EYE LENS PROTEINS AND PHYSICAL PARAMETERS AS TOOLS IN FRESHWATER FISH TAXGNCMIC INFORMATION

BY

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THESIS APPROVAL

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DEDICATION

THIS DISSERTATION IS DEDICATED TO MY LOVING WIFE
MRS. JAMILA MAHDI

AND TO

MY DAUGHTERS, AISHA AND AMINA

WHO BECAUSE OF THIS WORK COULD

NOT ENJOY MY FATHERLY ATTENTION FULLY.

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DECLARATION

I declare that this Thesis is the document of my reserch work. It has not been submitted in any form for another degree, diploma or other certificates at any institution. Information derived from published and unpublished work of others has been duely acknowledged in the text.

ABDULLAHI MAHDI

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ABSTRACT

(1) Length - weight measurements were made on the fish species examined and statistical analysis carried out on the data.

(2) Eye lens nuclear proteins were examined electrophoretically.

(3) Differences were found between all the species studied and the results obtained indicated significant inter-specific variation.

(4) In the electrophoretic study, correlation between the similarity of the electrophoretic patterns and the closeness of the relationship between species was observed.

(5) The results indicate that physical parameters and eye lens proteins have considerable potential as sources of taxonomic information.

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ABBREVIATIONS AND SYMBOLS

mg	milligram, milligramme
m	metre
l	litre, 1,000 cubic centimetres
dl	decilitre, 100 cubic centimetres
cm	centimetre
mm	mellimetre
ml	millilitre, 1 cubic centimetre
g	gram, gramme
%	percentum - used interchangeably
^{o}C	degree contigrade
S.E	Standard Error
R	Coefficient of correlation
>	greater than
<	less than
P	probability
Fig	Figure
SL	Standard Length
TL	Total Length
BW	Body Weight
Na^{+}	sodium ion
CL^{-}	chloride ion
NaCL	sodium chloride
BD	Body depth
NEPA	National electric power authority

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GLOSSARY

Electrophoresis.	Transport of substances, as of colloidal particles, resulting from differences in electrical potential.
Neoplasm.	Addition of tissue generally pathological.
Polymorphism.	Occurence of different forms of individual in the same species. Occurence of different forms, or different forms of organs, in the same individual at different period of life.
Speciation.	The evolution of species; development of specific quality; species formation.
Taxonomy.	The laws of classification as applied to natural history.

CHAPTER ONE

INTRODUCTION

The eye lens is a unique biological entity. It has proven to be a valuable source of polymorphic proteins. These proteins have found special application where biochemical genetic information is desired, for example, in population and taxonomic studies (Smith and Goldstein, 1967; Smith, 1971; Eckroat, 1974; O'Rourke, 1974; McDvitt and Collier, 1975; Blake, 1976; Weinstein and Yerger, 1976 a, b; Gruber and Cohen, 1978; Smith, 1978; Benz, 1980; Love, 1980; de-Jong, 1981). Smith (1982) demonstrated that proteins extracted from sequential layers of the lens core (nucleus) may provide a picture of phylogenetic development. He hypothesized and proved that (a) with increasing depth (i.e. increasing earliness of ontogeny) of nuclear lens layer, the proteins are more primitive (analogous to the greater antiquity of fossils with depth of earth stratum); (b) in an advanced animal, the proteins from the deepest nuclear lens layer resemble the proteins in a more superficial nuclear lens layer from a primitive animal; and so (c) it should be possible to use proteins from the nuclear lens layer to establish phylogenetic relationships.

Proteins of the eye lens in addition to the above uses are employed as markers of (1) behavior, such as swimming ability (Smith and Clemens, 1973), as well as dominance and perceptual acuity (Ramos and Smith, 1975); and (2) the environment (Bon et al, 1967), such as water layer (bottom

or surface) (Gruber and Cohen, 1978), high water turbidity and low light intensities (Weinstein and Yerger, 1976b), and a nocturnal setting. Zigler and Sidbury (1974) observed that rat and rabbit are similar in their percentage composition of the soluble lens proteins and the electrophoretic patterns obtained by using these proteins; but they differ considerably from calf and sheep although the two groups belong to the same family - the arteriodactylan family (Romer, 1966). The fact that the rat and rabbit are animals of similar life style, both being nocturnal, may well be related to these findings. In some cases, environmental influence on lens proteins do not appear (Lowenstein and Bettelheim, 1979), and the relationship involved seems to be phylogenetic. Calhoun and Koening (1970) pointed out that the electrophoretic distribution of the soluble proteins of the lenses are determined by phylogenetic relationships and not environmental ones. They concluded that the distributions of soluble proteins in the lenses are therefore valuable in taxonomic studies. Smith (1983) pointed out that probably there is a variety of influences on the lens proteins, in addition to the basic one of providing a matrix for transparency and elasticity.

The nuclear lens proteins have special features which make them desirable in studies such as this. Smith and Gilamn (1982) have reviewed the features and briefly these features of nuclear lens proteins include (1) resistance to denaturation, which enables lens samples to be taken under environmental conditions (such as at docks and markets)

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that would denature many other proteins; (2) high concentration, the highest in any tissue in the vertibrate body; (3) purity, as they are not contaminated by other tissue proteins, and (4) little or no turnover, as the lens nucleus is an inert nonmetabolizing structure. However, there is evidence that in some fish species certain proteins undergo age-related post-translational changes (Smith, 1983).

Electrophoretic procedures have most often been used in the study of nuclear lens proteins. These proteins are ideal for population and taxonomic studies of fishes. The electrophoretic method of choice is cellulose acetate electrophoresis. Mackie (1980) pointed out that the various electrophoretic techniques now available are the most reliable methods for identifying the species of fishes when the usual differences based on morphology are uncertain.

Because blood proteins and enzymes are such a sensitive system for studying genetic variation, proteins ofthe eye lens nucleus, an inert structure (Reeder and Bell, 1965), were investigated in fresh water fishes and found to be more suitable for this purpose. These nuclear lens proteins are very stable, tolerating temperatures as high as 79°C before precipitating (Smith, 1965) and withstanding relatively harsh procedures, for example, lack of refrigeration for 5 days without denaturing (Smith, 1969c). Furthermore, nuclear lens proteins do not fluctuate physiologically (that is with substrate availability or diet), rhythmically or seasonally throughout the post-embryonic life of the animal. This is because the adult lens proteins laid down very early

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in development are fully present shortly before or after the time of birth and are not turned over (Reeder and Bell, 1965).

Numerical analyses have been carried out to throw more light on species differences. Oni et al (1983) pointed out that there is species difference in the condition factor of fishes. The coefficient of condition or condition factor, has been determined for finfish (Lagler, 1972) and shellfish (Adegboye, 1981; Lahti and Lindquist, 1981). Reports on length-weight relationships in freshwater fishes in this region are few and they include those of Olatunde 1977) and Adegboye (in press).

Condition factors, length-weight relationships and means of fresh weight, total length, standard length body depth and body width were calculated and the results obtained used to throw more light on the taxonomic information being sought by electrophoretic methods in this study.

The objectives of this study are:

(1) to identify by cellulose acetate electrophoretic technique the available species in the families Characidae, Mochokidae and Cichlidae;

(2) to find out if electrophoretic pattern differences exist between male and female fish of the same species;

(3) to find out if size differences in the same species have effect on the band patterns;

(4) to establish differences at family level by electrophoresis and

(5) to establish species differences by numerical

methods.

538 fishes were used in this study and they represent 9 species in the family Characidae, 5 species each in the families Mochokidae and Cichlidae.

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CHAPTER TWO

LITERATURE REVIEW

2.1. UTILIZATION AND ECONOMIC IMPORTANCE OF FISHES.

Taxonomic studies of various groups of fishes are pursued because of the various relationships that exist between man and the fishes and among the fishes themselves. Fishes are utilized by man as food, fish meals and fish fertilizers, fish oils, and in the manufacture of glue. Interaction between fish and man include the use of fish in scientific studies, recreational fisheries and use of fish for aquarium display. Some negative or unpleasant relationships exist between man and the fishes (Bond, 1979).

2.1.1. FISH AS FOOD

As a staple article of food, fish must have found favour with man at a very early stage of his history. Whether cooked, salted, smoked, preserved in one way or another, or eaten raw, as in Japan and the Hawaiian Islands, the popularity of fish-flesh is world-wide. Fish-flesh compares favourably with beef or other meats in the ease with which it contained proteins and fats are digested by human body. It has been shown that man is able to digest completely as much as 93.2 per cent of the protein content of tinned Salmon, and 93.1 per cent of that of fresh Mackerel, and can make use of 93.2 per cent and 95.2 per cent respectively of the fatty content of the same fishes (Norman, 1975).

The muscular tissue or flesh of a fish is made up of 65 to 80 per cent water, about 16 to 23 per cent proteins

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and a greater or lesser amounts of fat (Norman, 1975). In addition, the flesh of a fish contains relatively large amounts of vitamins, substances indispensable to an adequate and properly balanced diet. The vitamins are drived by the fishes from plankton, which directly or indirectly provides the source of food for all fishes.

In tropical countries freshwater fishes provide a valuable source of food supply, but, the world over, it is the marine fishes that form the bulk of the food of mankind. In different parts of the world deep-rooted prejudice against the use of some fishes as food exists. In Malaysia Tilapia is considered as a poor man's food or a low class food. A number of factors contributed to the low acceptability of this fish. They include price, appeatance of the fish and attitudes of the consumers. Tilapia is cheap compared to other fresh-water fishes hence does not get into the daily diet of the higher-income group. In most developing countries anything that is cheap is considered as belonging to a low class; "a social attitude which is difficult to change" (Zain, 1979).

2.1.2. FISH BY PRODUCTS

In addition to providing man with food most fishes yield a number of by-products which may be of some commercial importance. Oils of various grades, ranging from the crude oils used in certain manufacturing processes to medicinal cod-liver oil arevobtained from fishes.

Fish meals and fish fertilizers are products of economic importance, that succeed in using up all the waste parts

of the fish. Fish meal is used to feed poultry, cattle, trout, catfish and other domestic animals (Bond, 1979), and is particularly reliable for chicken and young animals, as it contains proteins in a readily digestible form, as well as high percentage of calcium (Adegboye, 1975, 1981; Norman, 1975).

Other than meal and oil, fishes are used in the manufacture of glue, as a source of leather, silver pigment for certain paints and many other minor items or products (Bond, 1979, FAO, 1968). Fish glue is a product obtained mainly from such fishes as the Cod, Haddock, Pollach and Hake (Norman, 1975).

The skins of sharks and Rays and other fishes are used to provide the shagreen used for covering card cases, jewel boxes, sword scabbards, and for ornamental work of all kinds. The silvery scales of the Bleak (Alburnus) a cyprinid fish found all over Europe, were used extensively in the manufacture of artificial pearls.

2.1.3. BIOLOGICAL CONTROL

Fishes are used to control organisms considered undesirable. Probably the best known of the insect-controlling species are the various members of the family Poeciliidae, especially the genus Gambusia. One species, G. affinis, called the mosquito-fish, has been introduced into many areas in different continents. Several fishes feed upon fresh-water snails, thereby destroying intermediate hosts of parasites of man. Example of such fishes include certain African cichlids and the balck or mud carp of Asia

(Mylopharyngodon piceus).

The grass carp (Ctenopharyngodon idella) feeds almost exclusively on aquatic plants, ingesting prodigious amount daily. Although not all the amount taken is digested, the vegetation is shredded by the fish's pharyngeal teeth and pa ssed through the alimentary canal, becoming in effect, a fertilizer for other plant growth. Usually the activity of the carp promote phytoplankton growth, so that rooted plants are destroyed not only by being eaten but by the shading due to phytoplankton blooms. Tilapia species feed upon filamentous algae and soft vascular plants. Some are efficient at removing vegetation from irrigation systems, and are used for weed control in ditches in the South Western United States.

In some instances predatory fishes are used to control populations of other fishes. In Tilapia culture in rice fields, for example, a few snakeheads (Channa) are often added to crop some of the excess juveniles.

2.1.4. SCIENTIFIC STUDIES

In scientific field of studies fishes are excellent subjects for the study and demonstration of anatomy, physiology, ecology, evolution, and other aspects of science. They are well-suited to systematic studies because (a) they are abundant in species and numbers, widespread, and readily available; (b) they possess many characteristics that are especially well-suited for taxonomic analyses and statistical treatment; (c) environmental correlations are weel marked; (d) many have proven suitable for experimental analysis under laboratory condition and (e) intergradation and

hybridization are relatively common and provide tests for genetic relationships (Lagler et al, 1977).

2.1.5. RECREATION

Recreational fisheries or fishing for fun originated from hook-and-line fishing for food fishes. Speed, stamina, and leaping abilities exhibited by many fishes have allowed them to put up noble struggle to prevent capture, and the lightening of tackle to give the fishes a fighting chance can be seen as a natural development transforming a serious matter of food gathering into a form of play. Sports fishing for many anglers serves a dual purpose for they utilize their catches as food. African game fishes included the Nile perch (Lates niloticus) and the veracious tigerfish (Hydrocynus goliath)(Bond, 1979).

Colour, form, motion, and habits of many fish species have attracted many aquarists in many parts of the world. Home aquaria and ornamental pond enthusiasts are estimated to number more than 20 million in the U.S.A. and about 2 million each in Canada and Japan (Bond, 1979). Nations of Europe and Asia import ornamental fishes. Because of the relative ease of culture, care, and shipping, freshwater species are used much more than marine species.

Brazil, Colombia, Guyana, Singapore, Hongkong and Thailand are some of the major exporters of aquarium fishes. Usually fishes are captured by means of traps, seines, or dip nets by individuals who then sell them at a collecting point from which they are transported to exporters. The export trade in ornamental fishes from Hongkong is worth

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about 4 million dollars per year, that from Singapore about 4.5 million dollars per year. The annual value of aquarium related trade in the U.S.A. is estimated at about 700 million dollars (Bond, 1979).

Various countries and states are placing restrictions on the transport of aquarium fish for a variety of reasons. Some countries fear the depletion of the supply of certain native fish species. Other countries prohibit export or import of species declared endangered or especially rare. Some species considered potentially harmful to humans or to the environment of a country where they might be introduced are restricted from free trade. Certain stingrays, stone fishes, lionfishes, and weavers are listed as undesirable in the U.S.A.

2.1.6. HARMFUL FISHES

The relationship between fishes and man are not always pleasant. Throughout the many orders of fishes there are species known to cause illness or death when eaten while others have stinging spines that introduce venoms. These poisonous and venomous fishes constitute genuine hazards to divers, fishermen, and bathers in the natural habitat of the fishes, and to aquarists and diners who might come into contact with fishes or flesh in areas far removed from their origin. Ciguatera is the most widely known type of poisoning caused by fishes. This poisoning causes nausea, vomiting, abdominal pain, reversal of hot and cold sensation, and numbness of the mouth. Other sypes of symptoms may include headaches, muscular aches, dizziness, and,

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occasionally, blistering and loss of skin on hands and feet. Examples of fishes that cause this poisoning include morays (Muraenidae) and baracuda (Sphyraenidae) (Bond, 1979).

Some fish families contain species capable of inflicting painful stings that combine mechanical injury with release of venom. The stingrays and Synodontis are good examples of these families.

Electrogenic species such as Torpedo; Electrophorus and Malapterurus (electric ray, eel and catfish) are injurious to man. They can all cause pain and temporary numbness when touched. As man eaters sharks draw the most attention.

2.1.6. DISEASE VECTORS

Various species of fishes harbour parasites that can affect man directly in areas where freshwater fishes are eaten raw or without sufficient processing. Most of the parasites involved are worms-nematodes (roundworms), cestodes (tapeworms), and trematodes (flukes).

2.2. FISH IDENTIFICATION

The above relationships between fishes and man are of great economic importance. For this reason, studies such as the taxonomic studies of fish have to be pursued in order to throw more light on the relationship between the fishes themselves. For these studies to be successful, proper identification of the fishes is desirable.

Although of great importance to management, proper identification of fishes is often difficult to attain. At least in the early stages of work, an investigator

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should have his attempts at identification verified by someone qualified to do so (Lagler, 1972). Sometimes specimens are taken to museums and compared with materials previously identified by experts. The United States National Museum, Washington, D.C. and Museum of Zoology of the University of Michigan are the best able to provide this service in the United States. In Britain, the British Museum of natural history is also very efficient in this respect. Locally no museum of such a nature exists but one is always sure of getting the services of the above museums when they are approached.

Beside museums certain individual specialists who are willing to cooperate help in the identification of fishes. Identification can proceed by the help of pictorial guides. Books written by Reed (1967) and Holden and Reed (1972) are very useful in the identification of local fish species. Also identification can proceed by the help of keys. Lowe-McConnell (1972) and Lewis (1974) have provided such information on many local fish species.

Some members of the families Characidae, Mochokidae and Cichlidae described below are identified for this electrophoretic studies by the help of pictorial guides, keys and the help of individual experts.

2.2.1. FAMILY CHARACIDAE

The family Characidae is represented in the Northern States of Nigeria by three genera and fifteen species, all of which are pelagic predators. Members have elongated, fusiform bodies, usually silvery in colour and covered with

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cycloid scales, but scales are not present on the head (Reed, 1967). Well developed rayed fins and a small adipose dorsal fin is present. The lateral line passes along the lower side of the flanks. Teeths, especially those in Hydrocynus are well developed. The flesh is white and tasty, but fine and sharp bones make eating difficult. The three genera are Hydrocynus, Macralestes and Alestes.

2.2.1.a. HYDROCYNUS

The genus Hydrocynus is represented in the same region as stated above by four species. Large mouth and a single row in each jaw of large pointed teeth which are razor-sharp on both edges, spaced well apart, and can be seen even when the mouth is closed are important characteristics. (Fig.1). Their common name of Tigerfish is as a result of these teeth. They have streamlined bodies, silvery in colour and have deeply forked caudal fins. Their nostrils are close together near the eye and are separated by a valvular flap. The lateral line passes along the full length of the sides.

Tigerfish usually inhabit the main rivers but they are occasionally found in swamps commonly around shallow sandbanks. They seem to travel singly and not in large schools (Reed, 1967). The shape of the mouth indicates that Hydrocynus are predators. Insects and water beetles form the bulk of the food for the young while the adults prey upon other fish, especially Alestes.

Only species obtained during the period of this work (October, 1983 to April, 1984) are described. Hydrocynus

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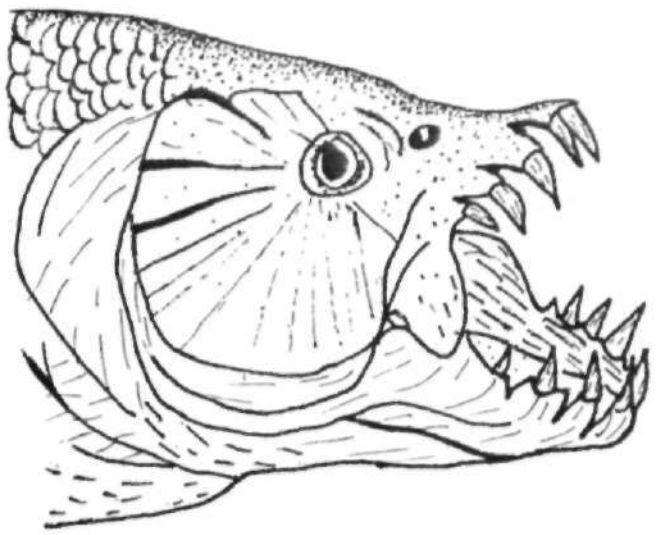

FIG·1 HEAD OF HYDROCYNUS

semonorum, Dagot, Fig. 2, is deeper in relation to its length than the other two species seen. The tail is less deeply forked and has shorter lobes. The distance from the snout to the dorsal fin is 1.6 - 2.0 times as great as the distance from the dorsal to the adipose fin. The body is 3.3 - 4.0 times as long as its depth. There are 49 - 52 lateral line scales - 7.5 to 8.5 series above and 5.5 series below the lateral line. The eye has a small adipose eyelid. The colour is uniformly bright with scarcely a trace of longitudinal stripes-the only Hydrocynus without distinct strips.

Hydrocynus lineatus Bleeker, Fig. 3, is smaller than the other species. It has six distinct longitudinal stripes on each row of scales above the lateral line and usually one or two rows beneath the lateral line. These stripes are formed by a small black spot on each scale. The tail has long, pointed lobes of equal length and is deeply forked.

The colour is generally silvery and the dorsal fin is grey or yellowish, often with the anterior part reddish. The adipose dorsal is usually white at the base and the remainder black. The pectoral, ventral and anal fins are light yellow, orange or pink; the upper lobe of the caudal fin is grey, yellow or orange and the lower lobe is bright red. The upper part of the eye has an orange-red mark.

Hydrocynus forskali Cuvier, Fig. 4, is long, slender with a deeply forked tail. The adipose fin is grey in colour and smaller than that of other species. The distance

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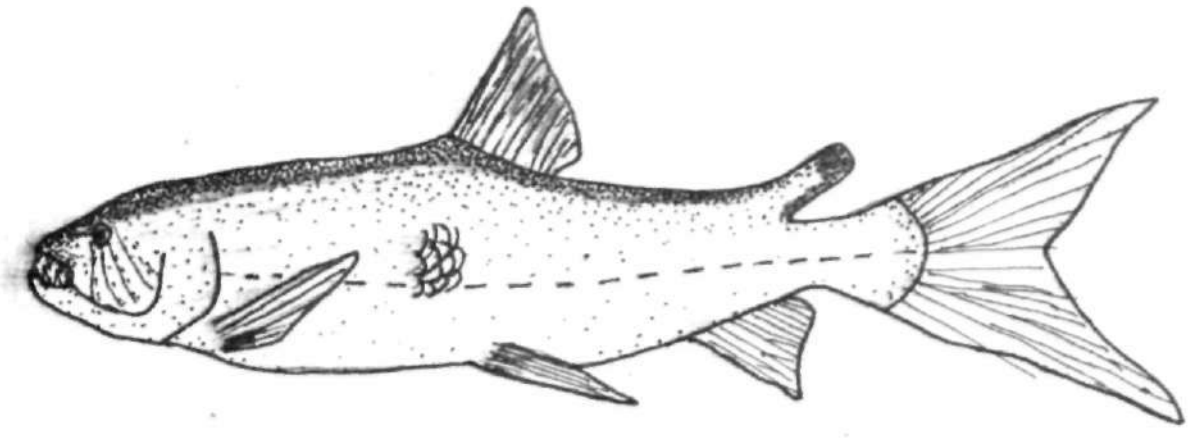

FIG. 2 HYDROCYNUS SOMONORUM

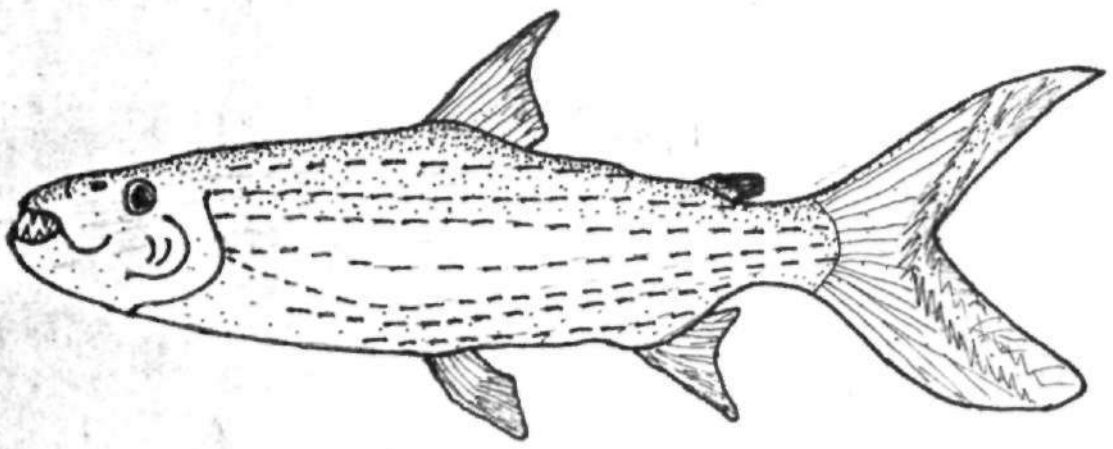

FIG. 3 HYDROCYNUS LINEATUS

from the snout to the dorsal is 1.4 to 1.5 times as great as the distance from the dorsal to the adipose fin. The body is 4.5 - 5.0 times as long as it is deep. There are 48 - 53 lateral line scales; 7.5 series of scales above and 4.5 - 5.5 series below the lateral line. The eye has a well developed adipose eyelid.

On the back the colour is grey or olive-green; the sides are silvery and there are dark, longitudinal stripes along each row of scales above the lateral line. The dorsal fin is grey, with the distal rays slightly darker. The upper lobe of the caudal is grey and the lower one bright red. The anal fin is orange, especially the anterior part. The pectorals and ventrals are yellow.

2.2.1.b. ALESTES

The genus Alestes has at least nine species in Northern Nigeria (Reed, 1967). They have medium to elongated silvery bodies typical of pelagic fish. Cycloid scales cover the body and the cheeks have large sub-orbital plates. The nostrils are close together near the eye and are separated by a valvular flap. The dorsal fin is in line with, or to the rear of the ventrals and there is a small adipose fin. The lateral line is complete and runs low along the sides. Sexes are easily determined by the shape of the anal fin which in females is straight or concave and in males is convex. Fig. 5.

Most species of Alestes are common, perhaps the commonest in the region. They are found in swamps; small

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creeks and rivers. Shallow, sandy habitat in rivers is preferred by the larger species where they live near the surface and are reputed to feed on plankton, insects larvae, water beetles, snails and plants.

Alestes baremose (joannis), Fig. 6, has a long slender body the standard length being equal to 4.1 to 5.1 times the depth of the body. The dorsal fin has 2 simple and 8 branched rays and the anal 3 simple and 22 - 28 branched rays. There are 44 - 51 small, weak scales in the lateral line. The eye has an adipose eyelid.

The body is silvery in colour, the back bluish-grey and the belly white. The upper lobe of the caudal fin is clear or tinged with yellow; the lower lobe, which is often slightly longer than the upper one, is bright red, and the deeply-forked tail is bordered on the inner edge with a dark bank. This species is very common in this region.

Alestes nurse, Ruppell, Fig.7, is a very common, medium sized species. Its body is strongly compressed, has a slightly projecting snout when the mouth is closed, and a bright red tail. The dorsal fin has 2 simple and eight branched rays, while the anal fin has 3 simple and 11 - 14 branched rays. There are 27 - 32 large scales in the lateral line and 5.5 series of scales above the lateral line.

The body is generally silvery on the sides and olive-bronze on the back. There is a dark patch near the end of the caudal peduncle and a less distinct, reddish mark above the eye. The dorsal, anal, ventral and adipose fins, and sometimes the pectorals, are also tinged with red. It

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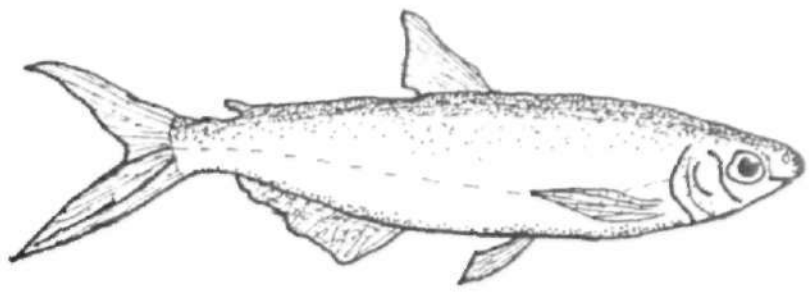

FIG. 6 ALESTES BAREMOSE

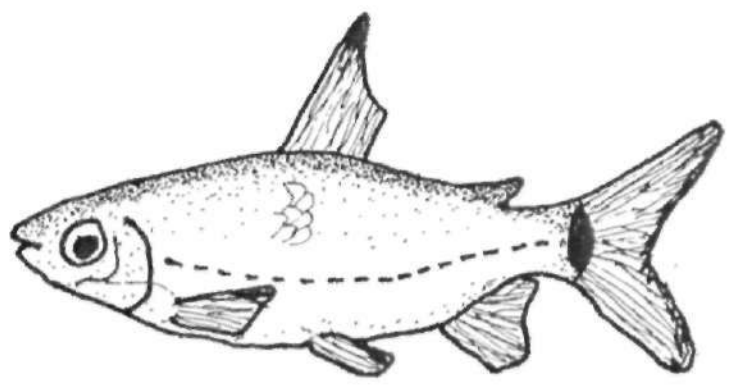

FIG. 7 ALESTES NURSE

grows to a length of about 200 mm and is very common in most habitats.

Alestes leuciscus, Gunther, Fig., 8, is a small species having a maximum length of about 70 mm. The colour of its tail is sulphur-yellow. The dorsal and anal fins are pale lemon and the adipose is yellowish-orange. The sides of the body is silvery, the back, grey, and the belly white. When alive, a bluish stripe is evident, extending from the median rays of the tail through the caudal peduncle and sometimes about one-third of the length along the side. Young specimens do not usually show these.

The dorsal fin has 10 rays, two simple and the rest branched, while the anal fin has 3 simple and 15 - 17 branched rays. There are 27 - 29 scales in the lateral line and 5.5 rows of scales above the lateral line. A. leuciscus are hardy and attractive in an aquarium.

Alestes macrolepidotus (Cuvier and Valencienne) Fig. 9, is by far the largest of the Alestes. It grows to at least 500 mm, and weight of more than 2 kilogrammes.

Their dorsal profile is flattened on the top of the head. They have a prominent snout, big eyes and large, strong scales of which there are 22 - 26 in the lateral line. (The specific name, meaning "large scaled," refers to this character). The tail is large, not deeply forked and yellow in colour. The colour of the body is greyfish-olive on the back, lighter on the sides, becoming white on the lower sides and belly. The pectorals, ventrals, and anal fins are marked with red, and the adipose dorsal is

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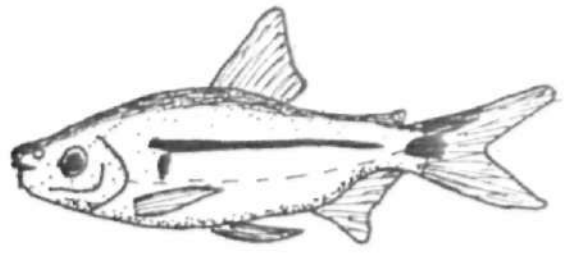

FIG. 8 ALESTES LEUCISCUS

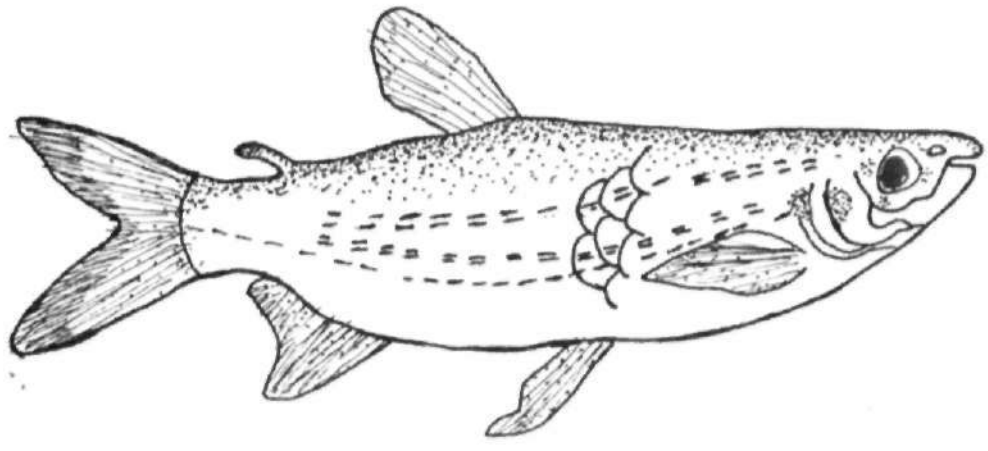

FIG. 9 ALESTES MACROLEPIDOTUS

always bright red in colour. Patches of yellow or orange are found above the eye and under the chin.

