THE AFRICAN JOURNAL OF *Tropical Hydrobiology and Fisheries*

(Afr. J. Trop. Hydrobiol. Fish.)

Vol. 4 No. 1 1975

Special Issue 3

East African Literature Bureau
NAIROBI DAR ES SALAAM KAMPALA

SPONSORS

Hydrobiologists from East, Central and West Africa with substantial support from other African countries, Fishery Scientists in the United States, Canada, U.K., Europe and the Soviet Union.

EDITOR

Dr. John Okedi, Director E.A.F.F.R.O., Jinja, Uganda.

SUB-EDITOR

S. Wanambwa (Mrs.)

PROGRAMME

The African Journal of Tropical Hydrobiology and Fisheries will only accept original and well supported ideas on techniques, methodology and research findings from scientists, fishery officers, fishery economists and sociologists.

The Journal will therefore strengthen the African research scientist by making research material available and also increasing the awareness and utility of aquatic resources.

Its quality will conform to International standards, and will be published in English and French.

MANUSCRIPT ADDRESS

Manuscripts should be addressed to E.A.F.F.R.O., East African Freshwater Fisheries Research Organisation, East African Community, Box 343, Jinja, Uganda.

REPRINTS

Authors will receive 60 reprints free of charge. Extra reprints may be procured on cost.

PUBLISHER

East African Literature Bureau, P.O. Box 30022, Nairobi, Kenya.

ISSUES

The Journal consists of one volume a year, consisting of two issues with approximately eighty pages each.

SUBSCRIPTION

Annual subscription within East Africa Shs. 35. Outside East Africa, East African Shs. 70, US $ 10.00.

PRELIMINARY OBSERVATIONS ON THE FEEDING OF *TILAPIA NILOTICA* LINN. IN LAKE RUDOLF

B. J. HARBOTT

Lake Rudolf Freshwater Research Projects, Fisheries Department, Ferguson's Gulf P.M.B. Kitale, Kenya

INTRODUCTION

Tilapia nilotica is commercially very important throughout the Ethiopian region including the major rivers in West Africa, the Chad basin, the Nile and its associated lakes. The *Tilapia* fishery of Lake Rudolf is at present small, but potentially important, particularly on the eastern shores of the lake where fishing intensity is low.

Little detailed work has been carried out on the ingestion, digestion and assimilation of food by this fish. The first comprehensive studies to be reported have been by MORIARTY and his co-workers on Lake George (MORIARTY, C., 1973; MORIARTY, C. & MORIARTY, D., 1973; MORIARTY, D., 1973; and MORIARTY, D., & MORIARTY, C., 1973). No reliable records of *Tilapia* gut contents from Lake Rudolf are available before those of FISH (1955) although intermittent visits to the lake have been made since the Cambridge Expedition of 1930–1931 (TREWAVAS, 1932). This report records preliminary findings of a newly-instigated sampling programme, prompted by the work of MORIARTY *op., cit.*, to investigate the diurnal feeding cycle of *T. nilotica* in Lake Rudolf.

MATERIALS AND METHODS

Fish were caught from a sandy beach on the northern side of Ferguson's spit (Figure 1). The shore shelved steeply to a depth of 6m. It was exposed to occasional northerly winds and was free from vegetation apart from isolated plants of *Potamogeton pectinalis*. The substrate varied from coarse sand on the margin, to mud in deeper water.

Most fish were caught with a beach seine of 50m. length, 4m. depth and 2″ mesh size. Additional material was collected from catches made by the local Turkana fishermen in the same locality, but the data from these fish were included only if information on time of capture was reliable.

Immediately following capture, total length and weight of each fish were recorded. The stomachs and intestines were removed and treated separately. In certain cases, gut contents were removed for pH measurements using an E.I.L. model 30c portable meter and glass electrode. This material was then suspended on $MgCO_3$ covering glass fibre filter discs (Whatman G.F.A.) before the proportions of phaeophytin *a*: chlorophyll *a* were determined. A modification of the method described by

