Life history of *Chrysichthys* catfish in Volta Lake, Ghana

by

Chief John Vanderpuye

An Abstract of

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Approved:

In Charge of Major Work

For the Major Department

For the Graduate College

Iowa State University
Ames, Iowa

1979

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Chief John Vanderpuye

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Iowa State University

This study, undertaken during 1974 to 1977 in Volta Lake, investigated the identification, abundance and distribution, reproductive biology and weight-length relationships of four *Chrysichthys* species (*C. auratus*, *C. walkeri*, *C. velifer* and *C. furcatus*). The species were separated on basis of position of the dorsal fin, color of the barbels and the body and shape of the caudal fin and its lobes. Gill rakers also proved of some value.

The Volta Lake, on the Volta River in Ghana, is the largest man-made lake (area: 8,700 km^2). It was dammed in 1964 and reached the maximum controllable level in 1968. The northern narrower arms are of riverine character and the southern section, lacustrine. Water temperatures range between 26.5 to 30.5°C throughout the year. Except in periods of overturn (usually between December to March and June to August), dissolved oxygen is considerably reduced below 10 m. Ampem station, established on one of the main arms of the lake, was sampled monthly (except 9 out of 29 months) with gill nets of graded mesh size, a beach seine, traps (hoop nets) and rotenone. Other stations, in the various sections of the lake, were also sampled occasionally.

In 1965 *Chrysichthys* were relatively abundant near the dam at Akosombo. Sampling in 1970 showed a decline and a more even lakewide

distribution with indications of higher abundance in the southern (more lacustrine) areas. Thereafter, abundance fluctuated seasonally with more fish being caught in the rainy season. *Chrysichthys* were seldom found deeper than 10 m, probably because of low dissolved oxygen concentrations. *Chrysichthys* also were seldom found in higher currents.

Length frequency data did not indicate different year classes or spawning periods but were characterized by single modes which remained fairly constant over a 6-month period.

Spawning *C. walkeri* and *C. auratus* were taken in traps fabricated from bamboo stems. Spawning was in a sheltered bay at depths of 1.0-1.5 m over a firm substrate and egg masses were placed in darkened interior of the bamboo traps. The smallest (standard lengths) spawning males, and females were respectively 76 mm and 82 mm (*C. auratus*) and 82 mm and 72 mm (*C. walkeri*). Males were larger than their mates in 42 of the 43 pairs collected in the bamboo traps.

The number of eggs per female increased linearly with weight for *C. walkeri* and with weight and length for *C. velifer* and linearly with the log lengths of *C. walkeri* and *C. auratus*.

The slopes for functional regressions of log weight on log length did not differ significantly from 3.0 for *C. walkeri* and *C. velifer* but was less than 3.0 for *C. auratus* and *C. furcatus*.

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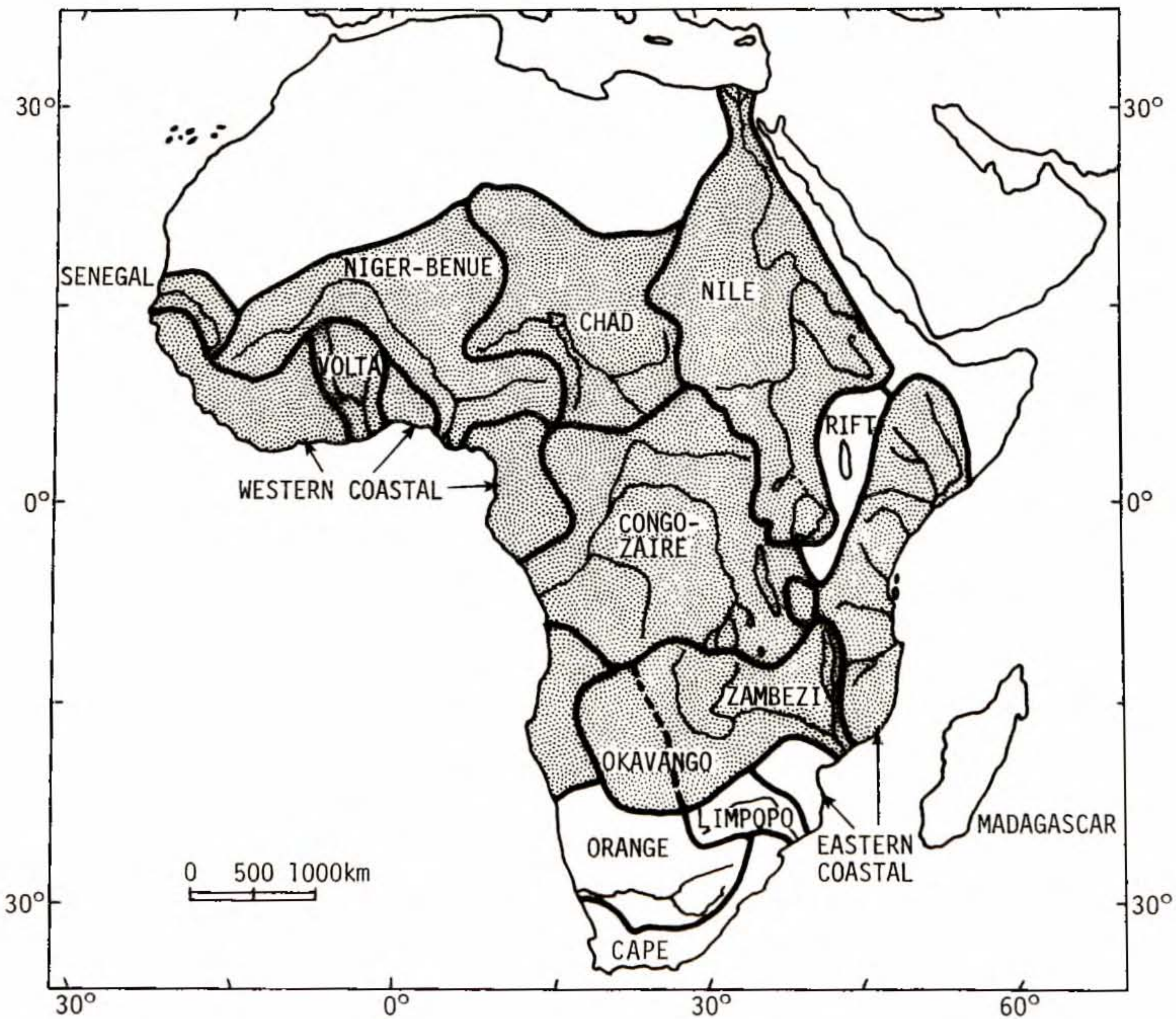
INTRODUCTION

The present study forms part of the research program of the multi-disciplinary Volta Lake Research Project (formed in 1968) which aims at (among other things) the rational exploitation of the fish resources of the lake.

In a multi-species fishery, the efficiency envisaged by Henderson et al. (1973) could be achieved if for each species, harvest could be related to 1) the proportion of the species in the population and 2) the biotic potential of the species. The latter factor in particular, presupposes knowledge of the life history of the species. Unfortunately, this is not available for many Volta Lake species.

Comparison of experimental with commercial catch estimates (Vanderpuye, 1972) in Volta Lake, showed that while certain species (mainly Tilapia spp) were being over-harvested in relation to their apparent proportion in the populations, others were being under-harvested. Chrysichthys fell into the latter group (categorized with 'others'). The present study provides information on some aspects of the life history of the four species to aid in rational exploitation. Aspects covered include: identification, abundance and distribution, reprodictive biology and weight-length relationships.

Chrysichthys catfish (Family: Bagridae) have been reported from practically all the river systems of tropical Africa within latitudes 25°N and 25°S and from Tanzania in the east to Senegal in the west (Jayaram, 1966) (Fig. 1). Within this geographical range, 40 species have been identified (Jayaram, 1955). Four species in Volta Lake are



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ZAMBEZI
OKAVANGO
LIMPOPO
ORANGE
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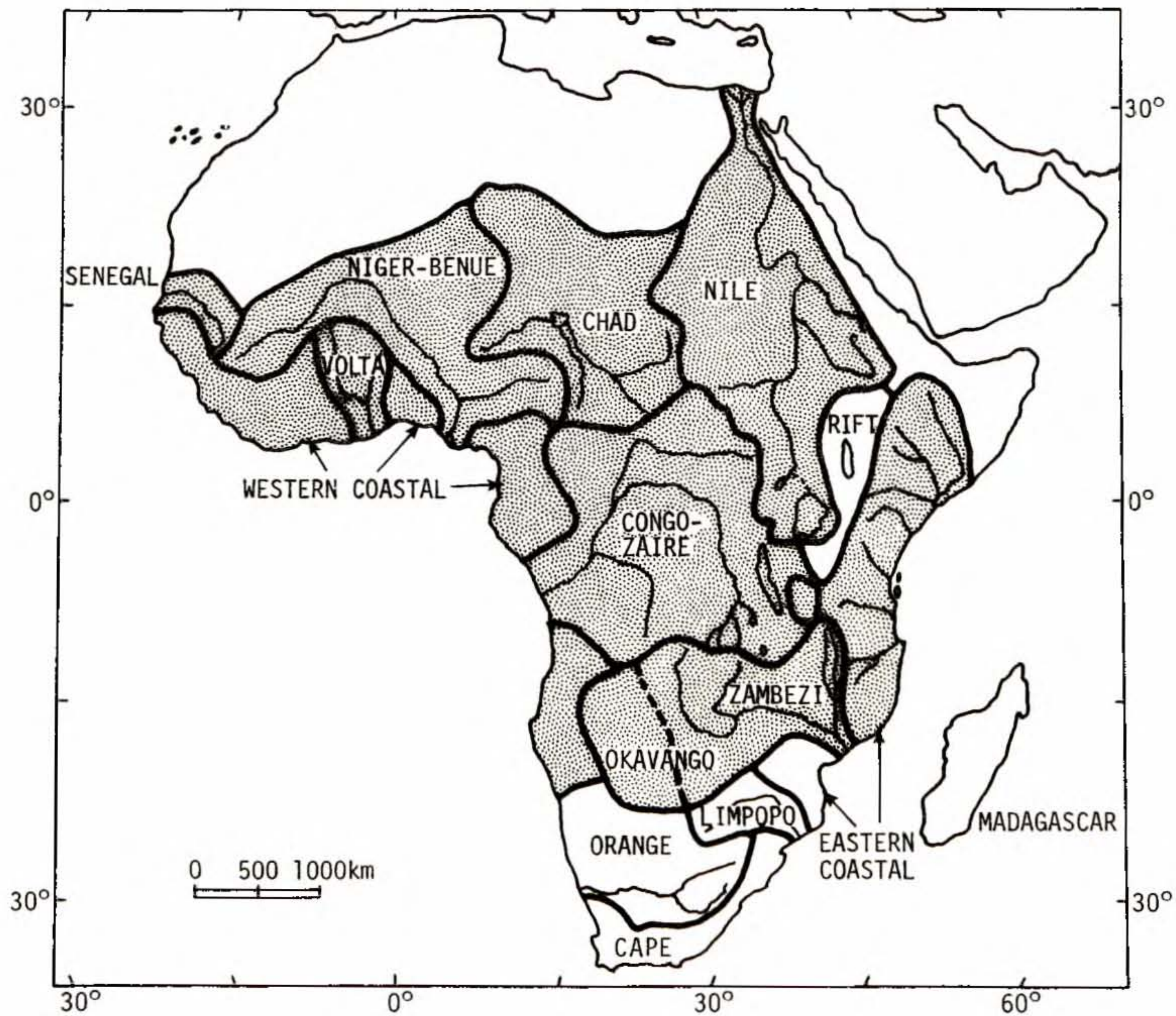
CAPE
0 500 1000km

Fig. 1. Map of Africa showing river basins with those, in which *Chrysichthys* have been recorded, stippled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CAPE
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C. velifer (Norman), C. auratus (Geoffroy Saint-Hilaire), C. walkeri (Gunther) and C. furcatus (Gunther). Most species of Chrysichthys are found in freshwaters but a few occur in both fresh and brackish waters of coastal lagoons (Chauvet, 1972). In many West African countries, Chrysichthys spp support thriving commercial fisheries (Chauvet, 1972; Ikusemiju and Olaniyan, 1977).

The importance of the genus has been overshadowed by Tilapia, which has been the subject of considerably more research and study. The bibliography of African freshwater fish, published by the Food and Agriculture Organization (FAO) of the United Nations (Matthes, 1973), lists 360 references under Tilapia and only 3 for Chrysichthys. None of these references has any bearing on the biology of the latter. More recently, some aspects of the biology of C. walkeri, C. nigrodigitatus and C. filamentosus in Lekki Lagoon, Nigeria (Ikusemiju, 1976 ; Ikusemiju and Olaniyan, 1977) and age and growth of C. nigrodigitatus in Ebrie Lagoon, Ivory Coast (Dia, 1975) have been published.

C. nigrodigitatus and C. walkeri are among 25 fish species considered by the FAO sponsored Committee on Inland Fisheries of Africa to be of high interest for future of fish culture in Africa (Micha and Frank, 1975). In Nigeria, where experiments on breeding of C. nigrodigitatus were in progress, no break-through had been recorded in spawning of C. nigrodigitatus in captivity via natural or artificial means (B. Ezenwa, Nigerian Institute for Oceanography and Marine Research, Lagos; personal communication, August, 1977). This may be attributed to lack of sufficient knowledge on the biology of the species.

Alestes baremose was dominant in the fish population when the lake was first filling (1964), but Chrysichthys became dominant during the next year (Petr, 1967). The percentage occurrence of Chrysichthys rose from 21.7% in January, 1965, to 79.7% in July, and fell again to 36.9% in August (Wuddah, 1967). Thereafter, the genus has maintained a lower status of abundance in the fish population. The reason for this sudden rise and decline is not clear. Ewer (1966) reported that deoxygenation during early stages of impoundment led to the death of a variety of fishes prominent among which were Chrysichthys. Loiselle (1972) who sampled 23 littoral stations (depth less than 1.5 m) scattered around the lakeshore, stated that C. auratus and C. velifer comprised 7.5% and 18.3%, respectively, of the littoral ichthyomass. C. velifer was the species with the highest ichthyomass, outstripping Sarotherodon niloticus (Tilapia nilotica) which ranked second with 13%.

Lewis (1974) found an increase in the catch of Bagridae (comprised mostly of Chrysichthys) relative to the catches of other families after the formation of the Kainji Reservoir, Nigeria. Lelek (1973) classified Chrysichthys as of occasional occurrence in Kainji Reservoir and showed that it had followed the usual pattern of sudden rise and later decline in abundance which has been demonstrated for many fish species following impoundment. During the filling of the Kossou Reservoir (less than 500 km from the Volta Lake), Roest (1973) recorded that C. velifer was the second most abundant species in the reservoir, following Alestes baremose.

Presently, there is little emphasis on a Chrysichthys fishery in Volta Lake because of small size of the fish (apparently stunted) and their comparative low vulnerability to gill net capture. At my main sampling station of Ampem, however, fishermen nightly dragged small-meshed seines along the shore and used the catches (usually juveniles) as bait for *Lates niloticus*.

The identification of *Chrysichthys* spp has always been difficult (Jayaram, 1955; Daget and Iltis, 1965; Micha and Frank, 1975). During the initial stages (1968-69) of the Volta Lake Research Project (VLRP) only *C. walkeri* and *C. nigrodigitatus* were recognized. The single criterion used for separating these two species was the shape of the head. *C. walkeri* was considered to have a broader head than *C. nigrodigitatus*. Loiselle (1972), who had worked in other water bodies in West Africa before joining the VLRP in 1969, pointed out that *C. velifer* was being misidentified as *C. nigrodigitatus*. The latter, he contended, was an estuarine species which did not exist in the Volta Lake. Moreover, *C. walkeri* was made up of *C. walkeri* and *C. auratus*. A fourth species, *C. furcatus*, was also present but rare.

During the present study, specimens were sent to Dr. Thys van den Audenaerfe of the Musée Royal de l'Afrique Centrale, Tervuren, Belgium, for confirmation of the identification of the species. In a personal communication (December, 1974), Dr. Thys stated that local, geographical and size- or sex-linked variation of these fishes are unknown, undescribed, or badly described. In his opinion, the whole genus is in need of a detailed revision. Notwithstanding this view, I have followed Loiselle's identifications. What seems unresolved, is the difference between *C. velifer* and *C. nigrodigitatus*. Since *C. nigrodigitatus* is apparently not present in Volta Lake, there was no opportunity to make comparison. After acknowledging difficulties inherent in identification of *Chrysichthys* spp., Micha and Frank (1975) stated that in Kossou Reservoir, one can distinguish between *C. nigrodigitatus* and *C. velifer* by examining the dorsal fin which reaches the base of the adipose in *C. nigrodigitatus*. In a personal communication (April, 1977) however, Frank could not confirm this fact.

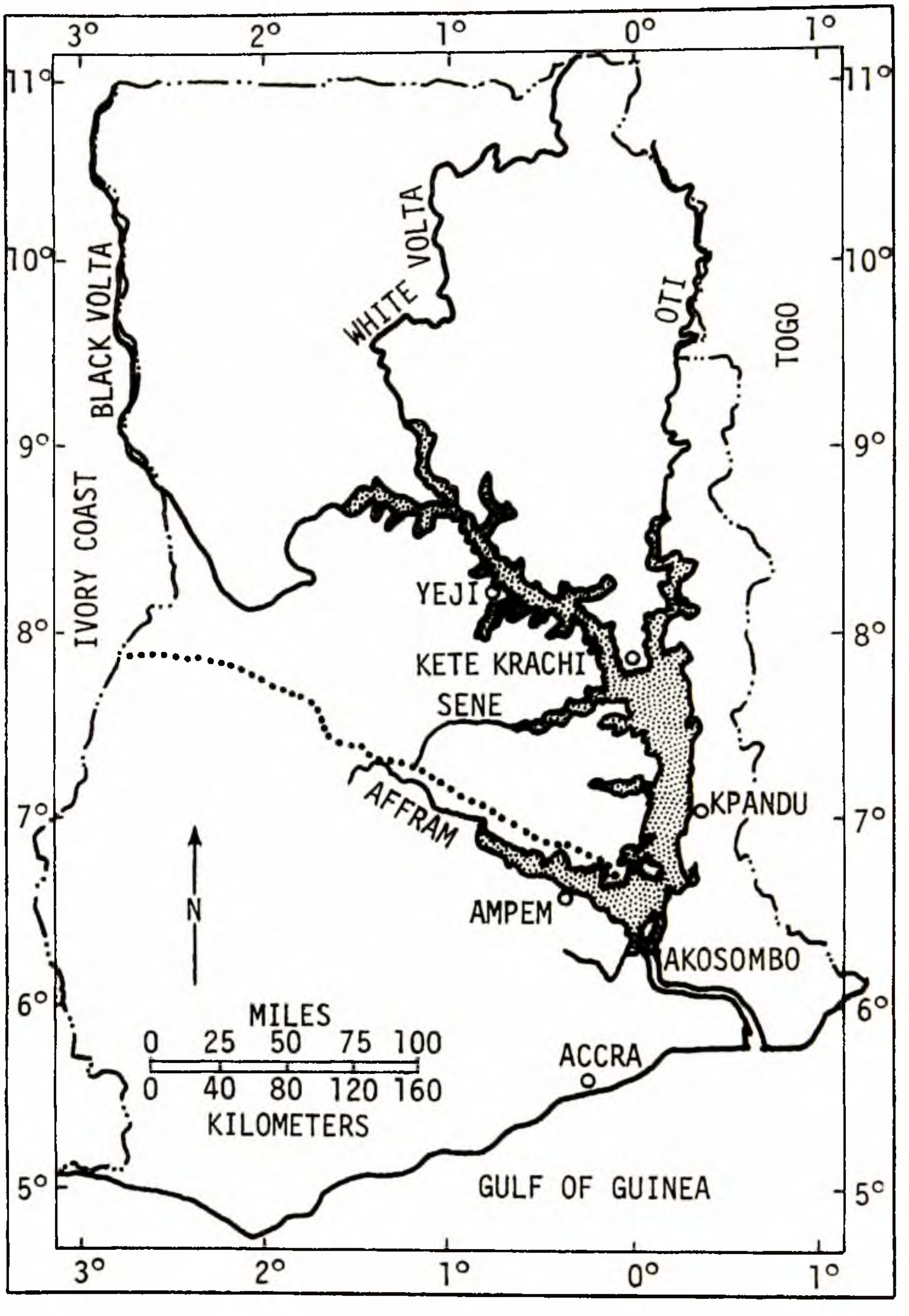
The Volta Lake

With a surface area of about 8,700 km^2, the Volta Lake, located on the Volta River, is the largest man-made lake in the world (Fig. 2). It covers about 4% of the total surface area of Ghana and lies between longitudes $1^o30'$W and $0^o20'$E and latitudes $6^o15'$N and $9^o10'$N at an altitude of 85 m above sea level when full. Other morphological data are as follows (Czernin-Chudenitz, 1971):

Total length	400 km
Maximum width	23.8 km
Average width	6.9 km
Maximum depth	75 m
Average depth	18.8 m
Total shoreline (including islands)	5,300 km
Volume	164.8 km^3
Shore development	16.0

The relationship of depth to surface area and volume follows:

Fig. 2. Map of Ghana showing position of Volta Lake



••••••••• Boundary between northern savanna and southern tropical forest.

Water depth	Area		Volume	
m	km^2	%	km^3	%
0 - 9.14	2,810	32.20	66.464	40.3
9.14 - 25.0	3,367	38.58	64.052	38.9
25.0 - 40.3	1,703	19.50	25.709	15.6
40.3 - 55.4	705	8.08	7.500	4.5
55.4 plus	143	1.64	1.083	0.7

Thus it is a moderately shallow lake with extensive shoreline and shallow margin. Such a morphometry should be conducive to rapid mineral recycling with attendant high fish production. Unfortunately, no detailed study has been done on this aspect of the lake's limnology. A review of the available data on the mineral cycling in the lake and below the dam by Livingstone (1974), however, led to the conclusion that the lake was oligotrophic.

Three sections of the lake are distinguished (Czernin-Chudenitz, 1971):

(a) The northern part is influenced mainly by the Black Volta and consequently is of riverine character. Surface and bottom temperatures are equal all year round and current is quite perceptible, especially during the rainy season. Oxygen is present in sufficient quantities (40% saturation) to support fish life clear to the bottom. (Areas 5, 6, 7, and 8, referred to later, comprise this northern part, Fig. 6).

(b) The southern part is of truly lacustrine character. Although the temperature gradient is always very slight (except in the surface layers) stratification could be observed with a metalimnion at a depth of 25 - 35 m (Areas 2, 3, and 4).

(c) The inundated river arms are generally similar to the main lake. The upper reaches assume a riverine character while the lower parts grade into the lacustrine main body of the lake (Area 1).

In the deeper layers the warmest temperature was 27.8°C and the coldest 25.7°C. More extreme temperatures were found in bays. The highest recorded was 33.6°C in shallow water within Pistia beds.

Turbidity is greatest in the northern sector of the lake during the rainy season when the large tributaries (the White and Black Voltas and the Oti) discharge turbid waters into the lake. Turbidity generally decreases towards the south. For example: in August 1968 (a month of moderate rains), Czernin-Chudenitz (1971) recorded 30, 45, 230, 220, and 270 cm transparency during a north to south transect sampling.

The main water body lies in the Guinea savanna climatic zone with a precipitation of 890 - 1520 mm per annum (Boateng, 1967). The extreme southern part falls in the zone with more rainfall, and with June being the wettest month. Another smaller peak of rainfall occurs in September and October. There is a tendency towards a reduction of the June peak and an emergence of one peak in September as one progresses from south to north. Rainfall is the single most influential environmental factor on the hydrobiology of the lake and consequently, on the ecology of the fishes. During the rainy season (1) the temperature is lowered resulting in thermal overturn, (2) surface dissolved oxygen concentration declines (a result of the mixing), (3) nutrients are recycled to the surface from the bottom and (4) nutrients are washed into the lake and tributaries by run-offs.

Aquatic plants grow luxuriantly along much of the lake's margin to a depth of ca. 3 m. Hall et al. (1971) discerned three zones in the drawdown vegetation. These are:

(1) Sedge zone: dominated by Cyperus spp, Fimbristylis spp, and Ludwigia spp.

(2) Perennial grass/Polygonum zone: made up mostly of Vossia cuspidata, Polygonum senegalense, Echinochloa spp, Brachiaria mutica, and Leptochloa caerulescens. They also observed that the larvae of Povilla, an important fish food, live in the hollow stems of Polygonum and Vossia.

(3) Annual forb zone: dominated by Indigofera spp, Tephrosia spp, Imperata cylindrica, and Schizachyrium sanguineum.