Alestes brevis Boulenger, Fig. 10, resembles the preceeding species but the top of the head is shorter, its length being not much more than its greatest width. It has 21 - 23 lateral line scales.

Alestes "X", Fig. 11, This species was not identified using available books and keys. Expert help was spught but identification proved difficult.

The species is small attaining a maximum length of about 70 mm. Its tail, dorsal, anal and adipose fins are yellow. The body is silvery on the sides, olive-green on the back and white on the belly.

The dorsal fin has 2 simple and 8 branched rays and the anal fin has 3 simple and 14 - 17 branched rays. There are 27 - 29 scales in the lateral line and 5.5 rows above the lateral line.

2.2.2. SYNODONTIS SPECIES

The next family in this study is the family Mochokidae, comprising Synodontis and Chiloglanis. The commonest genus in this family is Synodontis, in which there are more species than in any other catfish genus. At least 21 species of Synodontis have been recorded from the Niger. Needless to say, this bewildering array leads to difficulties of identification (Hoden and Reed, 1978).

Synodontis are characterised by having short, stumpy bodies and a head shield, that is, the whole of the head region as far as the bases of the dorsal and pectoral fins

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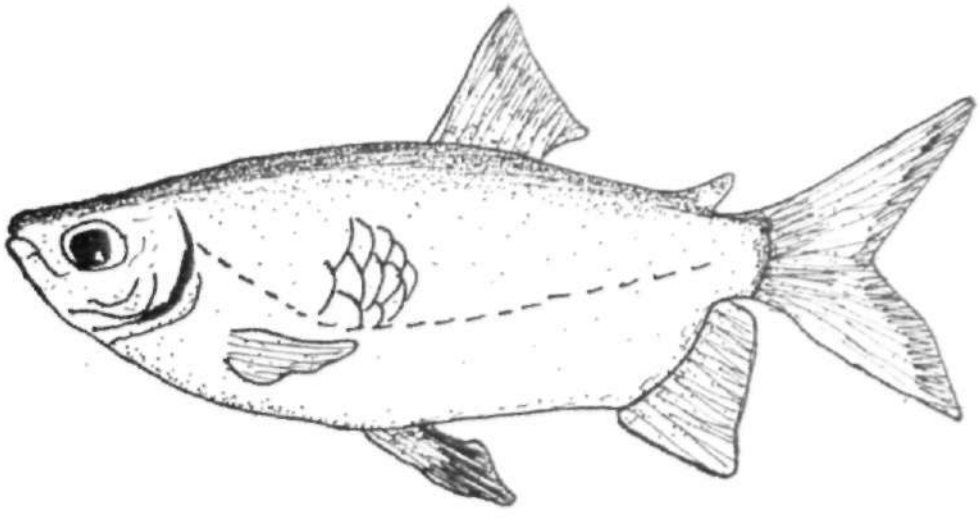

FIG . 10 ALESTES BREVIS

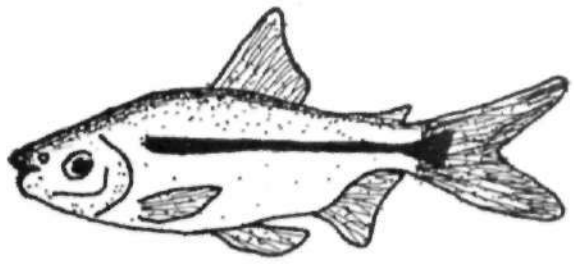

FIG . 11 ALESTES "X"

is ossified, the bone usually being rough and granular. Their dorsal fins are rather short, consisting of a strong serrated spine and 6 - 7 branched rays followed by a large adipose fin. The anal fin is short-based and the tail is deeply forked and has pointed lobes. The pectoral fins have strong serrated spines. All Synodontis have a pair of maxillary and two pairs of mandibular barbels the latter being branched or ramified. The nostrils are widely separated from each other and the anterior one is tubular. The eyes are lateral or superolateral and have a free border. The mouth has well developed lips with a series of fine, more or less c curved teeth planted in the lower lip, somewhat like a comb. A key character used in identifying Synodontis is the number of those teeth-the mandibular teeth. The number of these teeth will be given in parentheses immediately after the specific name is first mentioned. A band of conical pre-maxillary teeth exists, but the palate is toothless. The gill membranes are confluent with the skin of the isthnus. The air-bladder is large and free and the long intestine forms numerous convolutions.

The pointed serrated spines of all Synodontis can inflict a painful pain if they are not handled with care. Some small poison glands are associated with the spines in some species and this can cause great pain but treatment with disinfectants remove the pain (Reed, 1967).

Females produce large numbers of small yellowish eggs. The testes of males are in the form of a convoluted ribbon, white or greyish in colour.

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Synodontis batensoda, Ruppell (Fig. 12) (27 -59, most commonly 41 - 54) is one of the commonest species. It is socty black on the belly; the sides, back and dorsal fins are brownish grey, sometimes with a purplish tinge. The caudal and anal fins are greyish, with numerous dark spots forming vertical bands, especially marked on young specimens (Reed, 1967). S. batensoda has the peculiar habit of swimming upside down. This enables it to use the water with the highest oxygen content because the pools it inhabits are often stagnant.

Synodontis clarias, Linnaeus (Fig. 13) (5 - 9) has the body of a slate-grey colour, and, bright pink tail, the upper lobe of which is elongated (Reed, 1967). The colour becomes uniform after it has been preserved for a while in formalin.

A distal membrane exists at the base of the maxillary barbel with finely tuberculated branches. It is the only Synodontis having the maxillary barbel branched on the outer edge (Reed, 1967). The dorsal spine is strongly curved and the soft terminal part is produced into a short filament. Juveniles have also the first and second rays of the dorsal fin elongated.

Synodontis filamentosis, Boulenger, (Fig. 14) (17 -23), can be recognised by its dorsal spine, the end of which is drawn out into a long filament which reaches the base of the tail fin. It has a rounded snout, oval-shaped eyes and a long, slender body. The maxillary barbels are broadly margined at the base and the mandibular ones have numerous

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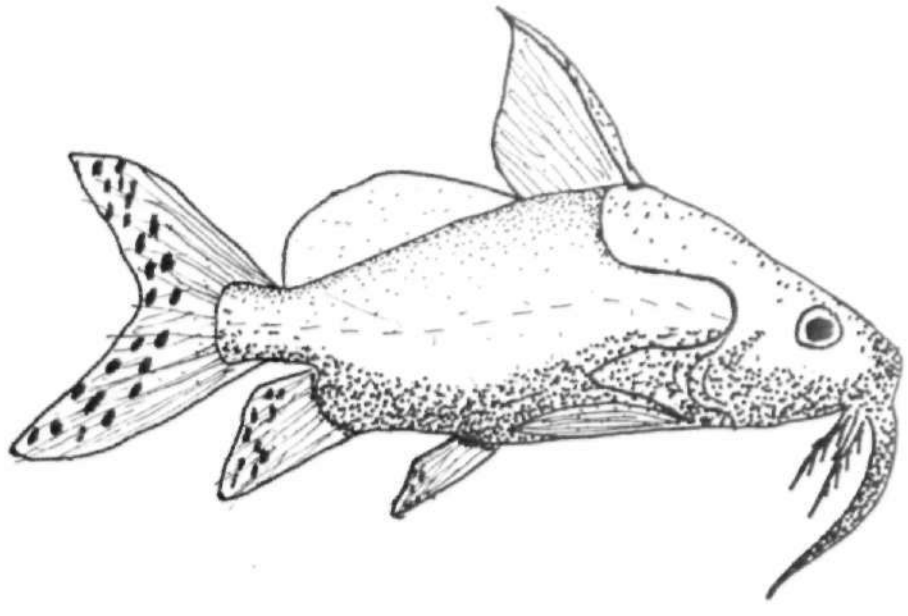

FIG . 12 SYNODONTIS BATENSODA

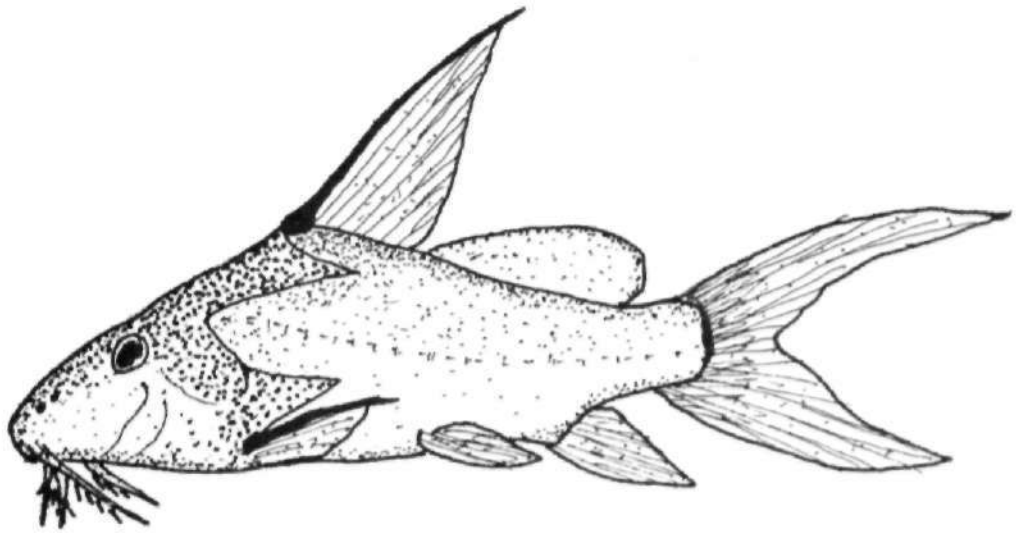

FIG . 13 SYNODONTIS CLARIAS

long and ramified branches. The pectoral spines are lightly serrated on the exterior and deeply toothed on the interior edge (Holden and Reed, 1978).

The colour of the body is yellowish-grey marked with an irregular pattern of black spots. The belly is white and the caudal lobes are bordered near the exterior with black. The dark spots are more conspicuous in young specimens where they are arranged in three, more or less distinct bands on each side of the body. S. filamentosis does not grow very large and it is common over rocky bottoms and is rarely found in flood plains (Holden and Reed, 1978).

Synodontis eupterus, Boulenger Fig. 15\ (40 -56), has the enterior soft rays of the dorsal fin about uniformly elongated, giving a "square-sail rig" shape to the first dorsal fin. The dorsal spine is very strong and the relatively long pectoral spine is moderately serrated on the outer edge and deeply serrated on the inner one. The upper lobe of the deeply forked caudal fin is usually the longest. The maxillary barbels have straight fringing membranes. The external mandibular barbels have long ramifications and the inside ones have short ramifications, forming tubercles near the base.

The body colour is uniformly olive, with small round black spots on the body and on all fins, Juveniles have the spots serried into an irregular pattern of dark tiger-like stripes. S. eupterus is a small species.

Synodontis schall, Block and Schneider, Fig. 16 (20 - 36) always has the skin densely villose. It has a rounded

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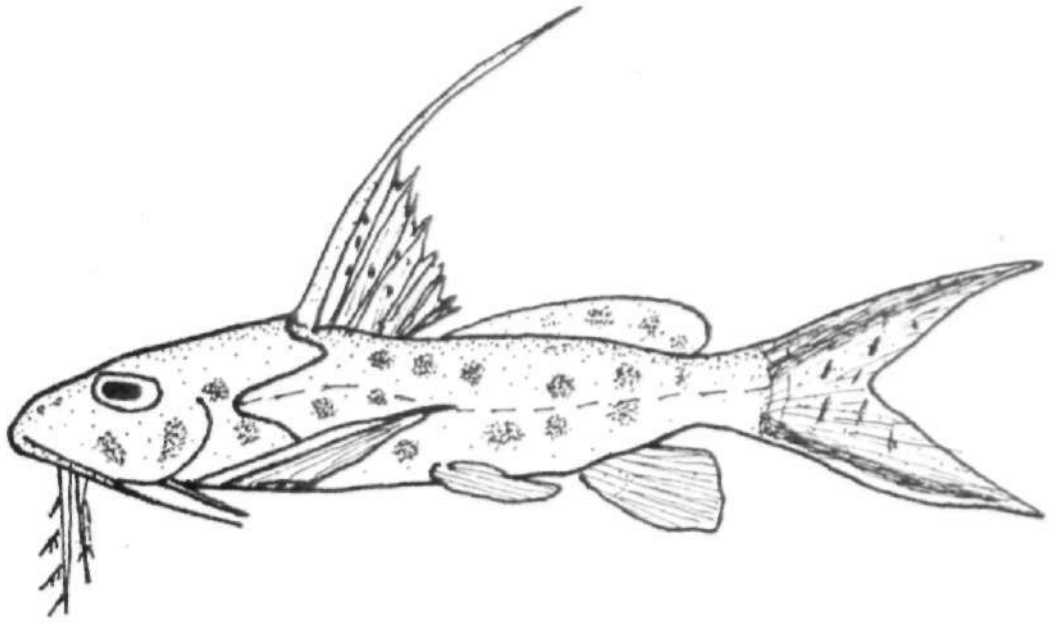

FIG. 14 SYNODONTIS FILAMENTOSIS

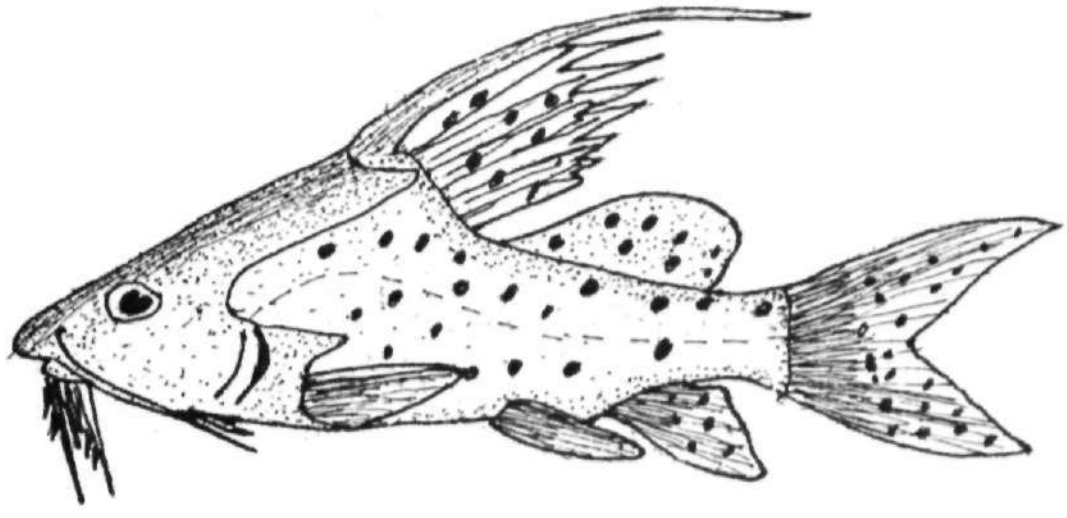

FIG. 15 SYNODONTIS EUPTERUS

snout and the lips are moderately developed. The maxillary barbel usually has a very narrow membrane, visible only at its base. The external mandibular barbels have long ramifications and the internal ones have short branched tubercles near the base. The upper lobe of the caudal fin is longest and is sometimes prolonged into a filament; the caudal fin being always deeply forked. The pectoral spines are deeply serrated on the rear edge and usually prolonged into filaments of about half their own length.

The body is greyish or olive-brown and whitish ventrally in adult specimens. The paired fins and the anal fins are sometimes blackish. Numerous dark spots on the body and fins are found on medium sized specimens. The snout is usually streaked with yellow (Reed, 1967).

2.2.3. CICHLIDAE

The family Cichlidae consists of bony, perch-like fishes whose body is usually bilaterally compressed. Most bony fishes have two pairs of nostrils, but in all Cichlids there is a single nostril at each side of the head, and this feature alone is sufficient to distinquish them from fishes of almost all other families, and certainly from all African freshwater fishes (Fryer and Iles, 1972). The head is incompletely covered with scales. A single well developed dorsal fin whose anterior fin rays take the form of spines and are usually more numerous than the soft posterior rays exists. The pelvic fins, which have an outer spine and five soft rays, are located well forward on the trunk. The mouth is protactile; that is the jaw can be protruded. This is of

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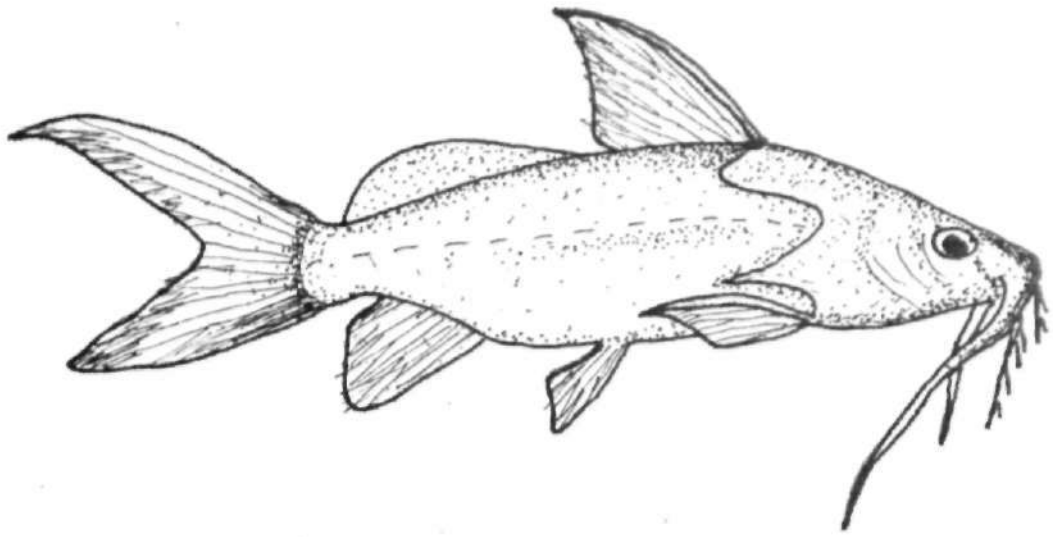

FIG. 16 SYNODONTIS SCHALL

great relevance to feeding habits. The jaws are armed with teeth which are very variable both in structure and number in different species. All these teeth are located on the jaws themselves; none being found on the bones which comprise the palate.

This family has produced an enormous variety of species in African fresh waters. Many of them are characterised by extremely specialised feeding habits, which have enabled them to live in peculiar environments (Holden and Reed, 1978). All available feeding niches, including some rather unexpected ones, appear to have been exploited by one or other of these fishes. Most of this specialisation has occurred in East and Central African lakes. In West Africa the unspecialized species are commonest (Holden and Reed, 1978). Non-specialization is typical of the Nilotic fish fauna and it indicates that there has always been a considerable amount of interchange between the different river systems. When populations of a species become isolated and prevented from inter-breeding by geographical barriers they evolve in separate directions. Specialization leading to the evolution of new species occur as a result of this isolation.

Lack of specialization does not mean lack of success. In favourable areas, shallow rivers and flood plains, Cichlids are the most abundant group of fish in West Africa. Tilapia form 90 per cent by number of the whole fish population in the Sokoto river for example (Holden and Reed, 1978).

The Northern States of Nigeria has two genera of

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Cichlids - Hemichromis and Tilapia are common. The genus Hemichromis contains two ubiquitous species - H. bimaculatus and H. fasciatus; while the genus Tilapia contains three species which are very much ubiquitous in local waters. They are T. galilaea, T. nilotica and T. zilli. Trewavas (1973) suggented the removal of T. galilaea and T. nilotica from the genus Tilapia on the basis of their mouth breeding habit. This led to the recognition by some authors of Sarotherodon as a distinct genus in which the two species and all other mouth breeding Tilapia were placed.

Hemichromis bimaculatus, Gill, Fig. 17 DXIV - XV, 9 - 12; A III, 7 - 9 is a small species, adult individuals rarely exceeding 10 cm in total length (Reed, 1967). It is elongated and moderately compressed, the snout pointed and the mouth rather small. There is usually a conspicuous black spot, bordered in gold at the upper rear corner of the operculum; a second large spot on the middle of the side. These spots give this species its specific name "bimaculatus." A third, often inconspicuous spot is also found on the caudal peduncle. The general colouration is usually ochre or tan, with a faint irridescent spangle on each scale and more spangles on the dorsal and caudal fins (Reed, 1967). Breeding individuals become brilliant red, the males tending slightly to violet and the females more toward orange-red hues; at the same time the spangles enlarge and take on a luminous blue colour, and deep black bar runs through the eye to the mouth. These brilliant colours have made the fish a favourite in the aquarium trade, where it is known

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as the "jewel fish." (Reed, 1967; Holden and Reed, 1978).

The jewel fish is particularly fond of fish fry and insects. H. bimaculatus has a very wide distribution including virtually the whole of West Africa, Central and Southern Africa, and even turns up in subterranean springs in remote regions of the Sahara desert. They seem to prefer creeks and swamps, rather than the larger rivers. They are usually found near grassy banks or in dense aquatic vegetation preferably in clear water with little or no current (Holden and Reed, 1978).

Hemichromis fasciatus Fig. 18 DXIV - XV, 11 - 13; A III, 8 - 11, grows to a considerably larger size than the preceeding species, exceptional individuals measuring 250 mm have been recorded (Holden and Reed, 1978). The five dark spots on the flanks makes it readily distinguishable from the other species. The larger and differently shaped mouth permits ready identification even when the spots are not showing. It is also more slender and elongated.

The colouration of this species varies so greatly that description is difficult (Fryer and Iles, 1972; Holden and Reed, 1978). Non-breeding individuals are dark greenish or yellowish, with the characteristic black patches on the sides. The dorsal fin and upper lobe of the tail are edged with red in adult specimens and the operculum eye-spot is bordered with vivid red.

H. fasciatus is a carnivore and feeds heavily on small fish, including the young of its own near relatives

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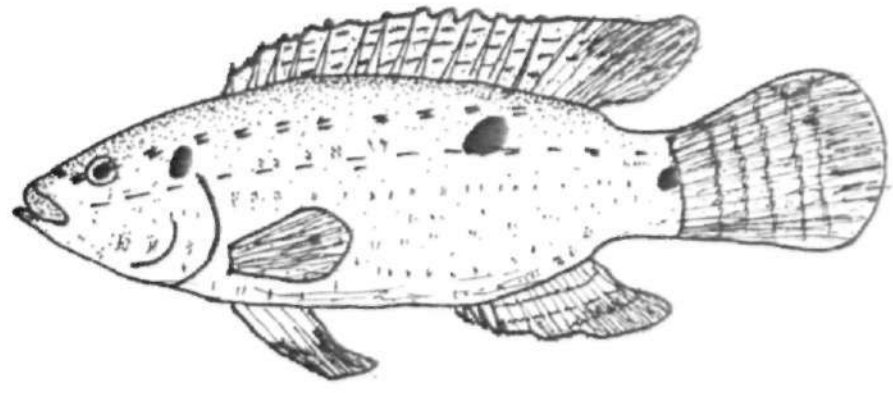

FIG. 17 HEMICHROMIS BIMACULATUS

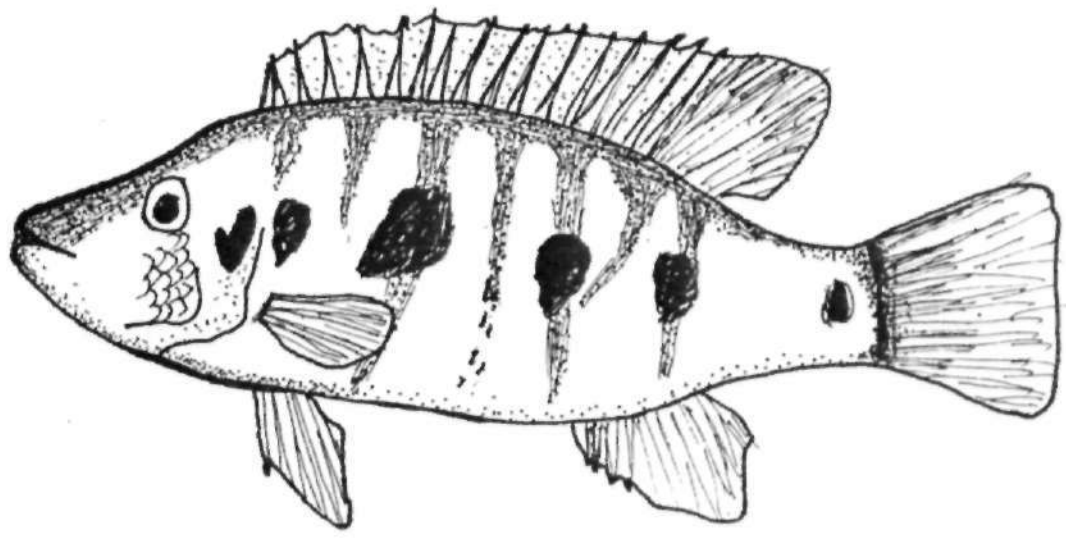

FIG. 18 HEMICHROMIS FASCIATUS

as well as insects and their larvae. Because of this habit the adults are rather solitary and tend to avoid one another rather than forming schools. However, they are most devoted parents and pairs may often be seen shepherding large schools of young. This species is found in ponds, swamps and streams and it penetrates the smallest bodies of water.

Two distinct colour phases of H. fasciatus have been reported by Reed (1967). Non-breeding individuals of both forms are rather dark-greenish or yellowish in colour, with the characteristic black spots along the sides. The dorsal and caudal fins are edged with red in adult specimens, and the opercular eye-spot is bordered in vivid red, particularly in the B form.

During breeding and when dying H. fasciatus A shows a red or pink colour on the throat and belly region; the body is bronzy yellow and the black spots are very dark. H. fasciatus B never show red on the ventral surface, though large individuals have much red along the upper flanks between the spots. During courtship, the B form becomes very dark with a black throat and a tendency for the spots to fade out. When tending young, this form is vivid yellow with the pelvic fins and the body spots contrasting in jet black (Reed, 1967). The dentition of the two forms was observed to vary.

Members of the genus Tilapia have very deep, laterally compressed bodies. Their scales are large, usually cycloid and they have a double lateral line; one lateral line starts near the head but instead of running continuously to

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the tail, it stops almost level with the posterior end of the dorsal fin and a second lateral line begins underneath it and continues to the tail. At the base of the second half of the dorsal fin is a black spot, the "Tilapia spot," which is more pronounced in some species than others, and is always more prominent in juveniles.

A total of eight species have been described from West Africa but three species commonly occur in local waters.

Tilapia Zilli (Gervais) Fig. 19 DXIV - XVI, 11 - 13, A III, 7 - 10, is one such species. The distribution of this species is very extensive, including the Nile and Chad basins, West and North Africa. It penetrates the smallest bodies of water and can survive and reproduce under very adverse conditions.

T. Zilli is a somewhat elongated Tilapia with a characteristic profile, nearly flat below and strongly convex dorsally. Individual reaching a length of up to 30 cm are uncommon and the usual adult size is about 20 cm in total length. It is rather dark in colour with indistinct dark barring on the flanks. The unpaired fins are heavily mottled with dark grey, usually with a pinkish tinge, and the characteristic "Tilapia spot" at the base of the soft dorsal persists even in quite large individuals. This species can show a dark, nearly wine-red colour at the throat, best seen in breeding fish or when the fish is just dying on removal from water.

This species has the heaviest pharyngeal teeth and coarsest gill rakers among Nigerian Tilapia (Reed, 1967).

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The teeth in the jaws are also quite stout and feel sharp to the touch. This is in keeping with its diet of insect larvae and coarse plant material. T. Zilli is extremely hardy and adaptable.

Tilapia galilaea (Artedi) or Sarotherodon galilaea (Trewavas), Fig. 20, DXV - XVI 12 - 14; A III, 10 - 11, is the most easily recognised species of the genus Tilapia or Sarotherodon because of its silvery grey to green colour, the only markings being a series of black spots which form incomplete bars on the flanks, when they are present. The edge of the tail fin is tinge pink. The throat may also be flashed slightly pink in the breeding season (Holden and Reed, 1970). This species is deep-bodied, small-mouthed and eminently microphagous with very numerous gill rakers and correspondingly fine pharyngeal teeth (Reed, 1967). It eats both phytoplankton and epi-phytic plants.

Tilapia nilotica Linnaeus or Sarotherodon nilotica (Trewavas), Fig. 21 DXVII - VII, 12 - 14; A III, 8 - 10, is readily identified by the white and blue-black vertical bars on the soft part of the dorsal fin and on both the tail and anal fins. The body is elongated, generally dark in colour, with even darker bands on the back. Often each scale is tipped with white; the throat and belly are white, except in the breeding season when the former becomes a deep red. This is one of the largest Tilapia, reaching a considerable length of about 50 cm. In keeping with the size of fish, there may be up to 2,000 eggs in a clutch.