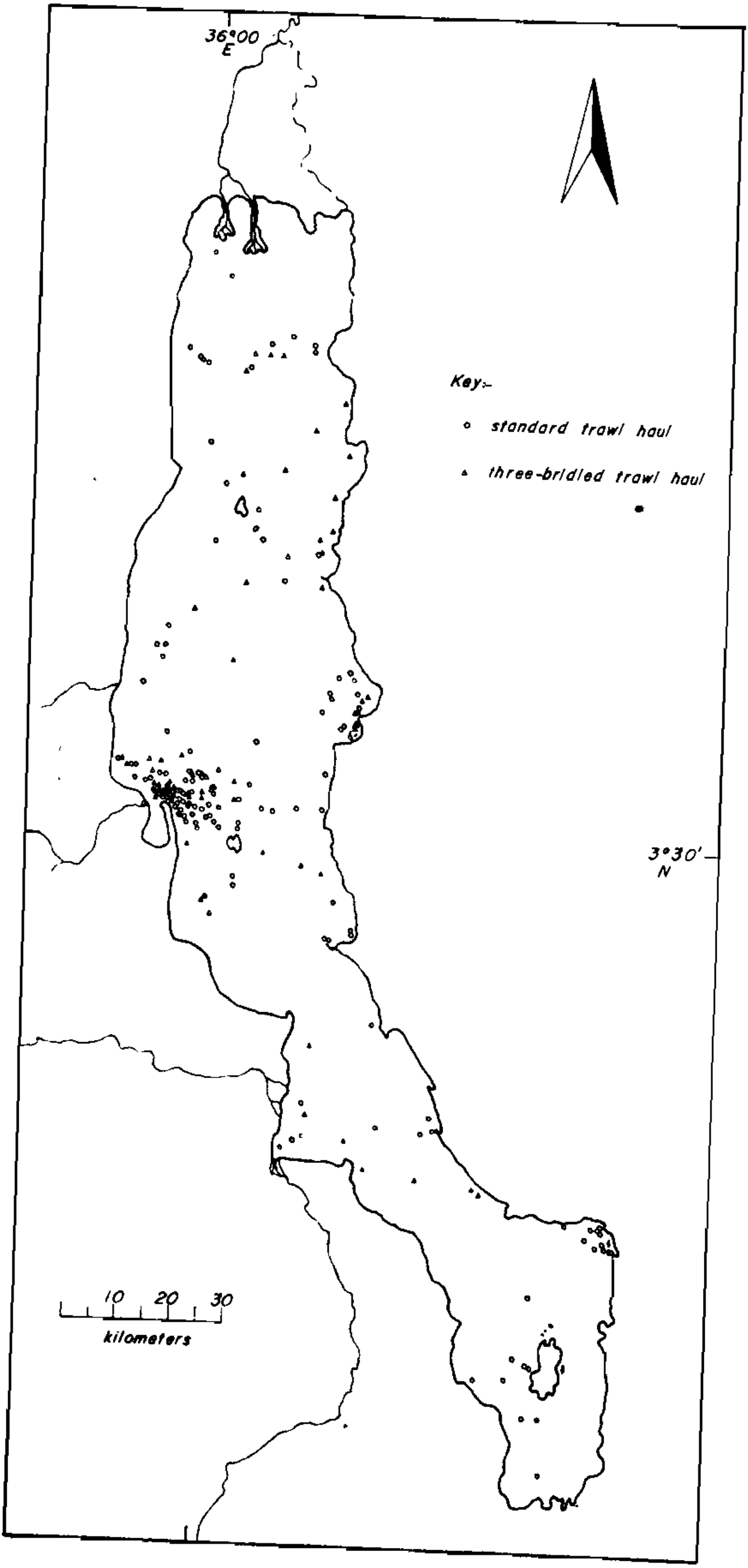

Fig. 1. Map of Lake Rudolf.

GOLTERMAN (1969) was used, readings being taken on a Pye-Unicam SP 600 series 2 Spectrophotometer. Dry weight of stomach and intestine contents were measured after drying to constant weight at 70°C.

Unconcentrated water and samples of the mud/water interface were taken for plankton examinations and counts were made using a Prior inverted microscope.

RESULTS

Condition Factor

Figure 2 shows the regression line for logarithmic plots of weight against length for the population studied. The general condition of the fish was excellent and very few parasites were found.

The overall mean condition factor was calculated (TESCH, 1968) from

$$K = \frac{100\ w}{l3}$$

(where w is the weight in grams and l the length in centimetres). A value of 2.28 was recorded.

Composition of Food

The species and proportions of organisms identified from gut contents were generally very similar to those available in the plankton. The dominant algae were the blue-greens *Spirulina laxissima*, *S. terebriformis* *Anabaena spiroides* and *Chroococcus* spp. with a few *Micorocystis* colonies visible. The diatoms *Navicula* spp. *Achnanthes* spp. and *Cymbella* spp. formed the remainder of the phytoplankton in the gut. Zooplankters were generally scarce. *Mesocyclops leuckarti*, *Thermocyclops hyalinus*, *Tropodiaptomus banforanus* and *Diaphanosoma excisum* were found dispersed throughout the gut, but cells of the protozoan *Thuricola folliculata* were patchy in distribution, often being found in dense clumps.

The diatoms, protozoans and invertebrates identified were digested in the fore-gut, but some of the identifiable blue-green algal cells appeared intact, even in the rectal region.

FEEDING RHYTHMS

From the dry weights of stomach and intestine contents, a clear diurnal feeding rhythm emerges. Results for *T. nilotica* size group of mean length 17.8cm (range from 16.5–18.5 cm) and wet weight of 137 g. are shown in figure 3.

These fish had empty stomachs until the onset of feeding at 08.00 hours. Feeding continued until 14.15 hours. Throughout this period, the rates of fresh material entering the stomach and intestine were constant. In each case, a regression line has been calculated.

When the gut contents are plotted as a percentage of the calculated dry body weight (figure 4), a similar pattern emerges, though the rate of decrease in intestine contents weight is clearer.

If values for all the fish investigated are plotted on axes similar to figure 4 (figure5), a rather different pattern is seen. The population ranged in length from 16.5 cm to 52.0 cm, and the larger fish commenced feeding earlier, soon after 05.00 hours and continued feeding longer until 18.00 hours.