Pierce (1971) reported that aquatic plants which were common in certain areas included: Ceratophyllum demersum, Pistia stratiotes, Lemna sp, Salvinia nymphellula, and Ultricularia inflexa.

With the exception of Distichodus rostratus and Alestes spp, Volta Lake fishes do not feed on the aquatic weeds (Lawson et al., 1969). The plants, however, form substrates for aquatic invertebrates which serve as important food for fish.

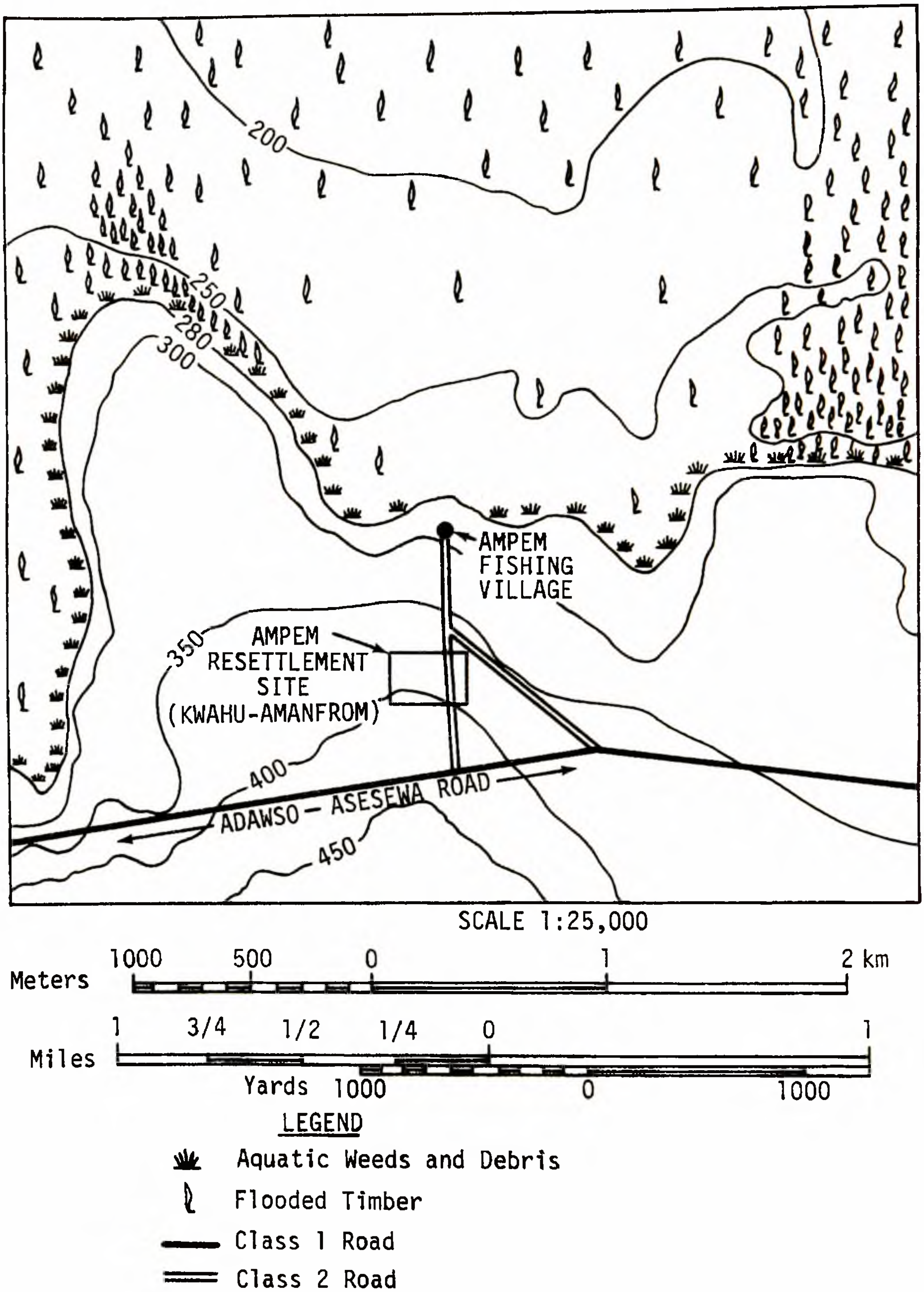
Except for 3 or 4 experimental areas of a few hectares located on the Affram arm (Area 1), the basin was not cleared of timber and brush before flooding. The resultant flooded vegetation has contributed considerably to the ecology of the lake environment and the nature of the fishery. Two important consequences have been that (1) the biomass of periphyton has exceeded by many times, the biomass of benthos (Petr, 1969), and (2) fishing gear is limited to the stationary type.

Main Study Area

The main study area (Fig. 3) was that section of the lake within about 5 miles of the village of Ampem, located on the southern shore of the Affram arm (Area 1). As operational base for field studies, Ampem has the following advantages: (1) it is an important road-head which is accessible throughout the year; (2) it is only about 50 km from VLRP headquarters at Akosombo; (3) it is an important fishing village and lakeside market which meant that experimental fish catch data could be checked closely with those of the commercial fishermen; (4) the VLRP has lodging facilities at the village; (5) the littoral zone is among a few areas along the Affram arm which were cleared of vegetation before flooding, thus facilitating the use of beach seine for sampling; and (6) Loiselle's study on the inshore fauna of the lake indicated that populations of Chrysichthys in the Affram arm, as a whole, might be higher than the average for the lake.

Unlike the rest of the lake, which is located in Guinea savanna vegetative zone, the Affram arm is located in a moist semi-deciduous forest with some trees reaching heights of over 60 m (Boateng, 1967).

Fig. 3. Map of Ampem Station showing contours (in feet) above sea level (the 280 ft. contour represents the shoreline when the lake is full)


200
250
280
300
350
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450
AMPEM
FISHING
VILLAGE
AMPEM
RESETTLEMENT
SITE
(KWAHU-AMANFROM)
ADAWSO — ASESEWA ROAD
SCALE 1:25,000
Meters
1000 500 0 1 2 km
Miles
1 3/4 1/2 1/4 0 1
Yards 1000 0 1000
LEGEND
Aquatic Weeds and Debris
Flooded Timber
Class 1 Road
Class 2 Road

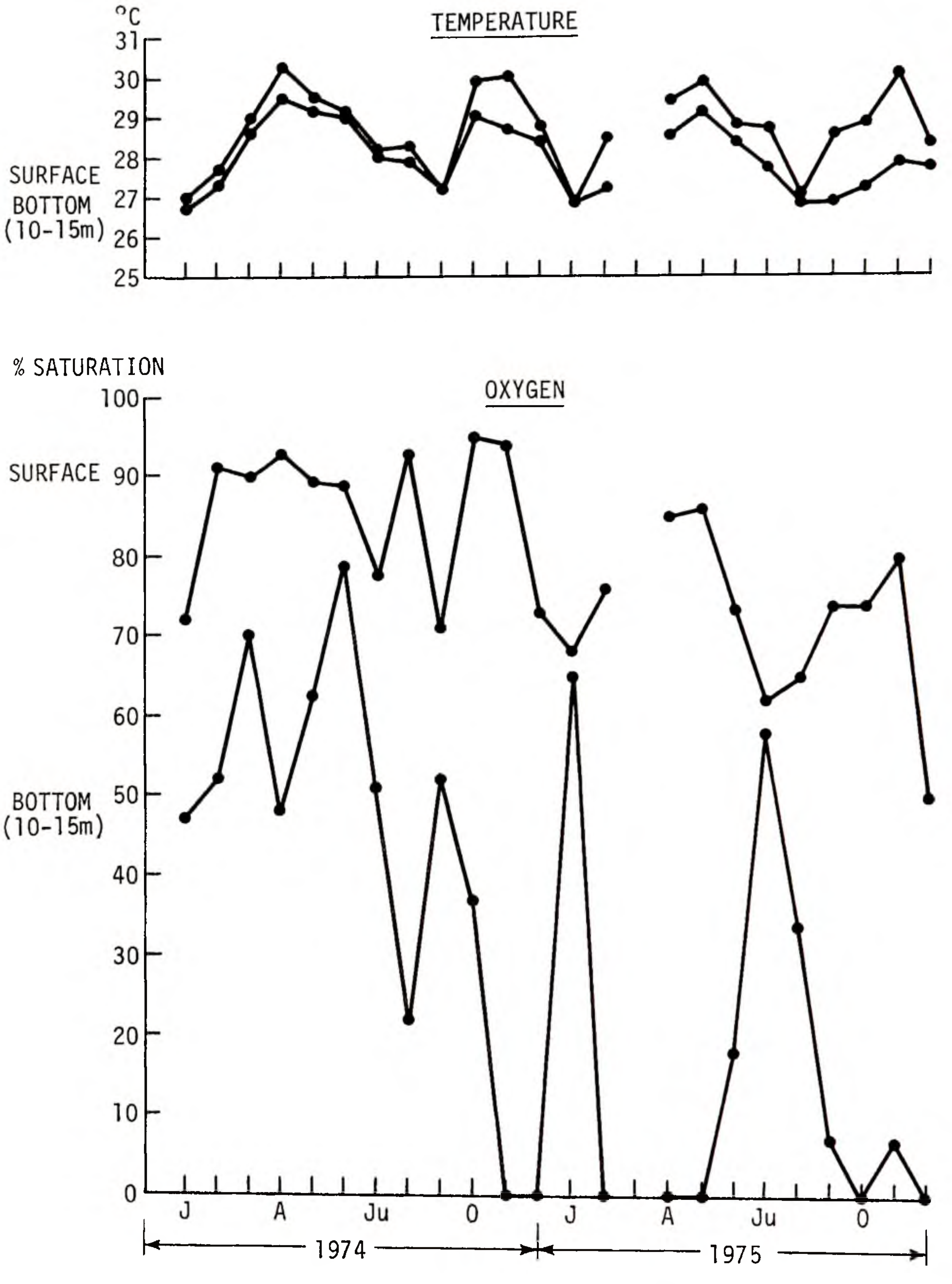
Much of this type of forest was drowned during the formation of the lake. Though many softwood trees have been felled by the burrowing activities of beetles, many hardwood species still stand with their bare dried tops reaching out 20 - 30 m above the water surface. The shore is gently sloping back to the hills about 5 km from the lake.

The Affram area is well known for its frequent algal blooms. This may indicate that this shallow basin is richer in nutrients than the other arms.

Biswas (1972) showed a positive correlation between dissolved oxygen and phytoplankton in Volta Lake. Thus dissolved oxygen concentration in the Affram may be higher than the average for the lake. Czernin-Chudenitz (1971) stated that at the Affram confluence area, he observed a sharp drop in dissolved oxygen between 20 and 30 m, varying according to the location of the thermocline. Oxygen rich water, however, penetrated to a depth of 40 m twice in one year: in June, 1969 and December, 1969-February, 1970.

At the Ampem station in 1974 and 1975, dissolved oxygen in surface waters was between 70 and 95% saturation except for January, June, July, and December 1975 (Fig. 4) but became depleted in the bottom waters. Water temperatures were from 26.6 to 30.0^{o}C and were always higher at the surface than the bottom. During August 1974, January and July 1975, the difference between surface and bottom dissolved oxygen was considerably reduced. The difference during the last two months was so small that overturn was apparent. This pattern is similar to the seasonal pattern observed for the whole lake. As explained by Czernin-Chudenitz

Fig. 4. Surface and bottom temperatures and dissolved oxygen at Ampem, January 1974 to December 1975 (data from Limnology Section of Volta Lake)


°C
TEMPERATURE
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29
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SURFACE
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% SATURATION
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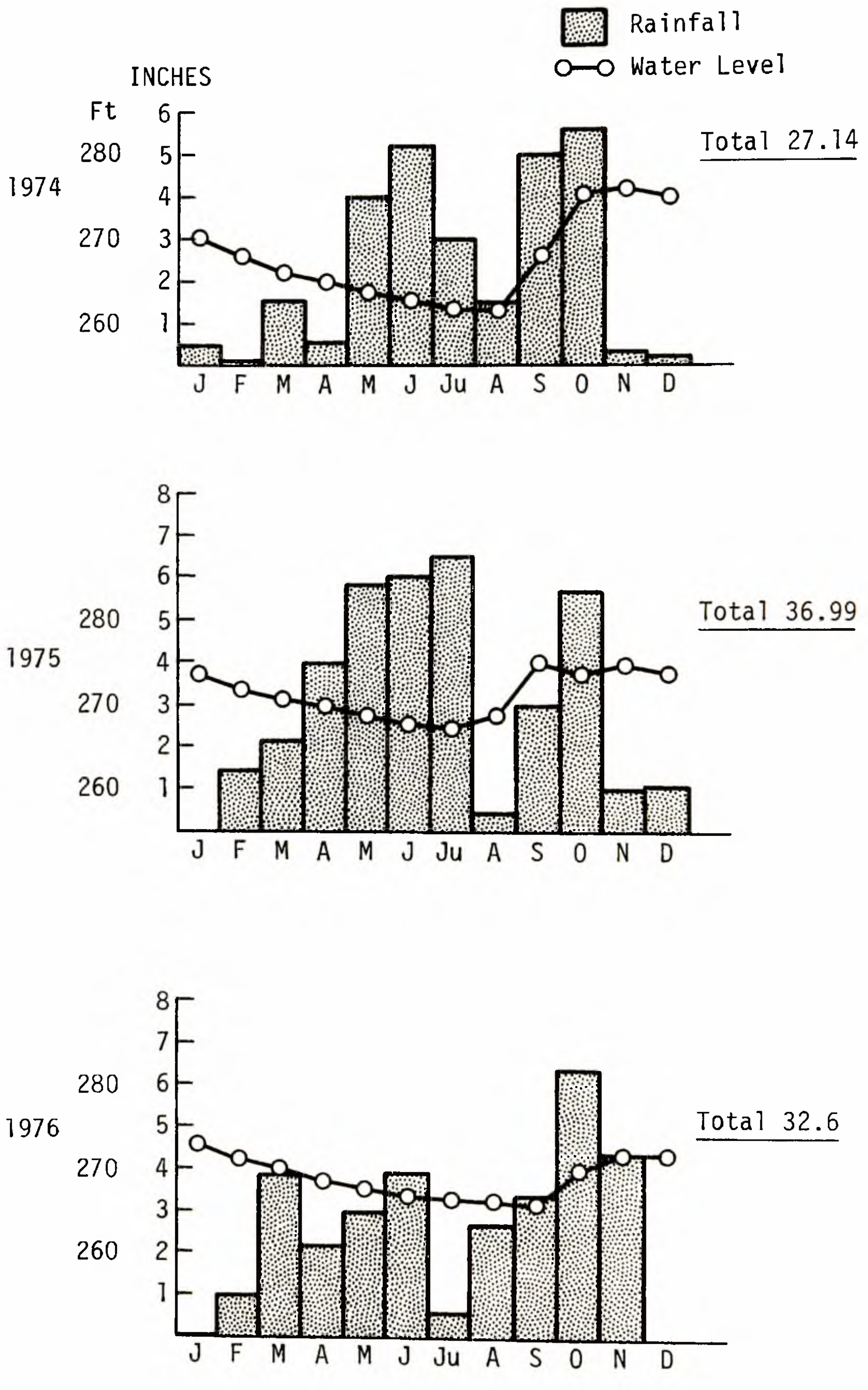
(1971), the two overturns result from the effect of dry and cold north-east trade winds which blow over the lake during December to March and from floods during June to August. Because of these two overturns and their effect on the hydrobiology and fisheries of the lake, the VLRP prefers to separate the year into the following quarters: December - February, March - May, June - August, September - November. The same quarters have been used in the present study.

Rainfall and water level during January 1974 to December 1976 were obtained from Ghana Meteorological Services and the Volta River Authority, respectively (Fig. 5). Two peaks of rainfall in a year were recorded: one in June - July and the other in October. Total rainfall for the period averaged 790 mm per annum. Lowest water levels were in July - September (a period of low rains) and the peaks in November - December (a period of declining rains). The continued drop in water levels from May through July when much of the rainfall came indicates that the water levels in the arm are more controlled by rainfall in other parts of the lake's watershed than by the rainfall in the Ampem area.

The Affram arm has more than its share of aquatic plants owing to the comparatively high nutrient concentration in this section of the lake. The submerged aquatic plant, Ceratophyllum demersum is well established in inshore waters. At certain localities at Ampem, thick beds of this plant rendered the operation of seines ineffective. The commonest emergent semi-aquatic plant is Polygonum senegalense which often occurred in thick stands. Other aquatic plants included Ludwigia

Fig. 5. Ampem Station--Monthly rainfall and water level, 1974-1976



Rainfall
Water Level
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Ft
1974
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270
260
6
5
4
3
2
1
Total 27.14
J F M A M J Ju A S O N D
1975
280
270
260
8
7
6
5
4
3
2
1
Total 36.99
J F M A M J Ju A S O N D
1976
280
270
260
8
7
6
5
4
3
2
1
Total 32.6
J F M A M J Ju A S O N D

stolonifera, Alteranthera sessilis, Pistia stratiotes, Echinocloa spp and Cyperus spp.

Many fallen trees littered the shallow water area in which the hoop nets were set. These trees had been pitted by beetles and the resultant burrows were inhabited by nymphs of the mayfly, Povilla adusta.

Bottom types at this station were silty-sand at the shore and clayey clumps in deeper water.

A station at the village of Suborni (about 5 km from Ampem) was also occasionally sampled to determine bottom type preference of Chrysichthys. This station has a sharper sloping shore than that of Ampem. Sparse vegetation was observed growing in depressions and crevices of rocks which dominated the shore landscape.

The Fishery

The construction of the dam at Akosombo was completed in May 1964 and the water reached the maximum controllable level in 1968. Stock assessment studies (Evans and Vanderpuye, 1973) and quarterly commercial catch estimates (Bazigos, 1971) started in 1968 and 1969, respectively. Results of these studies suggest that the fish populations reached their peak in abundance in the quarter, August to October, 1969, when the total commercial catch was estimated at 22,900 m tons. Catches dropped steadily through the three subsequent quarters. The estimated catch for May to July 1970, was 9,600 m tons. During the following quarter (August to October 1970), catch rose again to 11,300 m tons which was about half the magnitude of that of the previous year's peak. Thereafter, through July 1975, the quarterly catches fluctuated within the range 11,800 to 7,500 m tons with higher catches in the rainy season and lower catches in the dry season. The yearly catches indicated a minor downward trend from 1970 (39,000 m tons) to 1973 (35,000 m tons). Estimated catches for 1974 and 1975 were 37,000 and 42,000 m tons respectively.

While the total catch seems to have more or less levelled, comparison between 1970 and 1975 effort statistics (Coppola and Agadzi, 1976; catch assessment, unpublished data) show the following changes:

	1970	1975	% increase
Total number of fishing sites	883	1,479	67.5
Total number of fishermen	18,557	20,615	11.1
Total number of canoes	10,664	15,214	42.7

Thus all 3 indices of effort increased during the period meaning a decreased catch per unit of effort. An available figure for August to October 1972 (catch assessment; unpublished data) was 8.73 kg/fisherman/day.

In 1971, comparison of catch per unit effort in Lakes Nasser (Egypt), Kainji (Nigeria), Kariba (Zambia), and Volta (Ghana) showed catch in Volta to be the lowest (Regier, 1972). This observation was further confirmed when the Morpho-Edaphic Index (MEI) model of Regier et al. (1971) was used to calculate the potential catch. This model essentially predicts the total annual catch from Ryder's (1965) MEI, (that is, the total dissolved solids in mg/l (TDS)/mean depth in m) for a set of African Lakes. With a mean depth of 18.8 m (Czernin-Chudeintz, 1971) TDS of 70 mg/l (Welcomme, 1972), the calculated MEI for Volta Lake is

3.72. This value gave a predictive yield of 25 kg/ha/yr when intrapolated in the above model. The estimated actual yield, however, was 42 kg/ha (Bazigos, 1971). This indicates that the present catch is rather high and may probably be near the upper limit. Thus the fishery might have reached stage 3 (intense stage) of Henderson *et al.* (1973). They suggest that at this stage "development objectives must necessarily shift to maintaining the maximal yield and to improving efficiency rather than increasing catches".

Prior Studies on the Fish Species in Volta Lake

Major work on the fish species has centered on the distribution, abundance, and composition changes. The only known pre-impoundment studies were by Trewavas and Irvine (1947) and Roberts (1967). Their efforts resulted in the listing of 110 species for the Volta basin. From October 1964 (5 months after the lake had started filling) to August 1966 the Fisheries Department fished a battery (or gang) of experimental gill nets near the dam at Akosombo. Denyoh (1969) listed the order of their relative abundance as follows: *Clarias senegalensis*, *Clarias laeviceps*, *Ctenopoma kingsleyae*, *Alestes dentex*, *Alestes nurse*, *Alestes macrolepidotus*, *Schilbe mystus*, *Synodontis schall*, *Synodontis nigrita*, *Synodontis membranaceous*, *Synodontis obesus*, *Labeo coubie*, *Labeo senegalensis*, *Labeo chariensis*, *Labeo brachypoma*, *Chrysichthys nigrodigitatus* (really *C. velifer*), *Chrysichthys walkeri*, *Hydrocyon lineatus*, *Hydrocyon brevis*, and *Hydrocyon forskali*. Forty other species of lesser importance were also recorded. The catch data which he tabulated, however, did not agree with this sequence but rather, largely, with Wuddah (1967) who shows that from November 1965 - August 1966, Chrysichthys was the most abundant genus in experimental gill net catches.

Petr (1967; 1968b) and Petr and Reynolds (1969) showed that in the riverine condition, the bulk of the population consisted of mormyrids, characids, mochokids, and schilbeids and that during the first two years, many of these families (especially Mormyridae), completely disappeared while Tilapia (including Sarotherodon) became common in some parts of the lake. Later, there was (a) a decrease in number of Alestes baremose and an increase in Eutropius and Cynothrissa in Area 7; (b) an almost complete absence of Citharinus in Area 4 and (c) an increase in numbers of Tilapia in fish catches in Areas 6 and 7. Loiselle's (1972) studies on the fauna in inshore habitats revealed that Chrysichthys velifer had the highest biomass accounting for 18.3% of the littoral ichthyomass. Sarotherodon niloticus was second (13.9%) and C. auratus third (7.5%). As shown by Vanderpuye (1973), the clupeids (Cynothrissa mento and Pellonula afzeliusi) accounted for 23% by weight of the experimental gill-net catches for the period 1969 to 1973. Evans and Vanderpuye (1973) described the early development of the fish populations and fisheries of the Volta Lake.