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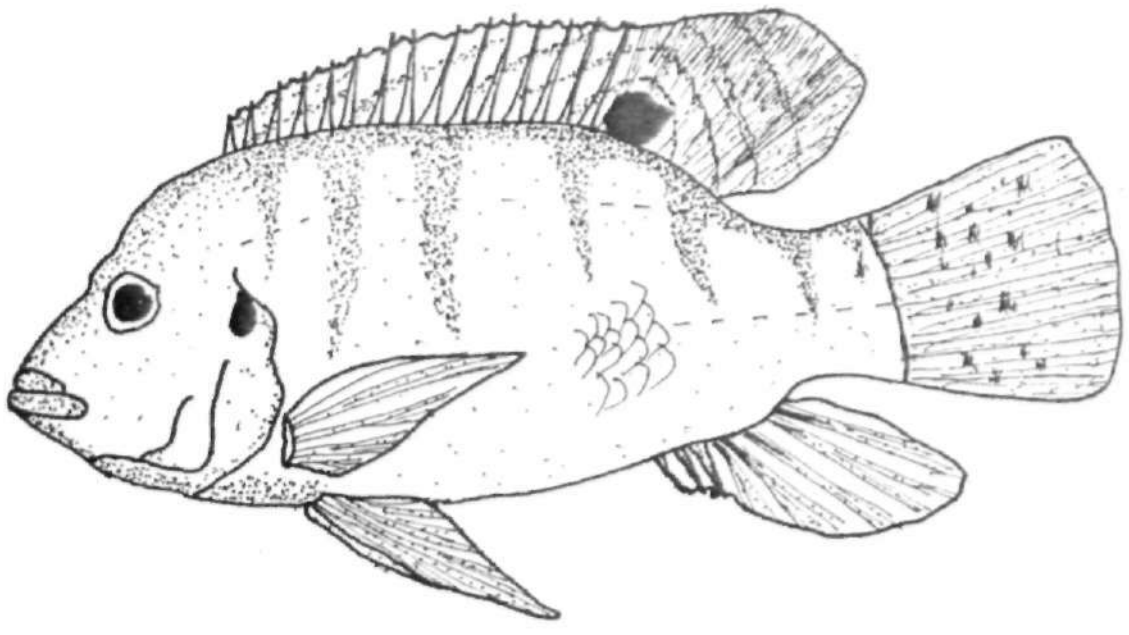

FIG. 19 TILAPIA ZILLI

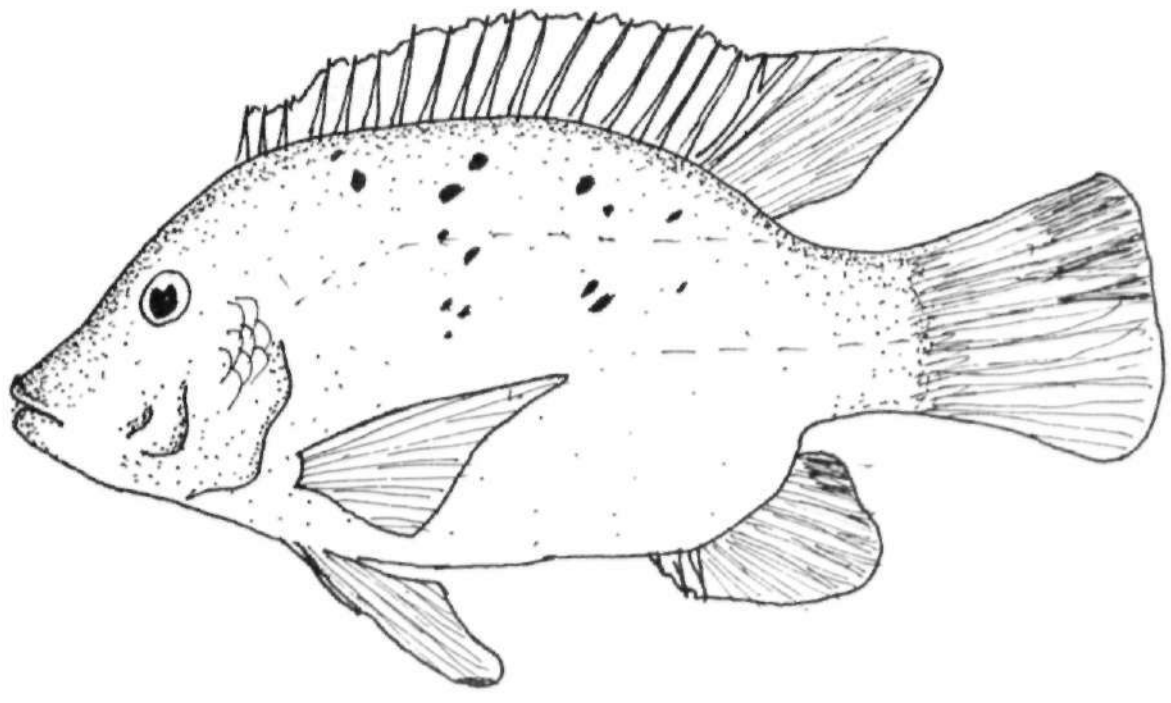

FIG. 20 TILAPIA GALILAEA

T. nilotica inhabits rivers and lakes and sizes vary depending on the habitat or the localities they are found. In the river Sokoto the greatest length is 34 cm while in the River Niger in the vicinity of the Kainji Dam it reaches 42 cm and grows slightly faster. As with all Tilapia, males grow to a larger size than females (Holden and Reed, 1978).

2.3. HISTORY OF FISH TAXONOMY

The history of fish taxonomy cannot be isolated from the history of animal taxonomy in general. The beginnings of taxonomy no doubt antedate recorded history, for it is one of man's characteristics that he likes to name and arrange things. Aristotle (383 to 322 B.C.) synthesized the knowledge of his time and formulated it into the beginnings of a science. Although he did not propose a formal classification, Aristotle provided a basis for such when he stated that "animals may be characterised according to their ways of living their actions, their habits and their bodily parts." His philosophy prevailed for nearly 2,000 years (Lagler et al, 1977). Of the Zoologosts who lived shortly before Linnaeus, John Ray (1627 to 1705), proposed a more natural system of classification than his predecessors and his work had a marked influence on Linnaeus (1707 to 1778). Linnaeus consistently applied what is known as the binomial system of nomenclature in the tenth edition of his monumental Systema Naturae (1758). By common consent, systematists throughout the world have agreed to regard the year 1758 as marking the commencement of the scientific naming of animals

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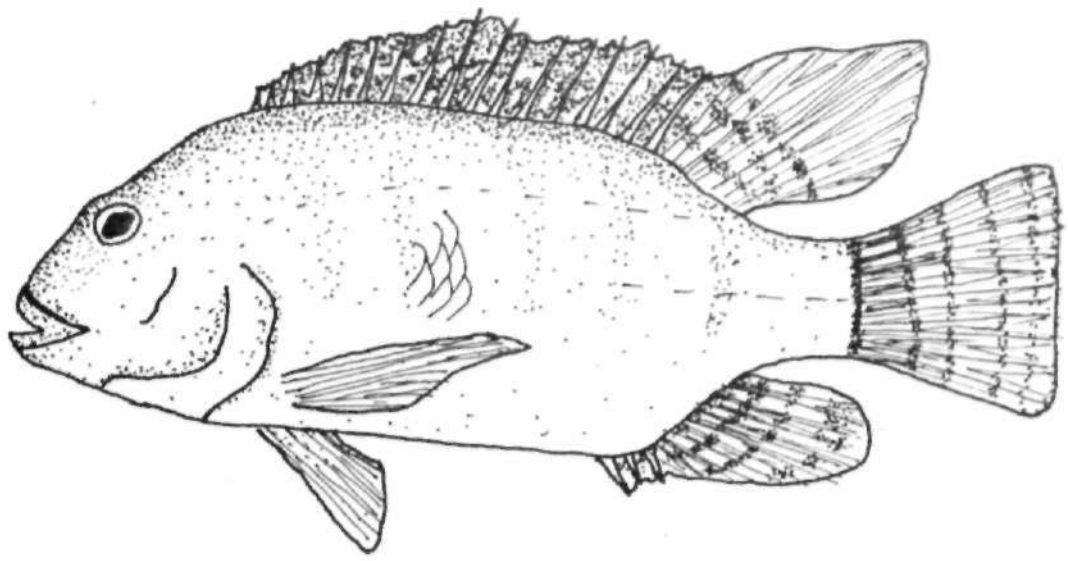

FIG. 21 TILAPIA NILOTICA

(Norman, 1975). Linnaeus was subsequently called the father of taxonomy. He provided a hierarchy of categories; variety, species, genus, order, class, and kingdom. Later the principal changes were, adding family and phylum. His system was so practical that it was quickly adopted, expanded, and elaborated and it dominated the field for the next century during which time species were regarded as immutable (Lagler, et al, 1977).

A century later, Charles Darwin's revolutionary theory of evolution produced a tremendous stimulation of biological thoughts and work. Workers in the decades immediately following his On the Origin of species, 1859, were concerned principally with discovering whether living organisms actually are decendants of common ancestors. Phylogeny was, therefore, the chief preoccupation of this period. The phylogenetic tree was introduced by Hackel (1866), and proved to be a useful and stimulating method providing taxonomists with a graphic means of expressing presumed relationships. This was a productive and exciting period in the history of taxonomy, and some of the keenest minds were attracted to the field by the reward of almost daily discoveries of new species and genera and, not infrequently, of new families or orders. However, by or before the end of the nineteenth century, the period of such major discoveries among the higher animals was over. Those who were anxious to describe new orders, families, and genera now resorted to refining the classification and splitting the existing categories. As might be expected, some of this

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splitting was necessary and beneficial, but in other cases it led to a disintegration of natural categories by concealing true affinities. Taxonomy fell into disrepute during the close of the nineteenth century and early twentieth century due in part, to such excessive splitting.

The most recent phase in the development of systematics has been characterized by study of evolution within species. The more diverse the data brought to bear on classification the more reliable the resulting arrangement is likely to be. The modern systematist may be able to draw information from such varied fields as biochemistry, physiology, genetics, behavior, ecology, geographical distribution, paleontology and cytology to supplement and strengthen the more conventional laboratory data of morphology and anatomy.

Taxonomy, the study of the theoretical bases, principles and procedures necessary to an understanding of relationships is the source of information for classification (Lagler et al, 1977). It is important at the outset to distinguish between classifying things and naming or identifying them; for these two activities are totally different. Classification involves scientific philosophy that uses inductive procedures that allow us to place individuals into previously established taxa.

Systematics involves both taxonomy and classification. It is the science that deals with the kind and diversity of living things and with their arrangement into a natural classification. Basically a study of the evolutionary relationships of organisms systematics lies at the foundation

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of biology and it is elementary, in ensuring a sound structure to look to the foundations. A system of classification provides the means for attacking the problem of the origin and evolution of life. Everyone is, at heart, a classifier, whether by virtue of necessity or because of mere curiosity.

Relationships among living things are the direct result of what has happened during their evolutionary history; that history is a real phenomenon, whether or not we may be able to reconstruct it precisely (Lagler et al, 1977). All approaches to understanding the systematics of organisms are limited to the study of similarities and differences and are basically comparative in principle. Renewed interest in the methods and theory of classification has been enhanced by the development of a new subject-protein taxonomy (Crick, 1958) and by the development of the computer and the coming of whole new areas of inquiry designated numerical taxonomy, including cladistics.

The primary function of classification is to create order out of chaos by leading to accurate identification of individuals, and to their ranking or arrangement into various taxa, since it is impossible to discuss or think about organisms without first assigning them names. To do this also requires the application of biological nomenclature to the group (Taxa) that are recognised. Nomenclature involves the application of distinctive names on the basis established rules.

One aim of classification is that of convenience. The categories of the systematist are based on degree of

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similarity so that the more closer two organisms are related the more character they will usually share. Latin names were applied to animals and plants long before 1735, when Linnaeus first attempted to catalogue all the known kinds, and it no doubt became apparent even in the most primitive societies that it was useless to make observations on a plant or animal unless one knew its name.

The second function of classification is that of serving as a guide to relationships. Modern classifications are based on phylogeny, but classification and phylogeny are distinct and should not be confused. Phylogeny is the actual evolutionery history of organisms and is natural, continuous and dynamic. Classification is the result of human efforts to interpret or reconstruct phylogeny, and it is arbitrary in that many classifications may be constructed from the same phylogeny. The evolutionary history of a group entails one, and only one, phylogeny; but, in developing a sound interpretation of the origin and evolution of such a group, scientists propose various schemes of classification that undergo changes as new light is shed on the course of evolution (Lagler et al, 1977).

Protein taxonomy as a subject is now throwing more and more light on plant and animal classification. Protein molecules determine the form and function of living things. The significance and remarkable scope of their functions are exmplified in: enzymatic catalysts, transport and storage, coordinated motion, mechanical support, immune protection, generation and transmission of nerve impulses,

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and control of growth and differentiation (Stryer, 1975). Proteins are made from intricately folded chains of amino acids. The primary structure of each protein - the sequence in which its amino acids units are linked together - is governed by the sequence of subunits in the nucleic acid of the genetic material (Suttie, 1972). The proteins of an organism are therefore the immediate manifestation of its genetic endowment (Smith and Goldstein, 1967; Nei, 1972; Dessauer, 1974; and Stephen, 1974).

Dayhoff (1969) pointed out that from a biochemical point of view a fungus and a man are different primarily because each of them has a different complement of proteins. Yet human beings and fungi and organisms of intermediate biological complexity have some proteins in common. These homologous proteins are quite similar in structure, reflecting the ultimate common ancestry of all living things and the remarkable extent to which proteins have been conserved throughout geologic time. Because of this conservation the millions of proteins existing today are in effect living fossils: they contain information about their own origin and history and about the ancestry and evolution of the organisms in which they are found.

Because of very similar observations as above, as long ago as 1958, Crick pointed out that "before long we shall have a subject called protein taxonomy," or biochemical systematics (Tsuyuki and Roberts, 1966). Sibley (1963) pointed out that the biochemical study of proteins was just comparative morphology at the

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molecular level. Dayhoff (1969) suggested that slowly changing proteins will provide the best information on long-term evolution and rapidly changing ones "will provide higher resolution for sorting out closely related species. Population genetic studies which have been carried out on many commercially important species of fish have enabled fisheries biologists to identify unit stocks and often confirm data produced by classical meristic studies (Smith, 1969c; O'Rourke, 1974). Wright (1966) made the important point that taxonomic methods like protein taxonomy are not substitutes for traditional morphological approaches but are auxiliary to them. However, if a taxonomic problem cannot be readily resolved by morphological comparisons there is almost certainly some experimental approach which will throw light on the situation. Hubby and Throckmorton (1965) observed that morphological differences are roughly correlated with protein differences when they were working on protein differences in Drosophila.

Protein taxonomy employs the following argument: a type of protein such as haemoglobin, which in different species has the same function, may show specific differences in the rate at which it migrates through a medium under the influence of an electric current. Lowe-McConnel (1978) pointed out that these differences in electrophoretic mobility reflects differences in the fine structure of these proteins which have a genetic basis. The potential value of protein analysis in taxonomy is emphasized by the fact that such differences can exist between species whose

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gross morphology may be very similar. The correlation between electrophoretic patterns and protein structure is providing a firmer base upon which biochemical taxonomy may work (Knox, 1979).

2.4. ELECTROPHORESIS

Electrophoresis encompassed all operations in which charged molecules migrate in electric fields through solutions (Clark and Switzer, 1977). The basic principle of electrophoresis is straight forward. If two electrodes across which a potential difference exists are placed in an aqueous solution of NaCl the cation, Na^+, will move towards the cathode (the negative pole) and the anion, Cl^-, will move towards the anode (the positive pole). Assuming the solution to be more or less neutral then only small concentrations of H^+ and OH^- will be present. It is the Na^+ and the Cl^- ions that carry the bulk of the current, a situation readily ap reciated by remembering that the conductivity of aqueous NaCl greatly exceeds that of pure water (Sergent, 1975).

All types of electrophoresis are governed by the single set of general principles illustrated by the equation below:

$$\text{mobility of a molecule} = \frac{[\text{applied voltage}] \quad [\text{net charge on the molecule}]}{[\text{friction of the molecule}]}$$

Namely, the mobility or rate of movement of a molecule increases with increased applied voltage or increased net charge on the molecule. Conversely, the mobility of a

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molecule decreases with increased molecular friction caused by molecular size and shape. Total actual movement of molecules increases with increased time for mobility involves rate of movement (Clark and Switzer, 1977).

If the voltage or current applied to an electrophoresis system is constant throughout the electrophoretic run, the mobilities of the molecules being resolved will then reflect the other terms of the equation above, namely net charge and frictional characteristics.

Electrophoretic separation of large macromolecules follow the general principles of the equation, but other factors influence the eventual resolution of macromolecules. In line with the equation the friction of molecules within electrophoretic systems reflects, both molecular size and shape. Molecular shape is not very significant in small molecules, in which bonds are free to rotate, so size alone defines their friction. However, macromolecules often have defined shapes with specific axial ratios (i.e. length-to-widths rations) (Clark and Switzer, 1977). As a result, both size and shape influence migration. Molecules with high axial rations demonstrate less electrophoretic mobility than more spherical molecules that have equal weight and equal charge. In addition, macromolecules may deviate from the basic electrophoretic principles of the equation because of interaction with salt ions in their immediate environment or because of intermolecular charge-dependent associations. The predictions of electrophoretic mobilities for macromolecules are complicated.

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Recent investigations have utilized electrophoretic techniques to distinguish population subunits instead of the identification methods by tagging, growth studies, and numerous meristic and morphometric determinations (Weinstein and Yerger, 1976 a, b).

2.5. EYE LENS

The lens is an entirely epithelial structure. The formation of the lens starts from the embryonic stage of development. From the 5th week of development (13 mm) of the human embryo the lens continues to grow, cytologically isolated from its surroundings (Heyningen, 1962). A further growth is the result of cell division in the single layer of epithelium at the anterior surface of the lens, and the subsequent elongation of the daughter cells so produced.

The lens continues to grow, throughout life, at a decreasing rate, the older cells losing their nuclei and becoming more and more compressed in the centre (or nucleus) of the lens, and fresh fibres being continually added at the periphery.

Thus the lens has several unusual features (1) it is cytologically isolated from its surroundings at an early embryonic stage and therefore there is no interchange of cells between the lens and its surrounding tissues. (2) It contains solely epithelial cells at all stages of development. (3) Its growth never ceases and its weight increases throughout life.

Although constantly dividing, the epithelium does not normally undergo neoplastic change. Mann (1947) has shown

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that its natural immunity to neoplasia is primarily associated with its avascularity. After the degeneration of the vascular plexus surrounding the lens, which occurs before or soon after birth, the lens has no blood supply, but is surrounded by the aqueous and vitreous humours from which it must receive all its needs (Heyningen, 1962).

The function of the ocular lens is to refract incident light in order to focus images on the retina. The soluble lens proteins which include alpha, beta, and gamma crystallins, comprise over 90 % of the dry weight of the lens (Zigler and Sidbury, 1974). The function of the lens crystallins is to produce a matrix which is fully transparent to visible light and which remains so during lens accommodation. It seems likely that precisely ordered interactions among the various lens proteins would be required to produce such a system.

The lens is largely composed of proteins in extremely high concentrations (Manski et al, 1964; Yamada, 1966; Smith and Goldstein, 1967; Smith, 1983). These proteins have been divided into two groups, saline-soluble (crystallines) and insoluble (albuminoids). The crystallines have been separated into three main electrophoretic families, alpha, beta, and gamma in order of decreasing mobilities (Manski et al, 1964). Each of these proteins constitute a family of similar, but not identical proteins (Heyningen, 1962; Zigler and Sidbury, 1974). Protein with alpha crystallin characteristics has been found in all vertebrate species studied and has come to be regarded as a classical

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organ-specific protein. The species specificity of the eye lens protein pattern has been regarded as depending on beta and gamma crystallins. These proteins are very useful in the taxonomy of fishes provided the material is used as soon as possible after collection (O'Rourke, 1974).

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CHAPTER THREE

3. MATERIALS AND METHODS

3.1. FISH SPECIMENS

Fishes for this electrophoretic study were obtained from two regions - Gombe, Bauchi State, and Zaria, Kaduna State Fig. 22. A. nurse, S. macrolepidotus, S. schall and all the Cichlids were obtained from Zaria market. The remaining species were collected from Gombe and transported to the laboratory in cold boxes (Coleman). Many collection trips had to be made because of the persistent power failures at this end when the work was in progress.

The weight of each fish was taken on a top loading Mettler balance (model 1200). The body depth (Lagler et al, 1977) and body width were measured using vernier callipers (T.M. Draper No. 202) while the standard length and total length (Lagler et al, 1977) were obtained separately for each fish using a measuring board constructed in the department.

The coefficient of condition K was calculated by using the cube law.

$$K = \frac{\text{Fresh weight} \times 100}{(\text{Standard length})^3}$$

The data obtained from length-weight measurements were then subjected to statistical analysis. Members of the two genera Hydrocynus and Hemichromis obtained were so few that statistical analyses on their length-weight

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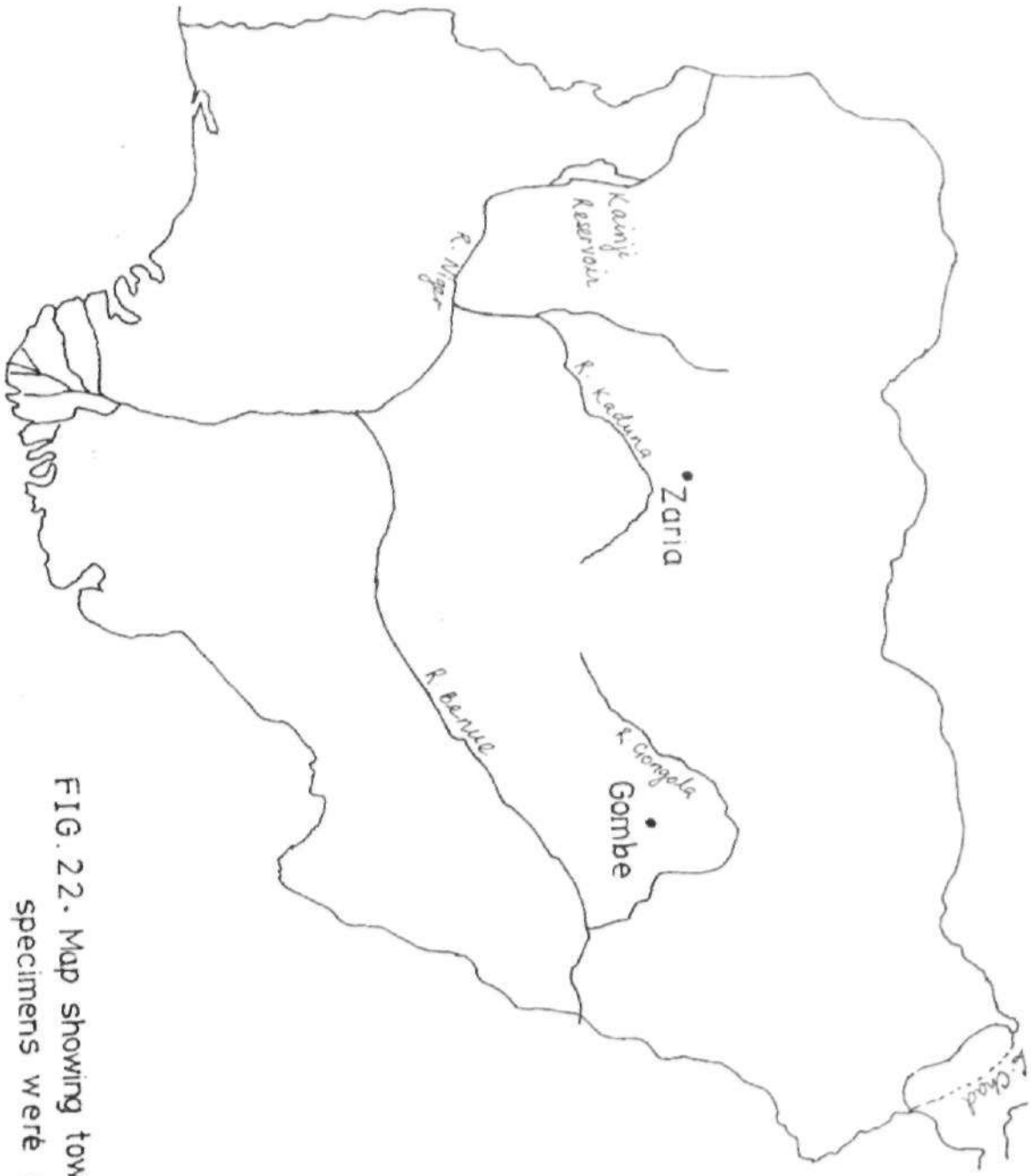

FIG. 22. Map showing towns where specimens were collected

data was not possible.

3.2. FISH LENS

Eye lenses were removed through a slit made in the corneas of the fish species. The lenses were placed in dry plastic containers (PHILIP HARRIS LIMITED C 76160/9) which were then sealed and stored frozen until ready for further processing.

Whole nuclei from the lenses of all the fish species were obtained for each fish by dissecting away the outer (cortical) lens layer (Smith, 1983) after thawing. Both nuclei of a fish were weighed on a Mettler balance (Type H16 Cap. 80 g) and were ground in a container (as above) using a glass rod. Protein extracts were prepared by macerating the nuclear material in a volume of 0.018g/dl. NaCl equal to ten times the wet weight of the lens nuclei (Smith, 1968). The lens extracts were swirled vigorously at approximately the fourth, eigth, and sixteenth hours during 24 hours extraction at about 8°C to remove salt (Smith, 1968).

The extracts were lightly centrifuge using Beckman 152 Microfuge (Made in U.S.A.), and the supernatant were electrophoretically processed in duplicate according to the method outline below:

3.3. EQUIPMENT

Elvi 18 power supply unit and Elvi 70 electrophoresis chamber (plate 1). Sample applicator and template (Helena) (plate 2). Micropipettes.

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Plate I. Elvi 18 power supply unit and Elvi 70 electrophoresis chamber.

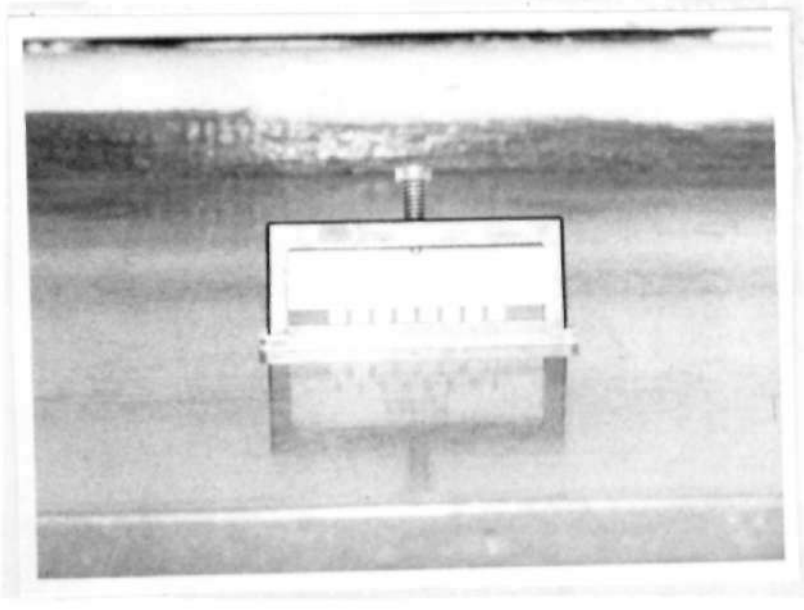

Plate II. Sample applicator and template.

3.4. SUPPLY

Cellulose acetate membrance - Celagram II.

3.5. CHEMICALS

Buffer: Barbitone buffer pH 8.6: 0.9g barbitone sodium, 0.1g barbitone and 10.0 ml. glycerol were dissolved in distilled water and diluted to 120 ml.

Stain fixative solution: 4 g of ponceau S stain dissolved in 1 litre of 5% trichloroacetic acid (T.C.A.).

Destaining solution 1: 5% glacial acetic acid.

Destaining solution 2: Absolute methanol.

Clearing solution: 20% acetic acid in methanol.

Equipments, supply, and chemicals were purchased from the following: Elvi 10 power supply unit and Elvi 70 electrophoretic chamber were purchased from elvi elettronica e chimica per laboretorio milano, pizzag, cesare, 14. The cellulose acetate membrane was supplied by shandon scientific instruments division: while all chemicals were purchased from the British drug houses (BDH) Ltd. laboratory chemicals division, Poole, England. The micropipettes were purchased from Beckman/Spinco Division, Palo-Alto, California, U.S.A.

3.6. PROCEDURE FOR ELECTROPHORESIS

Before applying the sample onto the cellulose acetate membrance, the following procedures were followed: Membranes were cut into 12 cm strips, the centre of each marked with pencil (HB) for reference. The name and sex or size of the fish whose eye lenses extract was to be used were written at the cathodic (negative) end of the

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strip with the pencil.

The membranes were then placed to soak for at least 10 minutes in the barbital buffer. The strips were drawn from the buffer solution in which they had been plunged and assembled on the supporting bridge complying with the reference notches. (The supporting bridge is found in the electrophoretic chamber). Two glass bars were used to stretch out and block the strips together with two paper wicks onto the frame. Each of the wicks is found on either side of the frame and is long enough to touch the base of the chamber (Fig. 24) when the supporting bridge is kept in place. Excess buffer on the strips was dried with whatman No. 1 filter paper.

400 ml of the buffer was poured into the chamber. The chamber was then inclined by lifting it from a short side in order that the buffer going beyond the middle sector, equilibrates hydraulically (Elvi 70 manual). Finally the supporting bridge, with the cellulose acetate membrane strips and paper wicks assembled, was placed into the chamber ready for sample application.

The eye lens nuclei protein extract was taken up using a micropipette and place in a groove in the template. The template allowed for either the drawing of the sample or the exact positioning of the applicator, with regards to the strips. Using the applicator the extract was taken from the template and placed in the centre of the strip. The tank cover was then put in place by sliding it from the right to the left.

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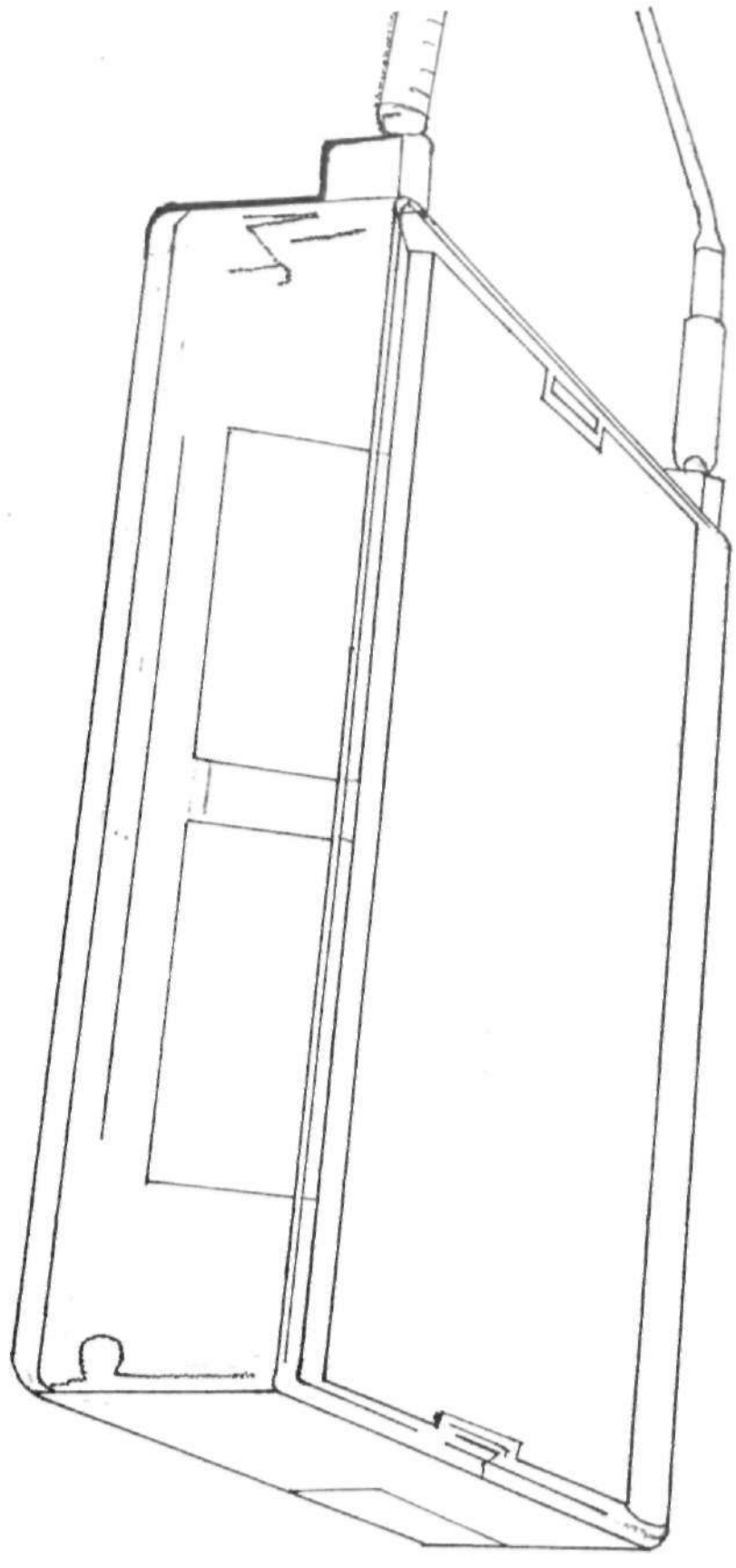

Fig. 27. Electrophoretic chamber with cellulose acetate papers and wicks in place.