GUT AND CHLOROPHYLL LEVELS

Measurements of pH were taken from several fish at different times of the day. From Table 1, it may be seen that mid-gut acidity did not vary greatly, but that the stomach pH dropped from around 4.0 after the onset of feeding, to 2.5 when feeding ceased.

Ratios of phaeophytin *a* to chlorophyll *a* remained similar throughout the day along the length of the intestine, with mean figures of 93%: 7% recorded. At no time was a clear colour change noticeable in the intestine contents, the material being a uniform grey/brown. However, the dorsal wall of the stomach exhibited a very dark area when

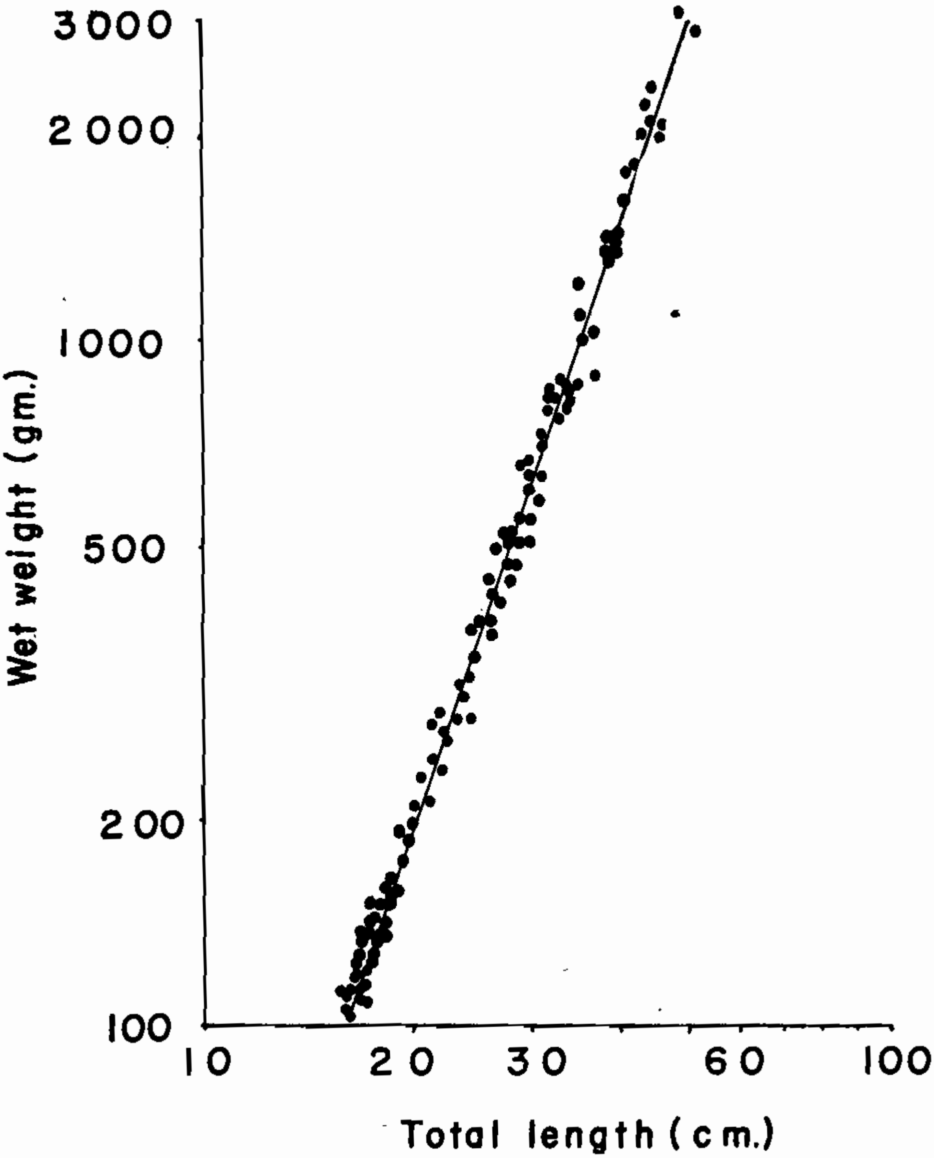

Fig. 2. Regression line of log weight to log total length for total population caught.