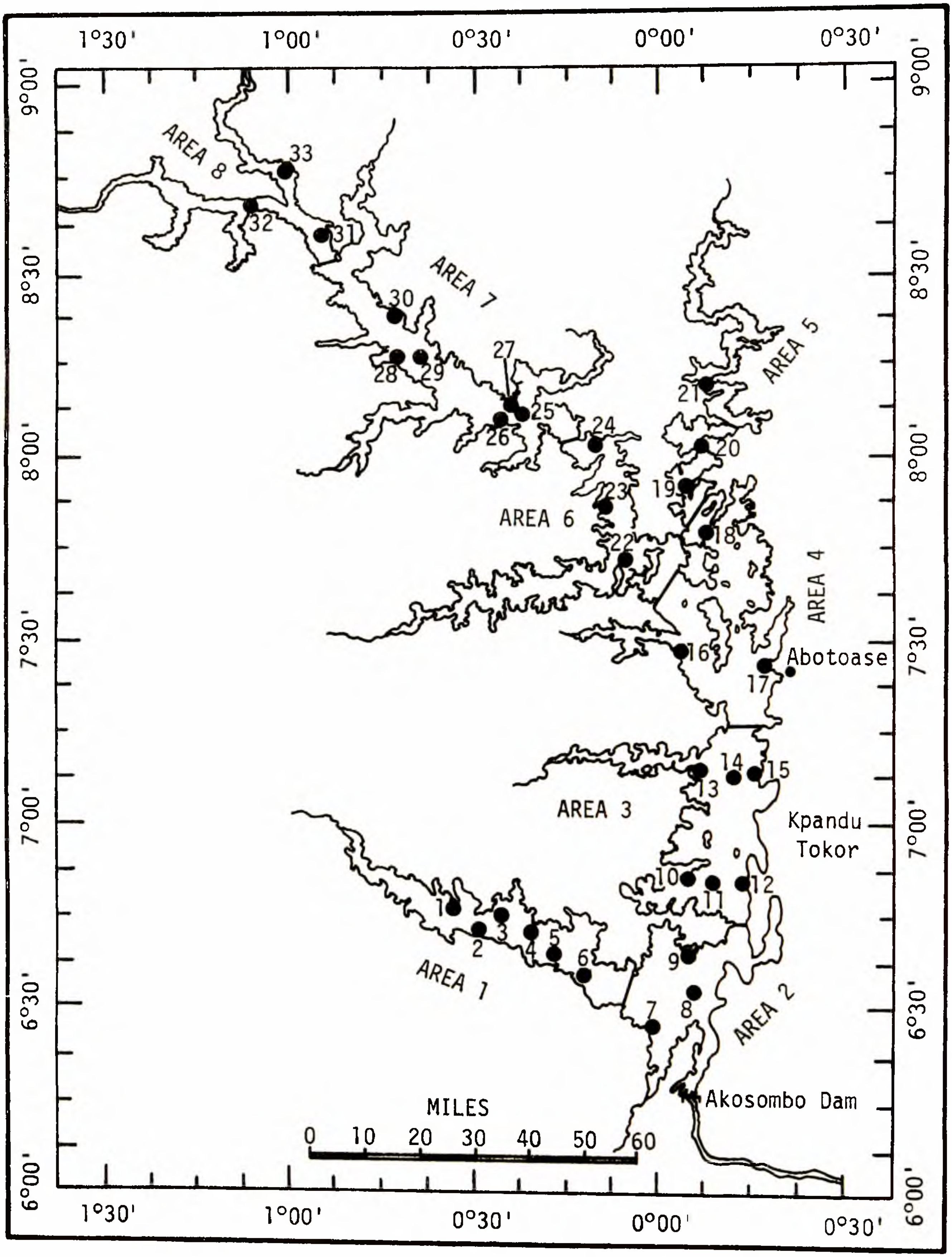
Work accomplished in the field of fish biology includes food preference of Mormyridae and Characidae in the Black Volta River and the Volta Lake (Petr, 1968a; 1974); reproductive biology of Tilapia species (Wuddah, 1967); food habits of some juvenile fish (Whitehead, 1969); feeding, migration and schooling of small pelagic fishes (Reynolds, 1970; 1971), and reproductive biology and food habits of four species of Alestes (Reynolds, 1973).

MATERIALS AND METHODS

Data on the distribution and abundance of Chrysichthys in Volta Lake were collected as part of the stock assessment program during the period May 1969 - October 1973. The selection of the sampling stations was based on eight geographical areas (also called strata) into which the lake had been divided, mainly for catch assessment purposes. In each of areas 1, 2, 4, 5, 6 and 8, three sampling stations were established: one in deep or open water and two inshore on opposite shores; in areas 3 and 7, the former representing the riverine north and the latter, lacustrine south, the number of stations were 6 (4 inshore and 2 offshore). This was designed to increase the precision of the estimate of the catch per station for these areas (Fig. 6). Sampling was solely by three batteries of gill nets of graded mesh sizes. Each battery was made up of 15 nets of mesh sizes from 13 to 205 mm (stretched mesh) at increments of 12.5 mm (.5 inch). While all nets were 30 m in length, depth was in 3 categories: 1.5, 3.0, and 9.1 m. Nets were set at about 18:00 h and lifted the following day at about 06:00 h. During recovery, notes were made of the vertical section of the net in which a fish was gilled. This was either top, middle or bottom. Length, weight, sex, and degree of maturity were recorded for each fish captured, except when the numbers were large and only a portion of the catch was sampled.

A separate sampling program, initiated in May 1974 and ended August 1977 (Table A-1) was directed toward the study of the life history of Chrysichthys spp in Volta Lake. After evaluating difficulties inherent in the

Fig. 6. Map - Sampling stations



1°30'
1°00'
0°30'
0°00'
0°30'
9°00'
8°30'
8°00'
7°30'
7°00'
6°30'
6°00'
AREA 8
AREA 7
AREA 6
AREA 5
AREA 4
AREA 3
AREA 2
AREA 1
Abotoase
Kpandu
Tokor
Akosombo Dam
MILES
0 10 20 30 40 50 60
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33

Table 1. List of sampling stations: all except 1, 5 and 6 were sampling stations in the stock sampling program (Index to numerals on Fig. 6)

Station	Area	Station	Area
1. Abochire	1	18. Azizakpoe	4
2. Adawso	1	19. Kpetsu	5
3. Suborni Junction	1	20. Dumbai	5
4. Kwame Jamara	1	21. Lidza	5
5. Ampem	1	22. Nsunua	6
6. Adidokpoe	1	23. Manoayikpo	6
7. Asekoko	2	24. Boafori	6
8. Dodi Island	2	25. Adormiabra	7
9. Worhekope	2	26. Lanto	7
10. Khoga	3	27. Awusakope	7
11. Khoga Offshore	3	28. Accra Town	7
12. Agornyomi	3	29. South East Yeji	7
13. Tsikpor	3	30. Awoyovikope	7
14. Mangoase Offshore	3	31. Aklor No. 1	8
15. Mangoase	3	32. Black Volta	8
16. Zikpo	4	33. White Volta	8
17. Breniassi	4		

sampling of a body of water of the magnitude of Volta Lake, I decided to make Ampem my main sampling station. Originally, this station was to be sampled for a period of 5 - 6 days in each month. It was expected that such a schedule would adequately monitor biological activities. A sampling circuit of the stock assessment stations was also to be undertaken biannually to monitor the relation of the Ampem study to the whole lake. Owing to logistic problems, however, such an ideal program could not be adhered to. This was especially so during those months when the other stations were sampled. Thus there were 9 out of 29 months (May 1974 - September 1976) when the Ampem station could not be sampled. From July 1976 to August 1977, a number of field trips with special objectives were undertaken. Some of these were: 1) collection of benthic samples; 2) search for breeding grounds of *Chrysichthys*; and 3) trial capture of *Chrysichthys* with bamboo traps.

To circumvent problems inherent in gear selectivity, the fish populations were sampled with a gang of gill nets of graded mesh size, a beach seine, traps (hoop nets), and rotenone.

The mesh size of the gill nets ranged from 13 - 86 mm (stretched mesh) at 12.5 mm intervals. There were 2 sets of this mesh size range: one was 3 m deep and the other 10 m deep. Each gill net was 30 m long. In inshore areas, effort was made to set these nets in waters equivalent to their depth. In offshore areas, the 10 m deep nets sampled the surface while the 3 m deep nets sampled the bottom. Nets were always set in the evening and recovered in the morning.

The overall length of the beach seine was 80 m. The length of the bag was 9.1 m. The opening of the bag was 20 m long and 6.6 m deep. The meshes in the bag were 36 and 40 mm, and in the wings, 40 mm. The dragging of the seine started from a depth of about 10 m, although this was not measured; on the average 6 hauls were made during a 5-day period. Hauls were either in the morning or evening or both morning and evening depending on the objectives in view at the time of sampling. Owing to under water obstacles (mainly plant debris and clay clumps), the beach seine was not always successfully operated.

The hoop nets were 8 in number. The stretched length of a net was 2.64 m. There were 6 hoops in a net. The largest hoop measured 80 cm in diameter and the smallest, 50 cm. The single lead was 20 m long. The traps were set in such a way that the lead of one touched the first hoop of another thus forming a barrier. For some time the leads were set parallel to the shore with the traps in alternately opposite directions to monitor the direction of movement of *Chrysichthys* in the night.

Rotenone was used in inshore areas, at depths usually less than 1 m. As a result of prior experiments (Loiselle, 1972), it was not administered in dosages recommended by the manufacturers but rather in litre units. Before the application of the chemical, the sample area was blocked off with a 25 mm mesh net. It is believed that complete kill was effected owing to the higher than normal concentrations used. Recovery of killed and dazed fish continued over a 24 h period.

Captured fish were always measured and both standard length and total length (from the anteriormost extremity to the end of the longer lobe of the tail fin) were recorded. The fish were then weighed. In cases of occasional heavy catches, either a random sample or a stratified subsample was taken and the rest counted and weighed. Depending on the size of the catch either all or a sample was sexed. A fish was sexed by cutting open the abdomen and examining the gonads.

The following categories of sexual maturity stages were utilized during the early part of the study.

Female:

1. Immature. No individual eggs clearly visible. Ovary small.
2. Developing. Individual eggs visible but not loose and free flowing.
3. Ripe. Eggs large and completely rounded but still opaque; when squeezed, eggs do not flow from body.
4. Spawning. Eggs translucent; flow from the body when squeezed.
5. Spent. Ovaries flabby and only a few scattered eggs (usually small and being resorbed) remain.

Male:

1. Immature. Testes very small; have smooth outline and more or less translucent.
2. Developing. Testes fairly enlarged; possess small side lobes; more or less opaque.
3. Developed. Testes reddish white; side lobes enlarged; no milt flows when cut.
4. Ripe. Testes white; considerably enlarged; milt flows when cut.
5. Spent. Testes still enlarged; well vascularized and flame red in color; no milt flows when cut.

In the above scheme, no distinction was made between 'resting' (stage after 'spent') and immature. The female reverted to the immature stage since it was not always easy to distinguish between these two stages by gross inspection in the field. The male reverted to the developed stage since the mature male can always be distinguished from the immature by the lobular appearance of the testes.

To make my data comparable to those of other FAO projects in Africa, stages of maturity suggested by Laevastu (1965) were adopted from August 1975 to the end of the study period. These are:

Stage 1. Virgin. Very small organs close under the vertebral column. Testes and ovaries transparent, colorless to gray. Eggs not visible to naked eye.

Stage 2. Maturing virgin and recovering spent. Testes and ovaries translucent, gray-red. Length half or slightly more than half the length of the ventral cavity. Single eggs can be seen with magnifying glass.

Stage 3. Developing. Testes and ovaries opaque, reddish with blood capillaries. Occupy about half of ventral cavity. Eggs visible to the eye as whitish granular.

Stage 4. Developed. Testes reddish-white. No milt drops appear under pressure. Ovary orange-reddish. Eggs clearly discernible; opaque. Testes and ovaries about two-thirds of central cavity.

Stage 5. Gravid. Sexual organs filling ventral cavity. Testes white, drops of milt fall with pressure. Eggs completely round, some already translucent and ripe.

Stage 6. Spawning. Roe and milt run with slight pressure. Most eggs translucent with few opaque eggs left in ovary.

Stage 7. Spent. Not yet fully empty. No opaque eggs left in ovary.

Stage 8. Resting. Testes and ovaries empty, red. A few eggs in the state of resorption.

Data on the gonad stages for this study have been organized on the lines of the earlier categories. This has meant the combination of some of the categories of Laevastu (1965). The following are the equivalents:

Male:

Categories	Stages: Laevastu	Stages: Earlier
Immature	1	1
Developing	2	2
Developed	3 and 4	3
Ripe	5 and 6	4
Spent	7	5

Female:

Categories	Stages: Laevastu	Stages: Earlier
Immature	1 and 8	1
Developing	2 and 3	2
Ripe	4 and 5	3
Spawning	6	4
Spent	7	5

On a few occasions, an attempt was made to determine sex by examination of the external genitalia in the field. The male can be distinguished from the female by the possession of a tubular genital papilla. The female has, in place of this male organ, a vent (or urinogenital opening). In breeding females, the vent is enclosed by two fleshy lobes which are continuous at their posterior aspect. These are highly vascularized and flame-red in color. Practically all individuals sexed were not in breeding condition. This, combined with the small size of the species, made sexing by external examination difficult. Sex was finally checked by dissection and inspection of the gonads. Then the ovaries were removed, fixed and preserved in Bouin's Picro-formol (Picric acid sat. sol. 75 parts; 40% formalin, 25 parts; and glacial acetic acid, 5 parts).

Stomachs were preserved in 7% formalin, whereas spines, vertebrae, and otoliths were put in coin envelopes and appropriately labelled.

Traps which simulated natural spawning sites were made from lengths of bamboo stems. Each was about 1.2 m long and 8 cm in diameter. The length of an internode ranged from 40 - 50 cm. Each bore a single rectangular window about 6 x 6 cm. There were dark chambers on each side of the window. Between 30 and 40 of these traps were set at the Ampem station for periods varying between 2 - 5 days. From June 3, 1977, trial fishing with them started in Ajena Bay. This is a well protected bay which serves as anchorage for the VLRP boats. The bottom of the set area was silty sand. Aquatic plants were present but sparse. The traps were weighted with stones and marked with small floats which were connected to the traps with twine. Depth of water was between 1.0 and 1.5 m.

Following success at capturing Chrysichthys auratus and C. walkeri with the bamboo traps, larger traps made from lengths of asbestos pipe were also set from September 14, 1977. The aim of this second experiment was to determine if C. velifer and C. furcatus which are larger species could similarly be captured. The asbestos pipes were about 1 m in length and the diameter was 12 cm. Each length had 2 windows on the same side. Each end was covered with a piece of black cloth which was held in place by a thread. Four of these were set in inshore waters with the bamboo traps and the other 4 in water about 6 m deep. These were set offshore in the midst of a cluster of drowned emergent trees.

In the laboratory, the volume of each ovary was determined by water displacement. After counting the eggs in a 1 cc sample, the total number of eggs in each ovary was estimated on a simple proportion basis. Counts of right and left ovaries were added to provide a total count for a specimen. Average diameter of an egg was determined by taking 20 eggs from each of three sections of an ovary (top, middle, and bottom), measuring each set in a straight line, and then finding the mean of the 20.

IDENTIFICATION OF CHRYSICHTHYS SPECIES IN VOLTA LAKE

Many past investigators (Boulenger, 1911; Jayaram, 1966; and Daget and Iltis, 1965) have used several morphological and meristic characteristics to separate the species in the genus *Chrysichthys*. Some of these are: the length of the dorsal fin, shape of premaxillary teeth, ratio of head length to body length, ratio of the longest caudal ray to length of the median fin, and number of gill-rakers. The discovery that most of these characteristics may be environmentally modified or size- or sex-linked, has rendered keys for separating the species based on such characteristics unreliable. During this study many characters were evaluated for their reliability in separating the species.

Jayaram (1966) used the breadth of premaxillary teeth as an important taxonomic characteristic for identifying some of the species. In the present study little variation between species in this characteristic was discerned. Daget and Iltis (1965) stated that the number of the gill-rakers were stable in a number of *C. nigrodigitatus* they examined. Their count of 16 - 18 below the first branchial arch, however, differed from the 12 - 17 obtained by Boulenger (1911) for the same species. Hence they concluded that the systematic value of this characteristic is as undependable as the others. In Volta Lake the gill-raker counts, especially when divided into upper and lower, overlap so that they do not give precise identification (Table 2). A contributory factor might be due to the fact that the branchial arch of *Chrysichthys* does not bend acutely to permit easy division into upper and lower segments. If, however, whole counts

Table 2. Morphological comparisons between the four *Chrysichthys* species in Volta Lake

Character	*C. auratus*	*C. walkeri*	*C. velifer*	*C. furcatus*
No. examined	27	15	14	16
S.L.[a]	48 - 138	106 - 167	122 - 205	92 - 405
S.L./T.L.	.73 - .79	.72 - .78	.69 - .75	.71 - .81
S.L./L. head	2.86-3.78	3.09-4.07	3.20-3.86	3.08-3.84
Dorsal rays (No.)	6	6	6	6
S.L./D.F.H.	1.97-3.57	3.16-3.75	2.72-3.73	3.08-4.92
Longest D.R.	1st	1st	2nd	2nd or 3rd
Gill-raker count				
1) upper	8-13	10-14	22-27	18-28
2) lower	14-19	17-20	12-18	11-17
Anal ray count				
Branched	5-7	6-7	5-10	5-10
Unbranched	3-5	3-4	3-6	2-5

[a]Abbreviations: S.L. = standard length; T.L. = total length; L.Head = head length; D.F.H. = length of longest dorsal ray; D.R. = dorsal ray.

(upper and lower) are considered, a clearer pattern emerges (Table 3). The calculated confidence intervals ($P < 0.05$) of gill-raker counts (first gill arch) for *C. auratus* and *C. walkeri* were 26.52 - 28.82 and 28.96 - 30.90 respectively and those for *C. furcatus* and *C. velifer* were 34.99 - 40.13 and 37.43 - 40.71 respectively. Thus if the gill raker counts are less

Table 3. Comparison of number of gill-rakers of *Chrysichthys* spp in Volta Lake

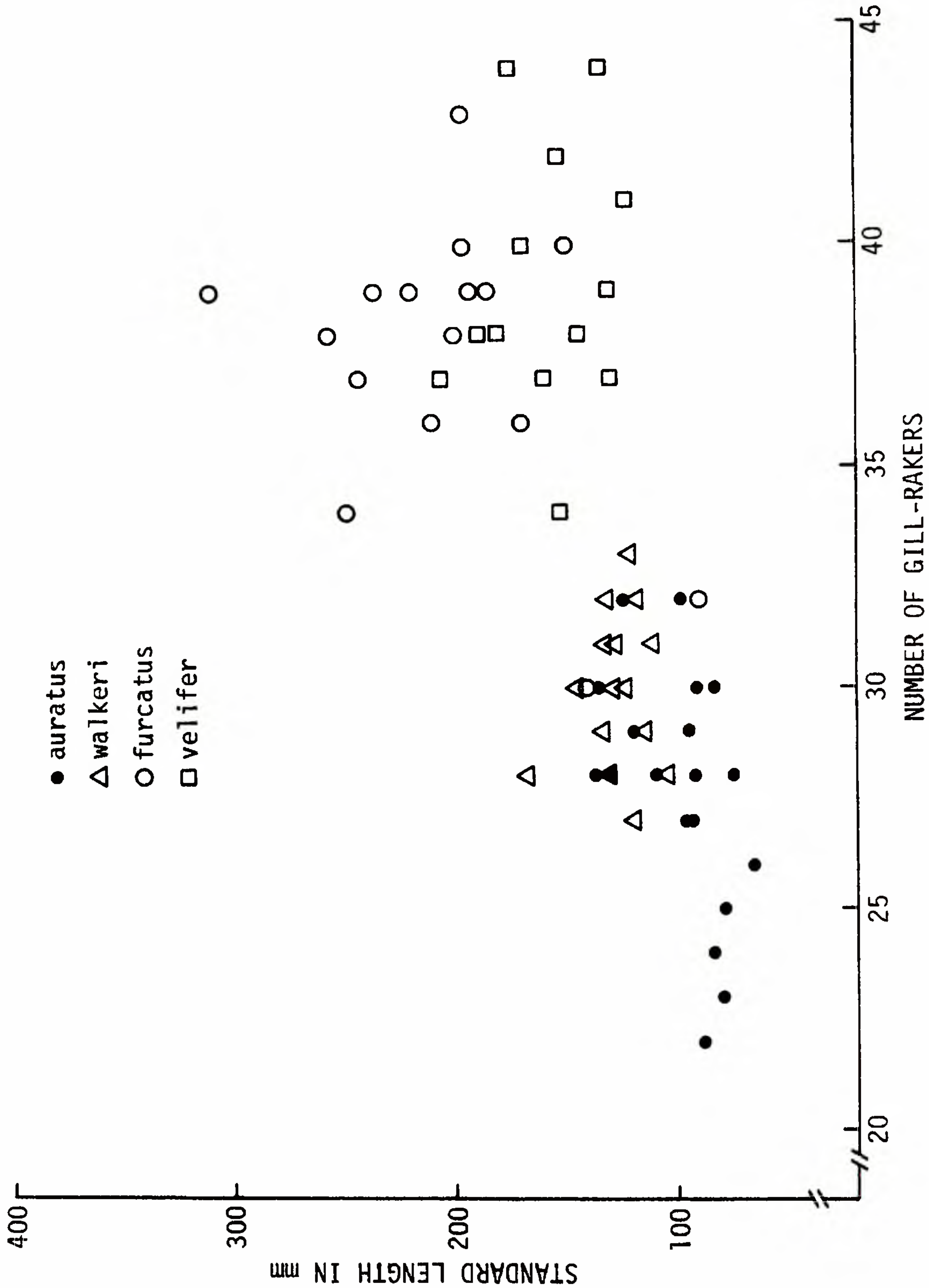
Species	No. specimens examined	Size range SL in mm	No. gill-rakers Mean	Range	95% confidence interval
C. auratus	21	16-138	27.67	23-32	26.52-28.82
C. walkeri	15	105-167	29.93	27-32	28.96-30.90
C. furcatus	16	92-310	37.56	30-43	34.99-40.13
C. velifer	14	122-195	39.07	34-44	37.43-40.71

than 32 the specimen is probably *C. auratus* or *C. walkeri* and if over 32, *C. furcatus* or *C. velifer*. In the former group, *C. walkeri* had a significantly higher mean count, 29.93, than *C. auratus*, 27.67 but the ranges overlap so much that the counts are of little value in separating the species. Specimens with counts of 23 to 26 are likely *C. auratus*.

Since the smaller species (*C. auratus* and *C. walkeri*) showed lower gill-raker counts than the larger species (*C. velifer* and *C. furcatus*), the question of whether the number of gill-rakers was correlated with size was investigated. There was no discernible trend within each species (Fig. 7). Both small and large fish of each species tended to have the same number of rakers distributed randomly within a range. This indicates that the gill-raker count could be relied upon, notwithstanding the size of the fish.

In my studies, the following characteristics were used in separating the species:

Fig. 7. Distribution of number of gill-rakers in _Chrysichthys_ spp in Volta Lake


auratus
walkeri
furcatus
velifer
NUMBER OF GILL-RAKERS
20
25
30
35
40
45
STANDARD LENGTH IN mm
100
200
300
400

a. Longest ray of dorsal fin, the first

1. barbels pinkish, olivaceous green back, pinkish silvery grey below: C. walkeri.

2. barbels yellowish, yellow-green back, light yellow-green below: C. auratus.

b. Longest ray of dorsal fin, second or third

1. caudal fin lobes almost equal: C. furcatus.

2. upper caudal lobe prolonged and somewhat hooked: C. velifer.

Apart from color, C. walkeri were separated from C. auratus in the field on basis of eye protrusion. From the ventral aspect, C. walkeri eyes protrude slightly more than those of C. auratus. No measurements were, however, taken during the study period to confirm this observation. Recently, at my request, staff of VLRP submitted data on orbital diameter, interorbital distance and width of the head in the eye region with which I hoped to validate this observation. Unfortunately, the data showed considerable variation with no clear-cut species differences. There is, however, need for further checking.

Some of the sex-linked characters noted during the breeding season were: 1) an extraordinary increase in the size of the head and buccal region of the male (Ajayi, 1972); 2) a change of color from bright silvery grey in both sexes to dusky grey; and 3) the development of a fold of skin which encloses the urinogenital opening of the female. The main environmentally-induced variation observed was in respect to color. For example: the downstream population looked darker than the Ampem population. But the Ampem population also looked darker than the population in the northern sector of the lake. It is interesting to note that the downstream waters are very dark as a result of dye material dumped into this section of the river by a textile factory. Also, the northern waters appear more whitish as a result of considerable silt brought into the lake by the large tributaries, the Black and White Voltas and the Oti River. Thus there is circumstantial evidence that the color variation might be an adaptation to background. Another variation was size. It is common knowledge that the same species in different bodies of water may have different growth rates and consequently different ultimate lengths. For example: 1) when I visited the Ivory Coast in 1976, I observed that the average size of C. walkeri caught by the commercial fisherman in the Ebrie Lagoon, was larger than the largest I ever caught in Volta Lake during this study; 2) in 1966 when Chrysichthys was the predominant species in Volta Lake, large sizes were caught but no measurements were recorded. Since then there has been a considerable diminution in size of many species including Chrysichthys.

The largest Chrysichthys caught during this study was a ripe male C. furcatus. It measured 41.8 cm SL (52.3 cm TL) and weighed 1.125 kg. The largest C. velifer measured 39.0 cm SL (51.1 cm TL) and weighed 1.00 kg. The heaviest of this species, however, measured 38.0 cm SL (49.0 TL) and weighed 1.08 kg. These were both females; the former had developing gonads and the latter was ripe. Similar statistics for the remaining two species were: C. walkeri, male; developing gonads; SL, 23.5 cm (TL, 36.0 cm); weight, 0.18 kg; and C. auratus, male; developing gonads; SL, 19.5 cm (TL, 26.5); weight, 0.12 kg. Large Chrysichthys specimens captured in other bodies of water in Africa and reported in the literature are presented in Table 4. Except for *C. furcatus* in Kainji Lake and *C. walkeri* in Lekki Lagoon, the reported sizes were larger than those captured in Volta Lake during the period of this study.