The power supply jacks were inserted into the chamber plugs, blocking the cover. The power supply unit was switched on and adjusted to 350 volts for 20 minutes. After the migration time was elapse, the power supply was switched off, the power supply cable disconnected, and the cover taken off. The strips were placed immediately into the stain fixative solution for at least 10 minutes after which time they were washed one by one in 5% glacial acetic acid. They were then rinsed twice in absolute methanol and dipped for 1 minute in the clearing solution. The wet strips were placed immediately on a piece of white cardboard, and carefully smoothed to remove wrinkles and air bubbles. The cardboard was sufficiently thick (for example, approximately 1 mm) so as not to curl during the drying process at ambient temperature.

The band patterns obtained on the strips were finally photographed.

CHAPTER FOUR

4. RESULTS

4.1. PHYSICAL PARAMETERS IN TAXONOMY

Physical parameter have been investigated to provide information on taxonomic differences in the species of fish used in this study. Species means for fresh weight, total length, standard length, body depth, and body width are shown in TABLES I, II, and III respectively for the three genera under investigation.

The relationships that exist between length and weight have also been investigated to provide additional information on taxonomic differences in the species of fish used in this study. Slopes of the regression lines obtained as a result of plots of length against length, length against weight or weight against length also provided information in this study. Species regression lines are shown in Fig. 39 through 47.

Length-weight relationships can be represented in the form of the condition factor, K. The condition factor was also a very useful source of taxonomic information.

4.1.1. ALESTES SPECIES

Among the six species of Alestes investigated in this study, A. brevis and A. macrolepidotus had the greatest dimensions as far as the physical parameters were concerned. The unknown species (Alestes "X") appeared to be the smallest of the six Alestes species (TABLE I).

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4.1.1.1. ALESTES brevis

The maximum total length observed in A. brevis was 19.7 cm and the smallest specimen measured 14.0 cm with a range of 5.7 cm. The mean total length was 17.4 cm while the median and mean deviation were 18.0 cm and 1.6 cm respectively.

A. brevis showed a maximum standard length of 16.0 cm and a minimum value of 11.1 cm with a range of 4.9 cm from the observations made. The mean standard length was 13.9 cm while the median and mean deviation were 14.5 cm and 1.3 cm respectively.

The maximum body depth observed in A. brevis was 4.3 cm and the smallest specimen measured 3.3 cm with a range of 1.0 cm. The mean body depth was 4.0 cm while the median and mean deviation were 4.2 cm and 0.3 cm respectively.

2.5 cm and 1.6 cm were the observed values for maximum and minimum widths respectively in A. brevis. A range of 0.9 cm was shown here. The mean body width of this species was 2.0 cm with a median and mean deviation of 1.9 cm and 0.25 cm respectively.

The maximum body weight observed in A. brevis was 80 g and the smallest specimen had a weight of 31.9 g with a range of 48.3 g while the median and mean deviation were 59.9 g and 13.9 g respectively.

4.1.1.2. ALESTES BAREMOSE

A. baremose showed a maximum total length of 16.5 cm and a minimum value of 10.8 cm with a range of 5.7 cm from the measurements made. The mean total length was 12.8 cm

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while the median and mean deviation were 12.2 cm and 1.4 cm respectively.

In this species the maximum standard length observed was 12.2 cm and the smallest specimen measured 8.2 cm. The mean standard length, median and mean deviation were 9.6 cm, 9.1 cm and 1.0 cm respectively.

The maximum body depth and the body depth of the smallest specimen were 3.5 cm and 1.7 cm respectively. The mean body depth, median and mean deviation were 2.2 cm, 2.0 cm and 0.4 cm respectively.

A. baremose had a maximum body width of 1.2 cm and the smallest specimen measured 0.6 cm with a range of 0.6 cm. The mean body width was 0.8 cm while the median and the mean deviation were 0.8 and 0.2 respectively

The maximum body weight of A. baremose was 18.5 g while the smallest specimen measured weighed 6.1 g giving a range of 12.4 g. The mean body weight, median and mean deviation were 9.8 g, 7.8 g and 3.2 g respectively.

4.1.1.3. ALESTES MACROLEPIDOTUS

The observed maximum total length in A. macrolepidotus was 25.2 cm and the smallest specimen measured 13.2 cm with a range of 12.0 cm. The observed mean total length was 17.7 cm while the median and mean deviation were 16.6 cm and 3.3 cm respectively.

The maximum standard length observed in A. macrolepidotus was 19.5 cm and the smallest specimen measured 10.3 cm with a range of 9.2 cm. The observed mean standard length, median, and mean deviation were 13.5 cm, 12.3 cm

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and 2.6 cm respectively.

In this species, the maximum body depth observed was 5.7 cm while the minimum was 3.3 cm with a range of 2.4 cm. The observed mean depth, median and mean deviation were, 4.1 cm, 4.0 cm and 0.4 cm respectively.

The maximum and minimum body width obaserved in the A. macrolepidotus specimens studied were 11.0 cm and 1.6 cm respectively with a range of 10.2 cm. The observed mean width, median and mean deviation were 2.9 cm, 2.1 cm, and 1.5 cm respectively.

This species had a maximum body weight of 126.2 g and the smallest specimen measured 17.0 g with a range of 109.2 g. The mean body weight, median and mean deviation were 48.8 cm, 33.3 cm and 29.5 cm respectively.

4.1.1.4. ALESTES LEUCISCUS

The maximum ttotal length observed in A. leuciscus was 11.7 cm and the smallest specimen measured 8.8 cm with a range of 2.9 cm. The mean, median and mean deviation values observed were 10.3 cm, 10.1 cm and 0.8 cm respectively.

The specimens used showed A. leuciscus had a maximum standard length of 9.2 cm and a minimum value of 6.4 cm while the range was 2.8 cm. The mean, median and mean deviation values were 8.1 cm, 8.2 cm and 0.8 cm respectively for this species.

The maximum body depth observed in A. leuciscus was 3.0 cm and the smallest specimen measured 1.9 cm in this respect. The range observed was 1.1 cm. The mean depth was 2.5 cm while the median and mean deviation were 2.4 cm

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and 0.3 cm respectively.

1.4 cm and 0.8 cm were the observed values for maximum and minimum body width respectively in this species, while the range was 0.6 cm. The mean width was 1.1. cm while the median and mean deviation were 1.0 cm and 0.2 cm respectively.

The maximum and minimum body weight of 20.6 g and 5.7 g respectively were observed with a range of 14.9 g in A. leuciscus. The mean, median and mean deviation were 12.6 g, 11.0 g and 4.1 g respectively.

4.1.1.5. ALESTES "X"

Specimens studied showed a maximum total length value of 9.7 cm and a minimum value of 7.2 cm with a range of 2.5 cm. The mean total length, median and mean deviation were 8.9 cm, 9.3 cm and 0.7 cm respectively.

The observed maximum and minimum standard lengths were 7.6 cm and 5.8 cm respectively, with a range of 1.8 cm. The mean, median and mean deviation values were 7.0 cm, 7.2 cm and 0.5 cm respectively.

2.7 cm and 1.8 cm were the maximum and minimum body depth respectively, with a range of 0.9 cm. The mean depth, median and mean deviation were 2.3 cm, 2.3 cm and 0.2 cm respectively.

The maximum body width in Alestes "X" was 1.1 cm and the smallest specimen measured 0.7 cm with a range of 0.4 cm. The mean width was 0.9 cm while the median and mean deviation were 0.9 cm and 0.1 cm respectively.

The maximum body weight observed was 11.4 g and a minimum

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of 3.8 g was seen. The range observed was 7.6 g. The mean, median and mean deviation values were 8.2 g, 9 g and 2.0 g respectively.

4.1.1.6. ALESTES NURSE

A. nurse showed a maximum total length of 15.2 cm and the smallest specimen measured 8.7 cm with a range of 6.5 cm. The mean total length was 11.1 cm while the median and mean deviation were 10.3 cm and 2.4 cm respectively.

The maximum standard length observed in A. nurse was 12.4 cm and the minimum was 6.7 cm with a range of 5.7 cm. The mean value for this parameter was 8.8 cm while the median and mean deviation were 8.1 and 2.1 respectively.

In body depth, the maximum and minimum values observed were 4.1 cm and 1.9 cm respectively with a range of 2.2.cm. The mean, median and mean deviation values here were 2.8 cm, 2.5 cm, and 0.7 cm respectively.

In terms of body width, the maximum and minimum values observed for A. nurse were 2.1 cm and 1.0 cm respectively with a range of 1.1 cm. The mean, median and mean deviation values were 1.4 cm, 1.3 cm and 0.4 cm respectively.

The maximum and minimum weights observed were 39.1 g and 6.6 g respectively with a range of 32.5 g. The mean, median and mean deviation values observed were 17.5 g, 12.2 g and 10.8 g respectively.

4.1.1.7. PHYSICAL PARAMETERS OF ALESTES SPECIES

As shown in TABLE I and summarized in Figures 24 to 28 the mean values for the physical parameters of A. brevis and A. macrolepidotus were higher than those of the other

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Table I. Physical parameters of 6 species of Alestes.

Measurements (Mean ± S.E.)	Alestes baremose	Alestes brevis	Alestes Macrolepidotus	Alestes leucisus	Alestes species	Alestes nurse
Fresh weight (gm)	9.807 ± 1.074	58.3 ± 4.931	48.808 ± 9.954	12.567 ± 1.370	8.167 ± 0.523	17.525 ± 2.454
TL (cm)	12.786 ± 0.452	17.355±0.574	17. 65 ± 1.133	10.289 ± 0.278	8.924 ± 0.180	11. 1 ± 0.500
SL (cm)	9.636 ± 0.333	13.873±0.482	13.475 ± 0.880	8.144 ± 0.292	6.962 ± 0.120	8. 8 ± 0.438
Body depth (cm)	2.236 ± 0.133	3.964±0.116	4.108 ± 0.178	2.467 ± 0.089	2.290 ± 0.059	2. 75 ± 0.157
Body width (cm)	0.821 ± 0.053	1.973±0.092	2.917 ± 0.798	1.089 ± 0.059	0.914 ± 0.029	1. 4 ± 0.080
Specimens (n)	28	22	24	18	42	33

species in this genus. The "X" species had the lowest values.

The mean values for fresh weight in this genus indicated that A. brevis was the heaviest. This was followed by A. macrolepidotus which was followed by A. nurse (Fig. 24). The mean fresh weight of A. leuciscus followed the above and this species was followed by A. baremose. The unknown species - Alestes "X" appeared to be the lightest.

Fig. 25 showed that A. macrolepidotus had the greatest total length. This was followed very closely by A. brevis which was followed by A. baremose. The mean total length of A. nurse came next which was followed by that of A. leuciscus. Alestes "X" had the least value of mean total length.

The mean standard length values, (Fig. 26), indicated in this study that A. brevis was longer than A. macrolepidotus which was longer than A. baremose. This species was followed by A. nurse which was longer than A. leuciscus. The shortest in terms of standard length in this genus was Alestes "X".

Fig. 27 indicated that A. macrolepidotus was deeper than A. brevis which was deeper than A. nurse. The next species was A. leuciscus which was deeper than A. baremose. Alestes "X" came last with the lowest value in body depth.

The mean values for body width (Fig. 28) indicated that A. macrolepidotus was the widest of all the Alestes species under investigation. This was followed in mean body width value by A. Brevis which was followed by A. leuciscus. A. nurse and Alestes "X" came next with the least value shown by A. baremose.

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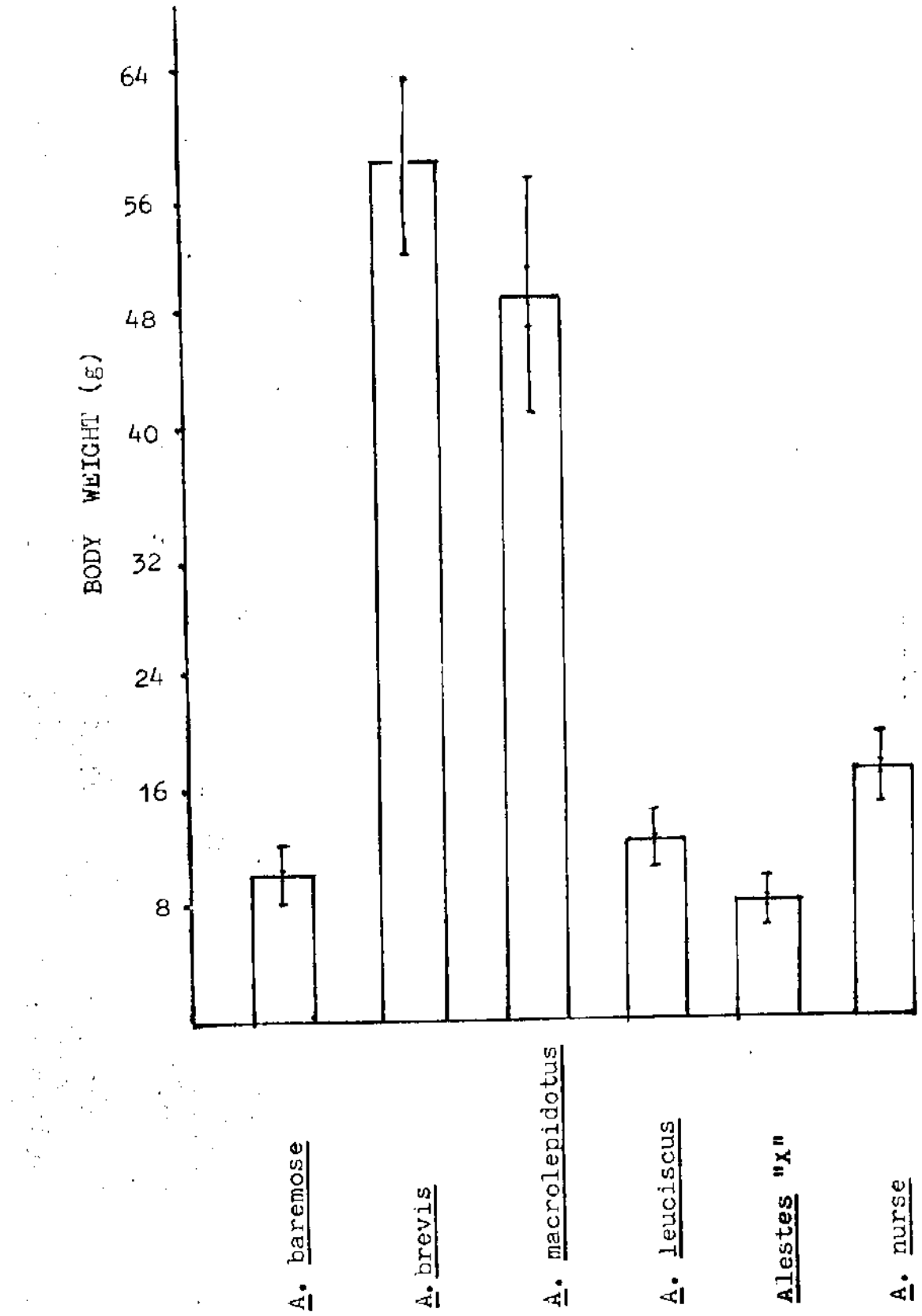

Fig. 24. Mean body weight of Alestes species ± S.E.

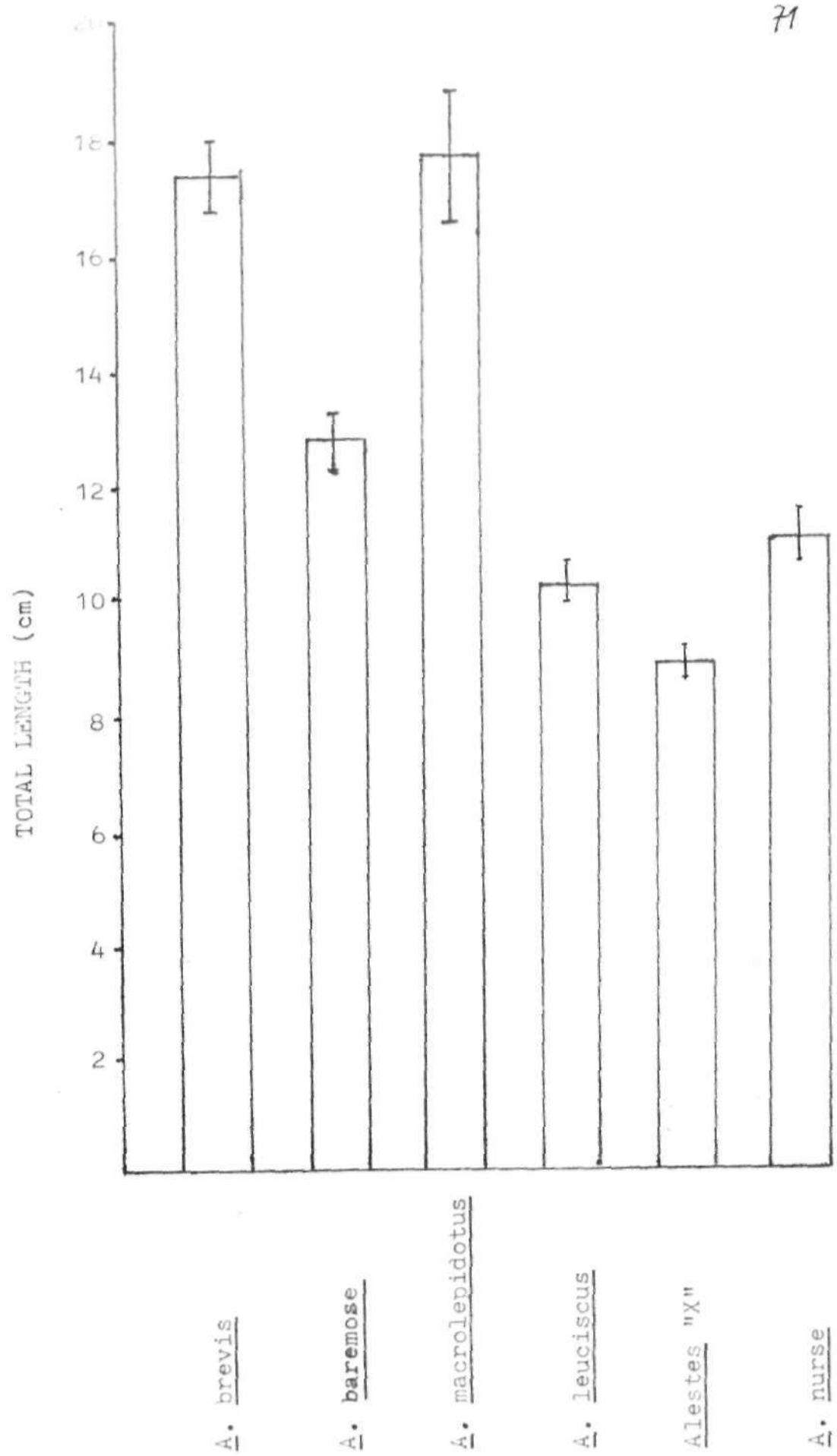

Fig. 25. Mean total length of Alestes species + S.E.

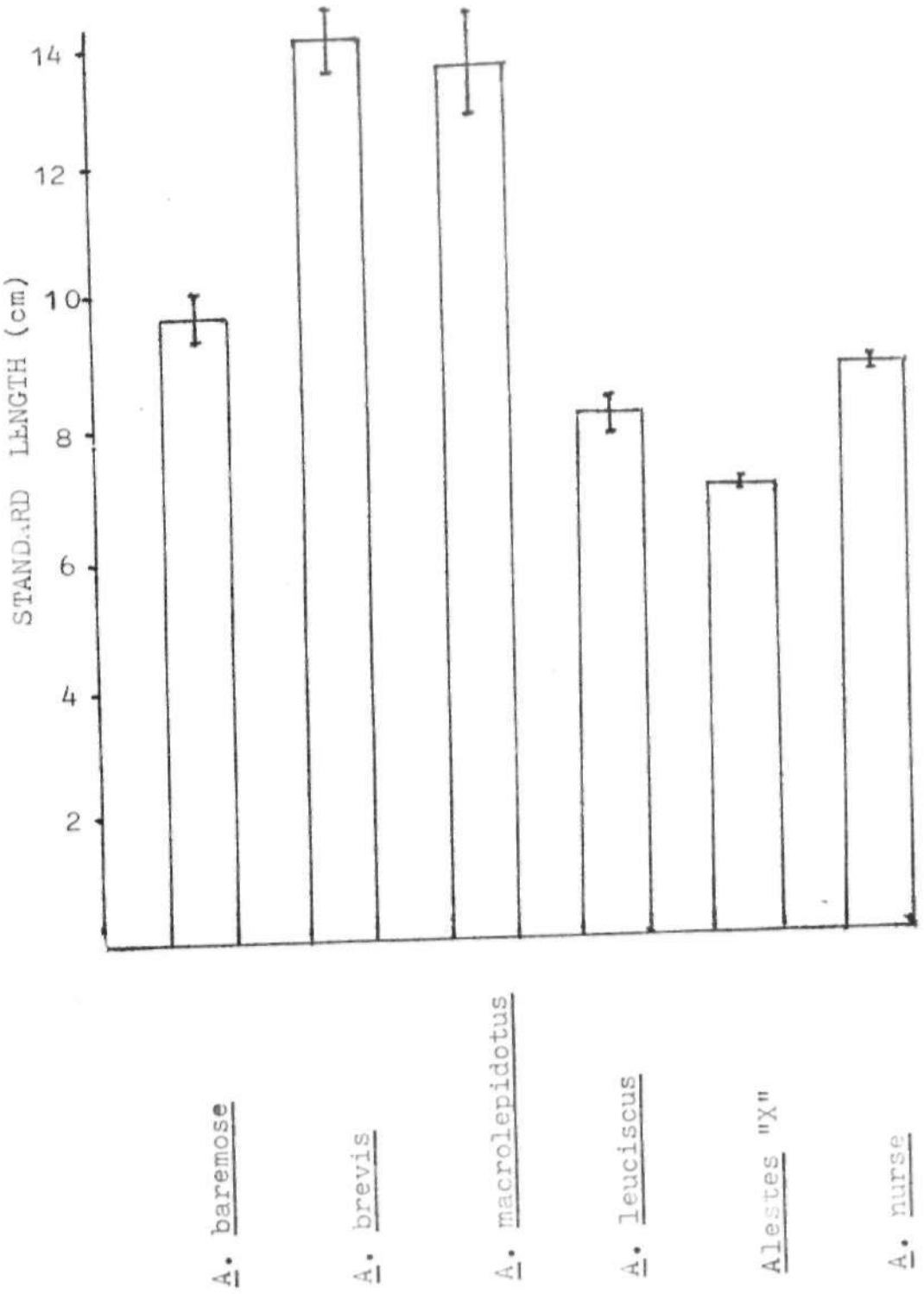

Fig. 26. Mean standard length of Alestes species + S.E.

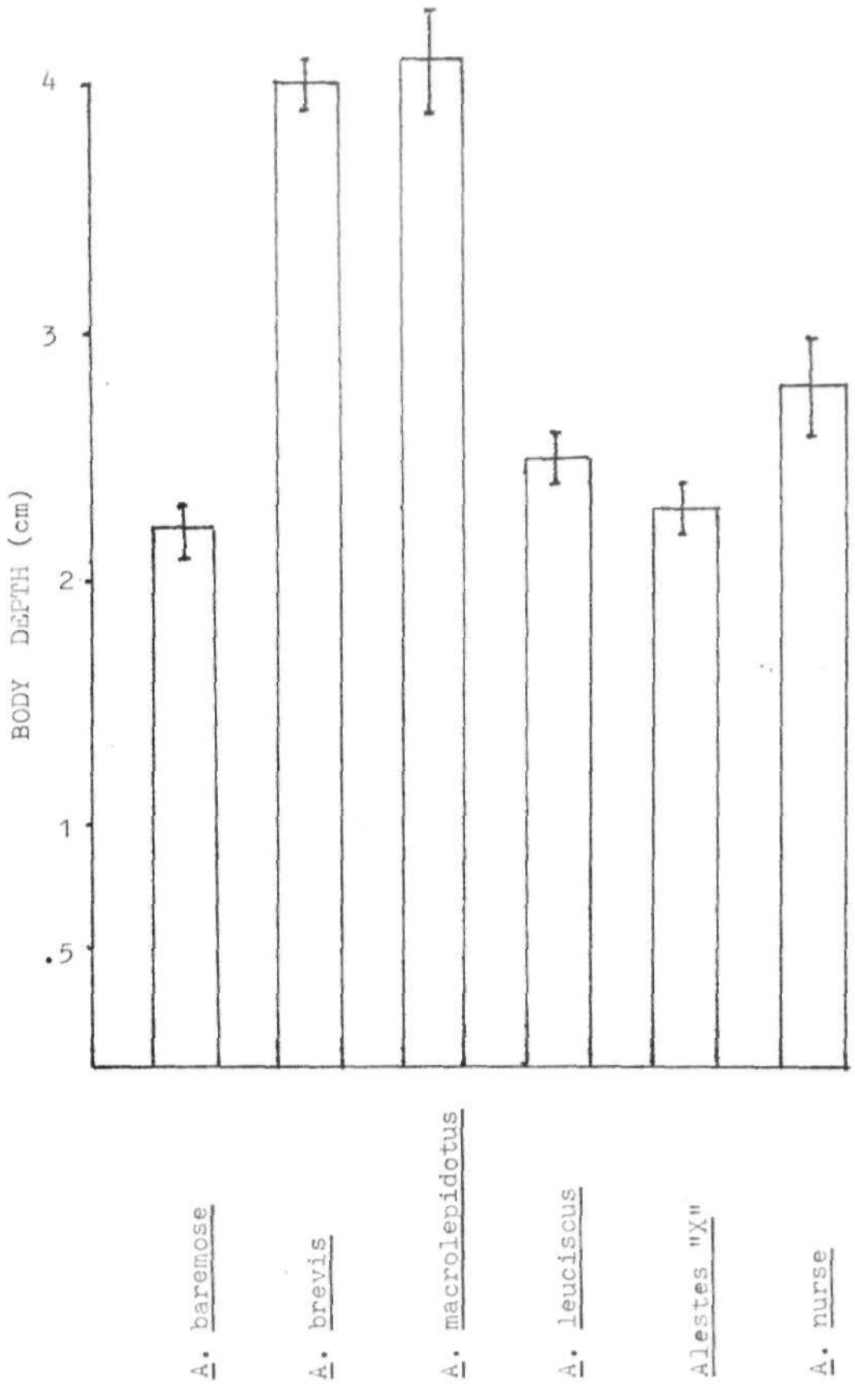

Fig. 27. Mean body depth of Alestes species ± S.E.

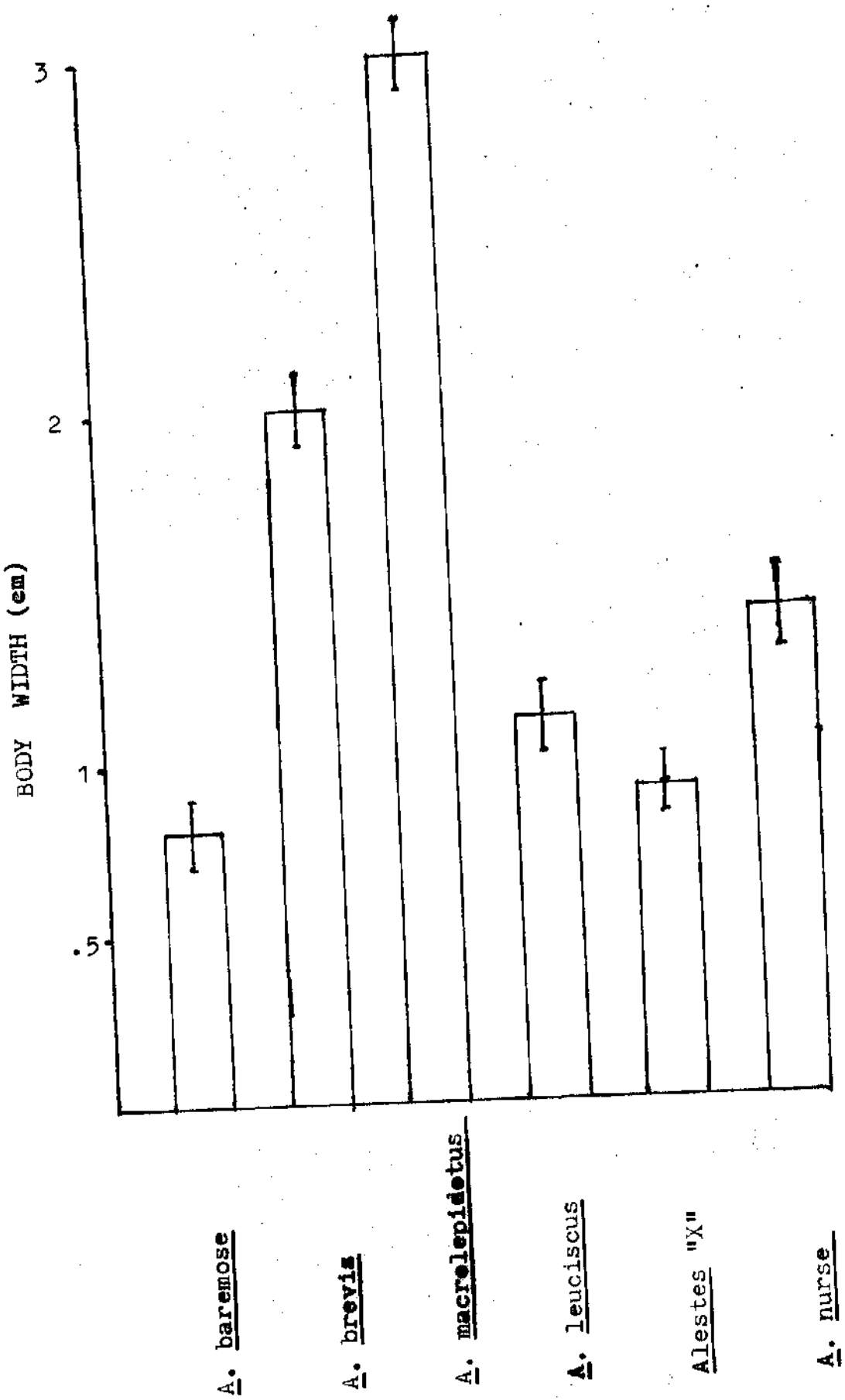

Fig. 28. Mean body width of Alestes species

± S.E.

4.1.2. SYNODONTIS SPECIES

Of the five species of Synodontis investigated in this study, S. clarias had the greatest dimensions as far as the physical parameters were concerned, while S. filamentosis appeared to be the smallest.

4.1.2.1. SYNODONTIS CLARIAS

The maximum total length observed in this species was 19.2 cm and the smallest specimen measured 16.9 cm with a range of 2.3 cm. The mean total length was 18.1 cm while the median and mean deviation were 18.2 cm and 0.7 cm respectively.

S. clarias showed a maximum standard length of 14.0 cm and a minimum value of 12 cm with a range of 2 cm. The mean standard length was 12.6 cm while the median and mean deviation were 12.5 cm and 0.4 cm respectively.

3.0 cm and 3.3 cm were the observed values for maximum and minimum body depth respectively in S. clarias with a range of 0.5 cm. The mean depth, median and mean deviation were 3.5 cm, 3.6 cm and 0.2 cm respectively.

The maximum and minimum observed body width values here were 2.7 cm and 2.4 cm with a range of 0.3 cm. The mean body width was 2.6 cm while the median and mean deviation were 2.6 cm and 0.1 cm respectively.

The observed maximum weight of S. clarias was 65 g and the smallest specimen weighed 40.9 g, the range being 24.1 g. Mean body weight, median and mean deviation were 50.7 g, 51.1 g and 5 g respectively.