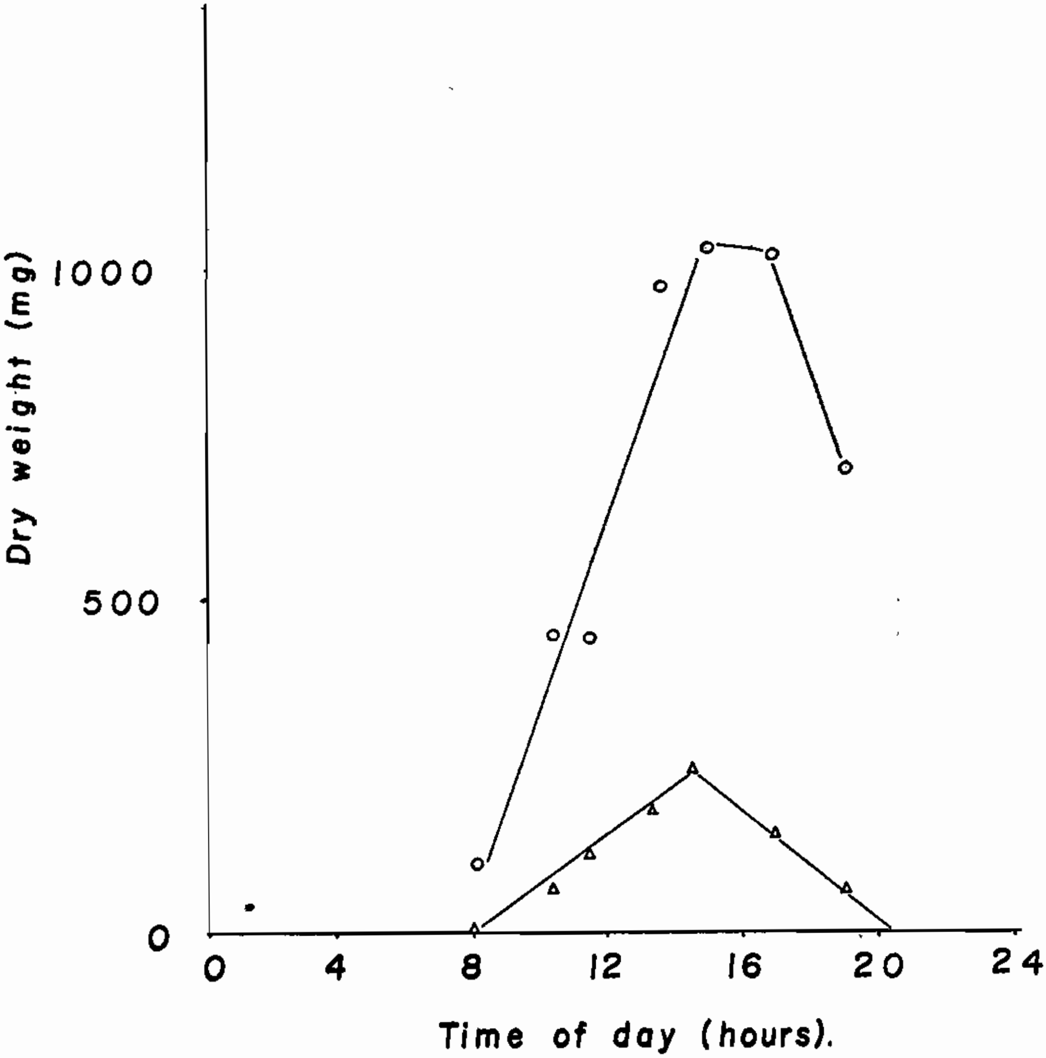

Fig. 3 Regression lines of dry weight of intestine (upper) and stomach (lower) contents of *Tilapia nilotica* ranging from 16.5-18.5 cm. total length with time.