The following descriptions apply to the species in the Volta Lake:

C. walkeri (Gunther 1899)

The color is olivaceous green on the back and pinkish silvery grey underneath. The barbels are pinkish. The base of the dorsal spine has a blackish spot. Sometimes the dorsal fin has crimson splashes at the margins. The adipose is clear. The snout is prominent and the eyes are large. The mean anal ray counts were: branched, 6 (range: 6 - 7), unbranched 3 (range: 3 - 4). The longest dorsal ray is the first. The upper caudal lobe is somewhat prolonged and hooked. The mean lower gill-raker count of the first branchial arch is 11 (range: 10 - 14) and the upper, 18 (range: 17 - 20).

While the above description is close to that of Daget and Iltis (1965), it differs slightly from that of Loiselle (1972) in respect to color. He describes *C. walkeri* as brown dorsally, beige on the flanks and paling to dirty white on the venter. It would appear that his description applies to individuals that have assumed the breeding color.

C. furcatus (Gunther 1864)

The large rounded dorsal fin and moderately forked caudal fin with almost equal lobes easily distinguish this species from the rest. The specimens I examined had the upper caudal lobe slightly longer and tapering than the lower. The color is dusky grey with iridescent greenish sheen on the back and silvery white beneath. The adipose has a dark

Table 4. Large specimens of *Chrysichthys* captured in other bodies of water in Africa

Species	Length (cm)	Weight (kg)	Location	Author
C. auratus	20.5 SL, 27.0 TL	0.201	Kainji Lake, Nigeria	Ajayi (1972)
C. nigrodigitatus	33.0 SL, 46.7 TL	0.750	Kainji Lake, Nigeria	Ajayi (1972)
C. nigrodigitatus	50.0 SL	2.400	Ogoue Lagoon, Ivory Coast	Loubens (1964, as cited in Micha and Frank, 1975)
C. furcatus	52.5 SL, 65.5 TL	3.075	Mid Niger, Niger	Daget and Iltis (1965)
C. furcatus	20.8 SL, 29.3 TL	0.165	Kainji Lake, Nigeria	Ajayi (1972)
C. walkeri	31.0	0.500	Ogoue Lagoon, Ivory Coast	Loubens (1964) as cited in Micha and Frank, 1975)
C. walkeri	51.0	3.00	Volta	Roman (1974, as cited in Micha and Frank, 1975)
C. walkeri	25.7 TL	-	Lekki Lagoon, Nigeria	Ikusemiju (1976)
C. cranchii	150.0	-	Confluence of Lualaka & Maka Rivers, Zaire	Poll (1950)
C. laticeps	154.0	148.00	Stanley Pool, Zaire	Poll (1950)

center with a translucent border. The part of the breast nearest the opening of the gill-chamber has an iridescent greenish blotch. The mean lower gill-raker count of the first branchial arch is 14 (range: 11 - 17) and the upper, 24 (range: 18 - 28). The mean anal ray counts are: branched, 8 (range: 5 - 10) and unbranched 4 (range: 2 - 5).

The identity of this species was not in doubt since the description tallies closely with those of Reed *et al*. (1967), Daget and Iltis (1965), and Loiselle (1972).

C. velifer (Norman 1923)

Like *C. auratus* and *C. walkeri*, the caudal fin is deeply forked. The upper caudal lobe is prolonged and somewhat hooked. The adipose has a dark center bordered by a translucent margin. The dorsal fin is high and sail-like. The fish is dusky above with dusky silvery sides and belly. The barbels and the caudal fins have a pinkish tinge. The mean anal ray counts are: branched 7 (range: 5 - 10), unbranched, 5 (range: 3 - 6). The mean lower gill-raker count of the first branchial arch is 15 (range: 12 - 18) and the upper, 24 (range: 22 - 27). The dorsal fin is long and filamentous with a black tip. The second dorsal ray is the longest. The dorsal fin is low in some while fairly high in others. This is evidenced in the fairly wide range of the ratio: standard length/ dorsal fin height (2.72 - 3.73). Those with long filamentous dorsal fin may be difficult to distinguish from *C. auratus longifilis*. But whereas in *C. velifer* it is either the second or third ray which is the longest, in *C. auratus longifilis*, it is the first.

C. auratus (Pfaff 1933)

The color is yellowish green, darker on the back and lighter ventrally. The dorsal and pectoral fins are lemon yellow. It is the smallest of the *Chrysichthys* species in Volta Lake. The eyes are larger than those of *C. velifer* and *C. furcatus* but smaller than those of *C. walkeri*. The longest dorsal ray is the first. The height of the dorsal fin is often very variable as evidenced by the ratio, standard length/dorsal fin height (1.97 - 3.57). *C. auratus longifilis,* in which the longest dorsal fin ray reaches all the way down the caudal fin was described by Reed *et al.* (1967) in River Niger. My specimens seemed to indicate a more or less continuous variation in the length of the longest dorsal fin ray rather than a separation into subspecies. The mean lower gill-raker count of the first branchial arch is 10 (range: 8 - 13) and the upper, 17 (range: 14 - 19). The mean anal ray counts are: branched, 6 (range: 5 - 7), unbranched 4 (range: 3 - 5).

ABUNDANCE AND DISTRIBUTION

With the exception of catches by the 13-mm mesh gill nets which usually consisted of the tiny species (mainly, Pellonula afzeliusi, Physailia pellucida, Paradistichodus dimidiatus, and Barbus spp), Chrysichthys accounted for 43.8% of the total catch at the Ampem station (Table 5) thus making it the most abundant genus, distributed as follows: C. velifer 23.3%, C. auratus 10.3%, C. walkeri 10.0% and C. furcatus 0.002%. Chrysichthys comprised an average of 34.5% (by number) of Loiselle's (1972) collections at 3 stations in the Afframm arm. C. velifer, C. auratus and C. walkeri contributed 19.8, 14.4, and 0.3% respectively (Table 6). Even though all three stations were sampled in a space of one month and only one sample was taken at a station, agreement between the two studies as regards general order of abundance was good. A more general picture is obtained from his sampling of 23 stations scattered throughout the lake which showed that Chrysichthys was the most abundant genus accounting for 25.8% of the littoral ichthyomass. This was made up of mostly C. velifer (18.3%) and C. auratus (7.5%). C. furcatus and C. walkeri made insignificant contributions.

During August 1974 to May 1975, various stations were sampled in Areas 3, 7, and 8. Traps and rotenone were used in Area 3 while gill nets were used in Areas 7 and 8. Depth sampled ranged from 0 - 3 m. The result of the survey (Table 7) showed that the bagrids (99% Chrysichthys) comprised 52% of the experimental catch. The varying efforts expended in the Areas and the different catching methods employed, precluded

Table 5. Numbers of *Chrysichthys* and other species taken at Ampem in survey samples (except for 13 mm mesh nets), June 1975 to May 1976, and percentages of *Chrysichthys* in the ichthyofauna[a]

Species	Periods[b] 1	2	3	4	Total	%
Chrysichthys auratus	122	500	195	132	949	10.3
C. walkeri	340	272	170	138	920	10.0
C. velifer	804	769	382	188	2143	23.3
C. furcatus	1	1	1	9	12	0.002
Total	1267	1542	748	467	4024	
Others	2431	1443	722	578	5174	
% *Chrysichthys*	34	52	51	45	43.8	

[a]Detailed data in Table A-2.

[b]Periods = 1 - June to August 1975
2 - September to November 1975
3 - December 1975 to February 1976
4 - March to May 1976.

Table 6. Distribution of *Chrysichthys* in Volta Lake during the period January to May 1970 (Data collected by Loiselle (1972); detailed data in Table A-3)

Area	No. of samples	*C. auratus*	*C. walkeri*	*C. velifer*	*C. furcatus*	Kg/ha
1	3	268	3	351	-	222.3
2	4	244	-	123	-	83.9
3	5	102	1	279	2	52.8
4	2	-	-	42	-	7.4
5	3	-	-	385	-	5.70
6	1	-	-	-	52	3.27
7	5	70	-	43	-	7.94
Totals		714	4	1223	54	

direct comparison of catches between areas. Comparison could, however, be made between Areas 7 and 8 where gill net was the only gear used. Catching effort in Area 8 was one-quarter that in Area 7. *Chrysichthys* caught in Area 7, was 69 as against 5 in Area 8. Thus it would appear that there were less *Chrysichthys* in Area 8 than in Area 7. In Area 3, examination of 186 individuals showed *C. walkeri* to be the most abundant, accounting for 78%. It was followed by *C. velifer* (12%) and *C. furcatus* (1%). Thus *C. walkeri* showed up more strongly in Area 3 during this period than it did during Loiselle's (1972) survey.

In Area 7, the order of abundance was *C. velifer* (47%), *C. auratus* (32%) and *C. walkeri* (17%). Only 3 *C. auratus*, 1 *C. velifer* and 1 *C. furcatus* were captured in Area 8.

Table 7. Numbers of bagrids and of other fish in catches in Areas 3, 7 and 8 during August 1974 to May 1975 taken by gill nets (excluding 13 mm mesh), traps and rotenone[a]

Family	Area			Total
	3	7	8	
Osteoglossidae	1			1
Mormyridae		18	2	20
Clupeidae	4	4		8
Characidae	14	99	81	194
Citharinidae	2	8	5	15
Schilbeidae	1	86	40	127
Mochokidae	11	26	4	41
Cichlidae	22	14		36
Malapteruridae	4			4
Centropomidae	4	7		11
Bagridae	441	72	5	518
Cyprinidae		8	4	12
	504	342	141	987
No. of stations sampled:	5	8	2	

[a]Detailed data in Table A-4.

Temporal and Areal Changes

Petr (1967) compared the commercial catch at Bui on the Black Volta River (the largest tributary of the Volta Lake) during the rainy season of 1965 with the catch of several lakeside fishing villages, and found the relative abundance of bagrids (mostly Chrysichthys) to be similar. Furthermore the results were similar to those of the Kainji Reservoir, Nigeria (University of Liverpool's Expedition Report, 1965, as cited in Petr 1967). The data in Petr (1967) indicate that no Chrysichthys were caught at Akosombo from January to April 1965 but Chrysichthys constituted 55% of the experimental catch at the station in November and December 1965. In February 1966, Chrysichthys made up only 1.47% of the catch at Kpandu (Area 3) and 1.78% at Ampem (Area 1). The localized abundance around Akosombo was similarly recorded by Wuddah (1967), who recorded catches of 79.66% and 79.90% in experimental gill nets in July 1966. This was followed by a decline to a lower level in August 1966; 36.93% of the experimental catch and 71.65% in nets run by the Fisheries Department (Wuddah, 1967).

From 1969 to 1972, the relative abundance of the fish species in the Volta Lake was monitored by the Stock Assessment Section of the VLRP (Table 8). Owing to logistic problems, periods within which a circuit of the stations was completed varied from 3 - 6 months. Further, the rigid webbing of the monofilament nets reduced the vulnerability of Chrysichthys to capture; especially that part of the vulnerability through spine entanglement in the webbing. Consequently, the Stock

Table 8. Temporal abundance of Chrysichthys in Volta Lake by seasons as monitored by standardized gang of experimental gill nets by the Stock Assessment Section of the VLRP during the period, December 1969 to February 1972 (Fishing effort in Areas 3 and 7 was twice that of the other areas)

Area \ Periods[a]	1	2	3	4	5	6	Totals
				C. auratus			
1	160	2	5	5	35	1	208
2	28	-	-	1	-		29
3	-	4	7	-	14	4	29
4	-	2	-	1	-	-	3
5	-	3	-	-	18	-	21
6	-	2	-	7	4	-	13
7	-	14	2	9	-	-	25
8	-	6	1	4	18	10	39
Totals	188	33	15	27	89	15	367
				C. velifer			
1	66	1	-	-	24	1	92
2	75	3	-	-	18	-	96
3	34	5	-	-	24	6	69
4	-	3	2	-	-	-	5
5	-	1	-	-	-	-	1
6	-	1	1	-	7	6	15
7	-	7	-	1	3	2	13
8	-	3	4	-	-	1	8
Totals	175	24	7	1	76	16	299

[a] Periods = 1. December 1969 - May 1970
2. June 1970 - September 1970
3. October 1970 - March 1971
4. February 1971 - April 1971
5. May 1971 - September 1971
6. September 1971 - February 1972.

Table 8. (Continued)

Area	Periods[a] 1	2	3	4	5	6	Totals
			C. walkeri				
1	78	-	5	5	32	-	120
2	18	-	-	-	32	-	50
3	4	4	p	-	3	2	14
4	-	-	1	-	-	5	6
5	-	-	1	2	1	-	4
6	-	-	6	-	-	8	14
7	5	30	13	5	1		54
8	1	9	2	1	52	114	178
Totals	106	43	29	52	121	129	440
			C. furcatus				
1	12	12	-	-	28	-	52
2	4	-	-	-	-	-	4
3	-	1	10	-	10	2	23
4	-	-	-	-	4	2	6
5	-	1	-	1	1	-	3
6	-	-	1	1	-	-	2
7	-	4	1	8	8	-	21
8	-	-	-	-	18	-	18
Totals	16	18	12	10	69	4	129

Assessment catch data on *Chrysichthys* were neither adequate in time nor in sample sizes. Nonetheless, it is possible to glean some information on the distribution and temporal changes in abundance. During December 1969 to May 1970, *C. auratus*, *C. velifer* and *C. furcatus*, were caught in the southern part (Areas 1 - 3) only, while *C. walkeri* was caught in both southern (Area 1 - 3) and northern (Areas 7 and 8) parts.

Chrysichthys showed more even distribution during June to September 1970; *C. auratus* and *C. velifer* were caught in all areas while *C. walkeri* and *C. furcatus* showed patchy distributions. Thereafter, the distribution continued to be patchy with the central areas (4, 5, 6) indicating lower abundance. Abundance for many areas increased during May - September 1971. It is noteworthy that *Chrysichthys* showed more continuous distribution and increased abundance during June - September 1970 and May - September 1971, the wet seasons for most areas of the lake. This might indicate increased activity of the fish during this time of the year. This is a phenomenon well noted among fish species in Volta Lake (unpublished commercial catch assessment data).

From the above temporal changes, it could be concluded that from around November 1965 (about a year after the lake had started filling) to May 1970, *Chrysichthys* was relatively abundant near the damsite at Akosombo. Sampling during June - September 1970 showed a decline in abundance and a more even lakewide distribution. Thereafter, abundance fluctuated seasonally with more fish being caught in the rainy season.

Petr (1967) recorded that *Chrysichthys* spp comprised 1.98% of catches in the Volta River and 0.52% of the catches in the Niger River. These proportions are far lower than have been realized since the formation of the lake. Lewis (1974) stated that there was an increase in Bagridae (mostly *Chrysichthys*) after the formation of the Kainji Lake, Nigeria. Thus it would appear that Chrysichthys prefers comparatively lacustrine to riverine environment. Since the formation of the Volta Lake, some fish families have disappeared from the southern lacustrine sector and are now confined more or less to the northern riverine sector (Table 7). These include: Mormyridae, Characidae (except Alestes macrolepidotus), Cyprinidae (except Barbus spp), Schilbeidae, Citharinidae (except Distichodus spp). Others, mostly the cichlids, have expanded in the southern lacustrine area. The present study shows that Chrysichthys have increased in abundance in all areas with indications of higher abundance in the southern areas.

Depth Distribution

Generally, the abundance of Chrysichthys decreased with depth (Table 9), indicating that the species prefer inshore habitats. Most of the small species (C. auratus and C. walkeri) were caught in 1.5 m deep water while most of the large species (C. velifer and C. furcatus) were caught in the bottom half of 3.0 m deep water. In 10.0 m depth, there seemed to be preference for middle waters by C. furcatus and C. velifer in that chi-square tests of independence indicated significant differences ($P < 0.05$)

Table 9. Distribution of Chrysichthys in gill nets in inshore and surface of offshore waters during the period December 1969 to February 1972, as monitored by a standardized gang of experimental gill nets by the Stock Assessment Section of the VLRP during the period December 1969 to February 1972

Species	Inshore						Offshore				
	1.5 m	3.0 m		10.0 m			3.0 m		10.0 m		
		T[a]	B	T	M	B	T	B	T	M	B
C. auratus	161	15	70	12	46	49	6	2	5	2	-
C. walkeri	183	34	130	8	14	19	10	8	3	4	6
C. velifer	89	24	135	22	46	10	9	-	1	5	7
C. furcatus	23	9	30	10	23	17	4	3	6	1	2
Totals	456	82	365	52	128	95	29	13	15	12	15

[a]Abbreviations: T = top, M = middle, B = bottom, here and throughout the dissertation.

in the numbers in the top, middle and bottom waters. In the same depth, C. auratus and C. walkeri tended to concentrate at the bottom two-thirds. The offshore nets which fished surface waters, caught only a few specimens indicating less preference for this zone of the lake. Bottom nets could not be set in this area because of flooded trees which made fishing ineffective.

Chernin-Chudenitz (1971) showed that for most areas in Volta Lake, oxygen concentration below 10 m is zero. Ajayi's (1972) laboratory study of oxygen tolerance of Chrysichthys, showed that experimental fish exhibited signs of distress when the ambient oxygen concentration was reduced to 0.46 mg/l. They finally died at a concentration of 0.30 mg/l. Thus it can reasonably be concluded that except for periods when the lake waters are holomictic and dissolved oxygen extends well to the bottom, Chrysichthys distribution may be confined to roughly a maximum depth of 10 m in Volta Lake. During this study, when gill nets were set at the bottom in the channel of the former Affram River (depth about 30 m), and near the mouth of a tributary stream (Oworobong River), the following species caught: Synodontis sp (6), Hydrocyon sp (3) and Lates niloticus. Dissolved oxygen at this depth was 47% saturation (3.61 mg/l) probably because of the inflow from the river. Inspection of catches of fishermen who fished deeper waters (because of intimate knowledge of the localities free of underwater obstructions) than I fished, showed that only Synodontis catfish may inhabit the deepest parts of the lake. There were catches which comprised Synodontis only and others with a sprinkling of large C. velifer. The latter catch might have been made at the fringe of the distribution of C. velifer. There is also the further suggestion that the distributions of C. auratus and C. walkeri end in shallower water than that of C. velifer.

Finally, low oxygen concentrations which have resulted in 'fish kills' in both Volta and Kainji Lakes, have first showed in mass death of Chrysichthys (Ewer, 1966; Petr, 1968b; Ajayi, 1972).

Notwithstanding this low tolerance for oxygen deficiency, fish are capable of penetrating into deoxygenated water for lengths of time (Sprugel, 1951). During those periods when the lake level rose and covered the marginal vegetation resulting in decomposition (zero oxygen saturation was recorded on many occasions during this study), Chrysichthys and other species were caught in traps set in the flooded bush overnight and were dead when the traps were lifted. The more advanced state of decomposition of Chrysichthys than the other species observed when traps were being tended the next day, seemed to indicate that they were the first to succumb to the anoxic situation. General kills of fish not trapped were not noted at this time, indicating that they probably moved to better water.

Catches were lower in the central areas (4, 5, 6) than in the rest. The central areas represent an interphase between the shallow riverine north and the deep lacustrine south. The most preferable area was 1, which was both lacustrine and shallow. Thus it would appear that depth and degree of flow, are two independent factors which interact to determine the distribution of Chrysichthys. Both increasing (1) depth and (2) flow, have negative effects.

Table 10. Area and depth distribution of <u>Chrysichthys</u> in Volta Lake as monitored by a standardized gang of experimental gill nets by the Stock Assessment Section of the VLRP during the period, December 1969 to February 1972

Area	Totals	Inshore						Offshore				
		1.5 m	3.0 m		10.0 m			30 m		10.0 m		
			T	B	T	M	B	T	B	T	M	B
1	510	169	37	118	21	96	44	7	4	9	-	5
2	175	111	11	49	4	-	-	-	-	-	-	-
3	134	26	8	68	12	4	8	4	-	2	2	-
4	18	2	4	6	1	1	-	1	-	-	-	3
5	28	6	6	11	-	1	1	3	-	-	-	-
6	52	16	6	18	1	5	2	-	-	-	2	2
7	229	78	3	71	7	11	22	12	9	1	8	7
8	117	48	7	24	6	11	17	2	-	2	-	-
	1263	456	82	365	52	129	94	29	13	14	12	17

Length-Frequency Distributions

Catches with rotenone, traps, gill nets of various mesh sizes and depths, beach seine and gill nets set at the bottom, provide an insight into size distribution in relation to depth. Though the seine net was usually paid out at a depth of about 10 m, it could only have been effective when the lead line contacted the bottom. The maximum depth of the seine was 6.57 m; hence the real depth sampled was less than 6.5 m.

Analysis of the data for C. velifer (Table 11), C. auratus (Table 12), and C. walkeri (Table 13), showed that, generally, size increased with depth. Inadequate data for C. furcatus (Table 14) have precluded a definitive statement for that species.

Usually, study of the length frequency distributions of the young at reasonably short intervals, e.g. monthly, provides an insight into periodicity or uniformity of spawning of a species. With the exception of C. furcatus, the rotenone reasonably sampled the young Chrysichthys; hence monthly length frequency distributions of collections with this chemical were studied with a view to identifying any possible trends (Tables 15 - 17). In September and October 1975, more and smaller individuals of all three species were collected which may indicate new recruitment. In November and December, the modal lengths were greater suggesting growth but the increases are more than might be expected particularly for November. C. auratus reaches a length of 88 mm at the end of the first year in Kainji Lake (Ajayi, 1972) and C. velifer spawns at about 100 mm. Since growth probably is year-round, monthly increases of 25 mm or more are unlikely. Sampling variation may account for all the monthly differences in these tables. If spawning were markedly seasonal it should show up even with this type of sampling.

In view of the foregoing discussion, length frequency distribution of larger fish which usually inhabit deeper water was studied for the period April to December 1975 (Tables 18 - 20) for which there was least interruption of the monthly sampling schedule. When captures with the least selective of the sampling gear (beach seine) were analyzed, modes were

Table 11. Length frequency distributions of *C. velifer* captured with different types of gear and rotenone in varying depths during the period, October 1974 to November 1975[a]

Length groups SL in mm	Rotenone	Traps	1.5 m net	3.0 m net	Seine net	10.0 m net	Bottom set
36-49	16				3	1	
50-64	42	7			5		
65-78	33	12			22	2	
79-93	34	31	8	3	39	8	
94-107	11	42		3	67	3	1
108-121	10	28	2	7	63	10	2
122-136	5	47		8	261	23	2
137-150	4	39		15	387	23	8
151-164	2	30		3	243	12	2
165-179	2	21			139	17	
180-193	1	28		11	76	22	4
194-208	3	7		6	52	14	1
209-222	1	3		4	8	18	4
223-236		1		4	6	10	2
237-251				4		13	4
252-266				1	2	3	3
266-281						5	5
281-293						2	1
294-308						2	
309-323							1
324-337						1	1
338-352						1	
353-366						1	
367-380							1
Total	164	296	10	70	1373	191	42
Mean length (mm)	82	131	92	167	144	178	208

[a]This shows a general increase in size with depth. Methods of capture have been arranged in such a way that depth increased from left to right.

Table 12. Length frequency distribution of *C. auratus* captured with different types of gear and rotenone in varying depths during the period October 1974 to November 1975[a]

Length groups SL in mm	Rotenone	Traps	1.5 m net	3.0 m net	Seine net	10.0 m net	Bottom set
38-52	134				1		
53-68	177	18			7	1	1
69-83	52	11		3	19	5	1
84-98	8	31	7	14	31	5	1
99-114	2	16	1	2	37		
115-129	2	3		1	50	4	3
130-144	3	1		1	63	2	3
145-159	1				22	3	
160-175					8		
176-190		1			1		
191-205					2		
206-220							1
Total	379	81	8	21	241	20	10
Mean length (mm)	59	88	93	94	119	106	122

[a]This shows a general increase in size with depth. Methods of capture have been arranged in such a way that depth increased from left to right.

Table 13. Length frequency distribution of *C. walkeri* captured with different types of gear and rotenone in varying depths during the period October 1974 to November 1975[a]

Length groups SL in mm	Rotenone[b]	Trapsc	1.5 m net	3.0 m net	Seine net	10.0 m net	Bottom set
38-52	68			1	3		1
53-68	161	35			3		
69-83	56	36	2	3	14	27	2
84-98	19	480	16	20	48	50	2
99-114	11	35		1	71	3	1
115-129	3	9		11	142	12	1
130-144	6	9		4	175	21	7
145-159	1				54	7	
160-175		1			21	3	
176-190					11	1	1
191-205	1	1			2	3	
206-220	1					1	
221-235	1						
Total	328	606	18	40	544	128	15
Mean length (mm)	67	91	89	102	128	108	117

[a]This shows a general increase in size with depth. Methods of capture have been arranged in such a way that depth increased from left to right.

[b]Depth sampled: < 1.0 m.

[c]Depth sampled: 0.80 m.