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4.1.2.2. SYNODONTIS BATENSODA

The maximum and minimum observed total length were 17.1 cm and 11.9 cm respectively with a range of 5.2 cm. The mean total length, median and mean deviation were 14.0 cm, 12.3 cm and 2.2 cm respectively.

S. batensoda showed a maximum standard length of 12.5 cm and a minimum value of 9.4 cm with a range of 3.1 cm. The mean standard length was 10.7 cm while the median and mean deviation were 9.6 cm and 1.4 cm respectively.

The body depth was observed to have a maximum value of 3.9 cm and a minimum value of 2.7 cm with a range of 1.2 cm. The mean, median and mean deviation values were 3.2 cm, 2.8 cm and 0.5 cm respectively for S. batensoda.

The maximum body width observed in this species was 3.2 cm and the smallest specimen measured 2.3 cm with a range of 0.9 cm. The mean depth was 2.7 cm while the median and mean deviation were 2.4 cm and 0.3 cm respectively.

S. batensoda showed a maximum body weight of 67.8 g and the smallest specimen weighed 30.4 g with a range of 37.4 g. Mean weight, median and mean deviation values were 45.4 g, 32.8 g and 16.6 g respectively.

4.1.2.3. SYNODONTIS FILAMENTOSIS

The maximum total length observed in S. filamentosis was 19.0 cm and the smallest specimen measured 11.7 cm with a range of 7.3 cm. The mean total length was 14.9 cm while the median and mean deviation were 13.9 cm and 2.6 cm respectively.

S. filamentosis showed a maximum standard length of

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14.9 cm and a minimum value of 8.5 cm with a range of 6.4 cm. The mean standard length, median and mean deviation were 11.3 cm, 10.5 cm, and 2.0 cm respectively.

3.0 cm and 1.4 cm were the observed values for maximum and minimum body depth respectively with a range of 1.5 cm. The mean depth, median and mean deviation were 2.1 cm, 1.9 cm and 0.5 cm respectively.

The maximum and minimum observed body widths values were 2.5 cm and 1.4 cm with a range of 1.1 cm. Mean body width, median and mean deviation were 1.9 cm, 1.8 cm and 0.3 cm respectively.

S. filamentosis showed a maximum body weight of 51 g and the smallest specimen weighed 6.5 g with a range of 44.5 g. The mean body weight was 27.5 g while the median and mean deviation were 19.0 g and 16.7 g respectively.

4.1.2.4. SYNODONTIS EUPTERUS

The maximum total length value observed in this species was 13.9 cm and the smallest specimen measured 11.8 cm with a range of 2.1 cm. The mean total length was 12.8 cm while the median and mean deviation were 12.8 cm and 0.4 cm respectively.

S. eupterus showed a maximum standard length of 11 cm and a minimum value of 9 cm with a range of 2 cm. The mean standard length, median and mean deviation were 10.0 cm, 9.9 cm and 0.4 cm respectively.

3.2 cm and 2.5 cm were the observed values for maximum and minimum body depth respectively with a range of 0.7 cm. The mean depth, median and mean deviation were 2.8 cm, 2.7 cm

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and 0.2 cm respectively.

The maximum and minimum observed body width were 2.8 cm and 2.2 cm respectively with a range of 0.6 cm. The mean body width was 2.4 cm while the median and mean deviation were 2.4 cm and 0.1 cm respectively.

The observed maximum weight of S. eupterus was 44.0 g and the smallest specimen weighed 21.6 g; the range being 22.4 g. Mean body weight, median and mean deviation were 29.3 g, 28.1 g and 3.9 g respectively.

4.1.2.5. SYNODONTIS SCHALL

The maximum total length observed in S. schall was 19.7 cm and the smallest specimen measured 12.4 cm with a range of 7.3 cm. The mean total length was 15.4 cm while the median and mean deviation were 15.0 cm and 1.5 cm respectively.

S. schall showed a maximum standard length of 13.3 cm and a minimum value of 9.0 cm with a range of 4.3 cm. The mean standard length, median and mean deviation were 11.0 cm, 11.2 cm and 1.0 cm respectively.

Maximum body depth value observed in S. schall was 3.6 cm and the smallest specimen measured 2.6 cm with a range of 1.0 cm. The mean depth, median and mean deviation were 3.2 cm, 3.1 cm and 0.3 cm respectively.

3.5 cm and 2.0 cm were the observed values for maximum and minimum body width respectively in S. schall. A range of 1.5 cm was shown here. The mean body width of this species was 2.8 cm while the median and the mean deviation values were 2.7 cm and 0.4 cm respectively.

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The maximum body weight observed in S. schall was 70.1 g and the smallest specimen weight 19.9 g with a range of 50.2 g. The mean body weight was 38.7 g while the median and mean deviation were 34.5 g and 11.7 g respectively.

4.1.2.6. PHYSICAL PARAMETERS OF SYNODONTIS SPECIES

As shown in TABLE II and summarized in Figures 29 through 33 S. clarias had the highest mean values for the physical parameters, while S. filamentosis had the lowest values, generally speaking.

Fig. 29 indicated that S. clarias was the heaviest species in this genus. It was followed by S. batensoda in terms of weight, which was followed by S. schall. S. eupterus followed next with S. filamentosis coming last.

In total length (Fig. 30) S. clarias came first and it was followed by S. schall which was followed by S. filamentosis. S. batensoda followed S. filamentosis with S. eupterus showing the least value in mean total length.

The mean values for standard length in this genus indicated that S. clarias was the longest (Fig. 31). This was followed by S. filamentosis which was followed by S. schall. S. batensoda followed S. schall while S. eupterus had the lowest value for standard length.

Mean body depth values (Fig. 32) showed that S. clarias was the deepest. This was followed by S. schall which was followed by S. batensoda. S. eupterus came next followed by S. filamentosis.

Fig. 33 indicated that S. schall had the greatest width, followed by S. batensoda which was followed by S. clarias.

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Table II. Physical parameters of 5 species of Synodontis

Measurements (Mean ± S.E.)	Synodontis clarias	Synodontis batensoda	Synodontis filamentosis	Synodontis eupterus	Synodontis schall
Fresh weight (gm)	50. 7 ± 2.161	45.35 ± 5.497	27.47 ± 5.651	29.277 ± 1.552	38. 7 ± 4.096
TL (cm)	18,08 ± 0.261	14. 0 ± 0.725	14.92 ± 0.902	12.762 ± 0.149	15.385 ± 0.589
SL (cm)	12. 6 ± 0.187	10.68 ± 0.470	11. 3 ± 0.712	9.970 ± 0.153	11. 0 ± 0.387
Body depth (cm)	3.52 ± 0.063	3. 2 ± 0.173	2.13 ± 0.185	2.777 ± 0.055	3.185 ± 0.092
Body width (cm)	2.57 ± 0.029	2.67 ± 0.116	1.87 ± 0.121	2.377 ± 0.042	2.841 ± 0.127
Specimens (n)	20	20	20	26	26

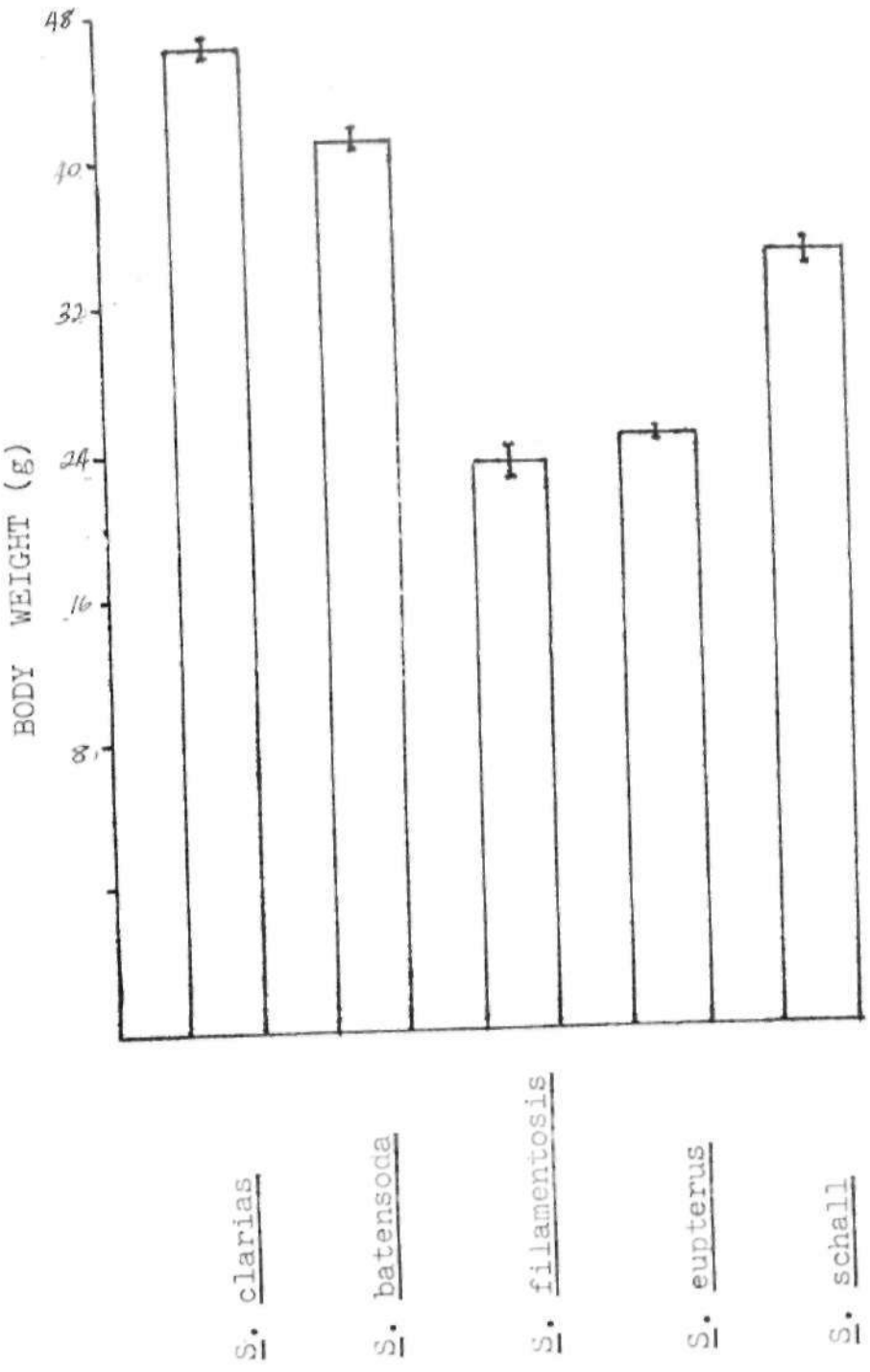

Fig. 29. Mean body weight of Synodontis species ± S.E.

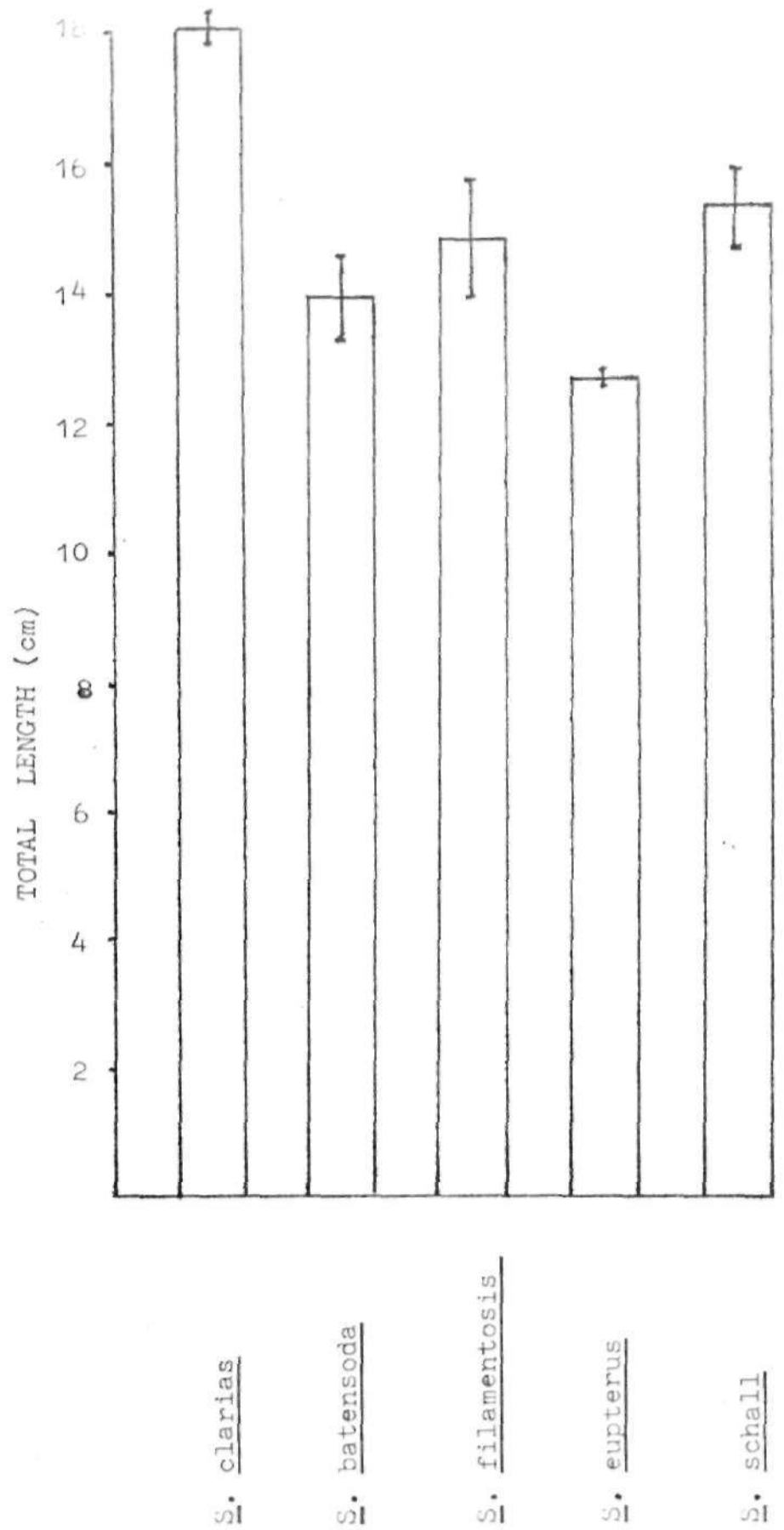

Fig. 30. Mean total length of Synodontis species ± S. E.

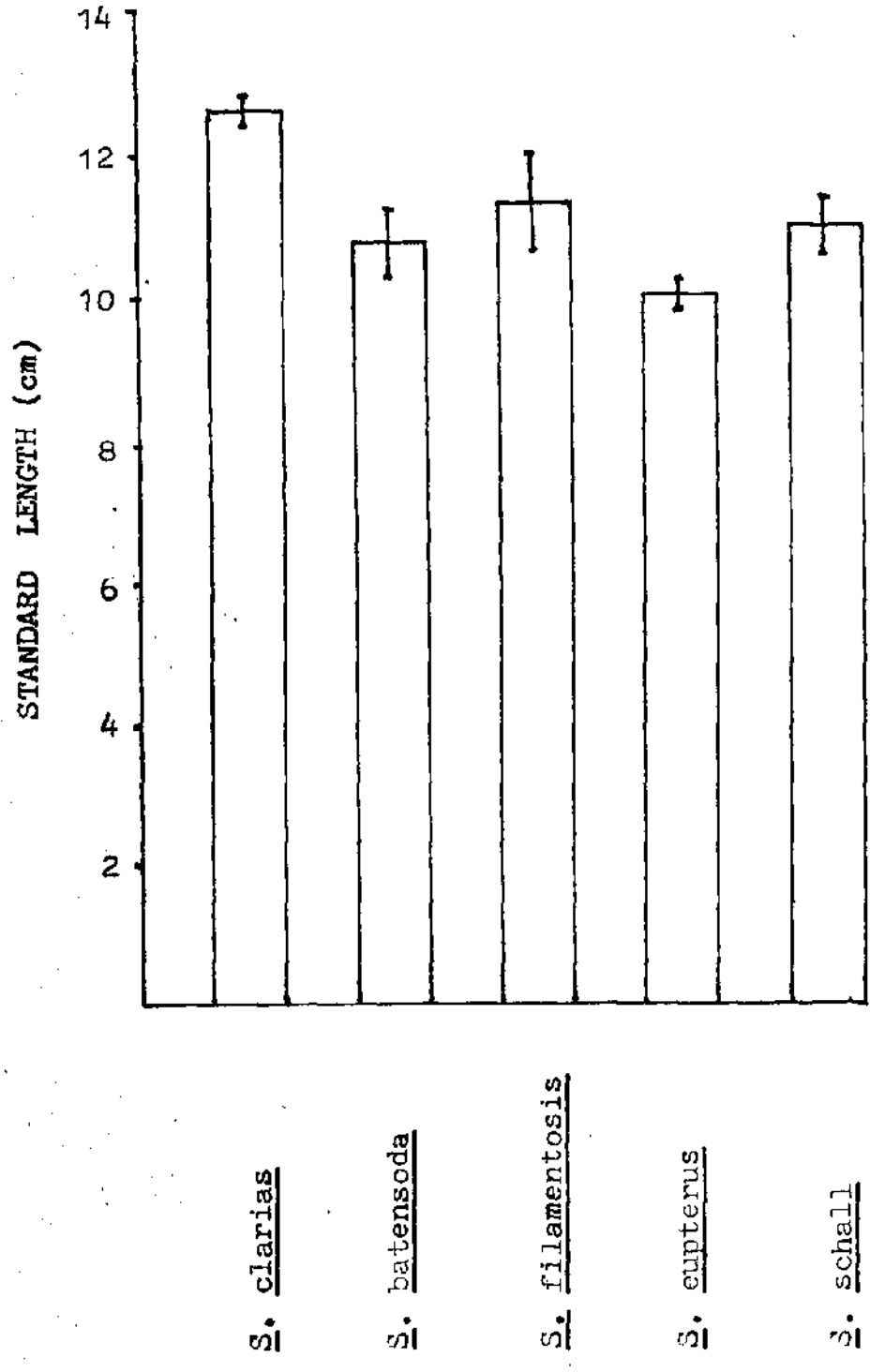

Fig. 31. Mean standardlength of Synodontis specie ± S.E.

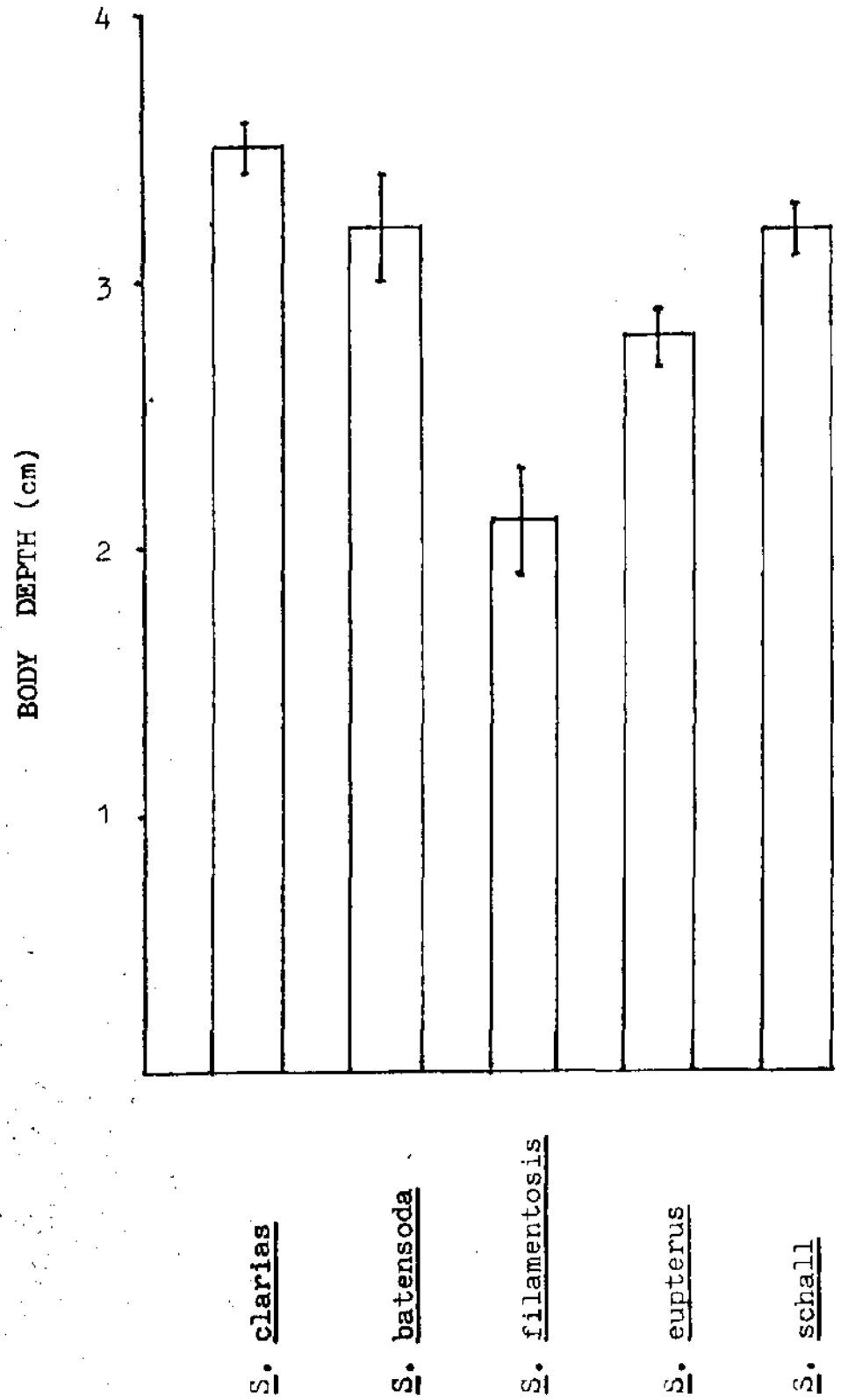

Fig. 32. Mean body depth of Synodontis species ± S.E.

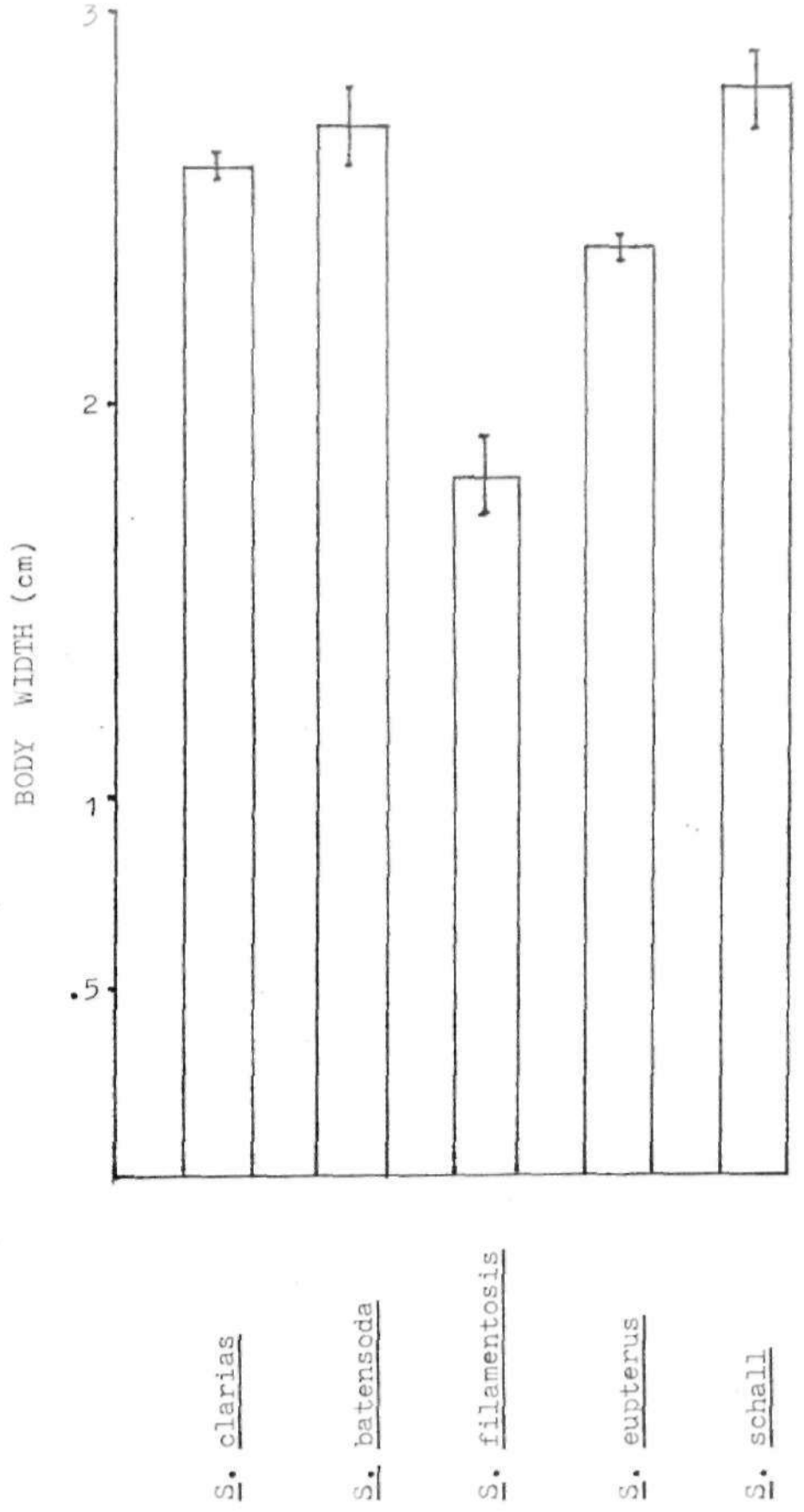

Fig. 33. Mean body width of Synodontis species ± S.E.

S. eupterus came next followed by S. filamentosis.

4.1.3. TILAPIA SPECIES

Among the three species of Tilapia investigated in this study, T. zilli had the greatest dimensions as far as the physical parameters were concerned. This is followed by T. galileae and then T. nilotica.

4.1.3.1. TILAPIA GALILEAE

The maximum total length observed in T. galileae was 17.8 cm and the smallest specimen measured 8.1 cm with a range of 9.7 cm. The mean total length was 13.4 cm while the median and mean deviation were 13.5 cm and 2.1 cm respectively.

T. galileae showed a maximum standard length of 14.3 cm and a minimum value of 6.0 cm with a range of 8.3 cm. The mean standard length was 10.2 cm while the median and mean deviation were 10.2 cm and 1.7 cm respectively.

The maximum body depth observed in T. galileae was 7.2 cm and the smallest specimen measured 2.1 cm with a range of 5.1 cm. The mean body depth was 4.9 cm while the median and mean deviation were 4.8 cm and 1.0 cm respectively.

4.0 cm and 1.4 cm were the observed values for maximum and minimum widths respectively of T. galileae. A range of 2.6 cm was shown here. The mean body width of this species was 2.4 cm while the median and mean deviation were 2.2 cm and 0.5 cm respectively.

The maximum body weight recorded was 114.6 g and the smallest specimen weighed 18.9 g giving a range of 95.7 g. The mean body weight was 53.2 g while the median and mean

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deviation were 49.1 g and 21.9 g respectively.

4.1.3.2. TILAPIA NILOTICA

T. nilotica showed a maximum total length of 21.7 cm and a minimum value of 6.7 cm giving a range of 15.0 cm. The mean total length was 13.5 cm while the median and mean deviation were 12.9 cm and 2.7 cm respectively.

The maximum standard length of T. nilotica was 17.0 cm and the smallest specimen measured 1.9 cm with a range of 15.1 cm. The mean standard length was 10.3 cm while the median and mean deviation were 9.7 cm and 2.3 cm respectively.

This species showed a maximum body depth of 7.7 cm and a minimum depth value of 1.9 cm giving a range of 5.8 cm. The mean body depth was 4.4 cm while the median and mean deviation were 4.0 cm and 1.0 cm respectively.

4.4 cm and 1.0 cm were the observed values for maximum and minimum body width respectively of T. nilotica. The mean body width was 2.5 cm while the median and mean deviation were 2.2 cm and 0.6 cm respectively.

The maximum body weight observed for this species was 140.1 g and the minimum weight recorded was 4.3 g; giving a range of 135.8 g. The mean body weight was 47.5 g while the median and mean deviation were 33.5 g and 30.0 g respectively.

4.1.3.3. TILAPIA ZILLI

T. zilli showed a maximum total length of 19.6 cm and a minimum value of the same parameter of 7.1 cm giving a gange of 12.5 cm. The mean total length was 14.1 cm

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while the median and mean deviation were 14.4 cm and 2.9 cm respectively.

The maximum standard length of T. zilli was 15.5 cm and the smallest specimen measured 5.6 cm giving a range of 9.9 cm. The mean standard length was 11.0 cm while the median and the mean deviation were 11.2 cm and 2.4 cm respectively.

6.7 cm and 2.8 cm were the observed values for maximum and minimum body depths respectively, of T. zilli with a range of 3.9 cm. The mean body depth, median and mean deviation were 4.7 cm, 4.7 cm and 0.9 cm respectively.

The maximum and minimum body width of T. zilli observed were 3.4 cm and 1.9 cm respectively, giving a range of 1.5 cm. The mean body width was 2.4 cm while the median and mean deviation were 2.4 cm and 0.3 cm respectively.

The maximum body weight of T. zilli was 130.4 g and the smallest specimen weighed 10.6 g with a range of 119.8 g. The mean body weight was 57.2 g while the median and mean deviation were 53 g and 28.1 g respectively.

4.1.3.4. PHYSICAL PARAMETERS OF TILAPIA SPECIES

As shown in TABLE III and summarized in FIGURES 34 through 38 the mean values for the physical parameters of T. zilli had the greatest dimensions, generally speaking. The dimensions of T. galileae were greater than those of T. nilotica.

The mean values for fresh weight in this genus indicated that T. zilli was the heaviest (Fig. 34). This was followed by T. galileae which was followed by T. nilotica. T. zilli

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Table III. Physical parameters of 3 species of Tilapia

Measurements (Mean ± S.E.)	Tilapia galileae	Tilapia nilotica	Tilapia zilli
Fresh weight (g)	53.165 ± 3.565	47.526 ± 4.804	57.182 ± 5.665
T.L. (cm)	13.365 ± 0.341	13.495 ± 0.442	14. 1 ± 0.589
S.L. (cm)	10.235 ± 0.281	10.305 ± 0.381	10.982 ± 0.458
Body depth (cm)	4.902 ± 0.172	4.365 ± 0.168	4.671 ± 0.172
Body width (cm)	2.415 ± 0.091	2.471 ± 0.095	2.441 ± 0.067
Specimen (n)	55	85	51

was longer in total length (Fig. 35) and standard length (Fig. 36) than T. nilotica which was longer in both the parameters than T. galilene.

Mean body depth values (Fig. 37) showed that T. galilea was deeper than T. zilli which was in turn deeper than T. nilotica. The body width mean values (Fig. 38) for T. niloti a was greater than that of T. zilli, which was greater than that of T. galilene.

4.2. LENGTH - WEIGHT RELATIONSHIPS AND TAXONOMY

The relative growth of one fish compared to that of another can be measured by taking length-weight measurements. Regression coefficients (TABLES IV, V and VII) obtained by regressing length against length, length against weight and weight against length can be used to show differences between fish species. Differences between species can also be shown by the slopes of the plot of length against weight or vice versa (Fig. 39-47).