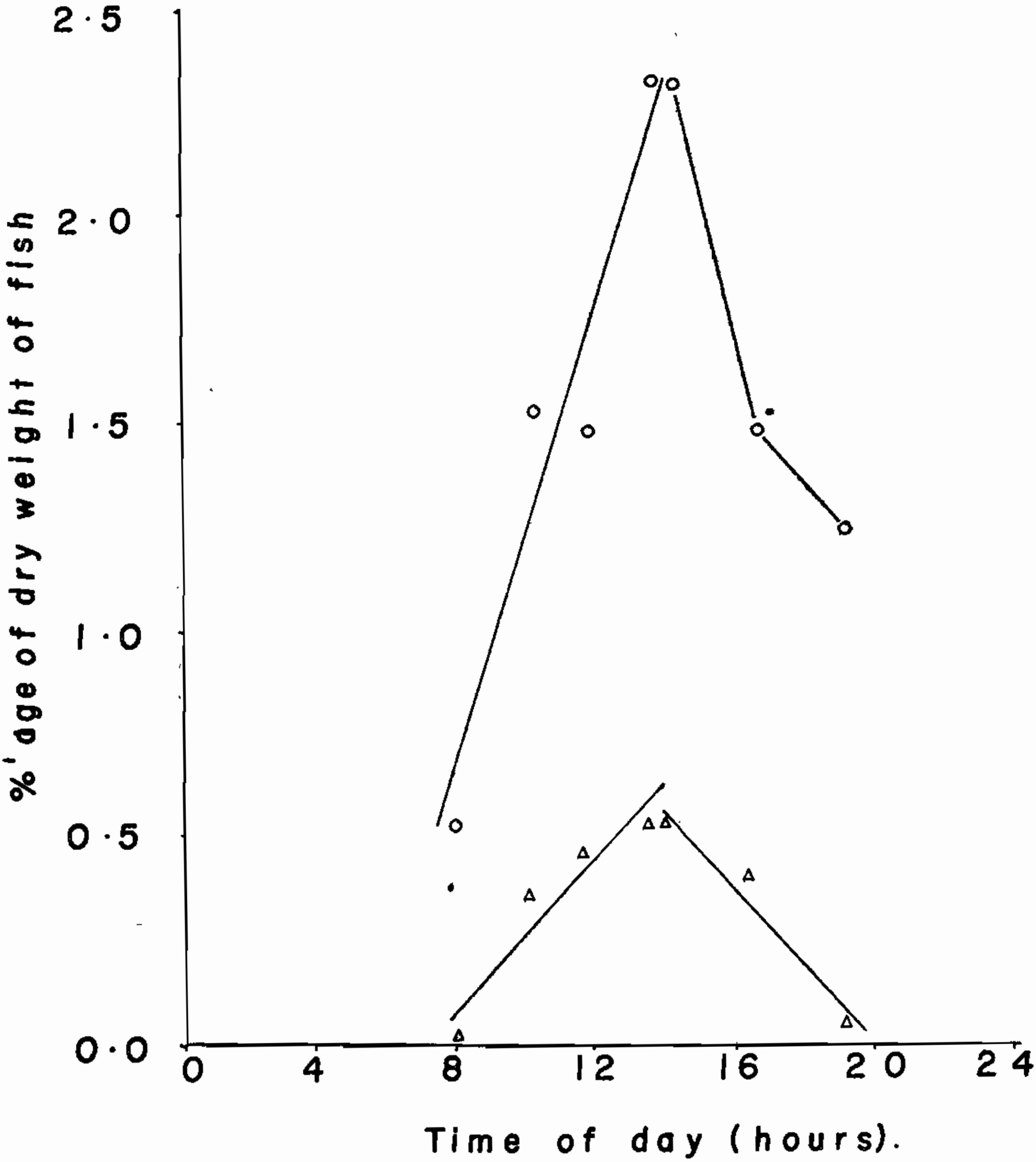

Fig. 4. Regression lines as in Fig. 3, but plotted as a %'age of the calculated dry body weights.

