TABLE 9.71

Size ranges of commercial catches of *Distichodus niloticus* and minimum sizes vulnerable to capture between December 1972 and February 1974.

Cooperative Branch	Sample Size	Size range (TL in cm)	Approximate minimum size vulnerable to gear (TL in cm)
Todenyang	2075	36 - 101	34
Lowarengak	1689	36 - 110	
Nachukui	1853	33 - 98	
Kataboi	2169	39 - 92	30
Kalokol	1324	42 - 91	
Kerio	1325	44 - 99	26