Table 14. Length distribution of *C. furcatus* captured with different types of gear and rotenone in varying depths during the period October 1974 to November 1975[a]

Groups	Rotenone	Traps	1.5 m net	3.0 m net	Seine net	Bottom set
53 - 68	1					
69 - 83	6					
84 - 98	2					
99 - 114	3					
115 - 129		1				
130 - 144		2			3	
145 - 159					1	
160 - 175		2			6	
176 - 190		2			2	
191 - 205		3			14	
206-- 220					3	
221 - 235		2		2		
236 - 250					1	
251 - 266		1				
Total	12	13	0	2	30	
Mean length (mm)	85	185		228	186	0

[a]General increase in size with depth is shown; methods of capture have been arranged in such a way that depth increased from left to right.

Table 15. Length frequency distribution of *C. velifer* (by months) during the period April - December 1975[a]

Length group (SL in mm)	Month								
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
30 - 49		-[b]					7		
50 - 69						3	17		15
70 - 89	1		3		1	16	3	1	8
90 - 109	6		3	2	3	4		10	2
110 - 129	2		6			1		6	
130 - 149			7					2	1
150 - 169			1					2	
170 - 189			2					1	
190 - 209			2						

[a]Rotenone captures at Ampem only.

[b]No sampling during May.

Table 16. Length frequency distribution of *C. auratus* (by months) during the period April - December 1975[a]

Length group (SL in mm)	Month								
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
30 - 39	-[b]	-[c]				2	1		
40 - 49					2	71	21		
50 - 59				2	3	85	54		32
60 - 69			4	2		32	25	4	22
70 - 79			1	2		8	4	5	14
80 - 89			1			6	2	7	1
90 - 99							1	4	2
100 - 109			1			1		3	
110 - 119			1					2	
120 - 129			1						

[a]Rotenone captures at Ampem only.

[b]No catch in April.

[c]No sampling during May.

Table 17. Length frequency distribution of *C. walkeri* (by months) during the period April - December 1975[a]

Length group S.L. in mm	Months								
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
30 - 39		-[b]				1	1		
40 - 49					1	18	25		3
50 - 59					2	15	49		25
60 - 69				1	1	4	18		25
70 - 79	1				4	1	5	3	4
80 - 89	9		1		1			1	1
90 - 99				1				2	1
100 - 109	2		1						
110 - 119	3		2					2	
120 - 129									
130 - 139								1	

[a]Rotenone captures at Ampem only.

[b]No sampling during May.

Table 18. Length frequency distribution of *C. velifer* (by months) during the period April to December 1975[a]

Length group S.L. in mm	Months								
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
30 - 49			-[b]						
50 - 69	2			1				1	
70 - 89	7			1	4				1
90 - 109	3		3	6	6	8	2		2
110 - 129	5		10	13	17	32	10	16	9
130 - 149	47	1	60	61	37	83	63	69	56
150 - 169	12	3	35	38	10	35	31	38	43
170 - 189	-	5	26	20	5	28	21	30	30
190 - 209	1	1	12	12	3	11	8	7	15
210 - 229			3	3		3	3	1	1
230 - 249							1	2	1
250 - 269									1

[a]Captures with seine net at Ampem only.

[b]Random sample from 380 specimens collected during the month.

Table 19. Length frequency distribution of C. auratus (by months) during the period April to December 1975[a]

Length group	Month								
S.L. in mm	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
30 - 39									
40 - 49									
50 - 59	1			2					
60 - 69			1	2	1	2	1	1	1
70 - 79	1		1	2	2	4	4	8	2
80 - 89	4				2	14	1	2	1
90 - 99	4			1	2	6	1	4	1
100 - 109	3	2	4	2		12		3	2
110 - 119	1		2	2	3	17	1	3	4
120 - 129	3		3	4	2	18	2	3	13
130 - 139	1		1	2	6	9	6	5	18
140 - 149	1		1	1	1	3	3	7	5
150 - 159			1	1		2	1		

[a]Captures with seine net at Ampem only.

not clear in all monthly collections of *C. auratus* owing to inadequate sample sizes. *C. velifer* and *C. walkeri* for which larger samples were collected, showed fixed modes at 140 and 125 mm, respectively.

While the mode may be fixed, proportion in the size groups may change with time. This concept was tested with the 3 abundant middle classes of *C. velifer* collections for the period, June to December 1975 (except August when the smallest sample size was collected) (Table 21). With number in size group 170 - 189 assumed to be one, ratios for the other size groups were calculated. The hypothesis that collections for a month was significantly different from this ratio at 95% level of probability was then tested. The results showed that there was no

Table 20. Length frequency distribution of *C. walkeri* (by months) during the period April to December 1975[a]

Length group S.L. in mm	Month								
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
30 - 39									
40 - 49									
50 - 59	1								
60 - 69			4	1					
70 - 79	2		3	3				2	
80 - 89	2		1	1				1	2
90 - 99	1		2	2		1		1	
100 - 109	4		6	6	3	2	2		
110 - 119	6	4	7	3	8	3		3	6
120 - 129	12	3	37	16	15	8	4	12	17
130 - 139	12	5	30	13	5	9		10	18
140 - 149	5	4	19	9	1	5	2	2	8
150 - 159		3	10	2	1	3		1	4
160 - 169	1	1	2	2	1	2	1	1	1
170 - 179	1		5		1			1	2
180 - 189			3	2			1		
190 - 199			1						
200 - 209			1						1
210 - 219			1						
220 - 229									

[a]Captures with seine net at Ampem only.

significant deviation from the ratio for the 6 monthly collections. There was no evidence of two or more modes which might suggest different year classes or spawning periods.

If the above picture is a true reflection of the population status, then the following conclusions may be drawn: 1) spawning had been continuous throughout the year with no well-defined peaks; 2) the population was in a steady state, that is, gains through growth, immigration, and recruitment were being balanced by losses through mortality and emigration during the period.

Table 21. Deviation of abundant size groups of *C. velifer* from calculated average ratio for the period June to December 1975 (except August when the smallest number of specimens were collected)

Length group S.L. in mm	Month June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Totals
130 - 149 (a)	60	61	37	83	63	69	56	392
150 - 169 (b)	35	38	10	35	31	38	43	219
170 - 189 (c)	26	20	5	28	21	30	30	155
	Calculated ratios if length group (c) is assumed to be 1							Av. ratio
(a)	2.31	3.05		2.96	3.00	2.30	1.87	2.58
(b)	1.35	1.90		1.25	1.48	1.27	1.43	1.45
(c)	1	1		1	1	1	1	1
								5.03
	Expected values:							
(a)	62.06	61.04		75.40	58.99	70.27	66.17	
(b)	34.88	34.30		42.38	33.15	39.49	37.19	
(c)	24.06	23.66		33.15	22.86	27.24	25.65	
Calc. X^2	0.227	0.960		2.850	0.563	0.359	3.209	

Rejection region at 95% level of probability: $X^2 = 5.99$

REPRODUCTIVE BIOLOGY

Maturity Stages

All data from the Ampem area relating to maturity of females have been grouped according to species and sizes (Tables 22 - 24). Results show that for all three species, stage 4 fish (spawning) were rarely encountered on the sampling grounds. This may indicate that ripe fish go to their breeding grounds for spawning at this stage, as indicated later in this study. Likewise, spent fish did not return to the sampling grounds until they were well advanced into the resting stage. At this stage, the maturity state of the gonad was not easily differentiated from that of an immature by gross examination. The highest proportion of females with active gonads was found in stage 2 (developing) where 72, 46, and 76% were recorded for C. auratus, C. walkeri, and C. velifer, respectively. The proportions diminished as higher stages of maturity were attained.

If maturity is defined as having gonads enlarged and the eggs well-formed (stage 3), the 70 - 79 mm group included the first mature females in C. auratus and C. walkeri and the 100 - 119 mm in C. velifer. The results would be about the same using stage 2 as the first indication of maturity. The smallest spawning female was 72 mm in C. walkeri and 82 mm in C. auratus (Table 25). These spawning fish were all collected in bamboo traps on the breeding ground and were either ripe or spent.

All female C. auratus, almost all female C. velifer, and most female

Table 22. Maturity of female *C. auratus* by size groups showing the number of fish at various stages of maturity in each 1 cm length group for all females sexed during the period December 1974 to November 1976

Length group S.L. in mm	No. of fish	Stage 1	2	3	4	5	% with active gonads
60 - 69	6	6					-
70 - 79	22	19		3			14
80 - 89	51	38	6	7			25
90 - 99	52	40	8	4			23
100 - 109	30	20	5	5			33
110 - 119	37	21	15	1			43
120 - 129	90	42	39	9			53
130 - 139	58	26	22	8	1	1	55
140 - 149	15	2	11	1		1	87
150 - 159	4	2	1		1		50
160 - 169	1		1				100
Totals	366	216	108	38	2	2	
% total		59	30	10	1	1	
Total active gonad		150					
% active gonad			72	25	1	1	

Table 23. Maturity of female *C. velifer* by size groups showing the number of fish at various stages of maturity in each 2 cm length group for all females sexed during the period December 1974 to November 1976

Length group S.L. in mm	No. of	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	% with active gonads
40 - 59	1	1					
60 - 79	5	5					
80 - 99	39	38	1				3
100 - 119	61	55	4	2			10
120 - 139	290	207	72	7	2	2	29
140 - 159	297	181	103	10	1	2	39
160 - 179	198	85	94	17	1	1	57
180 - 199	125	27	71	24		3	78
200 - 219	51	12	25	11	1	2	76
220 - 239	27	4	14	6	1	2	85
240 - 259	19	5	7	5		2	74
260 - 279	21	3	11	6		1	86
280 - 299	22	6	4	8	3	1	73
300 - 319	4		2	1		1	100
320 - 339	3			1	1	1	100
Totals	1163	629	408	98	10	18	
%		54	35	8	1	2	
Total active gonad	534						
% active gonad			76	18	2	3	

C. walkeri examined in the December 1974 to February 1975 period were classed as stage 1. Otherwise no clear seasonal trend in maturity was discernible from December 1974 to November 1976 (Figs. 8 - 10). The December to February period the next year showed maturity stages not different from the other periods of the year. After sampling with electro-shocker in Kainji Lake from March to November 1971, Ita (1972)

Table 24. Maturity of female C. walkeri by size groups showing the number of fish at various stages of maturity in each 1 cm length group for all females sexed during the period December 1974 to November 1976

Length group S.L. in mm	No. of fish	Stage 1	2	3	4	5	% with active gonads
70 - 79	10	8		1	1		20
80 - 89	36	22	2	10	2		39
90 - 99	25	17	3	5			32
100 - 109	31	12	12	6		1	61
110 - 119	44	18	14	9	2	1	59
120 - 129	95	32	32	27	1	3	66
130 - 139	88	39	24	24	1		56
140 - 149	42	8	14	12	5	3	81
150 - 159	24	9	7	7		1	63
160 - 169	10	4		5		1	60
170 - 179	4	1	1	2			75
180 - 189	3	1	2				16
190 - 199	1	1					-
Totals	413	172	111	108	12	10	
% total		42	27	26	3	2	
Total active gonad	241						
% active gonad			46	45	5	4	

Table 25. Length distribution of spawning *Chrysichthys* captured on breeding grounds

Size group S.L. in mm	*C. auratus* Numbers Male	*C. auratus* Numbers Female	*C. walkeri* Numbers Male	*C. walkeri* Numbers Female
70 - 79	1	-	-	2
80 - 89	2	5	7	13
90 - 99	1	5	6	9
100 - 109	5	3	5	4
110 - 119	-	4	6	3
120 - 129	2	1	8	1
130 - 139	1	-	5	-
140 - 149	2	-	3	-
150 - 159	1	-	1	-
Totals	16	18	41	32

reported that *Chrysichthys auratus* bred throughout the year, with a peak from September to November. This peak was evident in the large numbers of fry collected during that period. Loiselle (1972) stated that he observed *C. auratus* spawning in the main channels of coastal rivers in the neighboring country of Togo, from mid-April to late May. His ig

Fig. 8. Seasonal distribution of gonad maturity stages for female C. auratus, Dec. 1974-Nov. 1976

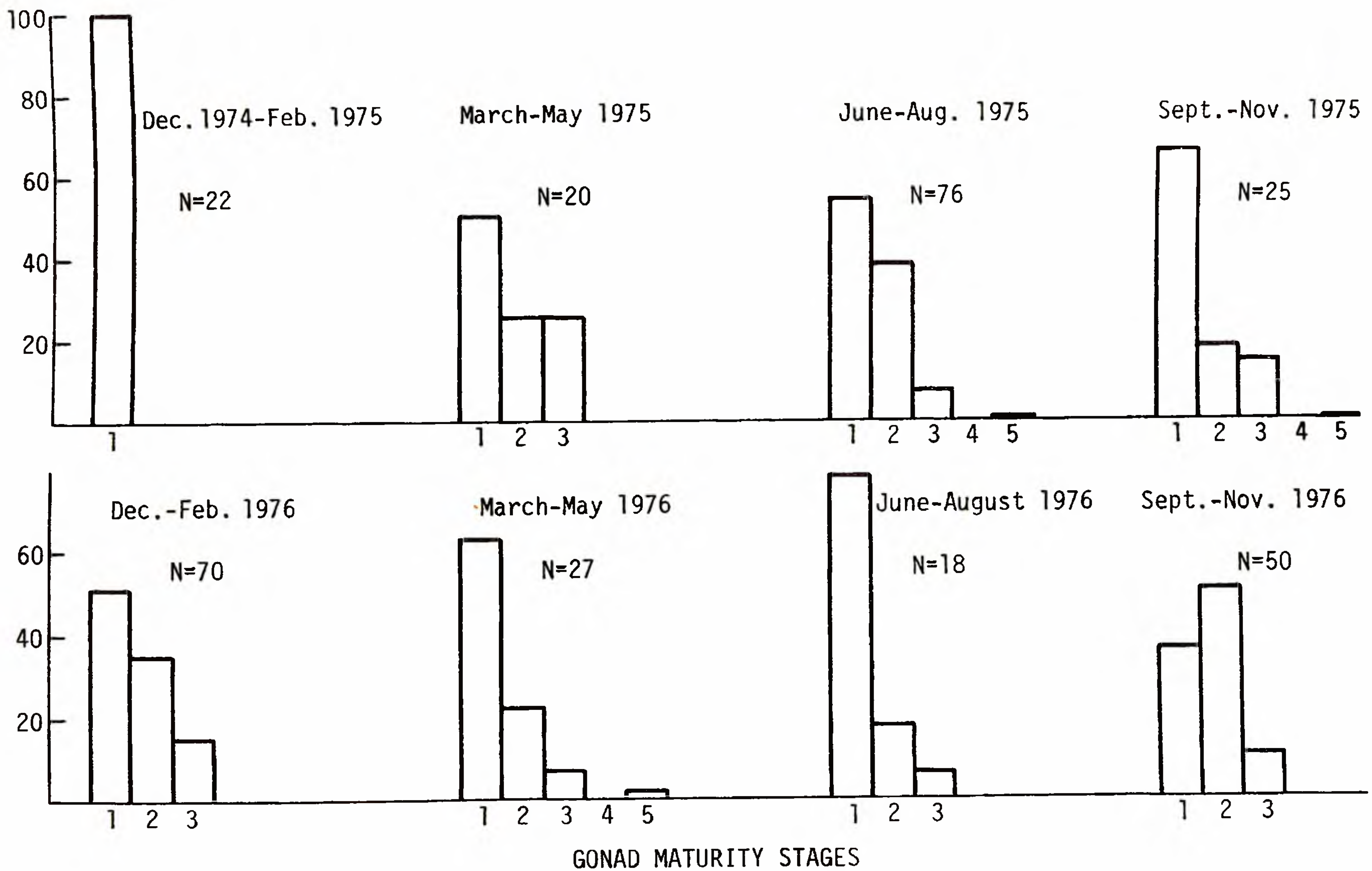

100
80
60
40
20
Dec. 1974-Feb. 1975
N=22
March-May 1975
N=20
June-Aug. 1975
N=76
Sept.-Nov. 1975
N=25
1
1 2 3
1 2 3 4 5
1 2 3 4 5
60
40
20
Dec.-Feb. 1976
N=70
March-May 1976
N=27
June-August 1976
N=18
Sept.-Nov. 1976
N=50
1 2 3
1 2 3 4 5
1 2 3
1 2 3
GONAD MATURITY STAGES

Fig. 9. Seasonal distribution of gonad maturity stages for female *C. walkeri*, Dec. 1974-Nov. 1976

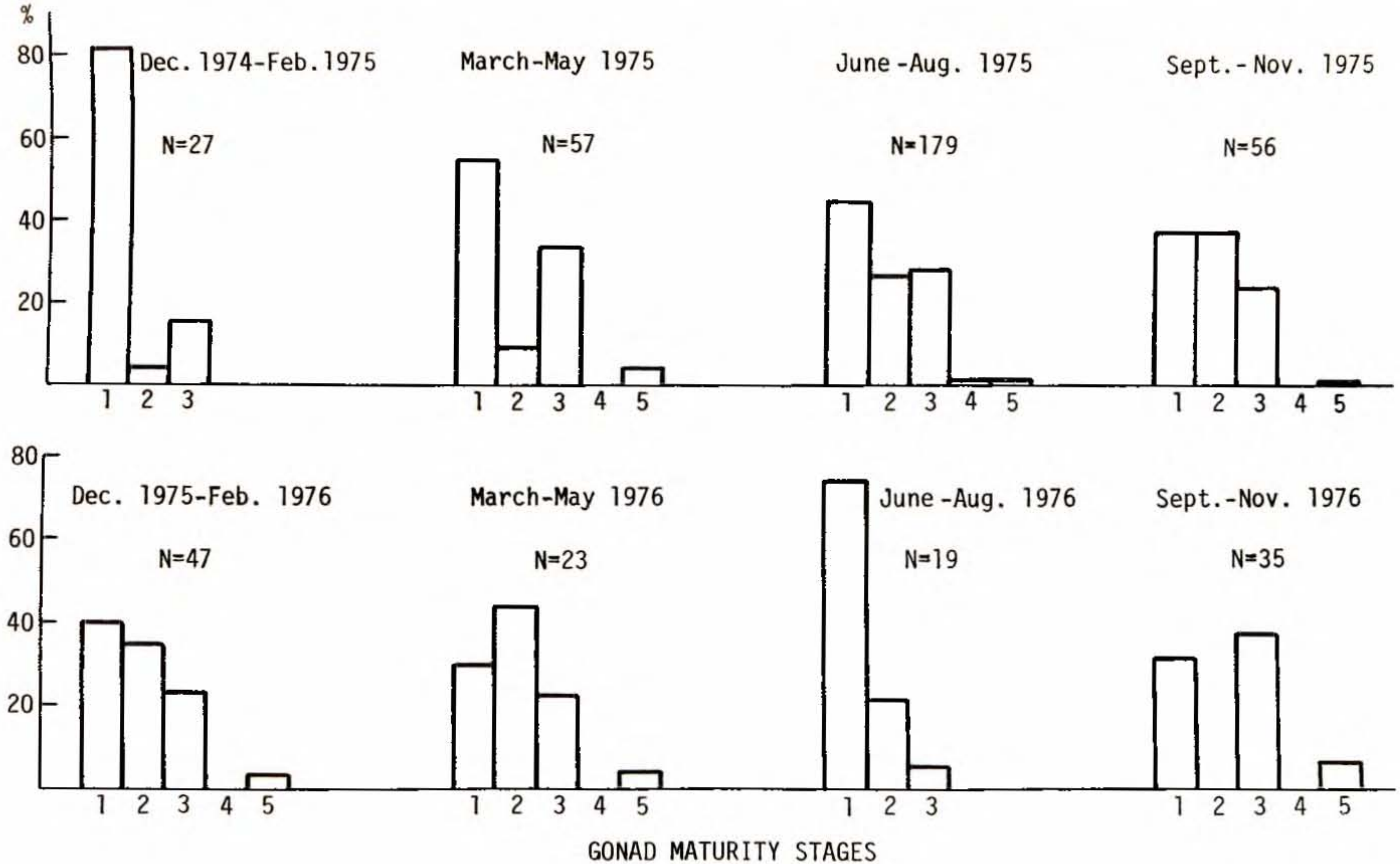
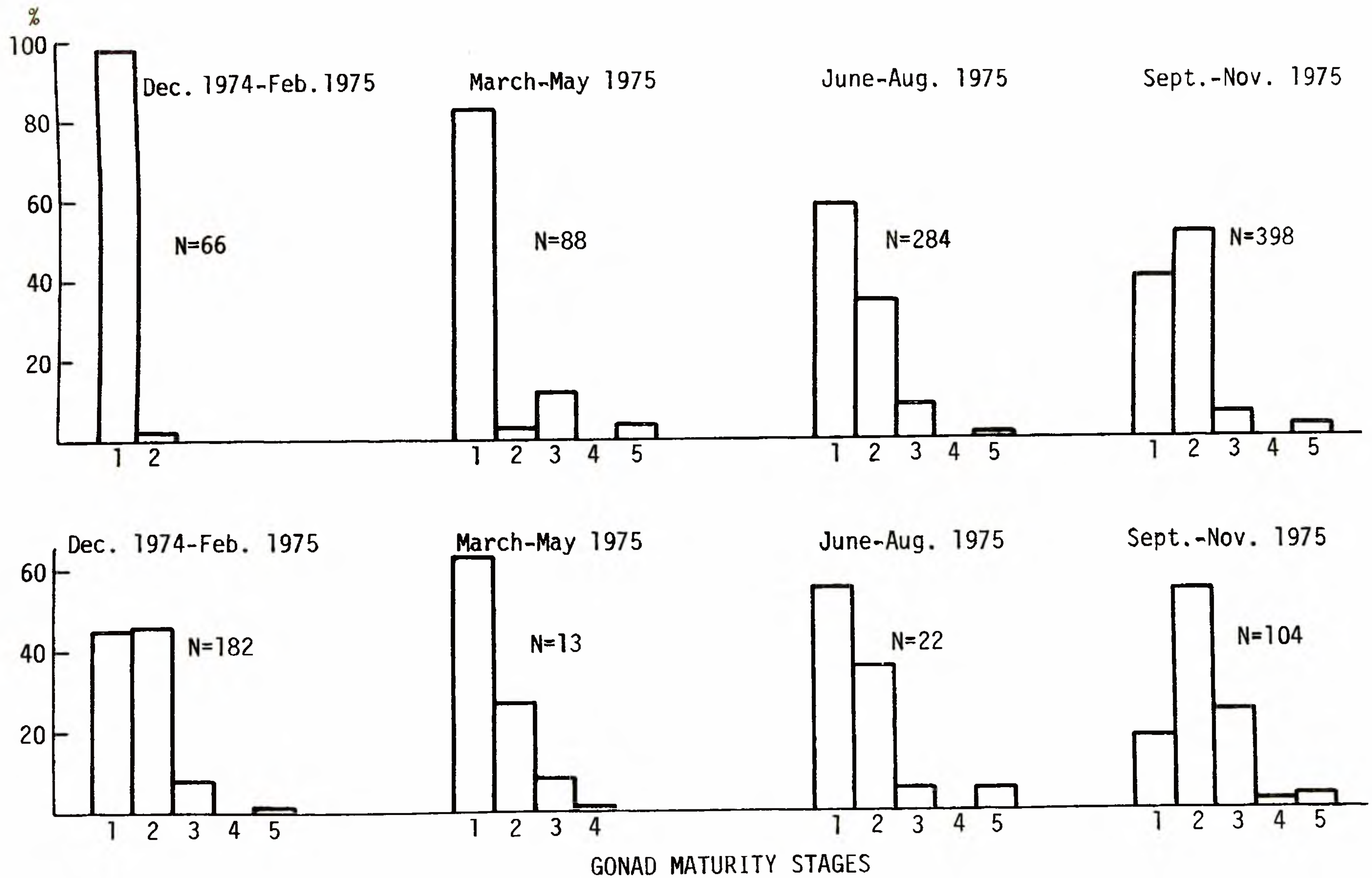

%
80
60
40
20
Dec. 1974-Feb. 1975
N=27
March-May 1975
N=57
June-Aug. 1975
N=179
Sept.-Nov. 1975
N=56
1 2 3
1 2 3 4 5
1 2 3 4 5
1 2 3 4 5
80
60
40
20
Dec. 1975-Feb. 1976
N=47
March-May 1976
N=23
June-Aug. 1976
N=19
Sept.-Nov. 1976
N=35
1 2 3 4 5
1 2 3 4 5
1 2 3
1 2 3 4 5
GONAD MATURITY STAGES

Fig. 10. Seasonal distribution of gonad maturity stages for female *C. velifer*, Dec. 1974-Nov. 1976


%
100
80
60
40
20
Dec. 1974-Feb.1975
N=66
1 2
March-May 1975
N=88
1 2 3 4 5
June-Aug. 1975
N=284
1 2 3 4 5
Sept.-Nov. 1975
N=398
1 2 3 4 5
60
40
20
Dec. 1974-Feb. 1975
N=182
1 2 3 4 5
March-May 1975
N=13
1 2 3 4
June-Aug. 1975
N=22
1 2 3 4 5
Sept.-Nov. 1975
N=104
1 2 3 4 5
GONAD MATURITY STAGES

observations apparently, did not extend beyond this period. Blache (1964, as cited in Loiselle, 1972) stated that this species commences spawning at the beginning of the flood season in June and July in Lake Chad. In Lekki Lagoon, Nigeria, Ikusemiju (1976) reported the collection of ripe ova and juvenile C. walkeri during most months of the year. However, most ripe fish were captured in March. In Kainji Lake, Ajayi (1972) similarly collected ripe C. auratus more or less throughout the year with a peak in June to October (rainy season). These studies suggest that though spawning may be year round, activities may peak during certain period(s) of the year. Results of the present study in Volta, however, showed no marked peaking.