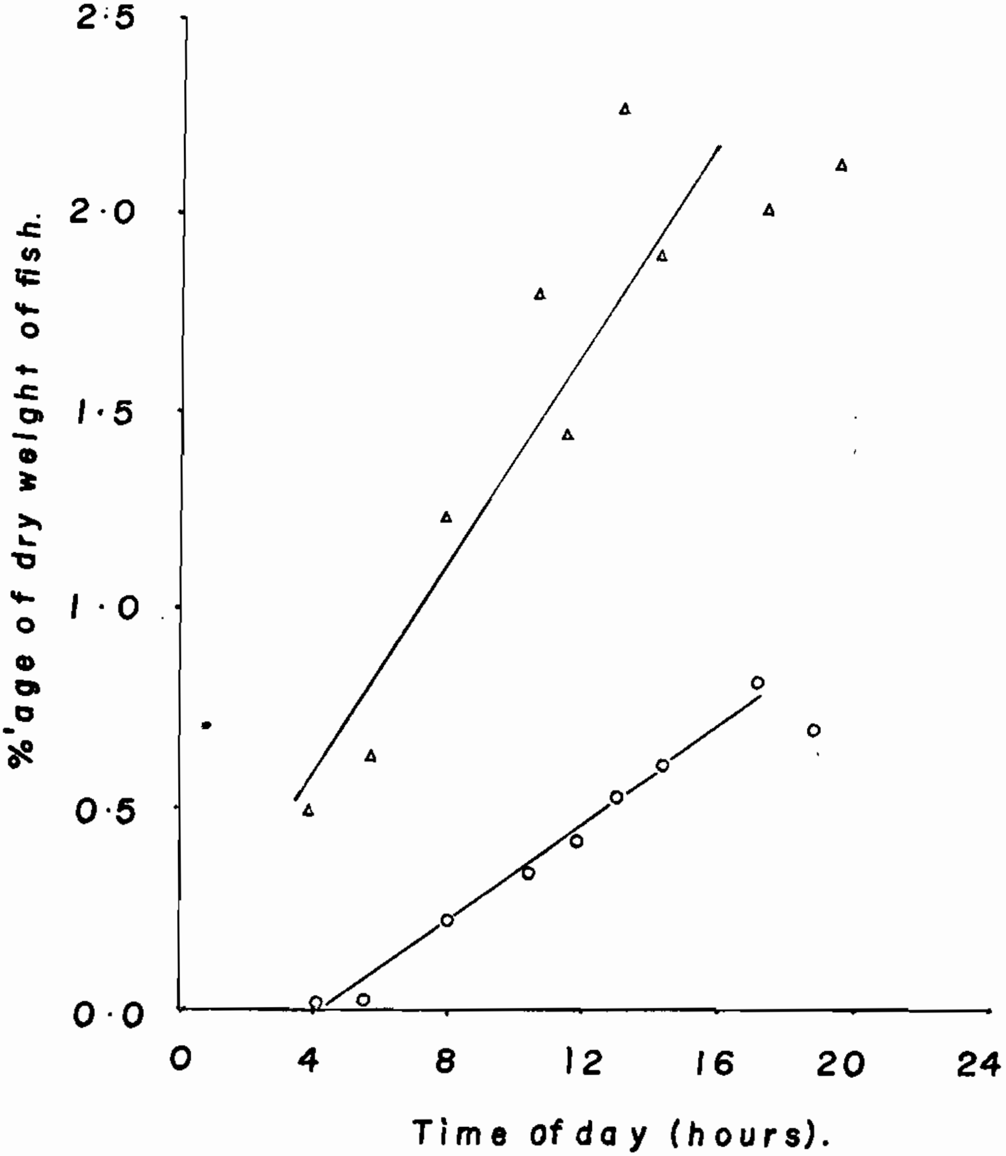

Fig. 5. Regression lines of gut contents, intestine (upper) and stomach (lower), for all fish caught; plotted as a %'age of the calculated dry body weights.

full. This region showed the lowest pH values of below 2.5 after cessation of feeding.

QUANTITY OF MATERIAL INGESTED

Assuming that when feeding ceases, it does so completely for that day and that the rate of increase is constant until the cessation of feeding, then the amount of material held in the stomach at that time, plus that contained in the intestine is the total ingested that day. Thus, for size group A. (figure 3) the weights are 242 mg. + 1,040 mg. + 1.282 g. dry weight.

DISCUSSION

Food of Tilapia nilotica

Earlier records quote *T. nilotica* as ingesting a wide range of food materials. WORTHINGTON (1929 & 1932) and WORTHINGTON & RICARDO (1936) found crustacea, chironomids and algae in *T. nilotica* guts from Lakes Albert, Edward, George, Rudolf and Baringo, but only phytoplankton in fish from Lake Victoria. POLL (1939) found stomachs and intestines of *T. nilotica* from Lake Edward to be full of "green lake plankton", while DAGET (1954) recorded *T. nilotica* inhabiting rivers in W. Africa to feed generally on phytoplankton, benthos and detritus. The population in Lake Kivu feed on a large planktonic *Spirulum* (CAPART, pers-comm. in FISH 1955). LOWE-McCONNELL (1958) summarised the situation by stating them to feed "primarily on algae throughout their life" though the "source of algae may vary from lake to lake".

There is no doubt that *T. nilotica* is capable of capturing small planktonic algae and bacteria aided by abundant mucus production in the bucal cavity (GREENWOOD 1953), but it seems unlikely that the pharyngeal mill is capable of rupturing small algal cells.

Blue-green algae have frequently been reported to pass unharmed through the digestive tracts of *Tilapia* spp. WHITEHEAD (1959) reports viable cells from faeces of *T. nigra*. FISH (1951) states that most of the ingested blue-green algal material is undigestable to *Tilapia*, with *Microcystis* colonies passing out entire, while diatoms were lysed. The same paper quotes *Tilapia nilotica* in Lake Rudolf as being exceptional in their ability to utilize the blue-green algae *Spirulina* and *Anabaenopsis*. It was stated that these algae were restricted to highly alkaline lakes such as Rudolf and Elmenteita, although subsequently, they have been reported to be widespread, occurring, for example, in Lake Victoria. COE (1966) reports the tiny *Tilapia grahami* of Lake Magadi to feed on epilithic blue-green algae.

FRYER & ILES (1972) suggested that the digestability of blue-green algae may be related to a high Na^{+}: Ca^{++} ratio. From TALLING & TALLING (1965) this figure is 142:1 for Lake Rudolf and over 3,888:1 in Lake Magadi, while the figure for Lake George is 0.8:1, (DUNN *et al.*, 1969; VINER 1969). Evidently the high proportions of ingested *Microcystis* which are assimilated by *Tilapia nilotica* in Lake George cannot be attributed solely to water chemistry.

FRYER & ILES (1972) conclude from the lack of a cellulase in *T. nilotica* guts that no blue-greens can be digested. FISH (1960), working with *T. mossambica*, found no enzymes capable of lysing blue-greens, while similar results were obtained for T. *nilotica* by MORIARTY, C. (1973). However, FISH (1960) reported acid-secreting tissue in the stomach wall, and GREENWOOD (1953) stated similar tissue to be present in *T. esculenta* stomachs.

Microcystis flos-aquae and *M. aeruginosa* are the most common phytoplankters in Lake George. They represent 40% of the phytoplankton biomass, half the planktonic blue-green algae (BURGIS *et al.*, 1973) and from the major dietary component of *Tilapia nilotica* in the lake. These colonia chroocoecalean prokaryotes are lysed *in vitro* by acid conditions below pH 1.65, a level reached by stomach contents of *T. nilotica* from Lake George after 3–4 hours feeding. Though acid secretion by the stomach (Table 1) of *T. nilotica* from Lake Rudolf was not seen to drop the overall pH of the stomach contents below 2.5, some blue-green algal cells stay in the stomach long enough for lysis to occur. MORIARTY (1973) records wide variation in pH from different areas of the stomach, and some ingested material obviously passes rapidly from oesophagus to pyloric sphincter, while some is carried down the ventral wall, being acidified, before moving into the intestine. Acid secretion appears to be stimulated by food ingestion in both populations.