4.2.1. ALESTES SPECIES

4.2.1.1. TOTAL LENGTH VS STANDARD LENGTH

Fig. 39 shows the regression lines obtained when total lengths were plotted against standard lengths for members of the genus Alestes. The slopes of the lines were 1.327, 1.182, 1.275, 0.885, 1.414 and 1.141 respectively for A. baremose, A. brevis, A. macrolepidotus, A. leuciscus, Alestes "X" and A. nurse. Their coefficients of correlation, R, values were 0.878, 0.993, 0.990, 0.830, 0.850 and 0.899 respectively. All these correlations were

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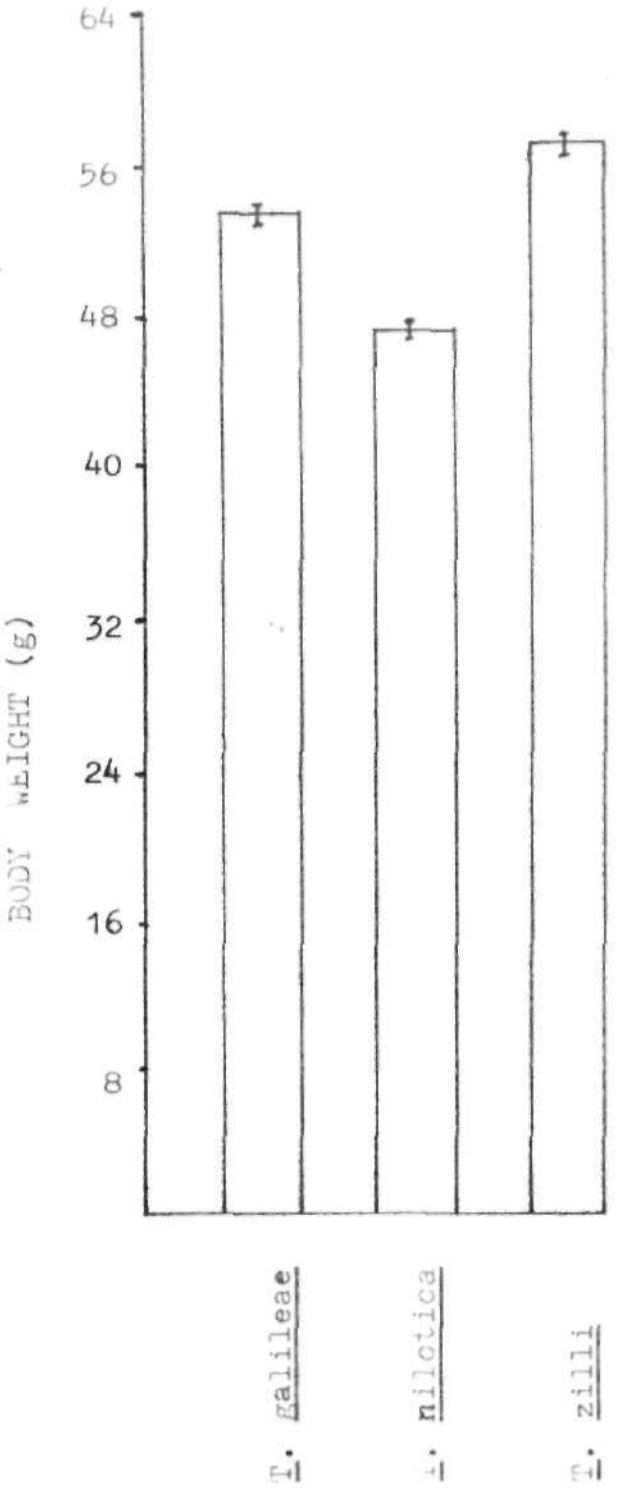

Fig. 34. Mean body weight in Tilapia species

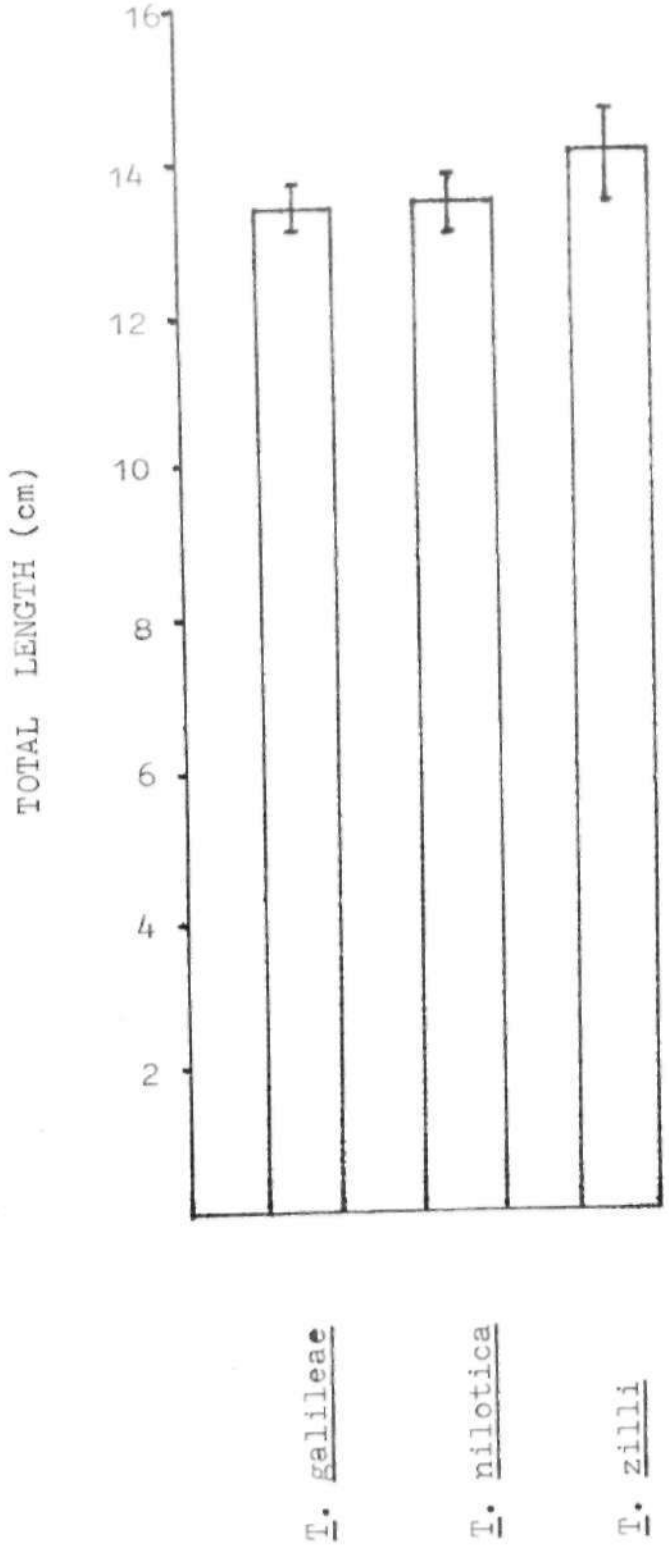

Fig. 35. Mean total length in Tilapia species ± S.E.

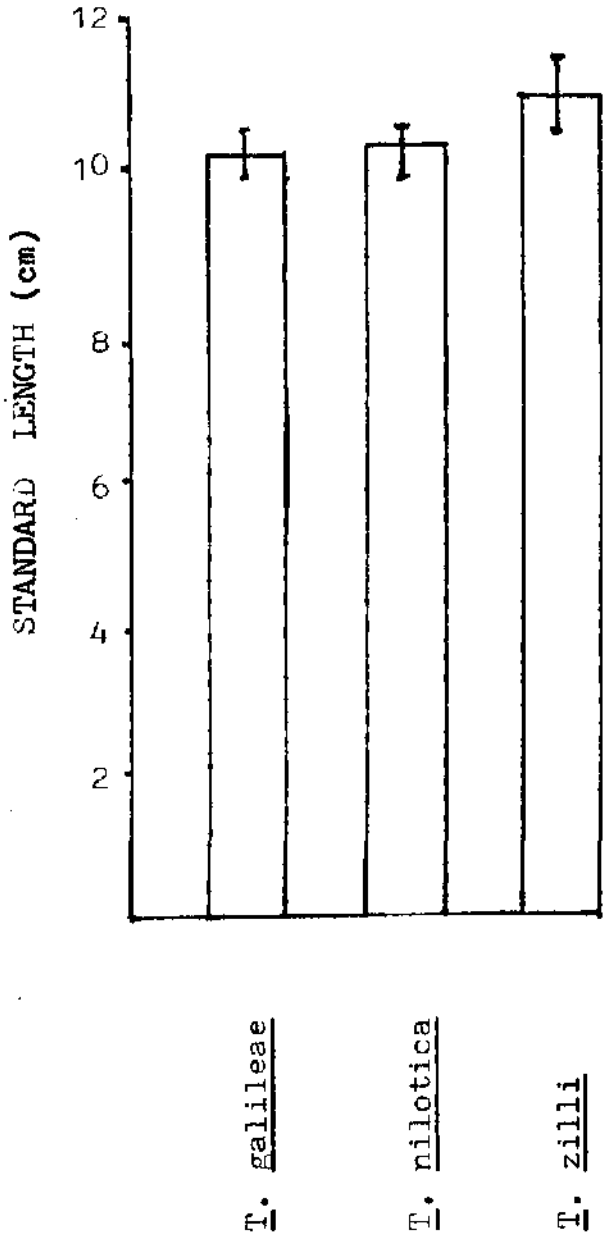

Fig. 36. Mean standard length in Tilapia species ± S.E.

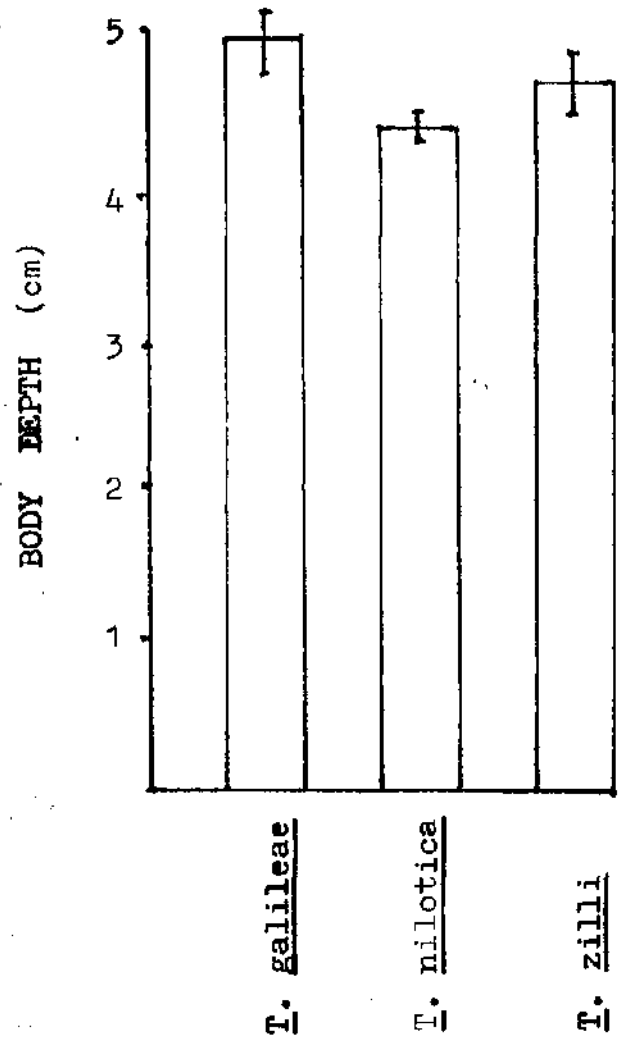

Fig. 37. Mean body depth in Tilapia species ± S.E.

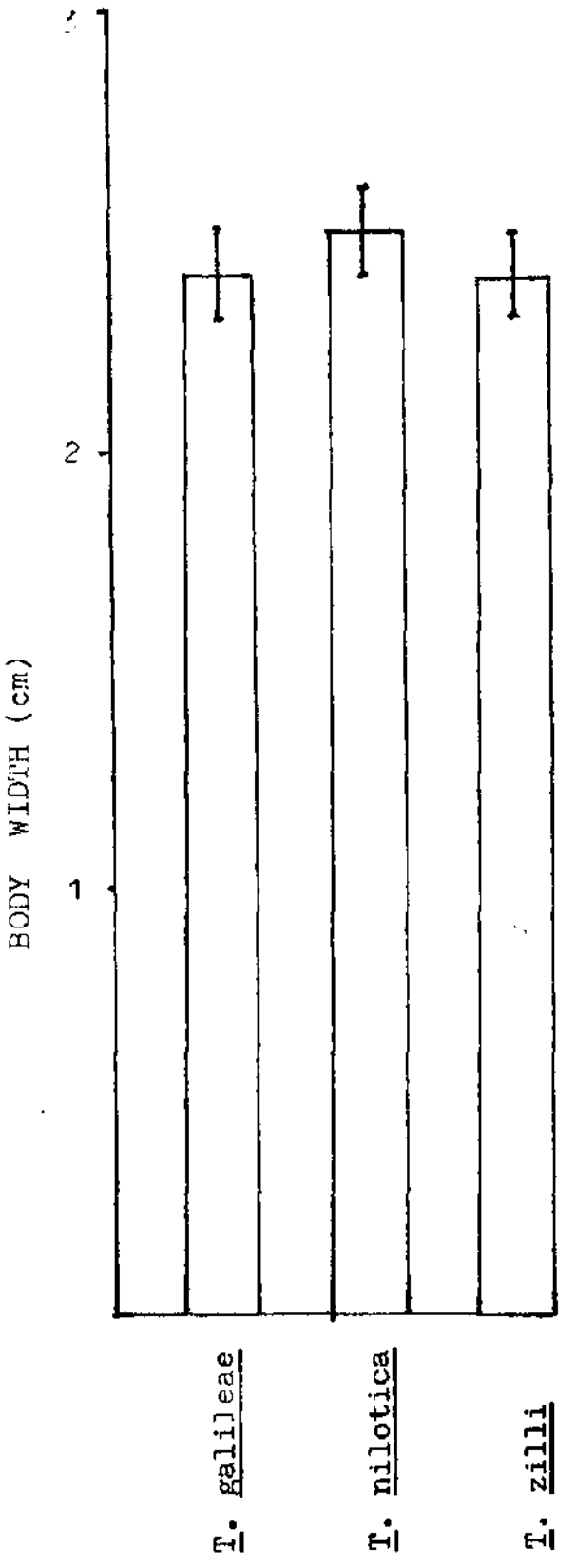

Fig. 38. Mean body width of Tilapia species ± S.E.

significant at $P < 0.001$ (TABLE IV).

4.2.1.2. STANDARD LENGTH VS BODY WEIGHT

The relationship between the standard lengths and body weights of Alestes species are shown in Fig. 40. The slopes of the lines were 5.824, 2.283, 0.153, 4.383, 3.75 and 5.392 respectively for A. baremose, A. brevis, A. macrolepidotus, A. leuciscus, Alestes "X" and A. nurse. Their R values were 0.920, 0.437, 0.139, 0.891, 0.886 and 0.916 respectively. There were no significant relationships between the standard length and body weight in A. macrolepidotus. The correlation in this species was not significant ($P > 0.05$). "R" was significant in the other species at $P < 0.001$ (TABLE IV).

4.2.1.3. BODY WEIGHT VS TOTAL LENGTH

Statistically significant relationships existed between the body weights and total lengths of members of the genus Alestes (Fig. 41). The slopes of the regression lines in descending order were 0.211 for A. leuciscus, 0.158 for A. nurse, 0.139 for Alestes "X", 0.122 for A. macrolepidotus, 0.105 for A. baremose and 0.077 for A. brevis. Their correlation coefficient values were 0.900, 0.985, 0.874, 0.173, 0.968 and 0.482 respectively. The correlation coefficient in A. macrolepidotus was not significant ($P > 0.05$). "R" was significant in the other species at $P < 0.001$ (TABLE IV)

4.2.2. SYNCDONTIS SPECIES

4.2.2.1. TOTAL LENGTH VS STANDARD LENGTH

The regression lines for the plots of total lengths against standard lengths for Syncdontis species are shown

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TABLE IV. REGRESSION EQUATION of 6 species of Alestes

Regression Equations	Significance R	P
Alestes baremose		
TL =-0.004 + (1.327 x SL)	0.878	< 0.001
SL = 4.852 + (5.824 x BW)	0.920	< 0.001
BW =-0.518 + (0.105 x TL)	0.900	< 0.001
Alestes brevis		
TL = 0.952 + (1.182 x SL)	0.993	< 0.001
SL = 9.368 + (2.283 x BW)	0.437	< 0.001
BW = 0.629 + (0.077 x TL)	0.482	< 0.001
Alestes macrolepidotus		
TL = 0.464 + (1.275 x SL)	0.990	< 0.001
SL =13.921 + (-0.153 x BW)	0.139	> 0.05
BW = 5.069 + (-0.122 x TL)	0.173	> 0.05
Alestes leuciscus		
TL = 3.078 + (0.885 x SL)	0.829	< 0.001
SL = 3.372 + (4.383 x BW)	0.891	< 0.001
BW =-1.081 + (0.211 x TL)	0.988	< 0.001
Alestes species		
TL =-0.918 + (1.413 x SL	0.850	< 0.001
SL = 3.533 + (3. 75 x BW)	0.886	< 0.001
BW =-0.323 + (0.139 x TL)	0.874	< 0.001
Alestes nurse		
TL = 1.060 + (1.141 x SL)	0.899	< 0.001
SL = 1.251 + (5.392 x BW)	0.916	< 0.001
BW =-0.352 + (0.158 x TL)	0.985	< 0.001

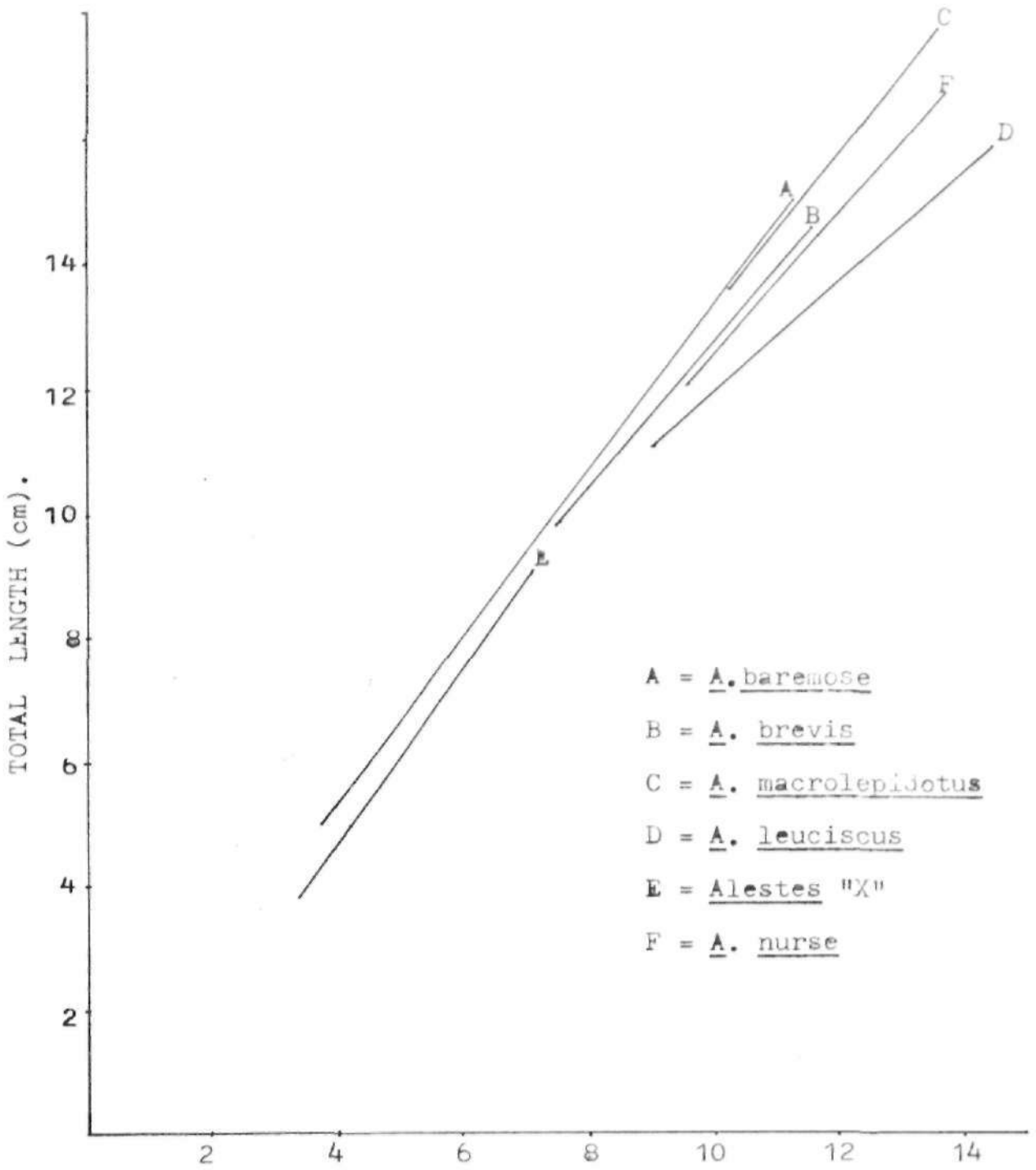

Fig. 39. Slopes for the relationships between total length and standard length for Alestes species.

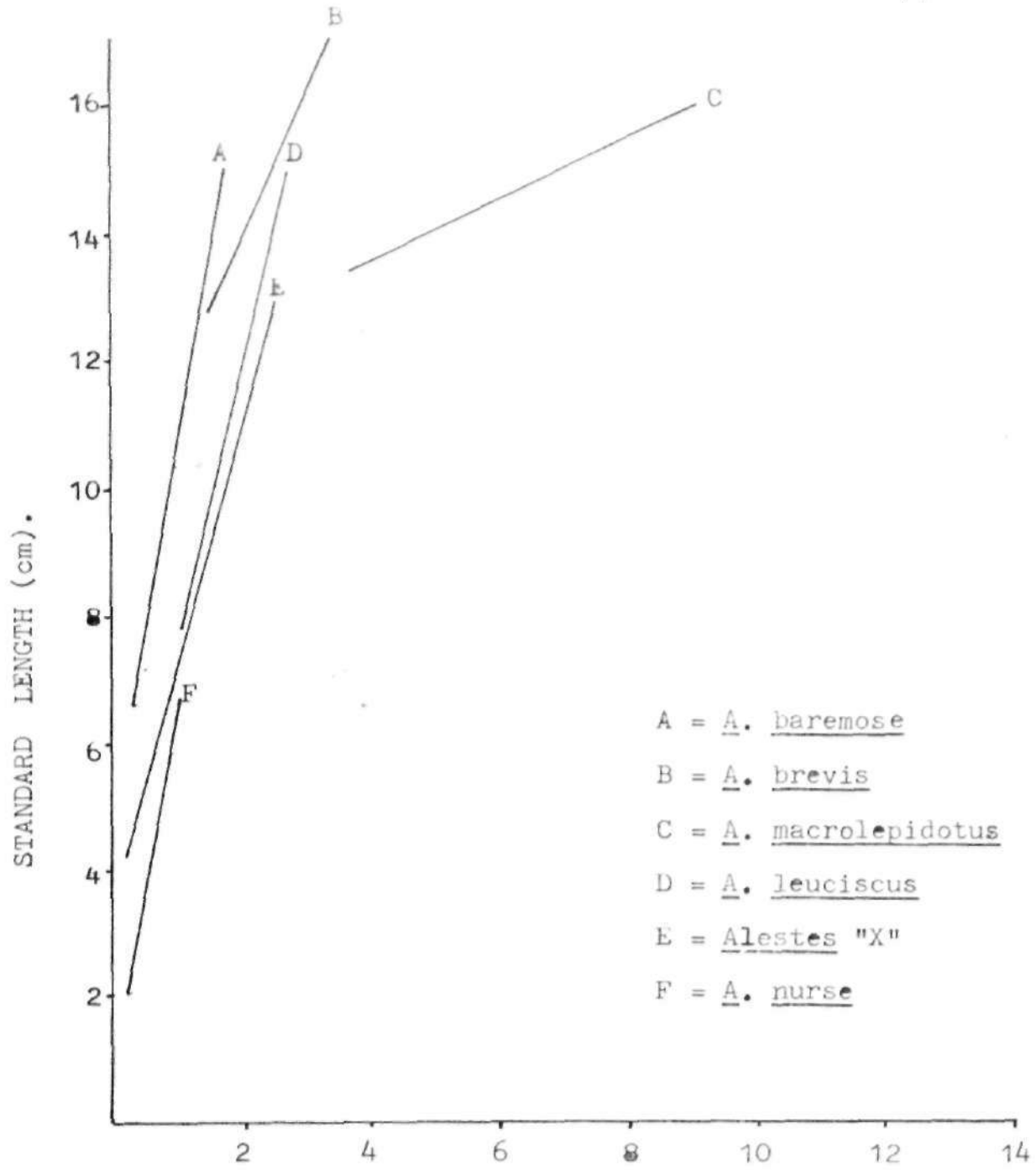

Fig. 40. Slopes for the relationships between standard length and body weight for Alestes species.

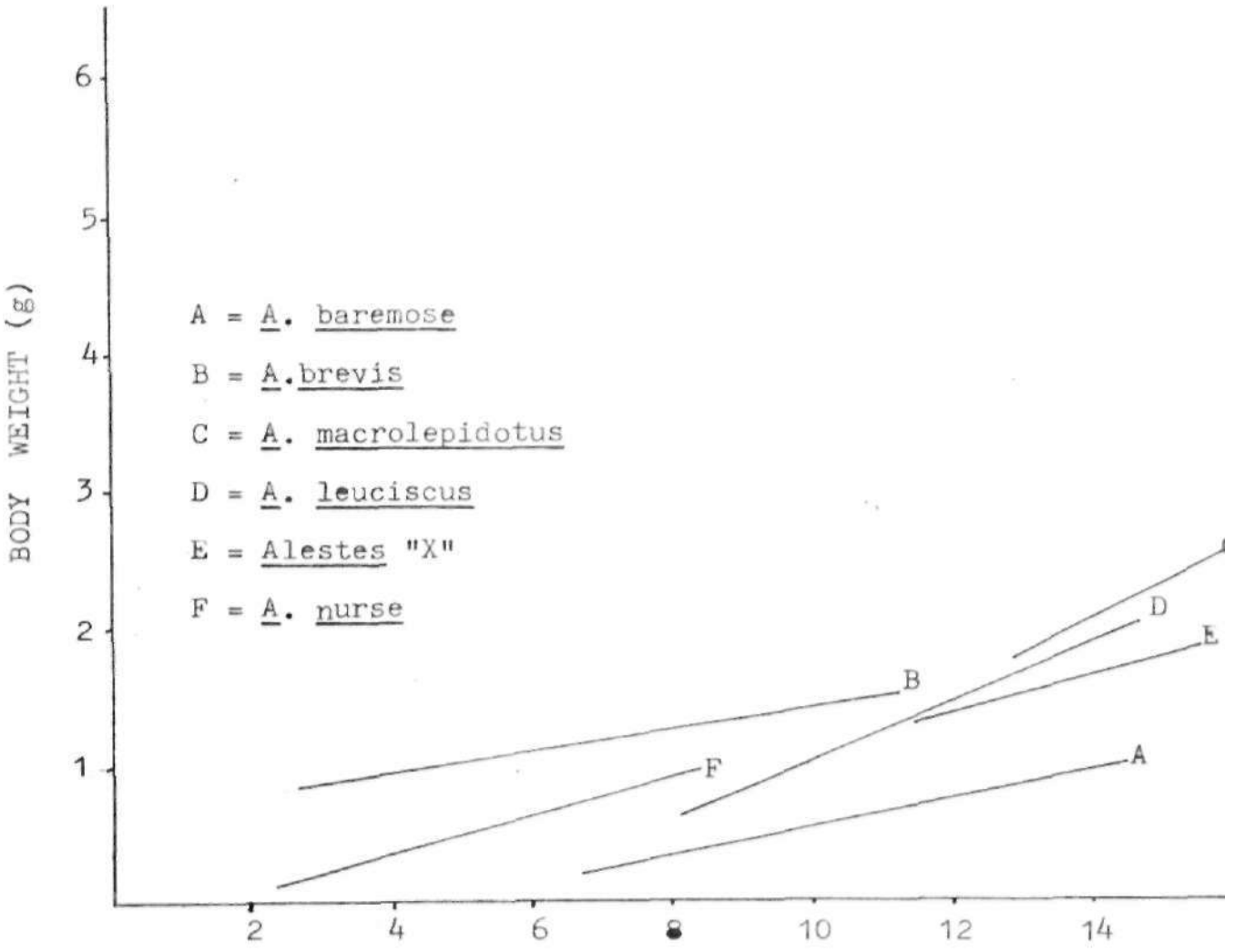

Fig. 41. Slopes for the relationships between body weight and total length in Alestes species.

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in Fig. 42. The slopes of the lines shown ascending order were 0.907 for S. eupterus, 1.078 for S. clarias, 1.259 for S. filamentosis, 1.41 for S. schall and 1.539 for S. batensoda. Their R values were 0.772, 0.994, 0.926 and 0.997 respectively. All the correlations were statistically significant ($P < 0.001$).

4.2.2.2. STANDARD LENGTH VS BODY WEIGHT. (FIG. 43)

The existence of statistically significant relationships was shown by the plot of standard length against body weight for Synodontis Species. The slopes of the lines were 4.074, 3.984, 5.824, 2.299 and 2.139 respectively for S. clarias, S. batensoda, S. filamentosis, S. eupterus and S. schall. Their "R" values were 0.636, 0.986, 0.993, 0.627 and 0.70 respectively. The correlations of standard length and body weight in S. clarias and S. eupterus were significant at $P < 0.003$. In the other species of Synodontis it was significant at $P < 0.001$ (TABLE V).

4.2.2.3. BODY WEIGHT VS TOTAL LENGTH

There were statistically significant relationships between the body weights and total length measurements in Synodontis species (Fig. 44). The slopes of the regression lines in ascending order were 0.088 for S. clarias, 0.133 for S. filamentosis, 0.158 for S. batensoda and 0.168 for both S. eupterus and S. schall. The correlation coefficient values were 0.785, 0.988, 0.989, 0.600 and 0.782 respectively. These correlations were significant at $P < 0.001$ except in S. eupterus where it was significant at $P < 0.004$.

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TABLE V. . REGRESSION EQUATION of Synodontis species.