Many previous investigators in temperate climes (June, 1953; 1971; Bodola, 1966; Otsu and Uchida, 1959) have reported that it is difficult, if not impossible, to categorize variations in the maturity stages of males of some species, mainly because of the extended period of running-ripe stage. In the tropics, Hopson (1972) made a similar observation on Lates niloticus. In the present study, the differentiation between immature and mature can be regarded as satisfactorily accurate but further designation can only give a rough guide since the distinction between the stages was not clear-cut.

Males first became mature (stage 2) at size 70 mm in C. auratus and C. walkeri, and 100 mm in C. velifer (Tables 26 - 28). These were the same sizes as found in the female. In Lake Chad, Blache (1964, as cited in Loiselle, 1972) observed a spawning male C. auratus which measured

Table 26. Changes in the maturity of male *C. auratus* with size, showing the number of fish at various stages of maturity in each 1 cm length group for all males sexed during the period September 1975 to August 1976

Size group S.L. in mm	Number	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
50 - 59	1	1				
60 - 69	10	10				
70 - 79	11	9	2			
80 - 89	28	27	1			
90 - 99	11	10	1			
100 - 109	14	10	4			
110 - 119	21	9	7	3		2
120 - 129	35	10	23	2		
130 - 139	26	14	8	3	1	
140 - 149	5		4	1		
150 - 159	3			3		
Totals	165	100	50	12	1	2

Table 27. Changes in the maturity of male *C. walkeri* with size showing the number of fish at various stages of maturity in each 1 cm length group for all males sexed during the period September 1975 to August 1976

Size group S.L. in mm	Number	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
50 - 59	1	1				
60 - 69	2	2				
70 - 79	5	4	1			
80 - 89	3	2	1			
90 - 99	4	4				
100 - 109	3	2	1			
110 - 119	6	2	4			
120 - 129	37	23	7	7		
130 - 139	42	18	13	9	1	1
140 - 149	14	3	8	3		
150 - 159	5		1	1	3	
160 - 169	6		3	2	1	
170 - 179	1				1	
180 - 189	1			1		
Totals	130	61	39	23	6	1

Table 28. Changes in maturity of male C. velifer with size showing the number of fish at various stages of maturity in each 2 cm length group for all males sexed during the period September 1975 to August 1976

Size group S.L. in mm	Number	Stage 1	2	3	4	5
60 - 79	4	4				
80 - 99	8	8				
100 - 119	14	10	4			
120 - 139	135	84	32	19		
140 - 159	152	68	64	19	1	
160 - 179	114	18	55	36	3	2
180 - 199	60	4	26	19	11	
200 - 219	21		6	10	5	
220 - 239	9		2	3	1	3
240 - 259	8		3		4	1
260 - 279	7			3	3	1
280 - 299	6		2	2	1	1
300 - 319	2			1	1	
320 - 339	1			1		
340 - 359	1			1		
Totals	542	196	194	114	30	8

70 mm standard length. Smallest males captured on the breeding grounds during this study measured 76 mm (C. auratus) and 82 mm (C. walkeri) (Table 22).

Overall, there were more higher stages of maturity among the larger individuals. Very few ripe and spent male C. auratus were captured. This observation matched an earlier one for females and further supports the suggestion that this species leaves for the breeding grounds earlier than the other species.

Sex Ratios

Tables 29 and 30 show changes in sex ratio with length of *C. auratus*, *C. walkeri*, and *C. velifer* for the periods September to November 1975 and December 1975 to February 1976. The former was a rainy season and the latter, a dry season. In parentheses are calculated chi-square for those groups whose total number exceeded 20.

In all three species, the females outnumbered the males in both the wet and dry season samples, but the ratios differed from the hypothetical 1 : 1 ratio only for *C. velifer* in the rainy season ($P < 0.001$).

The number of females to males were:

	C. auratus	*C. walkeri*	*C. velifer*
rainy season	1.11	1.14	1.28
dry season	1.26	1.11	1.12

There did not seem to be sexual difference in death or growth rates except for the fact that the 3 largest *C. walkeri* were all females (Table 29). The largest *C. auratus* was a male, however. More data should be collected to determine whether there is a difference in maximum size reached. In the dry season (Table 30), the 3 largest *C. velifer* were females but there were no differences between maximum sizes of the sexes in *C. auratus* and *C. walkeri*.

Ajayi (1972) found 1.31 and 1.35 as female/male sex ratios for *C. auratus* and *C. nigrodigitatus* respectively, in Kainji Lake. The ratio was as large as 4:1 in favor of females in *C. furcatus*. He, however, did not disclose the size of his samples nor period of collection.

Table 29. Sex-ratios at various lengths of Chrysichthys captured at Ampem during the period September to November 1975 (rainy season)[a]

Size group S.L. in mm	C. auratus Males	C. auratus Females	C. walkeri Males	C. walkeri Females	Size group S.L. in mm	C. velifer Males	C. velifer Females
50 - 59	1				60 - 79	1	1
60 - 69	11	6			80 - 99	3	7
70 - 79	5	7	1	4	100 - 119	10	19 (2.79)
80 - 89	17	14 (0.29)	2	2	120 - 139	95	112 (1.40)
90 - 99	5	9	1	4	140 - 159	83	106 (2.80)
100 - 109	7	10	2	3	160 - 179	66	80 (1.34)
110 - 119	11	14 (0.36)	1	4	180 - 199	34	36 (0.06)
120 - 129	13	16 (0.31)	16	15 (0.03)	200 - 219	10	12 (0.18)
130 - 139	9	10	14	12 (0.15)	220 - 239	8	12 (0.80)
140 - 149	1	4	6	5	240 - 259	3	8
150 - 159	1	1	3	3	260 - 279	1	8
160 - 169			3	1	280 - 295	5	4
170 - 179	1			1	300 - 319	2	1
180 - 189				2	320 - 339		2
					340 - 359		
					360 - 379		
					380 - 399		
Totals	82	91	49	56		321	410
	(0.47)		(0.47)			(10.84)**	

[a]Chi-square for large size groups (> 20) in parentheses.

Some samples suggest that female C. velifer aggregate during certain periods of the year: 1) a seine haul on September 18, 1975, caught 36 female C. velifer as against 21 males and 2) a bottom gill net set on October 26, 1975 caught 12 female C. velifer and no males. Of the latter sample, only 2 showed inactive gonads. Many of the rest were either ripe or near ripe. Hence there is the suggestion that such aggregations might be related to spawning.

Table 30. Sex-ratios at various lengths of Chrysichthys captured at Ampem during the period December 1975 - February 1976 (dry season)[a]

Size group S.L. in mm	*C. auratus* Males	*C. auratus* Females		*C. walkeri* Males	*C. walkeri* Females		Size group S.L. in mm	*C. velifer* Males	*C. velifer* Females	
50 - 59	1						60 - 79			
60 - 69	1						80 - 99	4	1	
70 - 79	5	3					100 - 119	4	4	
80 - 89	1	4		2	1		120 - 139	39	45	(0.43)
90 - 99	3	5			1		140 - 159	55	60	(0.22)
100 - 109	6	4			5		160 - 179	30	40	(1.43)
110 - 119	5	9		2	9		180 - 199	21	20	(0.02)
120 - 129	14	23	(2.19)	17	9	(2.46)	200 - 219	5	4	
130 - 139	18	20	(0.11)	13	13	(0.00)	220 - 239	1	5	
140 - 149	2	3		4	5		240 - 259	4	2	
150 - 159	1	1		1	4		260 - 279	4	1	
160 - 169				3	1		280 - 299		2	
170 - 179				2	2		300 - 319		1	
180 - 189							320 - 339			
							340 - 359			
							360 - 379			
							380 - 399		2	
	51	72		44	49			167	187	
	(1.74)			(0.27)				(1.13)		

[a]Chi-square for large size groups (> 20) in parentheses.

Size of Ovaries and Eggs

Ajayi (1972) reported that the left ovary of Chrysichthys in Kainji Lake was slightly longer and heavier than the right. At Volta Lake this difference was also observed in 4 specimens of *C. walkeri* and in 3 of 5 *C. auratus* (Table 31). The other two *C. auratus* had ovaries of equal size but they were small suggesting possible further development which might result in size differences. Mean increase in volume and weight after

Table 31. Comparison of size of left and right ovaries in *C. walkeri* and *C. auratus*

Ovary (vol. in cc) Left	Right	Left-right ratio	Fish length S.L. in mm
		C. walkeri	
2.0	1.7	1.18	102
3.5	3.0	1.17	170
1.0	0.5	2.00	95
2.8	1.2	2.33	
		C. auratus	
2.0	1.7	1.18	102
1.5	1.5	1.00	105
2.0	1.0	2.00	105
3.0	2.0	1.50	99
0.5	0.5	1.00	89

preservation of a sample of 10 ovaries were found to be 2.0% and 3.8% respectively. These measurements were made of ovaries preserved in Bouin's solutions reported under Methods.

Analysis of variance test as applied to diameters of 3 samples of 10 eggs each from the top, middle and bottom, from the left and then right ovaries of one specimen of *C. walkeri* gave non-significant F-ratios of 0.80 and 1.48 (with 2 and 27 d.f.; $p > 0.05$). Similar tests for an ovary each from *C. furcatus* and *C. velifer* also gave non-significant values of 2.78 and 2.48 respectively. Thus the eggs were about the same size in various parts of the ovary. Another test showed no significant difference between the size of the eggs in two ovaries from the same individual. Such observations are in agreement with the behavior whereby all eggs are shed within a short time; that is, Chrysichthys spp. are non-fractional spawners.

Calculated mean diameter of the eggs were: C. velifer, 1.66 ± 0.02 mm; C. auratus, 1.72 ± 0.05 mm; C. walkeri, 1.71 ± 0.02 mm; C. furcatus, 1.69 ± 0.01 mm. Thus the smaller species (C. auratus and C. walkeri) appeared to have larger eggs than the larger species (C. velifer and C. furcatus) although this difference was not statistically significant ($P > 0.05$). It is noteworthy that samples involved in the comparison were captured on the sampling grounds but not on the breeding grounds. The observation that C. auratus leaves the sampling grounds earlier than the rest, however, makes it doubtful that the same maturity stages were involved in the comparison. Almost all the eggs involved in the calculation were ripe but not in running condition. The mean diameter of eggs of 5 ripe and running specimens of C. auratus captured on the breeding grounds, was 2.24 mm indicating an increase of 30.2% over and above the mean size of eggs of individuals caught at Ampem which were classified as ripe. The mean size of the eggs of one specimen C. walkeri which was in ripe and running condition was 2.45 mm. Ikusemiju (1976) reported egg size range of 2.0 - 2.5 mm for C. auratus in Lekki Lagoon, while Imevbore (1970, as cited in Ikusemiju, 1976) recorded 3.23 and 2.61 mm for C. nigrodigitatus and C. auratus longifilis, respectively, in River Niger.

Fecundity

Bagenal (1966) suggested that the usual definition of fecundity as "the number of ripening eggs found in the female just prior to spawning", should apply to temperate regions. He thought the definition presupposes that there is a definite spawning season. This, however, is not the case in many tropical regions. Lowe (1955, as cited in Bagenal, 1966) defined fecundity as "the number of young produced during the life time of an individual". Bagenal considered that a more satisfactory definition suitable for both temperate and tropical species could be "the number of eggs laid during the average lifetime of an individual". In the present study since it was not possible to determine the number of times Chrysichthys spawned in a year, much less a lifetime, fecundity was simply assumed to be the number of eggs in a ripening ovary.

Ranges of individual fecundity estimates for the 4 species were as in Table 32. Within each species, fecundity varied among females but generally increased with size. For 21 specimens of C. walkeri (TL range: 133 - 245 mm) in Lekki Lagoon, Ikusemiju (1976) recorded fecundities of 896 to 4,168 eggs.

Least squares estimates of fecundity (F) in relation to body length (SL) and weight (W) were calculated for C. velifer and C. walkeri and to length alone for C. auratus (Figs. 11 - 13; Tables A-5 - A-8). The best fit on length of C. walkeri was:

$$\log F = -1.905 + 2.36 \log SL, \text{ or in exponential form}$$

$$F = -0.0124\ (SL)^{2.36}.$$

Table 32. Fecundity of *Chrysichthys* spp in Volta Lake during the period 1974 to 1977 (Detailed data in Tables A-5 - A-8)

Species	No. of specimens	Range of no. of eggs	Size range S.L. in mm	Weight (bm)
C. auratus	9	218 - 914	78 - 112	-[a]
C. walkeri	26	270 - 2690	79 - 170	12 - 95
C. velifer	23	1263 - 10,656	132 - 347	50 - 730
C. furcatus	4	599 - 15,938	160 - 335	110 - 565

[a]Only 2 out of 9 specimens were weighed.

The calculated coefficient of determination (r^2) which measured the goodness of fit of the regression line was 0.65. A similar calculation for a rectilinear equation was 0.56. Hence the former relationship provided the better fit. In *C. velifer*, however, a similar comparison (0.68 for rectilinearity and 0.57 for curvilinearity) favored rectilinearity. The rectilinear relationship was defined by the equation: $F = 4295 + 40.95\ (SL)$. For *C. auratus*, the curvilinear relationship was $F = -3.98 + 3.312 \log\ (SL)$. Only a small amount of data were available for *C. furcatus* (Fig. 14).

In many species, the relationship between length and number of eggs in the ovary is curvilinear (Bagenal 1966, Martinez and Houde, 1975). The rectilinear relationship in *C. velifer* might be due to: 1) the large variation in egg number for a given length and 2) insufficient data for