At no time in the present study were obvious colour differences seen in the stomach, intestine or faeces and from the phaeophytin: chlorophyll ratios recorded it appears that most of the algal cell lysis occurs in the stomach and fore-gut.

Rhythm and Amount Ingested

The fish referred to in figure 3 represent the size group caught in largest numbers throughout the sampling programme and hence were considered the most reliable for close study. Compared to the same length group from Lake George (MORIARTY *op. cit.*), they are 30g heavier, commence feeding later and cease earlier, feeding for 6 hours as opposed to 11–15 hours. (See later for growth comparisons).

However, the rates of increase in dry weight of stomach and intestine contents of 38 mg hr^{-1} and 80 mg hr^{-1} are only slightly higher than those from Lake George.

MORIARTY used the same direct method to estimate the total amount of plankton ingested per day. It is difficult to use indirect measurements based on growth rate as the seasonal changes in both lakes do not greatly influence opercular or scale ring formation. The total amount of material ingested by group A studied here was 1.28 g dry weight compared to 1.88 g by the same size group in Lake George. Thus *T. nilotica* in Lake Rudolf appear to attain

Table 1. The pH of gut contents at different times of the day.

Time.	Stomach	Intestine
07·32	3·95	7·00
10·35	3·45	6·80
13·35	2·82	7·10
18·30	2·56	7·36

greater weight per unit length from a lower dry weight intake.

Otherwise, the feeding patterns are generally similar. The present study shows that the intestine never completely emptied. Most of the intestine contained watery mucus at the onset of feeding, while the rectal region held material which was presumably ingested the previous day. In this size group, stomachs and fore-guts of fish caught before the onset of feeding were void and contracted. Likewise, the stomachs of fish from other size groups caught at 05.00 hours were empty, but by 08.00 hours all contained some plankton. Here again, the intestines examined were not completely empty before fresh material entered from the stomach. These larger fish also exhibited a slightly shorter feeding period than was recorded by MORIARTY, starting at around 05.00 hours and finishing at 18.00 hours.

From the daily ingested dry weights of various size groups of *T. nilotica* in Lake George, MORIARTY, C. & MORIARTY, D. (1973) calculated a regression equation of $y = 171 + 13.3x$, where y is the daily ingested dry weight, and x is the wet weight of the fish. If this is applied to the mean weight of fish studied here, the calculated amount is 10.82g day^{-1}, while the amount observed was 4.96 g day^{-1}. Thus these fish in Lake Rudolf are ingesting only 45% of the calculated value of *T. nilotica* of the same length in Lake George. While the regression equation may not necessarily be valid for fish of a size outside the range they studied, it covers size group A in the present study. Thus, the dry weight ingested is calculated to be 2.1 g day^{-1}, compared with an observed weight of 1.28g. day^{-1}.

These differences in food intake point to more efficient food turnover by *Tilapia nilotica* in Lake Rudolf.

Assimilation of Ingested Material

MORIARTY, D. & MORIARTY, C. (1973) show 43% of ingested carbon to be assimilated by *T. nilotica* from Lake George. Assuming that carbon constitutes 33% of the dry weight of phytoplankton, then it is calculated that a fish of 130cm. from Lake Rudolf would assimilate 6.0g. C. month^{-1}. From the results of MORIARTY, C. (1973) and FARMER & BEAMISH (1969), it is calculated that this fish needs approximately 2.6g. C. month^{-1} for growth and 2.75g. C. month^{-1} for standard respiration. Thus a balance of 0.65g. C month^{-1} remains available for other energy requirements.

Figures from LOWE-McCONNEL (1958) give a calculated condition factor of 2.1 for *Tilapia nilotica* in Lake Rudolf and 2.04 for *T. nilotica* in Lake George. Calculations from this study, and MORIARTY, C. & MORIARTY, D. (1973) give figures of 2.28 respectively. Thus it appears that *T. nilotica* from Lake Rudolf are of a better condition than eleswhere. A further point is that the length at first maturity of the fish is around 38cm in Lake Rudolf, compared to 22cm (BURGIS *et al.*, 1973) in Lake George.

No direct observations have as yet been made on the growth rate of *Tilapia nilotica* in Lake Rudolf, but the fact that the length at first maturity is high suggests a rapid growth rate. If the growth rate is indeed higher than elsewhere, then this could be the result of the more efficient untilisation of carbon from available food sources.

SUMMARY

Preliminary results from observations on the feeding of *Tilapia nilotica* in Lake Rudolf are presented. The fish exhibit a regular diurnal feeding rhythm, commencing between 05.00 hours and 08.00 hours and ceasing between 14.00 hours and 18.00 hours. The largest fish appear to feed longer.

Quantitative estimates of the daily food intake indicate less material to be ingested than by populations in other lakes.

The lysis of algae, intestinal pH and food material are also investigated.

ACKNOWLEDGEMENT: This work would have been considerably more difficult without the aid of Mr. Joseph Mwangi, Fisheries Assistant with the Fisheries Department, Ministry of Tourism & wildlife, Kenya, who helped with the collection of material and information. Thanks are also due to Mr. James Ogari, Fisheries Officer, for providing much useful information. The manuscript was read and criticised by Dr. A. J. D. Ferguson and Mr. A. J. Hopson (but I persisted), without whose help it would have been largely unintelligible. Mr. R. R. McConnel, Fisheries Development Officer, Lake Rudolf, afforted much advice.