Regression Equation	Significance R	P
Synodontis clarias		
TL = 4.443 + (1.078 x SL)	0.772	< 0.001
SL = 2.130 + (4.074 x BW)	0.636	< 0.003
BW = 0.987 + (0.088 x TL)	0.785	< 0.001
Synodontis batensoda		
TL =-2.441 + (1.539 x SL)	0.997	< 0.001
SL = 0.042 + (3.984 x BW)	0.986	< 0.001
BW = 0.453 + (0.158 x TL)	0.989	< 0.001
Synodontis filamentois		
TL = 0.696 + (1.259 x SL)	0.994	< 0.001
SL = 0.408 + (5.824 x BW)	0.993	< 0.001
BW =-0.116 + (0.133 x TL)	0.988	< 0.001
Synodontis eupterus		
TL = 3.717 + (0.907 x SL)	0.929	< 0.001
SL = 4.505 + (2.299 x BW)	0.627	< 0.005
BW = 0.238 + (0.168 x TL)	0.600	< 0.004
Synodontis schall		
TL =-0.127 + (1.410 x SL)	0.926	< 0.001
SL = 4.912 + (2.139 x BW)	0.701	< 0.001
BW = 0.256 + (0.168 x TL)	0.782	< 0.001

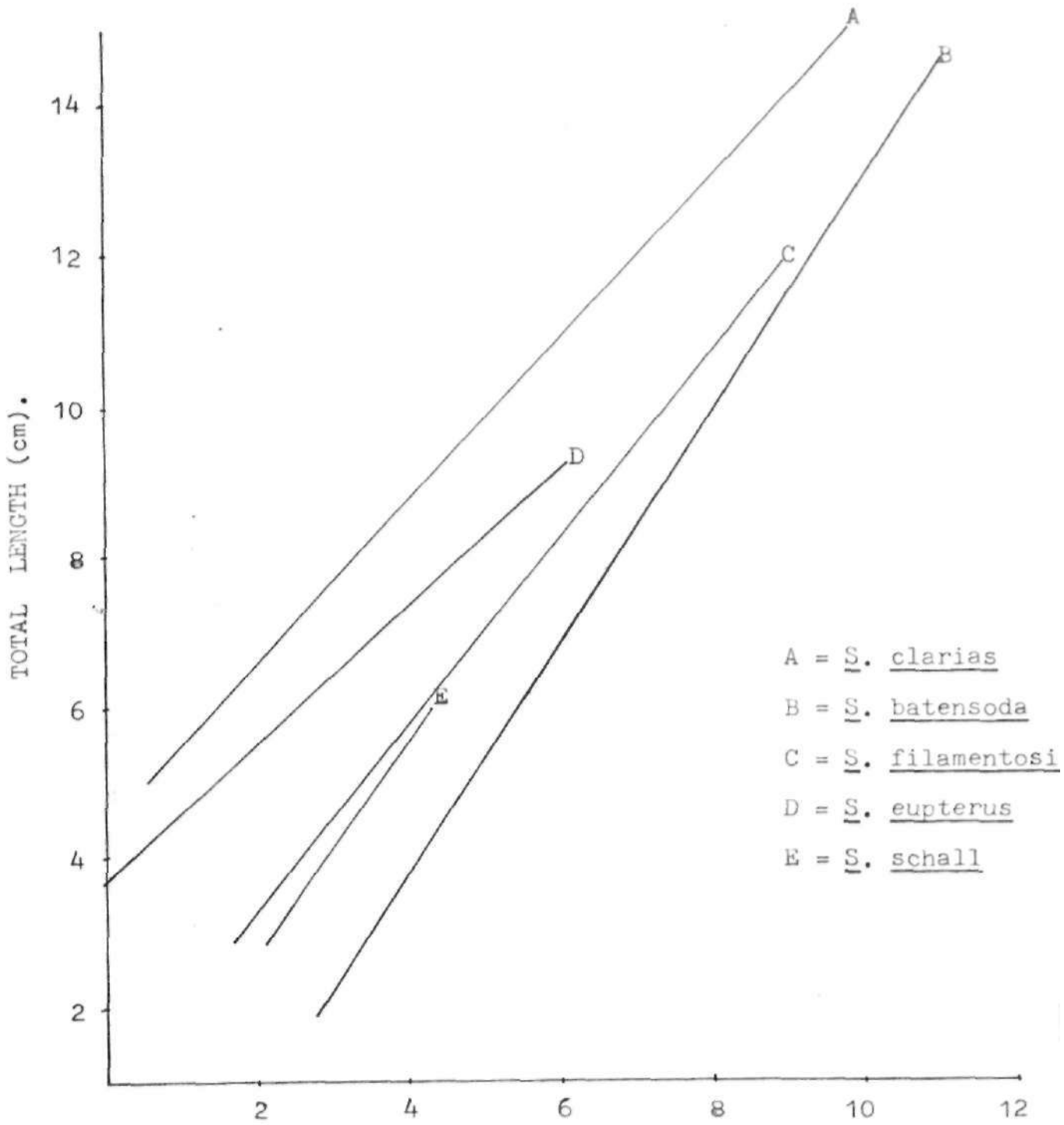

Fig. 42. Slopes for the relationships between total length and standard length in Synodontis species.

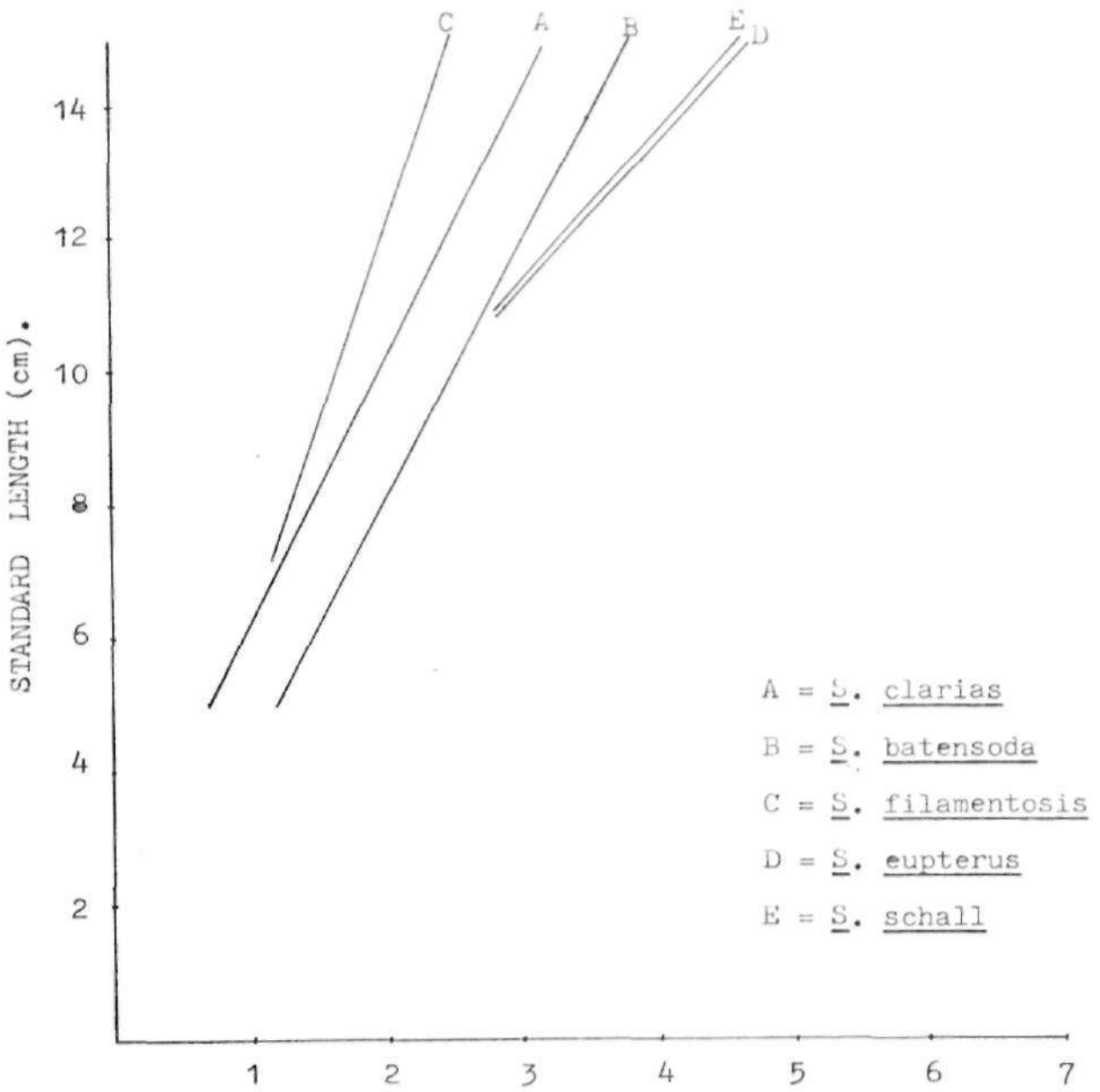

Fig. 43. Slopes for the relationships between standard length and body weight in Synodontis species.

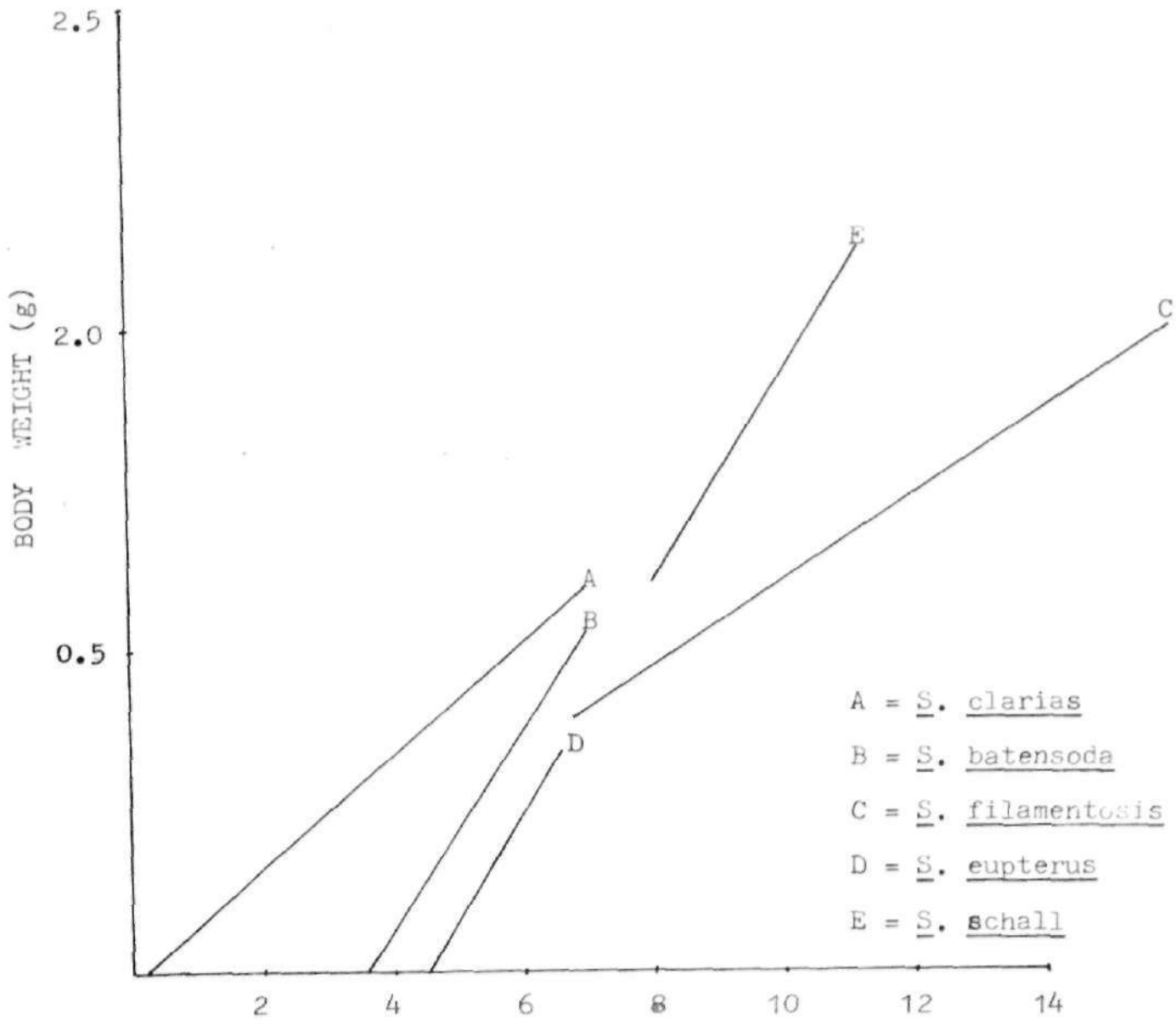

Fig. 44. Slopes for the relationships between body weight and total length in Synodontis species.

4.2.3. TILAPIA SPECIES

4.2.3.1. TOTAL LENGTH VS STANDARD LENGTH

Fig. 45 shows the regression lines for the plots of total length against standard length for Tilapia species. The slopes of the lines arranged in descending order were 1.257, 1.208 and 1.071 respectively for T. zilli, T. nilotica and T. galileae. Their R values were 0.998, 0.924 and 0.995 respectively. The correlations were significant at $P < 0.001$ (TABLE VI).

4.2.3.2. STANDARD LENGTH VS BODY WEIGHT

The regression lines for the plots of standard length against body weights for members of the genus are shown in Fig. 46. The slopes of the lines were 5.816 for T. zilli, 3.621 for T. nilotica and 2.532 for T. galileae. Their R values were 0.802, 0.901 and 0.816 respectively. The correlation in each case was statistically significant at $P < 0.001$.

4.2.3.3. BODY WEIGHT VS TOTAL LENGTH (Fig. 47).

Statistically significant relationships existed between the body weights and total length of Tilapia species. The slopes of the lines were 0.214, 0.205 and 0.089 respectively for T. galileae, T. nilotica and T. zilli. The correlation coefficient values were 0.807, 0.953 and 0.813 respectively. The R values were statistically significant ($P < 0.001$).

4.3. PHYSIOLOGICAL ROBUSTNESS AND TAXONOMY

The coefficient of condition or the condition factor K (Lager, 1972) measures the relative robustness of fish

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TABLE VI. . REGRESSION EQUATION of 3 species of Tilapia

Regression Equation	Significance R	P
Tilapia galilee		
TL = 1.007 + (1.208 x SL)	0.995	< 0.001
SL = 4.122 + (2.532 x BW)	0.816	< 0.001
BW =-0.447 + (0.214 x TL)	0.807	< 0.001
Tilapia nilotica		
TL = 2.454 + (1.071 x SL)	0.924	< 0.001
SL = 1.358 + (3.621 x BW)	0.901	< 0.001
BW =-0.292 + (0.205 x TL)	0.953	< 0.001
Tilapia zilli		
TL = 0.295 + (1.257 x SL)	0.998	< 0.001
SL =-3.215 + (5.816 x BW)	0.807	< 0.001
BW = 1.187 + (0.089 x TL)	0.813	< 0.001

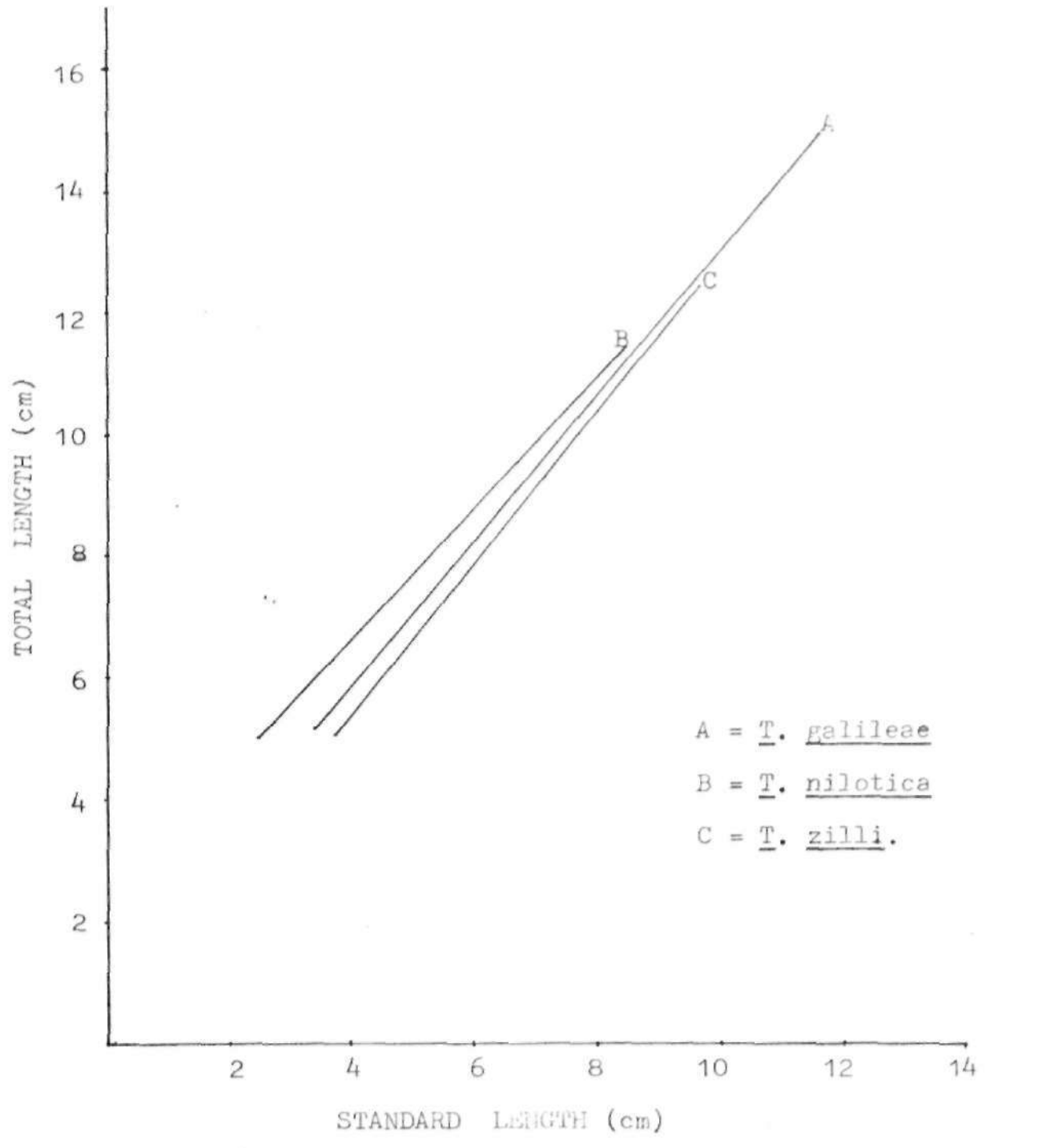

Fig. 45. Slopes for the relationships between total length and standard lenth for Tilapia species

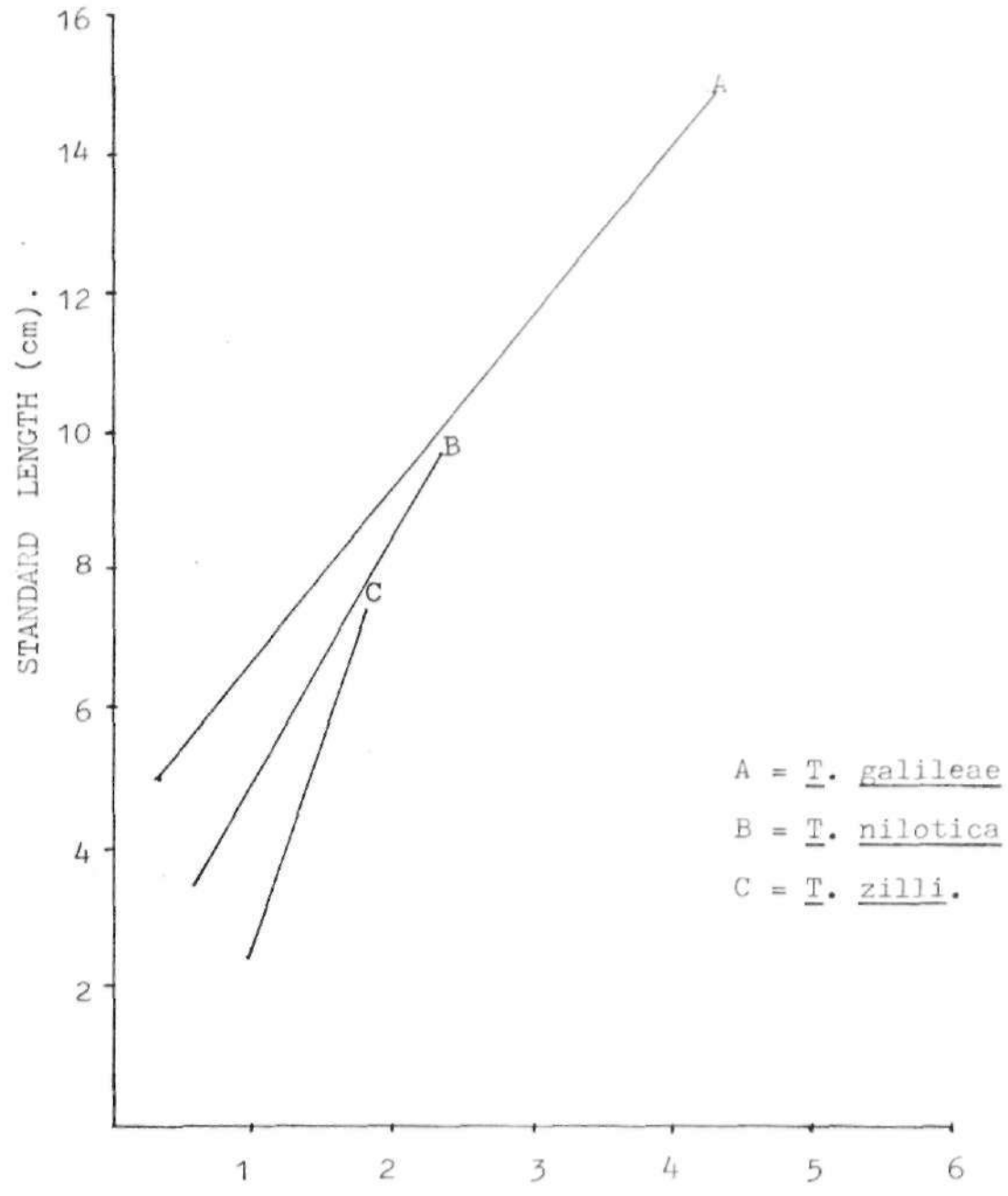

Fig. 46. Slopes for the relationships between standard length and body weight for Tilapia species

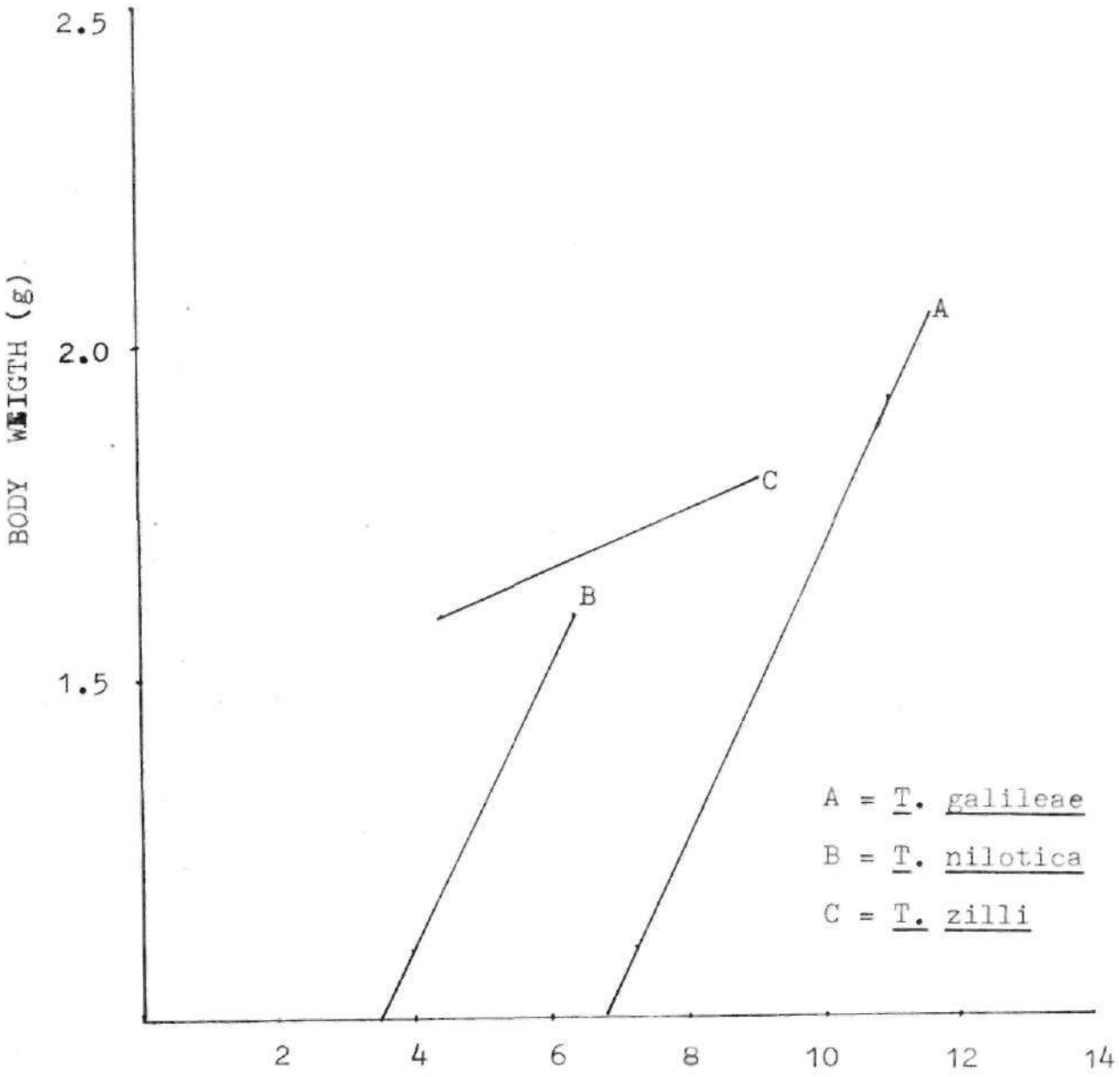

Fig. 47. Slopes for the relationships between body weight and total length for Tilapia spcies.

species. The values of K for the species studied were given in TABLES VII, VIII and IX and Appendix I.

Species means for K, the condition factor for Alestes species were 1.056, for A. baremose, 2.225 for A. brevis, 1.715 for A. macrolepidotus, 2.413 for A. leuciscus, 2.413 for Alestes "X" and 2.230 for A. nurse (TABLE VII).

For the Synodontis species the species means for K were; 2.507 for S. clarias, 3.565 for S. batensoda, 1.607 for S. filamentosis, 2.911 for S. eunterus and 3.341 for S. schall (TABLE VIII).

The species means for K for the Tilapia species were 4.186 for T. galileae, 3.342 for T. nilotica and 3.895 for T. zilli (TABLE IX).

The mean values of condition factor (K) for Alestes, Synodontis and Tilapia genera were 2.01, 2.80 and 3.80 respectively.

4.4. PHYSICAL PARAMETER SIMILARITY VALUES FOR ALESTES SPECIES, EXPRESSED AS POINTS

Points between 1 and 6 can be scored by a species in the genus Alestes. The species with the hgihest value of body weight, for example, scores 6 points, while that with the lowest value of the same parameter scores 1 point (TABLE X).

In the Synodontis species points between 1 and 5 were scored in the same manner as described above (TABLE XI): while in the Tilapia species the points scored were between 1 and 3 and scores were also made as described above (TABLE XII).

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Table VII. Condition factors for 6 Alestes species (K = Body weight (g) /S.L. $(cm)^3$).

K values					
Alestes baremose	Alestes brevis	Alestes Macrolepidotus	Alestes leuciscus	Alestes species	Alestes nurse
0.933	1.848	1.565	2.734	2.598	2.194
1.078	1.638	1.691	2.247	2.365	2.051
1.078	2.178	1.702	2.249	2.813	2.095
1.051	2.024	2.153	2.012	2.690	2.327
1.056	2.313	1.698	2.231	2.295	2.221
1.124	2.296	1.758	2.174	2.291	2.147
1.062	2.591	1.767	2.585	2.411	2.204
0.974	2.333	1.391	2.312	2.962	2.363
1.017	2.168	2.178	1.541	2.304	2.362
1.030	2.624	1.556	2.901	1.938	2.128
1.125	1.709	1.818	2.632	1.759	2.296
1.116	2.620	1.502	2.622	2.489	2.510
1.106	2.330	1.690	2.251	2.494	1.881
1.160	2.271	1.734	2.821	2.536	2.213
0.930	2.427	1.521	2.731	2.251	2.580
mean ± S.E.					
1.056±0.018	2.225±0.079	1.715±0.056	2.403±0.093	2.413±0.079	2.238±0.045

Table VIII. Condition factors (K) for 5 species of Synodontis

(K = Body weight (g) / S.L. $(cm)^3$)

K values				
Synodontis clarias	Synodontis batensoda	Synodontis filamentosis	Synodontis eupterus	Synodon schall
2.959	3.393	1.853	2.580	3.084
2.433	3.481	1.624	2.986	2.866
2.580	3.674	1.542	3.452	2.980
2.963	3.660	1.424	2.776	2.980
2.401	3.409	1.058	2.830	2.370
2.399	3.471	1.589	3.306	2.249
2.458	3.425	1.910	2.963	2.342
2.309	3.756	2.020	2.712	3.289
2.821	3.504	1.659	2.649	2.388
2.550	3.884	1.392	2.859	2.899
mean ± S.E.				
2.587±0.076	3.565±0.053	1.607±0.089	2.911±0.088	3.341±0.

TABLE IX Condition factors for 3 species of Tilapia

K values		
Tilapia galileae	Tilapia nilotica	Tilapia zilli
4.241	3.714	4.192
4.350	3.123	4.136
4.339	2.968	3.531
4.811	3.671	4.125
4.419	3.126	3.502
4.540	4.417	3.921
4.775	3.434	3.384
4. 594	4.182	3.416
4.746	3.422	4.024
4.416	3.245	2.714
3.827	3.701	3.629
4.817	3.822	3.721
4.144	3.378	3.320
4.040	3.000	3.200
3.762	3.323	3.975
4.673	2.979	6.036
4.542	2.309	5.638
4.140	2.170	4.140
3.931	3.040	3.692
4.252	3.446	3.542
4.218	3.539	3.681
4.087	3.058	3.479
4.460	4.361	3.817
4.208	2.609	3.668

TABLE X. Physical parameters similarity values for Alestes species expressed as points.

Physical Parameter	Alestes baremose	Alestes brevis	Alestes macrolepidotus	Alestes leuciscus	Alestes "X"	Alestes nurse
Body weight	2	6	5	3	1	4
T1	4	5	6	2	1	3
S1	4	6	5	2	1	3
BD	1	5	6	3	2	4
Bw	1	5	6	4	2	3
Slopes T1/S1	5	3	4	1	6	2
S1/Bw	6	2	1	4	3	5
Bw/T1	2	1	3	6	4	5
K	1	3	2	5	6	4
"R" T1/S1	3	6	5	1	2	4
S1/Bw	6	2	1	4	3	5
Bw/T1	6	2	1	4	3	5
TOTAL	41	46	45	39	34	47

1st Position 6 points
2nd " 5 "
3rd " 4 "
4th " 3 "
5th " 2 "
6th " 1 "

TABLE XI. Physical parameters similarity values for Synodontis species expressed as points.

Physical Parameters	S. clarias	S. batensoda	S. filamentosis	S. eupterus	S. ch
Body weight	5	4	1	2	3
Tl	5	2	3	1	4
Sl	5	2	4	1	3
BD	5	3	1	2	4
Bw	3	4	1	2	5
Slopes					
Tl/Sl	2	5	3	1	4
Sl/Bw	4	3	5	2	1
BwTTl	2	4	3	5	5
K	2	5	1	3	4
"R" Tl/Sl	1	5	4	3	2
Sl/Bw	2	4	5	1	3
Bw/Tl	3	5	4	1	2
TOTAL	39	46	35	24	40

1st	Position	5 points
2nd	"	4 "
3rd	"	3 "
4th	"	2 "
5th	"	1 "

TABLE XII. Physical parameter similarity values for Tilapia species expressed as points.