Fig. 11. *C. velifer* - Regression of fecundity on 1) length and 2) weight

<u>C. velifer</u>

Regression of fecundity on (1) length and (2) weight

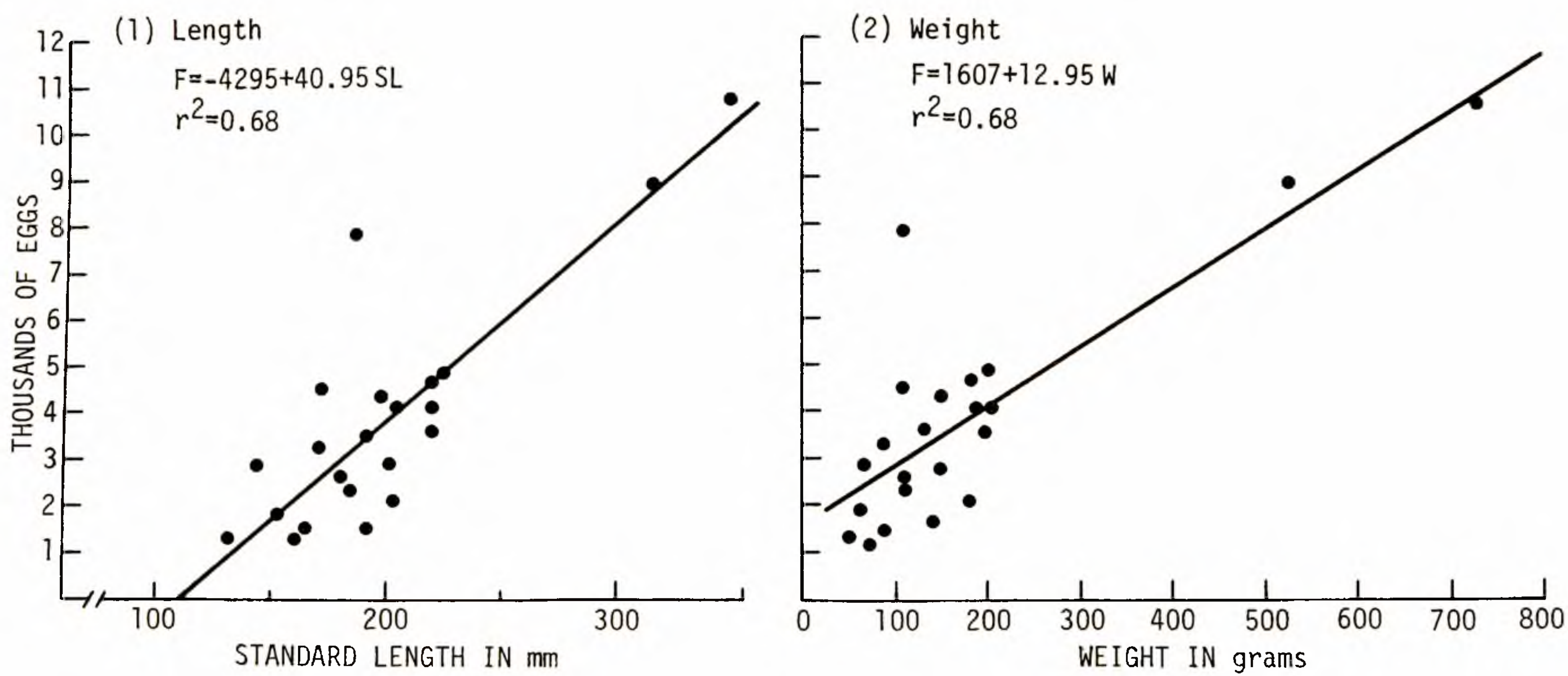


Fig. 12. C. walkeri - Regression of fecundity on 1) length and 2) weight

C. walkeri

Regression of fecundity on (1) length and (2) weight

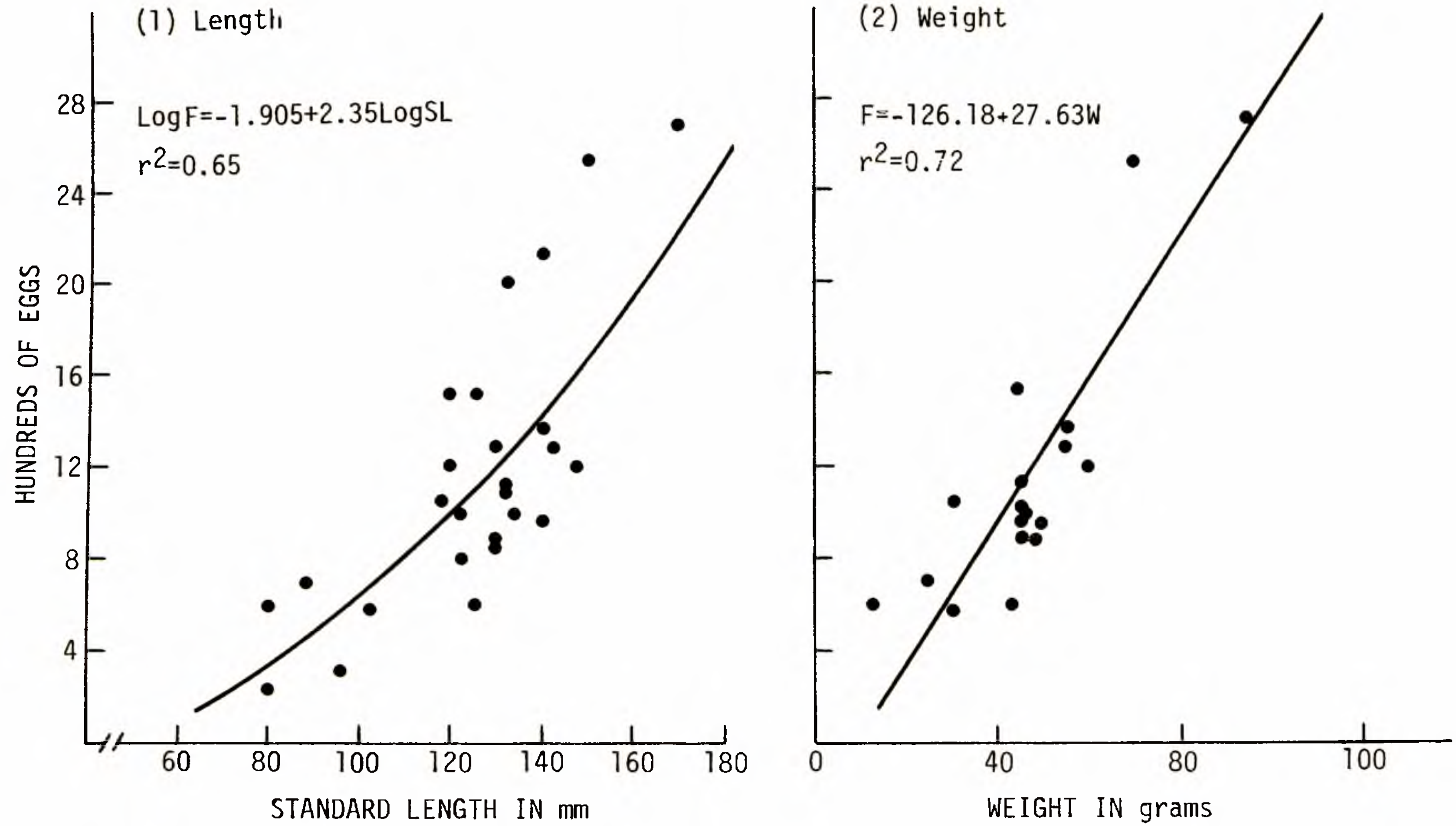


Fig. 13. *C. auratus* - Regression of fecundity on length

C. auratus

Regression of fecundity on length

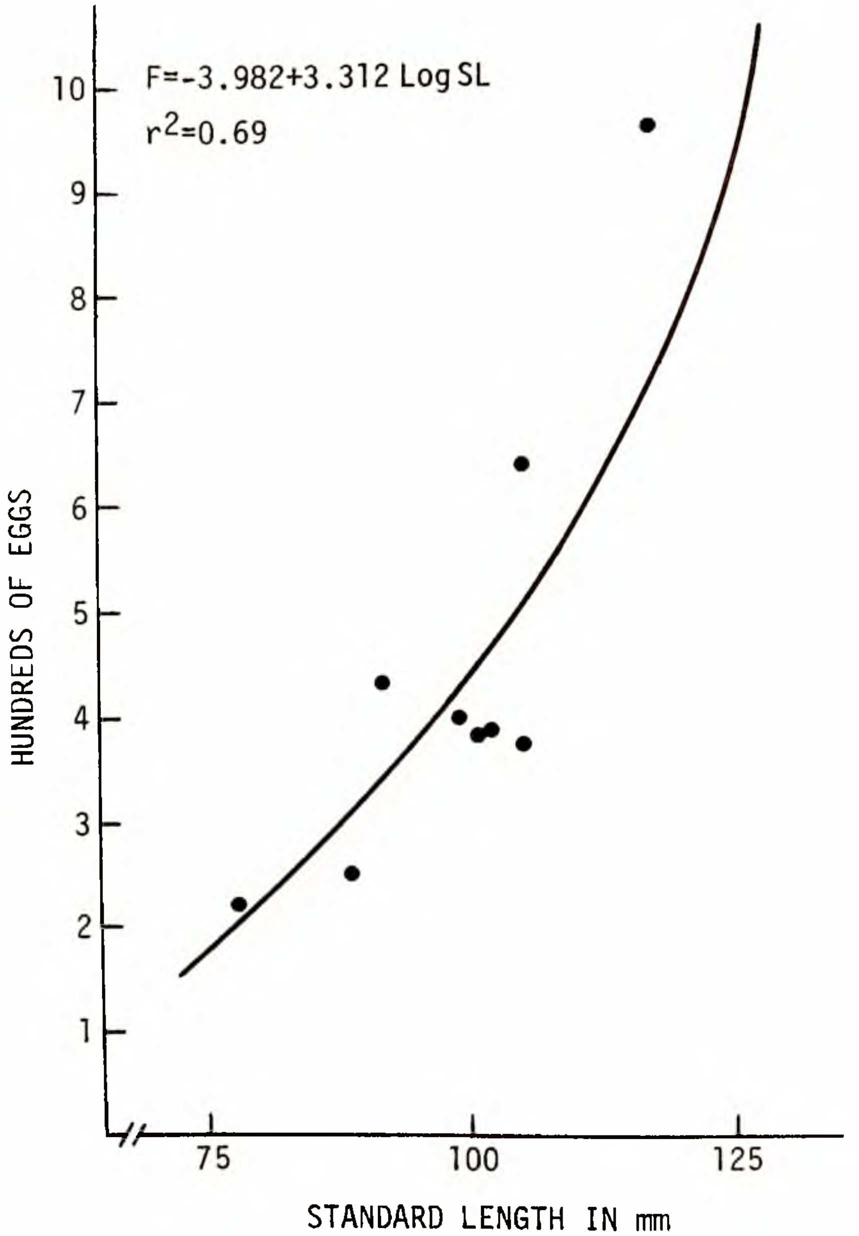
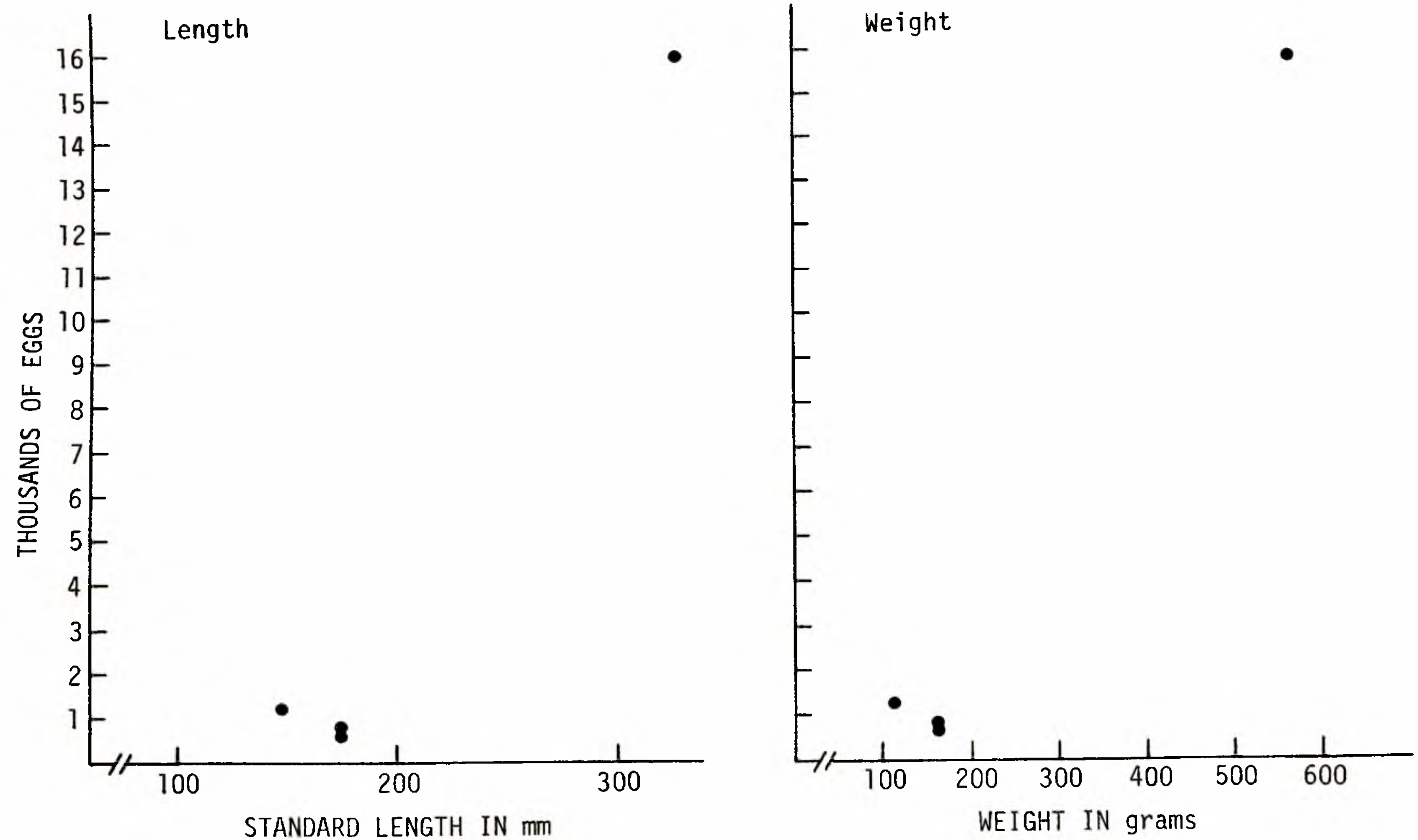


Fig. 14. C. furcatus - Regression of fecundity on 1) length and 2) weight

C. furcatus

Regression of fecundity on (1) length and (2) weight



large fish. Ikusemiju (1976), however, defined the relationship between total length and fecundity for C. walkeri with the rectilinear equation: F = -197.97 + 243.5(TL) where TL = total length in cm.

In both species, rectilinear equations provided the best fit for fecundity and weight data: C. walkeri: F = -126.18 + 27.63 W, r^2 = 0.72; C. velifer: F = 1607 + 12.95 W, r^2 = 0.68.

Preferred Spawning Site

Between 30 and 40 bamboo traps to catch spawning Chrysichtys were set near Ampem, for periods of 2 - 5 days in June and July 1977 but they caught nothing. During the same period the bamboo traps were set in Ajena Bay and spawning fish were taken. Ajena Bay is located in the Gorge area adjacent to the damsite and enclosed by high hills. The waters were almost always calm. The substrate in the set area was of silty sand and emerged aquatics were sparse. Compared with other inshore areas of the lake, the bottom was sharper sloping. The traps were set in waters ranging in depth between 1 and 2 m. It was noteworthy that only those compartments in the middle of the traps caught any Chrysichthys. These compartments had darker interiors than those at the open ends. The asbestos-pipe traps with wider diameters, set together with bamboo traps caught no fish. The eggs were embedded in, and firmly cemented to the substrate by a gelatinous matrix. It took several hard knocks on rocks to dislodge the spongy mass from the interior of the compartment.

No fish were taken until the traps had been in the water at least 7 days. Thus the failure at Ampem may have been due to the shorter periods that the traps were set. The larger size of the eggs in specimens taken at Ajena than Ampem and the lack of spawning fish at Ampem suggest that the traps may not have been successful even if left for longer periods.

From the above, the following general picture of the preferred spawning site of C. auratus and C. walkeri emerges: 1) calm shallow waters; 2) darkened interior of a hole or a crevice; and 3) a firm substrate for the deposition of eggs. These characteristics of the spawning site closely tallied with those described by interviewed fishermen. They added that the entrance to the nest is always directed away from the wind. This fact could not be ascertained in the calm waters of the Ajena Bay. It may, however, be the case in unsheltered areas.

C. velifer and C. furcatus were not collected in the area. Thus their preferred spawning site might be different from those of C. auratus and C. walkeri.

The electric catfish, Malapterurus electricus was the only other fish species caught in a few of the chambers. The size of the entrance limited specimens of this species to juveniles. M. electricus is known to possess a remarkable capacity for discharging high electric voltage which either dispels or stuns other fish which they then use as food. The size range captured, however, could only have dispelled Chrysichthys spawners. Their comparative scarcity in the ichthyofauna probably makes their competition with Chrysichthys for space relatively insignificant.

Spawning Behavior and Spawning

The fact that ripe male and female Chrysichthys started entering the traps after a 7-day period, tends to suggest that it takes time before the traps are accepted as part of the environment. Occasionally, only a single male or female was found in a compartment. Although efforts were made to ensure that no fish escaped during recovery of the traps, there was no way of determining if 100% success was achieved. Hence it could not be said with certainty that a female or male was the first to enter the spawning chamber. However, in all cases that eggs or larvae were found in a chamber, both male and female were present. Micha and Frank (1975) reported that both male and female care for the eggs. As earlier mentioned (page 42), at this time, the male's head is at the peak of its enlargement and the lower jaw deeply pouched. This gives the impression that the male might collect and incubate the eggs in the mouth as Sarotherodon species do. No evidence of this behavior was, however, observed.

Of 43 mating pairs collected with the traps, 42 showed the male bigger than the female. In the exceptional case, the female was only 5% longer than the male. For the rest, the size difference ranged from 0 to 75%. The smallest specimen captured in bamboo traps was a male (SL, 76 mm) and it was without a partner. Thus it would appear that the observed characteristic whereby the male of a mating pair was bigger than the female might be an important requirement for successful mating and consequent spawning. If females actually reach a larger maximum size than males (Tables 29 and 30), they may have difficulty finding mates.

Habitat Preference of the Juveniles

Two juveniles of either C. auratus or C. walkeri which might be about 3 weeks old and measured 13 and 15 mm (TL), were found sheltered in the asbestos-pipe traps set in 3.5 m deep water. This discovery was significant, in that throughout Loiselle's (1972) sampling survey of inshore habitats and the present study, no specimen smaller than 20 mm was captured. There is thus the suggestion that after the larval stage, the juveniles migrate into deeper water where they hide in the shelter of submerged vegetation until they reach a certain size (about 20 mm: the lower size range collected with rotenone) and then return once more into shallow waters.

WEIGHT-LENGTH RELATIONSHIP

Weight-length relationship computed from linear least squares regressions of log weight on log length (i.e., log W = log a + b log SL) (Table 31) for fish collected during the period 1974 to 1977 showed no significant difference in either slope (b) or intercept (log a) ($P > 0.05$) between male and female fish. (It was significant in *C. walkeri* in the first calculation. Closer inspection of plots of the data for *C. walkeri*, however, revealed the inclusion of an outlier which was obviously the result of human error. It was for a female fish which measured 30 mm and weighed 10 grams, thus making the calculated K, 37.04. Exclusion of this one point and recalculation, resulted in no significant difference between the two equations.) Weights, predicted for fish, in the mid-point of an abundant size class (130 mm for *C. auratus* and *C. walkeri* and 210 mm for *C. velifer* and *C. furcatus*) with the calculated equations, showed males slightly heavier than females in 3 of the 4 species. The difference was smallest in *C. walkeri* which showed females heavier than males. Since these differences were not statistically significant, the data for each species were pooled for the calculation of weight-length relationships. The regression slopes were significantly less than 3 ($P < 0.05$) for 3 species, but not for *C. walkeri*. Thus overall, it may be concluded that smaller individuals in the *Chrysichthys* population in Volta Lake were plumper than the longer members. Since the population structure was more or less constant during this period, it may further be concluded that as Chrysichthys grow older in Volta Lake they become poorer in condition.

This change in shape with growth is similar to that described for the smaller species of catfish (Fam. Ictaluriidae) in North America by Carlander (1969). The cause was ascribed to stunting in overcrowded populations with the larger fish in poorer condition. As earlier shown in this study, and in the survey of inshore fish fauna by Loiselle (1972), the ichthyomass of Chrysichthys in inshore shallows was higher than that of any other species. This, and the fact that individuals of the genus in Volta Lake are smaller in size than individuals recorded for some water bodies in West Africa (Ajayi, 1972; Ikusemiju, 1976; Chauvet, 1973), indicate that members of the Volta populations may be stunted and overcrowded. Stunting is often associated with overpopulation (dense populations in relation to carrying capacity).

Although Ricker (1973; 1975) has shown that the geometric mean regression is preferable, predictive regressions have been used in the above discussion because most comparable studies have used the predictive regression. The slope (v) of each geometric mean regression is computed by dividing the slope (b) by the correlation coefficient, (r) (Table 31). The slope for C. velifer, which significantly differed from 3.0 when calculated with b value, was no longer significantly different from 3.0 (Table 33). Hence with the geometric mean regression equation, C. walkeri and C. velifer had slopes which were not significantly different from 3.0

while C. auratus and C. furcatus had slopes which were significantly less than 3.0

When the data were further broken down into quarters (Table 34), it was observed that slopes were lowest in March to May for 3 species with the C. velifer slope being somewhat lower in June to August. The lack of clear-cut pattern may have resulted from combining data for several years but the data were not sufficient to consider each year separately. Lower slopes in some cases are associated with the post-spawning period when the larger fish are below normal weight because of loss of reproductive products, but the Chrysichthys of Volta Lake do not appear to have a well-defined spawning season.

Condition Factor

Another measure of the weight-length relationship is the coefficient of condition, K, where

$$K = \frac{W \times 10^5}{L^3} .$$

The coefficient of condition is an index of the weight-length relationship of the individual fish rather than of the population. Frequently, however, mean Ks are used in comparing populations, a practice which may lead to false conclusions if the slope of weight-length regression differs from 3.0.

Le Cren (1951) pointed out that the coefficient of condition will vary with length itself according to the expression $K = L^{n-3}$. Consequently,

Table 33. Log weight-log length regression equations by species and sex for *Chrysichthys* spp in Volta Lake during the period 1974 - 1977

Sex	No.	SL range	Loga[a]	b[a]	r	Predicted wt[b] in grams	v
			C. auratus				
Male	76	71-195	-3.945±0.309	2.626±0.510	0.896	40.0	2.929
Female	110	62-195	-4.078±0.164	2.671±0.080	0.955	37.0	2.797
Combined	186	62-195	-4.032±0.159	2.656±0.077	0.930	38.3	2.856
			C. walkeri				
Male	93	73-235	-4.679±0.191	2.972±0.091	0.960	40.0	3.096
Female	99	75-200	-4.648±0.173	2.964±0.082	0.964	41.5	3.075
Combined	192	73-235	-4.650±0.162	2.961±0.061	0.962	40.7	3.078
			C. velifer				
Male	203	83-343	-4.444±0.147	2.856±0.066	0.951	154.3	3.004
Female	280	75-330	-4.431±0.123	2.847±0.055	0.951	151.5	2.992
Combined	483	75-343	-4.440±0.094	2.851±0.042	0.951	151.6	2.998
			C. furcatus				
Male	37	85-418	-3.985±0.318	2.683±0.142	0.954	176.0	2.812
Female	58	85-310	-4.004±0.171	2.658±0.079	0.976	147.4	2.723
Combined	95	85-418	-4.083±0.170	2.707±0.770	0.963	159.7	2.811

[a] Log weight = loga + b log standard length.

[b] Predicted length in grams at 130 mm for *C. auratus* and *C. walkeri* and 120 mm for *C. velifer* and *C. furcatus*. These selected lengths represent the middle of the most abundant size class.

Table 34. Log weight-log length regression equations by species and quarter of the year for *Chrysichthys* captured in Volta Lake, during the period 1974 to 1977

Season	*C. auratus*			*C. walkeri*			*C. velifer*			*C. furcatus*		
	No.	a	b	No.	a	b	No.	a	b	No.	a	b
1. Dec.-Feb.	39	-4.527	2.895	71	-4.624	2.939	84	-4.687	2.955	-	-	-
2. Mar.-May	50	-3.309	2.327	32	-4.188	2.746	101	-4.272	2.773	64	-4.000	2.670
3. June-Aug.	62	-4.142	2.702	34	-4.964	3.124	163	-4.074	2.696	27	-4.206	2.760
4. Sept.-Nov.	35	-3.823	2.549	55	-4.516	2.904	136	-4.817	3.015	-	-	-

except where n = 3 (indicating isometric growth), condition factors of fish of different lengths cannot be directly attributed to features other than length. He therefore sounded a note of caution in comparing condition factors between fish of different lengths where n is not equal to 3. He suggested "alternate methods of analyzing condition which may be more suitable". These methods mainly involve the empirical calculation of the regression slope in the weight-length relationship equation for the population of interest and its substitution for the exponent 3 in the formula: $W = aL^n$, where n is equal to the empirically calculated slope value. This he referred to as the 'relative condition factor'.

Carlander (1969) pointed out that Le Cren's relative condition factor assumes that the slope is the same in the populations being studied and remains the same when collections in different seasons are compared. In the Volta Lake studies, the slopes are not always the same (Table 34).

The mean K values may be used for comparing the condition of one population with another or with others if 1) the regression slope does not differ from 3 or if there is no trend in K with length, 2) if the size distributions of the samples are truly representative of the size distributions of the populations, or 3) if the lengths of the fish are within the same fairly narrow size range in each sample. In the last case, the comparison is not between populations but between the fish of this size range in the populations. If fish of the same lengths are compared, the mean weights can be used rather than calculated K.

When the weight-length regression has been calculated (as in Tables 31 and 32) the expected mean K at each length can be calculated with the following formula:

$$\text{Log } K = \log_{10} a + 5 + (n-3)\log L \text{ .}$$

This was arrived at through the following reasoning:

$$\text{Coefficient of condition } K = \frac{W \times 10^5}{L^3}$$

But $W = aL^n$, therefore

$$K = \frac{aL^n \times 10^5}{L^3} = aL^{n-3} \times 10^5 \text{ .}$$

Hence:

$$\log_{10} K = \log_{10} a + 5 + (n-3)\text{Log}_{10} L \text{ .}$$

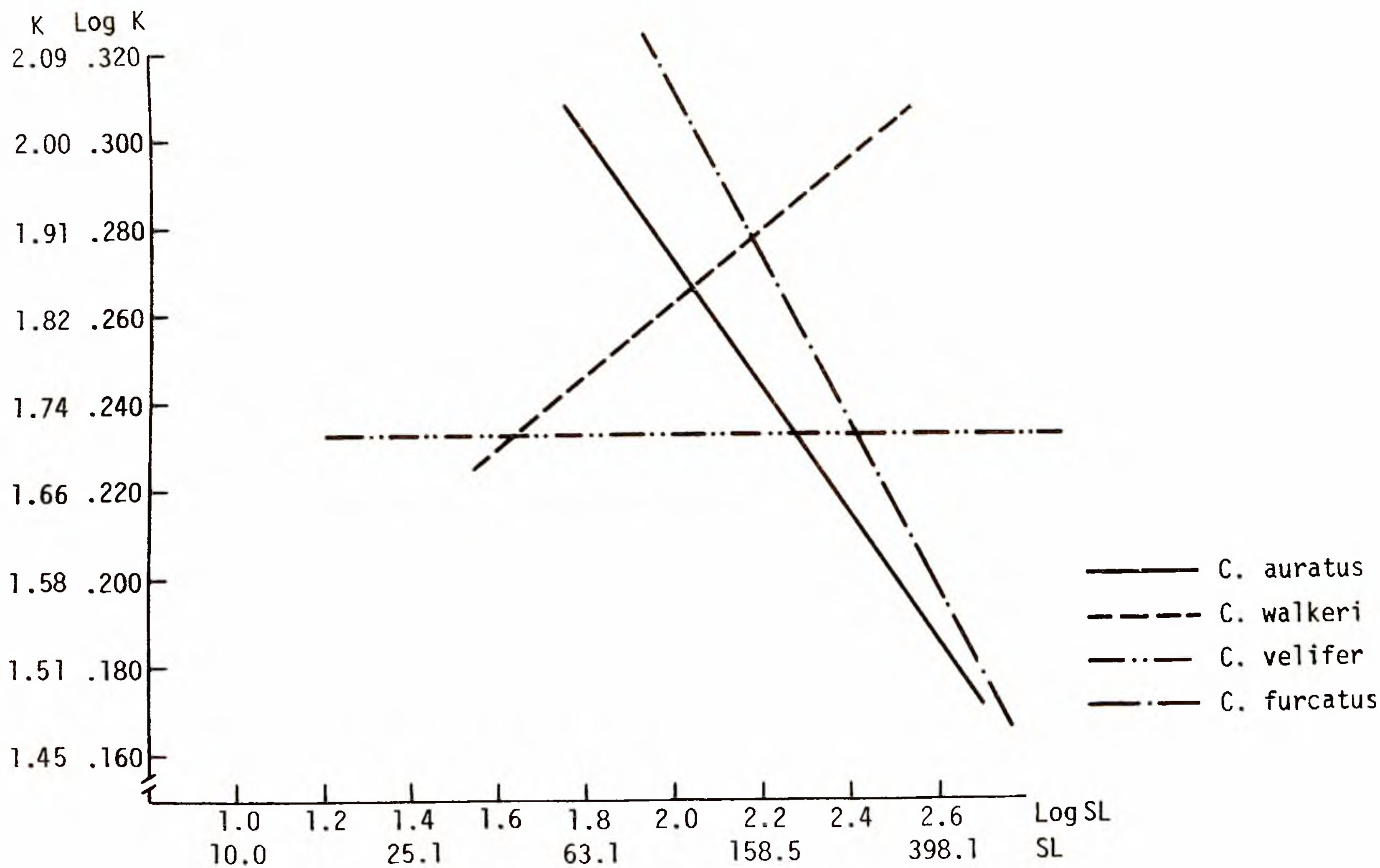
Regressions of log K on Log SL based upon geometric mean, LogW - log SL regressions are presented in Table 35 and Fig. 15. It should be pointed out, however, that the largest C. auratus were 195 mm C. walkeri, 235 mm and therefore the extension of the line beyond these points is theoretical

Table 35. Regressions of log K on log SL based upon geometric mean, log W-log SL regressions

	a	b
C. auratus	0.558	-0.143
C. walkeri	0.103	0.079
C. velifer	0.234	-0.001
C. furcatus	0.695	-0.191

Fig. 15. Regressions of log K on Log SL based upon geometric mean, Log W-Log SL regressions

Regressions of logK on LogSL based upon geometric mean, LogW-LogSL regressions



RECOMMENDATIONS FOR FUTURE RESEARCH

Some vital aspects of the life history which were not covered during this study include: age, growth and mortality rates. Knowledge of these parameters is essential in productivity studies of this nature. Past efforts to age Volta Lake fishes have been unsuccessful. In 1969 to 1970, a researcher (Mariam Brooks) of the Volta Basin Research Project of University of Ghana, explored all the known techniques of aging, using Volta Lake species. Her results in general were negative (Taylor, 1971). Earlier, Wuddah (1967) had reported inability to read scales of Volta Lake *Tilapia* spp.

Encouraged by reports from the Ivory Coast that *Chrysichthys walkeri* had been aged via spine sectioning and examination (Dia, 1975), I undertook a trip to that country to study the method. Sectioned spines of *Chrysichthys walkeri* in Ebrie Lagoon showed, fairly clearly, alternation of dark and light bands. Two dark bands were proved to be formed during the two periods of peak rainfall in a year. No similar bands were identified in the sectioned spines of Volta Lake *Chrysichthys*. At Iowa State University, about 6 - 10 otoliths were preliminarily examined under the scanning electron microscope for evidence of growth rings. These few did not show any consistent structural patterns which could be associated with any seasonal activities. It is however, recognized that more effort needs to be spent on this technique before a definitive statement can be made as to its utility. In Kainji Lake, Ajayi (1972) aged *C. auratus* by reading annuli of sectioned spines and vertebrae. Kainji Lake, however, is located at a higher latitude (10°00 - 10°50'N) than Volta Lake (6°15' - 9°10'N) and consequently, experiences more extremes of climate which might be conducive to growth ring formation. Ikusemiju (1976) used the progression of the modes in the length frequency distribution to determine growth rate of C. walkeri in Lekki Lagoon. This technique could not be used in the present study insofar as the modes appeared fixed for the period investigated.

Knowledge of mortality rates can be secured from age structure data or mark and recapture technique (Healey, 1975). Until Volta Lake fishes can be aged, efforts should be concentrated on the latter method.

During November 6 - 24, 1975, 14 Chrysichthys specimens were marked with Floyd spaghetti tags which were inserted through the dorsal muscles and secured between the interneurals. The fish were then kept in a circular pond of about 1 m radius. Tag retention time ranged from 11 - 18 days. In a following field experiment on November 28, 1975, 37 Chrysichthys specimens were marked and released at Ampem. There was one recovery on December 7 (i.e., 9 days after tagging) at about a mile offshore of same station. Though the experiment was terminated when available tags were used up, it was obvious that tag retention of 18 days would be of little value in determining mortality rates. Hence exploration of other methods has been planned for the future.

The present study has suggested that the Chrysichthys populations in Volta Lake were stunted although growth rates are not known. Growth rate and productivity could be increased if serious exploitation starts (Healey, 1975). Though there is no market objection to small fish in Ghana, the fishermen are not attracted to Chrysichthys fishery, probably because it has not proved profitable to harvest them with the present means of capture. The commercial fishery uses principally gill nets which accounts for about 75% of the catch. Bazigos (1969) estimated that for the first two quarters of 1969 an average of 97,043 units of gill nets, 859 cast nets, 2,714 lines, and 25,375 traps per day were used. Vanderpuye (1975) showed that in May 1969 - October 1973, there was a decline in catches of herbivorous Tilapia and a concomittant increase in carnivorous Lates. The two species comprised 63% by weight of the commercial catch from May 1969 to April 1972. Since the Tilapia fishery used almost exclusively gill nets and the Lates fishery, gill net and line, it may be reasonable to conclude that after these estimates in 1969, there was a relative decrease in gill nets and traps and increase in number of lines.