The project is financed jointly by the Fisheries Department, Kenya and the Overseas Development Administration, London (Research Scheme R2392).

Note:

The names of Lake Albert and Lake Edward have been changed to Lake Mobutu Sese Seko and Lake Idi Amin Dada respectively. Their former names are used in the text of this paper solely to facilitate comparisons with earlier references.

REFERENCES

Burgis, M. J., Darlington, J. P. E. C., Dunn, I. G., Ganf, G. G., Gwahaba, J. J. and McGowan, L. M. (1973). The biomass and distribution of organisms in Lake George, Uganda. *Proc. R. Soc. Lond. B.*, *184;* 271–298.

Coe, M. J. (1966). The biology of *Tilapia grahami* Boulenger in Lake Magadi, Kenya. *Acta. Trop. 23;* 147–177.

Daget, J. (1954). Les poissons du Niger supérieur. *Mém. Inst. fr. Afr.* noire, *36;* 341–344.

Dunn, I. G., Burgis, M. J., Ganf, G. G. McGowan, L. M. and Viner, A. B. (1969). Lake George, Uganda: A limnological survey. *Verh. Internat. Verein. Limnol, 17;* 284–288.

Farmer, G. J. and Beamish, F. W. H. (1969). Oxygen consumption of *Tilapia nilotica* in relation to swimming speed and salinity. *J. Fish. Res. Bd. Can. 26;* 2807–2821.

Fish, G. R. (1951). Digestion in *Tilapia esculenta. Nature, Lond., 167;* 900–901.

Fish, G. R. (1955). The food of *Tilapia* in East Africa. *Uganda J., 19;* 85–89.

Fish, G. R. (1960). The comparative activity of some digestive enzymes in the alimentary canal of *Tilapia* and perch. Hydrobiologia, *15;* 161–178.

Fryer, G. and Iles, T. D. (1972). *The cichlid fishes of the great lakes of Africa.* Edinburgh; Oliver and Boyd.

Golterman, H. L. In: Golterman, H. L. and Clymo, R. S. (Eds.) 1969. *Methods for Chemical Analysis of Freshwaters.* I.B.P. handbook, No. 8, Oxford, Blackwell.

Lowe-McConnell, R. H. (1958). Observations on the biology of *Tilapia nilotica* Linne. (Pisces, Cichlidae) in East African waters. *Rev. Zool. Bot. afr., 57;* 129–170.

MORIARTY, C. M. (1973). *Feeding of herbivorous fish in Lake George, Uganda.* M. Phil. Thesis. University of Nottingham.

Moriarty, C. M. and Moriarty, D. J. V. (1973). Quantitative estimation of the daily ingestion of phytoplankton by *Tilapia nilotica* and *Haplochromis nigripinnis* in Lake George, Uganda. *J. Zool., Lond., 171;* 15–24.

Moriarty, D. J. W. (1973). The physiology of digestion of blue-green algae in the cichlid fish, *Tilapia nilotica. J. Zool., Lond., 171;* 25–40.

Moriarty, D. J. W. and Moriarty, C. M. (1973). The assimilation of carbon from phytoplankton by the two herbivorous fishes; *Tilapia nilotica* and *Haplochromis nigripinnis. J. Zool., Lond., 171;* 41–56.

Poll, M. (1939). Exploration du Parc National Albert. Mission H. Damas (1935–36). Fasc. 6. Poissons. *Inst. Parcs Nationaux Congo Belge*, Bruxelles: 30–35 and 62–66.

Talling, J. F. and Talling, I. B. (1965). The chemical composition of African lake waters. *Int. Revue ges. Hydrobiol., 50;* 421–463.

Tesch, F. W., *In:* Ricker, W. E. (ed.). (1968). *Methods* for assessment of fish production in fresh waters. I.B.P. handb. No. 3. Oxford, Blackwell.

Trewavas, E. (1932). Scientific results of the Cambridge expedition to the East African lakes, 1930–31: 11. The Cichlid Fishes. *J. Linn. Soc.* (Zool.), *38;* 309–341.

Viner, A. B. (1969). The chemistry of the water of Lake George, Uganda. *Verh. Internat. Verein. Limnol., 17;* 289–296.

Whitehead, P. J. (1959). Feeding mechanism of *Tilapia nigra. Nature, Lond., 184;* 1509–1510.

Worthington, E. B. (1929). *A report on the fishing survey of Lakes Albert and Kyoga.* Crown Agents, Lond.; 1–136.

Worthington, E. B. (1932). *A report on the fisheries of Uganda.* Crown Agents, Lond.; 1–88.

Worthington, E. B. and Ricardo, C. K. (1936). Scientific results of the Cambridge expedition to the East African lakes, 1930–31. 15: The fish of Lake Rudolf and Lake Baringo. *J. Linn. Soc. (Zool.), 39;* 353–389.