The traps are made of either cane or wire. They have no leads and are set in the marginal weeds at the end of cleared paths which direct the fish into the traps. The present study has shown that the catch of one hoop net with a single lead might be as much as that of one gill net (30 m x 3 m long) set in 3 m deep water. A hoop net has the following advantages over a gill net: 1) it can be set in the marginal areas without the use of a boat; 2) the fishes are trapped and not gilled or entangled; hence recovery is easier resulting in saving of time; 3) less damage is done to the webbing thus cutting down on cost of maintenance; 4) fish are captured alive (except in anoxic environment) and thus the fisherman can lift the traps at more convenient time intervals and 5) although no figures are available, it might be cheaper to make a hoop net of the same catching efficiency as a gill net. Consequently, introduction of hoop net fishery to the commercial fisherman should lead to more efficient harvest of Chrysichthys.

About 1,000 Chrysichthys stomachs were examined for items eaten, during the present study. Unfortunately, field studies on degree of selection of organisms in the environment were not completed before I left Ghana; hence this aspect has not been reported on. I hope to continue this study on my return to Ghana because of its importance in productivity studies. Further, the position of Chrysichthys in the food web needs to be clearly defined. A preliminary investigation (Vanderpuye, 1975) showed that Chrysichthys may be one of the important food items for the much-relished Lates niloticus.

Chrysichthys auratus and C. walkeri were observed spawning in the sheltered Ajena Bay in shallow water. There is the need to pursue the search for the spawning areas of C. velifer and C. furcatus. The protection of the spawning areas might be necessary should it turn out that the preferred habitat is localized and in danger of being rendered unsuitable on account of human activity. The estimated 1,479 fishing villages scattered around the lakeshore makes this problem real and not imaginary.

Finally, it is recognized that almost all aspects of the life histories of these Chrysichthys in Volta Lake need further study. The present study gives leads as to the areas needing further study and to the methods to be used.

SUMMARY

Though Chrysichthys have been reported from practically all the river systems in tropical Africa, little is known about their biology. Species in the genus have not been adequately separated, identified, and described. This, in the main, is due to lack of dependable taxonomic characteristics. When some morphological and meristic characteristics used in the literature were tested, only number of gill rakers proved to be of some value at Volta Lake. In the present study, the following characteristics were used for identification: position of the dorsal fin, color of the barbels and the body, and the shape of the caudal fin and its lobes. Four species in Volta Lake are *C. velifer* (Norman), *C. auratus* (Geoffroy Saint-Hilaire), *C. walkeri* (Gunther), and *C. furcatus* (Gunther).

From around November 1965 (about a year after the lake had started filling) to May 1970, Chrysichthys was relatively abundant near the dam-site at Akosombo. Sampling during June - September 1970 showed a decline and a more even lakewide distribution. Thereafter, abundance fluctuated seasonally with more fish being caught in the rainy season.

At Ampem sampling station, Chrysichthys accounted for 43.8% of the total catch thus making it the most abundant genus, distributed as follows: *C. velifer* 23.3%, *C. auratus* 10.3%, *C. walkeri* 10.0%, and *C. furcatus* 0.002%.

During August 1974 to May 1975, Chrysichthys accounted for 52% of the catch in inshore portions (depth: 0 - 3 m) of Areas 3, 7, and 8.

Abundance of Chrysichthys decreased with depth, indicating that the species prefer inshore habitats. In most parts of the lake, except in periods of overturn, oxygen concentration below 10 m was 0. Since

Chrysichthys are sensitive to low oxygen concentration, their depth distribution might be limited to roughly 10 m in most parts of the lake. Catches with hoop nets in decomposing marginal vegetation devoid of dissolved oxygen, however, showed that Chrysichthys are capable of penetrating deoxygenated water for lengths of time.

Depth and degree of flow are two independent factors which interact to determine the distribution of Chrysichthys. Both increasing 1) depth and 2) flow have negative effects.

Length frequency distribution of catches with rotenone did not show seasonal changes in abundance of juveniles. While inadequate sampling technique may be responsible, it is argued that had spawning been seasonal, it would have shown up even with this type of sampling.

When monthly captures with the least selective of the sampling gear (beach seine) were analyzed, catches of C. velifer and C. walkeri showed fixed modes at 140 and 125 mm, respectively. There was no evidence of two or more modes which might suggest different year classes or spawning periods.

Fish in 'running' condition were rarely encountered on the sampling grounds. This indicated that ripe fish go to the breeding grounds for spawning before this stage. Likewise, spent fish do not return to the sampling grounds until they are well advanced into the resting stage.

Both male and female C. auratus and C. walkeri matured within the standard length range 70 - 79 mm. For C. velifer, it was 100 - 119 mm. The smallest spawning female was 72 mm in C. walkeri and 82 mm in C. auratus. No clear seasonal trend in maturity was shown by any of the species.

In C. auratus, C. walkeri and C. velifer, the female outnumbered the males in both the wet and dry season samples, but the ratios differed from the hypothetical 1 : 1 ratio only for C. velifer in the rainy season.

The left ovary was bigger than the right in 4 specimens of C. walkeri and 3 of 5 C. auratus. The other 2 C. auratus had ovaries of equal size but they were small suggesting possible further development which would result in size differences.

The smaller species (C. auratus and C. walkeri) appeared to have larger eggs than the larger species (C. velifer and C. furcatus) although this difference was not statistically significant ($P > 0.05$). Samples involved in the comparison were captured on the sampling grounds but noton the breeding grounds. The observation that C. auratus leaves the sampling grounds for the breeding grounds earlier than the rest, however, makes it doubtful that the same maturity stages were involved in the comparison.

Within each species, fecundity varied among females but generally increased with size. Least squares estimates of fecundity (F) on

(1) body length (SL) were:

C. walkeri, $\log F = -1.905 + 2.36 \log SL$.

C. auratus, $\log F = -3.98 + 3.312 \log (SL)$. Curvilinear equations best described the relationship in both species.

C. velifer, $F = -4295 + 40.95 (SL)$. Rectilinear equation best described the relationship.

(2) body weight (W) were:

C. walkeri, $F = -126.18 + 27.63 W$.

C. velifer, F = 1607 + 12.95 W.

Rectilinear equations best described the relationship in both species.

C. auratus and C. walkeri were captured with bamboo traps on the spawning grounds in the well sheltered Ajena Bay. Their preferred spawning site appears to be 1) calm shallow waters; 2) darkened interior of a hole or a crevice; and 3) a firm substrate for the deposition of the eggs.

Ripe male and female did not enter the traps until at least 7 days after setting. Of 43 mating pairs collected in the traps, 42 showed the male bigger than the female. It was concluded that this characteristic might be an important requirement for successful mating and subsequent spawning.

Two juveniles of either C. auratus or C. walkeri, of sizes 13 and 15 mm (TL) were caught sheltered in the asbestos-pipe traps set in 3.5 m deep water. This suggested that after the larval stage, the juveniles migrate into deeper water, where they hide in the shelter of submerged vegetation until they reach a certain size (about 20 mm: the lower size range collected with rotenone) and then return once more into shallow waters.

Weight-length relationship computed from linear least squares regressions of log weight on log length (i.e., log W = log a + b log SL) for (1) male and (2) female fish, showed no significant difference in either slope (b) or intercept (log a).

The regression slopes were significantly less than 3.0 for 3 species but not for C. walkeri. However with functional regression, C. walkeri and C. velifer had slopes which were not significantly different from 3.0

while *C. auratus* and *C. furcatus* had slopes which were significantly less than 3.0. Thus overall, smaller individuals in the population were plumper than the longer members. It was further concluded that as *Chrysichthys* in Volta Lake grow older, they become poorer in condition.

When the data were further broken down into quarters, it was observed that regression slopes were lowest in March to May for 3 species with the *C. velifer* slope somewhat lower in June to August.

When the weight-length regression has been calculated, the expected K at each length can be calculated with the following formula:

$$\text{Log } K = \log_{10} a + 5 + (n-3) \log L.$$

Areas recommended for either continuing or future studies include: 1) age and growth; 2) mortality rates; 3) food habits; and 4) identification and delineation of spawning areas. All are considered important for the rational management of the *Chrysichthys* fishery envisaged.

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APPENDIX

Table A-1. Field sampling schedule in connection with study of life history of *Chrysichthys* catfish in Volta Lake, Ghana

Period	Area	Station	Secchi disk	Oxygen	Temp.	Gill net	Beach seine	Traps	Rote-none	Remarks
1974										
22 May	1	Ampem				+		+		Preliminary survey
11-18 July	1	Ampem	+	+	+	+		+		
3-7 Aug	1	Ampem	+	+	+	+	+	+		
30 Aug	3	Agornyomi	+	+	+	+		+	+	
31 Aug-1 Nov.	3	Mangoase	+	+	+	+		+	+	
5 Nov.	3	Tsikpor	+	+	+	+		+	+	
15-20 Nov.	1	Ampem	+	+	+	+	+	+	+	
9-14 Nov.	1	Ampem	+	+	+	+	+	+	+	
1975										
14 Feb.	7	Awusakorpe	+	+	+	+		+		
15 Feb.	7	Lanto	+	+	+	+		+		
16 Feb.	7	S.E.Yeji	+	+	+	+		+		
17 Feb.	7	Accra Town	+	+	+	+		+		
18 Feb.	7	Awoyovikope	+	+	+	+		+		
19 Feb.	7	Adormiabra	+	+	+	+		+		
18-23 Mar.	1	Ampem				+	+	+	+	
19-24 April	1	Ampem	+	+	+	+	+	+	+	
14 May	7	Ghanakope	+	+	+	+				
15 May	7	SE Yeji	+	+	+	+				
16 May	8	Kafaba	+	+	+	+				
17 May	8	Buipe	+	+	+	+				
21 May	3	Kpandu	+	+	+	+				
30 May-4 June	1	Ampem					+	+	+	
16-26 June	1	Ampem	+	+	+	+	+	+	+	
15-24 July	1	Ampem	+	+	+	+	+	+	+	
12-20 Aug.	1	Ampem	+	+	+	+	+	+	+	
10-20 Sept.	1	Ampem	+	+	+	+	+	+	+	
22 Oct.-1 Nov.	1	Ampem	+	+	+	+	+	+	+	
7-29 Nov.	1	Ampem	+	+	+	+	+	+	+	
12-22 Dec.	1	Ampem	+	+	+	+	+	+	+	

Table A-1. Field sampling schedule in connection with study of life history of <u>Chrysichthys</u> catfish in Volta Lake, Ghana

Period	Area	Station	Secchi disk	Oxygen	Temp.	Gill net	Beach seine	Traps	Rote-none	Remarks
1974										
22 May	1	Ampem				+		+		Preliminary survey
11-18 July	1	Ampem	+	+	+	+		+		
3-7 Aug	1	Ampem	+	+	+	+	+	+		
30 Aug	3	Agornyomi	+	+	+	+		+	+	
31 Aug-1 Nov.	3	Mangoase	+	+	+	+		+	+	
5 Nov.	3	Tsikpor	+	+	+	+		+	+	
15-20 Nov.	1	Ampem	+	+	+	+	+	+	+	
9-14 Nov.	1	Ampem	+	+	+	+	+	+	+	
1975										
14 Feb.	7	Awusakorpe	+	+	+	+		+		
15 Feb.	7	Lanto	+	+	+	+		+		
16 Feb.	7	S.E.Yeji	+	+	+	+		+		
17 Feb.	7	Accra Town	+	+	+	+		+		
18 Feb.	7	Awoyovikope	+	+	+	+		+		
19 Feb.	7	Adormiabra	+	+	+	+		+		
18-23 Mar.	1	Ampem				+	+	+	+	
19-24 April	1	Ampem	+	+	+	+	+	+	+	
14 May	7	Ghanakope	+	+	+	+				
15 May	7	SE Yeji	+	+	+	+				
16 May	8	Kafaba	+	+	+	+				
17 May	8	Buipe	+	+	+	+				
21 May	3	Kpandu	+	+	+	+				
30 May-4 June	1	Ampem					+	+	+	
16-26 June	1	Ampem	+	+	+	+	+	+	+	
15-24 July	1	Ampem	+	+	+	+	+	+	+	
12-20 Aug.	1	Ampem	+	+	+	+	+	+	+	
10-20 Sept.	1	Ampem	+	+	+	+	+	+	+	
22 Oct.-1 Nov.	1	Ampem	+	+	+	+	+	+	+	
7-29 Nov.	1	Ampem	+	+	+	+	+	+	+	
12-22 Dec.	1	Ampem	+	+	+	+	+	+	+	

Table A-1. Continued

Period	Area	Station	Secchi disk	Oxygen	Temp.	Gill net	Beach seine	Traps	Rote-none	Remarks
1976										
13-18 Feb.	1	Ampem	+	+	+	+	+	+	+	
27 Mar.	4	Zikpo				+				
26 Mar.	4	Nketekwan				+				
20 Mar.	7	Awneakorpe				+				
11 Mar.	11	Dodi Island				+				
20-30 May	1	Ampem	+	+	+	+	+	+		
23 June-27 July	1	Ampem	+	+	+	+	+	+	+	
29 Aug.	1	Adidokpo								
30 Aug.	1	Kwame Jamara								
31 Aug.	1	Adawso								
2 Sept.	1	Abochire								
5-15 Sept.	1	Ampem	+	+	+	+	+	+	+	
1977										
1-8 June	1	Ampem				+	+	+	+	+Bamboo trap set.
23 June-2July	1	Ampem				+	+	+	+	+ "
26-31 July	1	Ampem				+	+	+	+	+ "
28 Aug-16 Sept.	1	Ampem				+	+	+	+	
1 July-14 Sept.	1	Ajena Bay	Bamboo trap settings							

Table A-2. Composition of fish catches at Ampem station during the period June 1975 - May 1976

Species	1975 June-Aug.	1975 Sept.-Nov.	Dec.75 Feb.76	1976 Mar.-May	Total	
Bagridae						
Chrysichthys auratus	122	500	195	132	949	
C. walkeri	340	272	170	138	920	4024
C. velifer	804	769	382	188	2143	
C. furcatus	1	1	1	9	12	
Bagrus bayad	-	4	3	1	8	
Auchenoglanis occidentalis	36	66	65	28	195	
Cichlidae						
Sarotherodon galilaeus	1134	122	63	57	1376	
S. niloticus	182	30	151	6	369	
Tilapia zilli/melanopleura	33	121	73	42	269	
Chromidotilapia guntheri	82	196	72	32	382	
Hemichromis fasciatus	181	140	71	96	488	
Hemichromis bimaculatus	128	127	103	68	426	
Anabantidae						
Ctenopoma kingslaye	-	3			3	
Clupeidae						
Pellonula afzeliusi	29,182	21,594	3449	8902	63,127	
Cynothrissa mento	46	104	6	-	156	
Cyprinidae						
Labeo coubie	-	-	1	-	1	
Barbus spp	165	9	13	79	266	
Centropomidae						
Lates niloticus	36	134	26	112	308	
Tetraodontidae						
Tetraodon fahaka	22	19	14	8	63	
Characidae						
Hydrocyon brevis	4	7	6	48	65	
H. lineatus	-	14	5	2	21	
Alestes macrolepidotus	2	7	2	8	19	
A. nurse	1	-	-	1	2	
A. baremose	-	2	-	-	2	
A. dentex	4	1	1	-	6	
A. leuciscus	1				1	

Table A-2. Continued

Species	1975 June-Aug.	1975 Sept.-Nov.	Dec.75 Feb.76	1976 Mar.-May	Total
Mochokidae					
Synodontis schall	279	247	31	15	572
S. gambiensis	23	12	-		35
S. nigrita	86	8	-	7	101
Synodontis spp	1	-	1	1	2
Schilbeidae					
Schilbe mystus	4	3	-	5	12
Lutropius niloticus	1	-	-	-	1
Physailia pellucida	751	382	3068	3050	7251
Osteoglossidae					
Heterotis niloticus	1	9	1	1	12
Citharinidae					
Distichodus rostratus	2	13	3	1	19
Paradistichodus dimidiatus	2341	1345	1171	471	5328
Mormyridae					
Mormyrops deliciosus	1	2	-	-	3
Gnathenemus pictus	-	1	1	-	2
Mormyrus rume	-	1	-	1	2
Petrocephalus bovei	-	6	-	1	7
Hyperopisus bebe	19	16	1	4	40
Marcusenius sp	-	2	2	1	5
Polypteridae					
Polypterus senegalensis	86	9	1	17	113
Clariidae					
Clarias lazera	1	-	-	-	1
Clarias sp	1	-			1
Heterobranchus bidorsalis	1	3	-		4
Gymnarchidae					
Gymnarchus niloticus	9	7	17	3	36
Ophiocephalus obscurus	14	2	2	11	29
Malapteruridae					
Malapterurus electricus	10	5	-	2	17
					85,170

Table A-3. Distribution of *Chrysichthys* in Volta Lake during the period Jan. - May 1970 (Data extracted and reprocessed from Loiselle (1972), numbers and weight (grams)

	Area	*C. auratus*				*C. walkeri*			
		No.	%	Wt.	%	No.	%	Wt.	%
Adowso	1	-	-	-	-	1	0.4	56	3.0
Suborni Junction	1	268	43.3	2965	34.7	1	0.2	1160	13.6
Kwame Jamara	1					1	0.3	281	14.7
Asekoko	2	234	68.4	1865	65.2				
Ajena Bay	2	9	0.2	65	2.2				
Ajena Bay SE	2	1	4.0	9	6.9				
Abotere	2								
Agornyomi No. 1	3	25	22.5	130	8.8				
Agornyomi No. 2	3	27	44.3	155	21.3				
Mangoose	3	36	36.4	335	13.2	1	1.0	10	0.4
Second Dodi	3								
Tsikpor	3	14	4.5	69	1.3				
Breniasi	4								
Azizakpoe	4								
Kpetsu	5								
Dumbai	5								
Lidza	5								
Boafori	6								
Lanto No. 1	7								
Lanto No. 2	7								
Lanto No. 3	7	66	5.7	1476	3.8				
Awoyorvikope	7								
Accra Town	7	4	1.3	300	14.4				

Av. biomass per station $= \frac{1458.73}{23} = 63.42$ gm.

C. velifer				*C. furcatus*				kg/ha
No.	%	Wt.	%	No.	%	Wt.	%	
10	4.3	140	7.4	-	-	-	-	9.70
341	55.0	4285	50.2					641.92
-	-	-	-					16.90
67	19.6	685	23.9					254.02
42	0.9	830	28.0					66.31
6	23.0	68	52.3					5.68
8	5.0	200	20.8					9.56
54	48.6	550	37.3					31.62
26	42.6	269	36.9					42.42
27	27.3	580	22.8					92.63
62	27.3	930	28.9	2	0.9	120	3.7	97.18
110	35.1	473	8.8					57.52
-		-	-					-
42	25.3	532	26.8					14.78
17	5.1	182	8.7					4.04
368	58.9	1200	48.4					13.35
-	-	-	-					-
				52	33.1	1140	14.0	61.41
5	7.9	26	18.3					3.27
-	-	-	-					-
38	3.3	1172	3.0					4.76
-	-	-	-					-
								31.66

Table A-4. Numbers of *Chrysichthys* and other species in catches in Areas 3, 7 and 8 during August 1974 to May 1975 (Catches by gill nets, excluding 13 mm mesh, traps and rotenone)

Family and species	Area			Total	
	3[a]	7[b]	8[b]	spp	Family
Osteoglossidae					1
Heterotis niloticus	1			1	
Mormyridae					20
Petrocephalus bovei		10		10	
Hyperopisus bebe		1		1	
Mormyrus rume		1		1	
M. deliciosus		1	1	2	
Gnathonemus harringtoni		3	1	4	
G. tamandua		2		2	
Clupeidae					8
Cynothrissa mento		4	4	8	
Characidae					194
Hydrocynus brevis		6	1	7	
H. lineatus	2	16	11	29	
A. dentex	4	40	17	61	
A. baremose		6	10	16	
A. macrolepidotus	1	8	2	11	
A. leuciscus	4	18	13	35	
A. nurse	3	3	16	22	
Micralestes acutidens		2	11	13	
Citharinidae					15
Citharinus citharus		1	5	6	
C. latus					
Distichodus rostratus	2	7		9	
Schilbeidae					127
Schilbe mystus		64		64	
Eutropius niloticus	1	22	40	63	

[a]Means of capture: traps and rotenone.

[b]Means of capture: gill nets.

Table A-4. Continued

Family and species	Area 3[a]	Area 7[b]	Area 8[b]	Total spp	Total Family
Mochokidae					41
Synodontis membranaceous		3	2	5	
S. nigrita	1			1	
S. schall	9	2	2	13	
S. gambiensis		21		21	
S. eupterus	1			1	
Cichlidae					36
Hemichromis fasciatus	6	6		12	
H. bimaculatus	2			2	
Chromidotilapia guntheri	3	2		5	
Sarotherodon galilaeus	4	1		5	
S. niloticus	7			7	
Tilapia zilli		5		5	
Malapteruridae					4
Malapterurus electricus	4			4	
Centropomidae					11
Lates niloticus	4	7		11	
Bagridae					518
Bagrus bayad		3		3	
Auchenoglanis occidentalis	1			1	
Chrysichthys auratus		23	3	26	
C. walkeri	159	12	1	172	
C. velifer	25	34		59	
C. furcatus	2		1	3	
Chrysichthys spp	254				254
Cyprinidae					12
Labeo brachypoma		1		1	
L. senegalensis		1	3	4	
L. coubie		6	1	7	
					987

Table A-5. Data from *Chrysichthys velifer* females used to estimate relative fecundity based on (1) length and (2) weight

Specimen	Standard length (mm)	Weight (gm)	No. of eggs	Relative fecundity (no./mm) (1)	Relative fecundity (no./gr) (2)
1	132	50	1263	9	25
2	145	65	2927	20	45
3	153	60	1880	12	31
4	160	70	1145	7	18
5	165	85	1549	9	39
6	170	85	3349	19	42
7	170	105	4439	26	42
8	183	110	2597	14	23
9	185	109	2343	12	21
10	185	112	7956	43	71
11	190	130	3547	18	27
12	190	136	1635	8	12
13	195	150	4354	22	
14	200	150	2875	14	29
15	205	180	2049	10	11
16	205	190	4060	19	21
17	220	200	3600	16	18
18	220	180	4752	21	26
19	221	205	4110	18	20
20	225	200	4866	21	24
22	315	525	8982	28	17
23	347	730	10656	30	14

Table A-6. Data from Chrysichthys walkeri females used to estimate relative fecundity based on (1) length and (2) weight

Specimen	Standard length (mm)	Weight (gm)	No. of eggs	Relative fecundity (no./mm) (1)	Relative fecundity (no./gr) (2)
1	79	-	270	3	-
2	80	12	600	7	50
3	88	24	698	8	29
4	95	-	325	3	-
5	102	30	580	6	19
6	118	30	1038	9	34
7	120	-	1180	10	-
8	120	-	1520	12	-
9	122	-	800	7	-
10	122	45	980	8	21
11	125	43	600	5	14
12	125	45	1532	12	34
13	130	45	895	7	20
14	130	-	1264	10	-
15	130	48	875	7	20
16	132	-	1980	15	-
17	132	46	1084	8	24
18	133	45	1134	8	25
19	134	46	1000	7	22
20	140	55	1382	10	25
21	140	-	2120	15	-
22	140	55	950	7	19
23	142	55	1280	9	22
24	147	60	1200	8	20
25	150	70	2530	17	36
26	170	95	2690	16	28

Table A-7. Data from *Chrysichthys auratus* females used to estimate relative fecundity based on (1) length and (2) weight

Specimen	Std. length (mm)	Weight (gm)	Number of oocytes	Relative fecundity No./mm	No./gm
1	78	-	218	2.79	-
2	89	-	249	2.80	-
3	92	10	426	4.63	42.6
4	99	-	396	4.00	-
5	101	-	376	3.72	-
6	102	-	383	3.75	-
7	105	-	642	6.11	-
8	105	-	374	3.55	-
9	112	30	914	8.16	30.47

Table A-8. Data from *Chrysichthys furcatus* females used to estimate relative fecundity based on (1) length and (2) weight

Specimen	Std. length (mm)	Weight (gm)	Number of oocytes	Relative fecundity No./mm	No./gm
1	160	110	1234	7.71	11.22
2	195	160	599	3.07	3.74
3	195	160	679	3.48	4.34
4	335	565	15938	47.58	28.21