Physical Parameter	T. galilaea	T. nilotica	T. zilli
Body weight	2	1	3
Tl	1	2	3
Sl	1	2	3
BD	3	1	2
Bw	1	3	2
Slopes			
Tl/Sl	1	2	3
Sl/Bw	1	2	3
Bw/Tl	3	2	1
K	3	1	2
"R" Tl/Sl	2	1	3
Sl/Bw	2	3	1
Bw/Tl	1	3	2
TOTAL	21	23	28

1st Position 3 points
2nd " 2 "
3rd " 1 "

4.5. INTERPRETATION OF ELECTROPHORETIC PATTERNS

The electrophoretic patterns obtained showed some degree of similarities and differences between similar fractions from different species of the same or different families. In each comparison of fractions between two different species, protein patterns can be classed either as shared or not shared. A species may have a protein with the same electrophoretic mobility as that found in another species or it may not.

The study conducted produced sets of electrophoretic patterns of proteins from the lens nuclei as shown in Plate III through Plate X.

4.5.1. FAMILY CHARACIDAE ELECTROPHORETIC PATTERNS

Representative electrophoretic patterns of available members of this family are shown in Plates III and IV.

4.5.1.1. GENUS HYDROCYNUS PLATE III

Here the electrophoretic run was carried out in duplicate for each fish species.

Hydrocynus forskali (A) shows three closely spaced fractions, the first two heavily stained while the third was faintly stained. Next, there were two broad, moderately stained fractions. Five protein fractions were revealled.

Hydrocynus lineatus (B) reveals three closely spaced fractions, the first two heavily stained, while the third was faintly stained. Next to these were two lightly stained fractions followed by a moderately stained one. Farthest to the left were another two lightly stained fractions the

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last one broad. A total of eight bands were therefore observed.

Hydrocynus somoncrum pattern (C) consists of three closely spaced fractions, the first two heavily stained, while the third was very faintly stained. Next is another very faintly stained band followed by two broad moderately stained fractions. This species reveals a total of Six protein bands.

4.5.1.2. GENUS ALESTES. PLATE IV

A. baremose (A) reveals one lightly stained band followed by two heavily stained ones. Following these were five lightly stained fractions, the last one to the left being long. A total of 8 protein fractions were indicated in this species.

A. brevis (B) shows to the extreme right a lightly stained fraction followed by two heavily stained ones. Next to these were three moderately stained fractions which were followed by a broad heavily stained fraction. At the far left, a long lightly stained fraction can be seen. 8 protein bands were therefore indicated.

A. macrolepidotus pattern (C) consists of one lightly stained fraction which was followed by three heavily stained ones. Next there is a moderately stained fraction which is followed by a broad heavily stained band. Farthest to these, were two fractions, the last one faintly stained which disappeared to the far left. In A. macrolepidotus 8 protein fractions were revealled from its eye lens protein extract.

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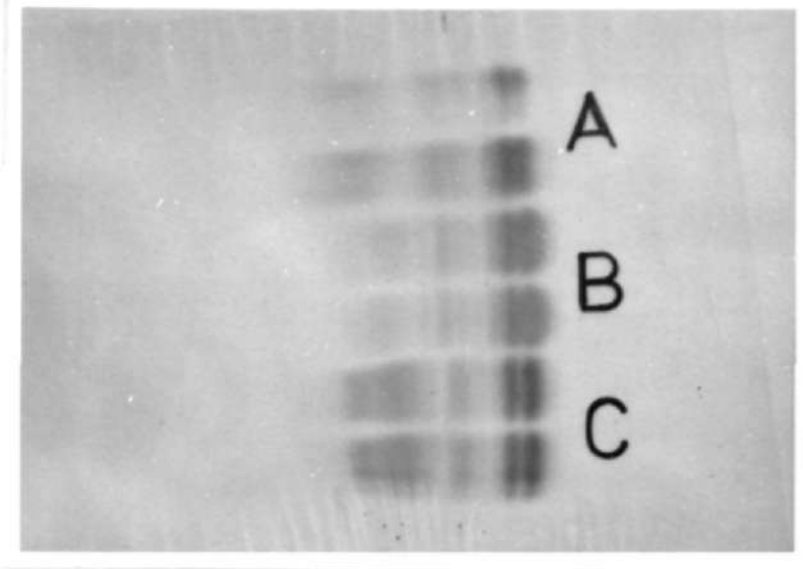

Plate III. Electrophoretic patterns of proteins from fish eye lenses nuclei. A = Hydrocynus forskali, B = H. lineatus, C = H. somonorum.

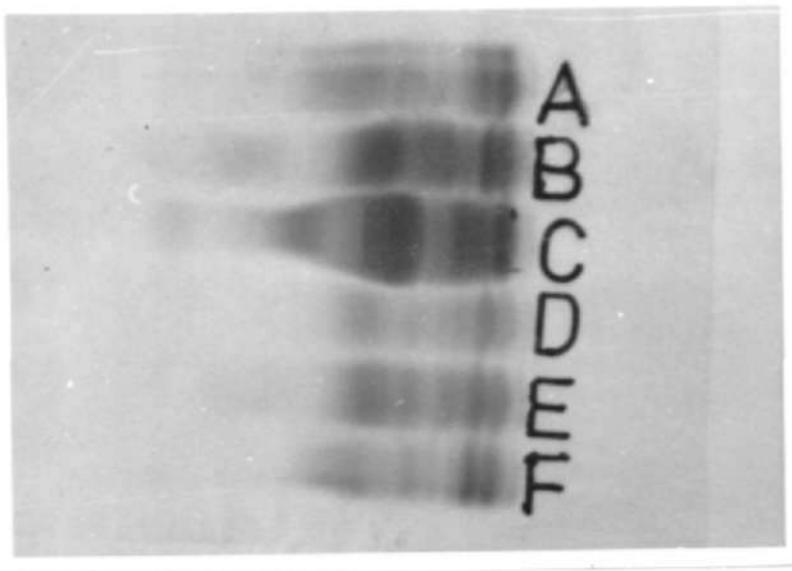

Plate IV. Electrophoretic patterns of proteins from fish eye lenses nuclei. A = Alestes baremose, B = A. brevis, C = A. macrolepidotus, D = A. leuciscus, E = A Alestes "X", F = A. nurse.

A. leuciscus (D) shows one lightly stained fraction and two moderately stained ones. Next there were four lightly stained fractions. A total of 7 bands were observed.

Alestes "X" (E) reveals one lightly stained fraction and five moderately stained others with the broadest at the far left. 6 protein fractions were indicated here.

A. nurse (F) shows one lightly stained fraction and two heavily stained ones at the far right. These were followed by four lightly stained fractions. The eye lens protein of this species appeared to be made up of 7 protein fractions.

4.5.2. FAMILY MORMYRIDAE ELECTROPHORETIC PATTERNS

Electrophoretic patterns of available members of this family are shown in Plate V and are described as follows.

4.5.2.1. GENUS SYNODONTIS PLATE V

S. schall (A) shows to the far right three heavily stained fractions and one to the left of these which was moderately stained. Next, there was a broad heavily stained fraction whose intensily and width reduces and desappeared to the far left. A total of 5 fractions were revealled here.

S. filamentosis (B) reveals two heavily stained fractions to the right and one lightly stained band. Next, was a light long band which desappeared to the far left. This species revealled 4 protein fractions.

S. eupterus (C) shows four well spaced moderately stained fractions followed by a very lightly stained long

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band that desappeared to the far left. 5 protein fractions were therefore revealled by S. eupterus.

S. clarias pattern (D) reveals three moderately stained fractions followed by a very light long band which desappeared to the far left.

S. batensoda (E) shows two well spaced moderately stained fractions. Next, there are two lightly stained fractions, the last one being long.

4.5.3. FAMILY CICHLIDAE ELECTROPHORETIC PATTERNS

Reprentative electrophoretic patterns of members of this family are shown in Plate VI and described below as follows.

4.5.3.1. GENUS HEMICHROMIS. PLATE VI

H. bimaculatus pattern (A) consists of three well spaced moderately stained fractions. Between the second and the third fractions is a very lightly stained fraction. Next, there are two lightly stained fractions followed by a broad and heavily stained fraction whose intensity reduces and disappears to the far left.

H. fasciatus (B) shows to the far right two heavily stained fractions the second being broad. Next to these is a faintly stained fraction followed by a broad moderately stained one. The fifth fraction is a very broad, heavily stained one whose intensity reduces and disappears to the far left.

4.5.3.2. GENUS TILAPIA. PLATE VI

T. galileae (C) reveals a heavily stained fraction

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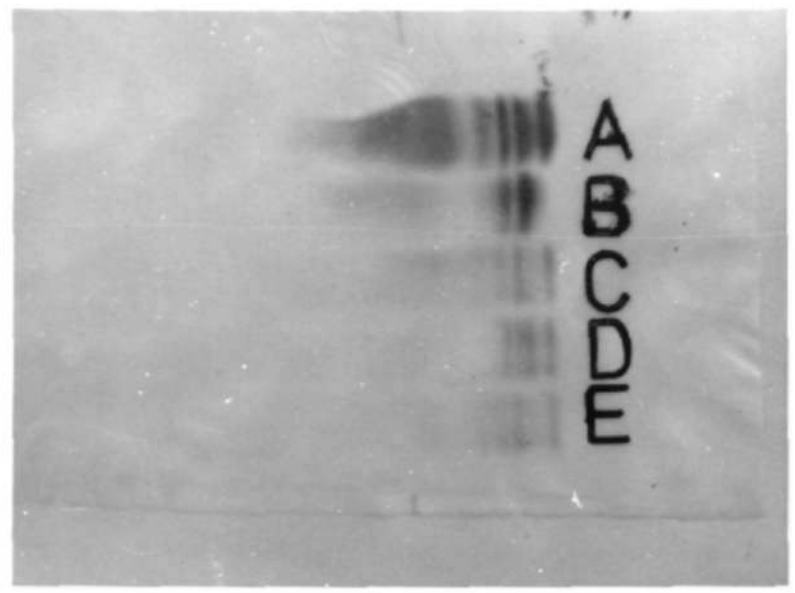

Plate V. Electrophoretic patterns of proteins from fish eye lenses nuclei: A = Synodontis schall, B = S. filamentosis, C = S. eupterus, D = S. clarias E = S. batensoda.

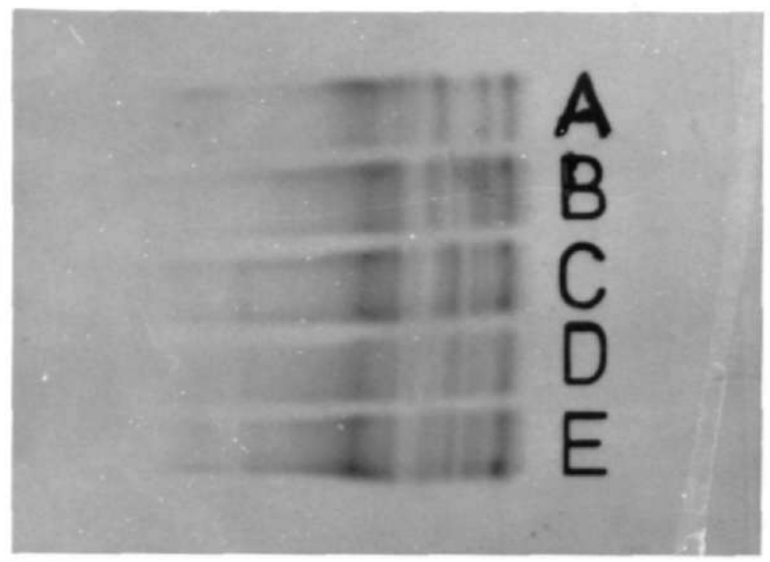

Plate VI. Electrophoretic patterns of proteins from fish eye lenses nuclei: A = Hemichromis bimaculatus, B = H. fasciatus. C = Tilapia galileae, D = T. nilotica E = T. zilli.

followed by one broad, moderately stained fraction. Next are another two bands that are close together - the first one to the right heavily stained while the second one to the left is lightly stained. This is followed by another faintly stained band. The remaining bands comprised of a very broad and heavily stained band followed by a very light band which disappears to the left.

T. nilotica (D) shows a heavily stained fraction followed by a moderately stained one which is broad. Next to these is another heavily stained fraction followed by two lightly stained ones. Farthest to the left is a broad heavily stained fraction followed by a faint one.

T. zilli reveals a heavily stained fraction followed by a broad moderately stained one. These are followed by another one, also moderately stained. Next, is yet another broad moderately stained band. Farthest to the left is a very broad heavily stained fraction, followed by another that is faintly stained at the far left.

4.5.4. SEXUAL DIMORPHISM AND SIZE DIFFERENCES INVESTIGATED BY ELECTROPHORESIS

Sex and size difference are investigated using the nuclear lens proteins. Representative electrophoretic patterns of members of the three families are shown in Plates VII, VIII and IX respectively.

4.5.4.1. GENUS ALESTES. PLATE VII

A. baremose (A) in all the four patterns reveals one lightly stained fraction followed by two closely spaced

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heavily stained ones. Next, there are five lightly stained fractions, the last to the left being long. Sexual dimorphism or size differences have not been shown by the electrophoretic patterns of the eye lens proteins from this species.

A. brevis pattern (B) reveals in all the four patterns, one lightly stained band followed by two heavily stained ones. Next, to these is a moderately stained fraction followed by two broad, heavily stained fractions. At the far left, a long lightly stained fraction was present. Sexual dimorphism or pattern differences as a result of size variations have not been observe.

A. macrolepidotus (C) shows in all the four patterns one lightly stained fraction. This was followed by three heavily stained ones. Next there is a moderately stained fraction which is followed by a broad heavily stained band. At the left hand side, there are two fractions, the last one faintly stained which disappears to the far left. Here also sex or size differences have not been observed from the patterns.

A. leuciscus (D) reveals one lightly stained fraction in all the four patterns. This is followed by two heavily stained fractions. Next, there are four moderately stained bands. Sex or size differences have not been shown.

Alestes "X" (E) shows one lightly stained fraction and five moderately stained others, with the broadest at the far left in all the four patterns. No differences have been observed in connection with sex or size.

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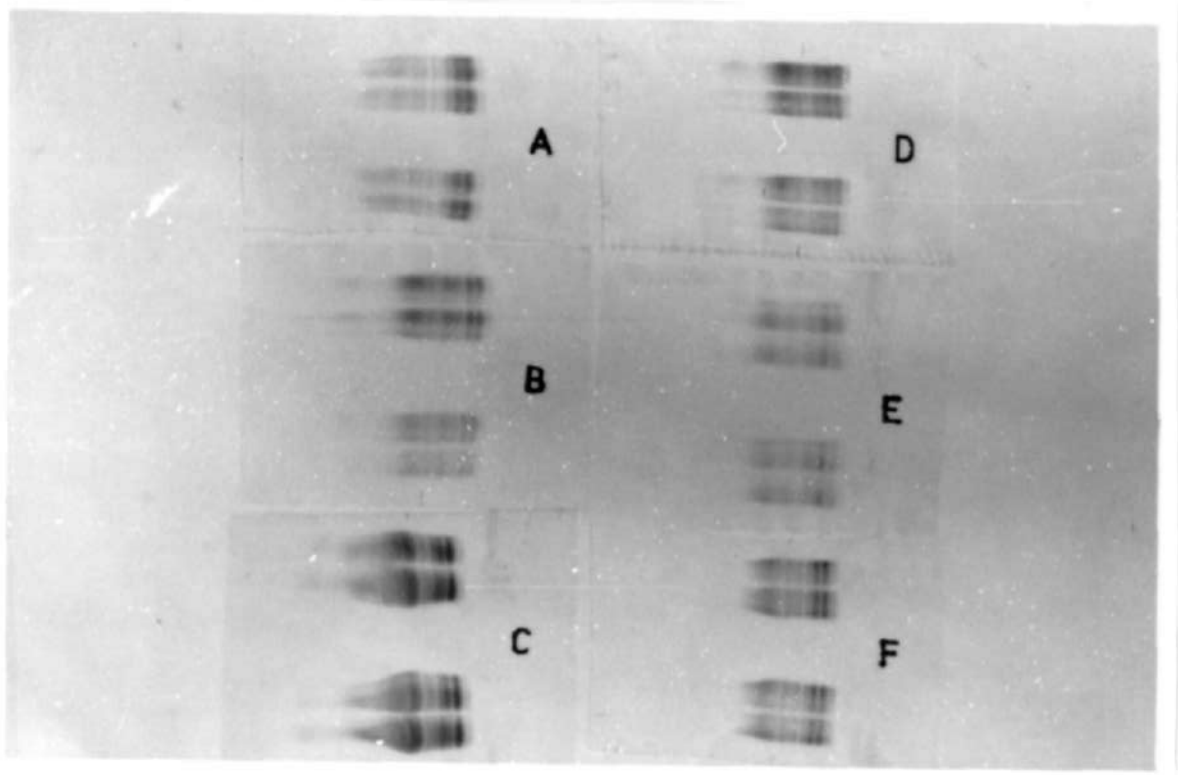

Plate VII. Electrophoretic patterns of proteins from fish lens nuclei. The upper and lower patterns of each of the first pairs are from a male and a female fish respectively; while the upper and lower patterns of each of the second pairs are from a small and a large fish respectively. A = Alestes baremose, B = A. brevis, C = A. macrolepidotus, D = A. leuciscus, E = Alestes "X", F = A. nurse.

A. nurse (F) shows in all the four patterns one lightly stained fraction and two heavily stained ones. These are followed by four lightly stained fractions. Differences in sex or size have not been shown in this case also.

4.5.4.2. GENUS SYNODONTIS. PLATE VIII

S. schall (A) reveals in all the four patterns three heavily stained fractions followed by a lightly stained one. Next, there is a broad heavily stained fraction whose intensity and width reduces and disappeared to the far left in all the four patterns. Here also sex and size differences have not been observed.

S. filamentosis (B) shows two heavily stained fractions and one lightly stained band in all the four patterns. Next, is a light long band which disappears to the far left. Eye lens protein patterns have not revealled sex or size differences in this species.

S. eupterus (C) reveals four well space moderately stained fractions followed by a very lightly stained long band that disappears at the far left in all the four patterns. Sex and size variations have not been observed.

S. clarias (D) shows four moderately stained fractions followed by a very light long band which disappears at the far left. This band arrangements was observed in all the four patterns. Variations in sex and size have not been shown.

S. batensoda (E) reveals two well spaced moderately stained fractions. Next, there are two lightly stained

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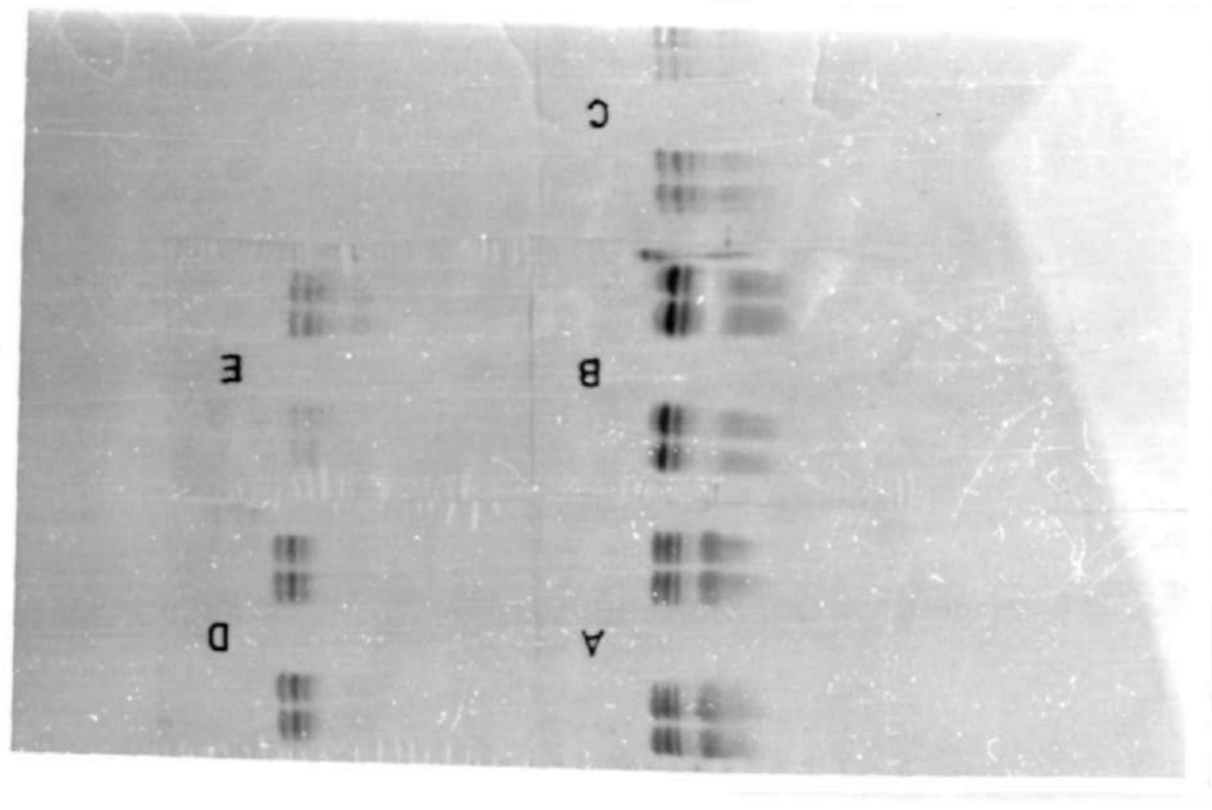

Plate VIII. Electrophoretic patterns of proteins from fish lens nuclei: The upper and lower patterns of each of the first pairs are from a male and a female fish respectively; while the upper and lower patterns of each of the second pairs are from a small and a large fish respectively. A = Synodontis schall, B = S. fillamentosis, C = S. eupterus, D = S. clarias, E = S. batensoda.

fractions, the last one being long. Sex and size variations have not been seen.

4.5.4.3. GENUS HEMICHROMIS. PLATE IX

H. bimaculatus (A) shows three fairly spaced fractions that are moderately stained in all the four patterns. Next there are two lightly stained fractions followed by a broad and heavily stained fraction whose intensity reduces and disappeared to the far left.

H. fasciatus (B) shows to the far right two heavily stained fractions. Next, to these is a faintly stained fraction followed by a broad moderately stained one. The last fraction to the left is broad and heavily stained. These observation were made in respect of all the four patterns.

4.5.4.4. GENUS TILAPIA. PLATE IX

T. galilene (C) reveals in all the four patterns e heavily stained fraction followed by two moderately stained ones. Next is another band that is very lightly stained. The remaining fractions comprise of a broad and heavily stained band followed by a very light one which disappears to the left. Sex and size variations were not indicated.

T. nilotica (D) shows a moderately stained fraction followed by five lightly stained ones. To the left of this is a broad heavily stained fraction. The results obtained here do not show sex or size differences.
T. zilli (E) reveals a heavily stained fraction followed by three moderately stained ones. These are followed by a broad heavily stained band which is followed by another

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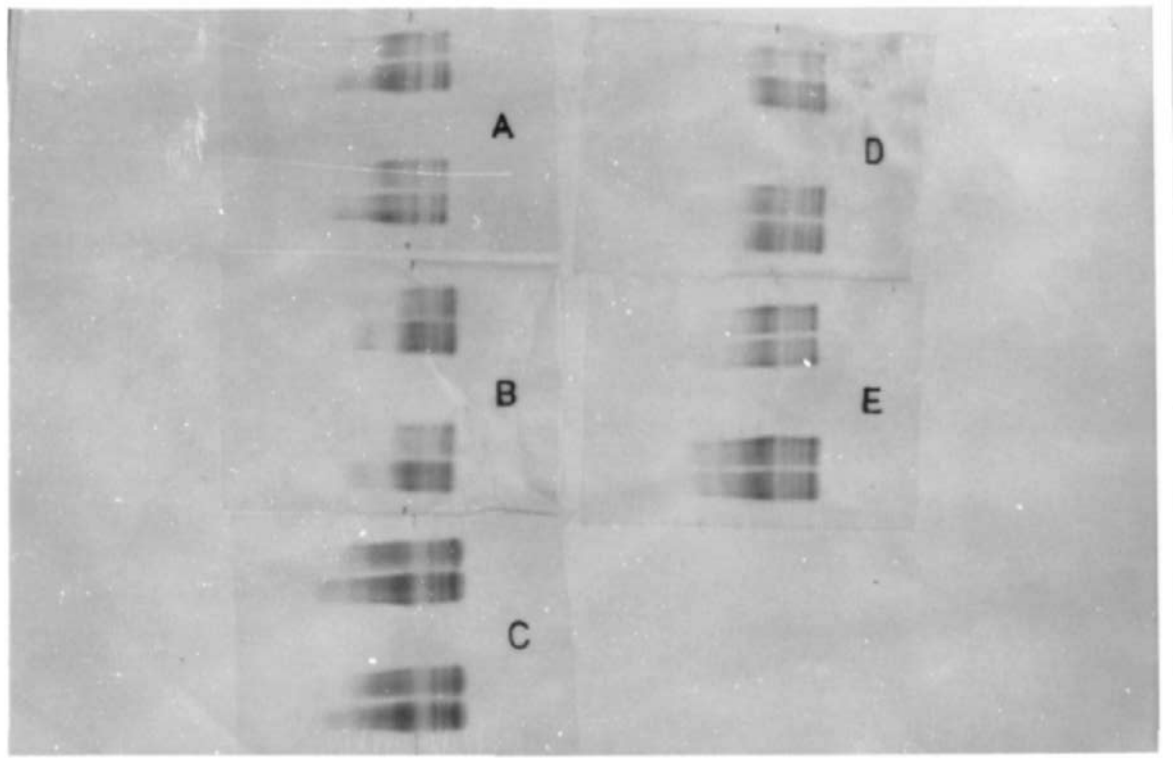

Plate IX. Electrophoretic patterns of proteins from lens nuclei: The upper and lower patterns of each of the first pairs are from a male and a female fish respectively; while the upper and lower patterns of each of the second pairs are from a small and a large fish respectively. A = Hemichromis bimaculatus B = H. fasciatus, C = Tilapia galileae, D = T. nilotica, E = T. zilli.

that is faintly stained. Differences in size have not been shown.

4.5.5. SPECIES PATTERNS FROM DIFFERENT FAMILIES USED TO INDICATE SIMILARITIES AND DIFFERENCES AT FAMILY LEVEL. PLATE X.

Alestes nurse (A) reveals one lightly stained fraction followed by two heavily stained ones. Following these, are four lightly stained fractions.

Synodontis schall (B) consists of three heavily stained fractions to the far right. These are followed by one to the left, which is moderately stained. Next there is a broad heavily stained fraction whose intensity and width reduces and disappeared to the far left.

Tilapia zilli (C) patterns show a heavily stained fraction followed by a broad moderately stained one. Next, there are two moderately stained fractions. Farthest to the left is a very broad heavily stained fraction followed by another that is faintly stained.

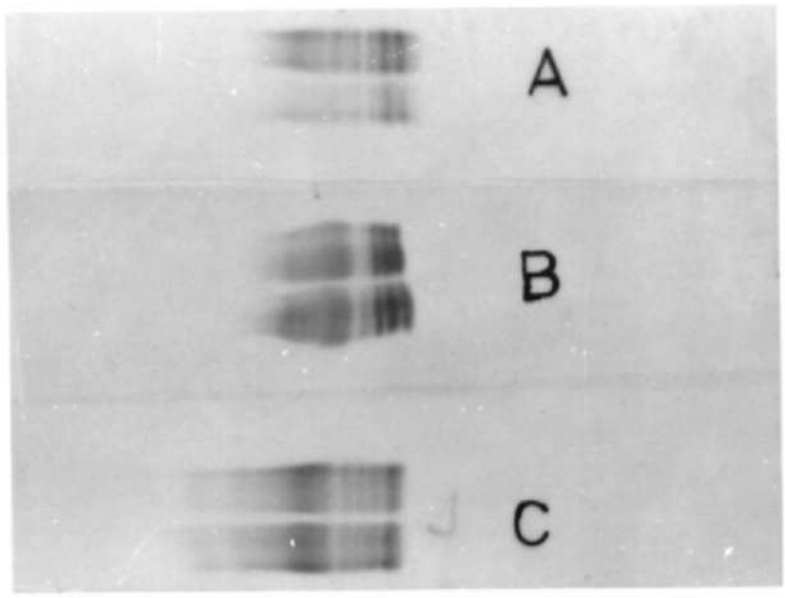

Plate X. Electrophoretic patterns of proteins from fish lens nuclei. Similarities and differences between members of the families Characidae (A = A. nurse) Mochokidae (B = S. schall) and Cichlidae (C = T. zilli).

CHAPTER FIVE

5. DISCUSSION

Physical parameters and eye lens proteins electrophoretic patterns are important sources of freshwater fish taxonomic information. The physical parameters include body weight, total length, standard length, body depth (Legler et al, 1977) and body width. The mean values for these parameters are species specific. Also species specific are the slopes and correlation coefficient, "R" values obtained from plots and regression of length against weight. The condition factor which is a measure of physiological robustness (Oni et al, 1983) of fish species shows differences between species.

The electrophoretic patterns of nuclear lens proteins from the many fish species studied are of high quality and reproducibility and they show distinct variations in number of fractions and in the fractional mobility, staining intensity, width and resolution of ractions. Because of these important properties, the eye lens protein patterns are of great value as sources of freshwater fish taxonomic information.

5.1. PHYSICAL PARAMETERS

Species means for length and weight are important in understanding the similarities and differences that exist between animals, particularly the fishes. Reed (1967) and Holden and Reed (1978) used means of length and weight as tools in the identification of local fish species.

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The means were used by the two authors to show some differences between species of the same genus. In this study,means of lengths and weight were used in the same manner. From all the observations made hardly were there any two species that showed the same mean values for a particular physical parameter. This therefore is a clear indication of the potential value of these parameters in fish taxonomy.

The ease with which these measurements are usually taken has put physical parameter values into use in many areas of research. These include fisheries biology and fish physiology (Cni et al, 1983).

The mean values of the parameters for Alestes, Synodontis and Tilapia species clearly indicate species variations. These values are therefore useful as sources of fish taxonomic information, although a number of limitations can militate against such use.

Such limitations include the many ways by which a fish's weight can change. changes in weight can occur as a result of seasonal changes, time of the year, and even time of day (Lagler, 1972). Sex and age of a fish can also account for weight differences. In Tilapia species, the male is always bigger than the female of the same age (Reed, 1967).

The length of a fish can also vary because of a variety of reasons. These include seasonal variations, geographical location, availability of diet, physiological condition, sex, and age of the fish.

Care must then be taken in the area of fish collection

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because of the above reasons. Collection should be done in the same season of fishes of the same species and if possible, of fishes of the same sex and age (Lagler, 1972). Inspite of these limitations weight data can effectively be used in species differentiation provided the fish species are collected in the same season and in the same locality (Lagler, 1972).

5.2. LENGTH-WEIGHT RELATIONSHIPS AND TAXONOMY

The relative growth of one fish can be compared to that of another by taking length-weight measurements. The relationships between length and weight are important in understanding the growth rates of animals, particularly the fishes (Cni, et al, 1983). The importance of determining the relationships between the body weight and body length of fishes was first summarized by Lagler (1972).
Cni et al (1983) pointed out that from the regression equations obtained from length-weight relationships it is possible to estimate weight from known length of fish and vice versa.

In this study slopes of regression lines and correlation coefficient "R", values were used in fish species differentiation. Differences between species can be observed in the differences between the slopes and the differences between the "R" values. Slopes and "R" values can be affected by all the limitations found in weight and length measurements. Nevertheless, these values appear to be good sources of fish taxonomic information because no two fish species show the same values.

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values were finally added up for each species (See TABLES X, XI, and XII). The fish with the highest total similarity value is then placed first in the taxonomic order. This arrangement is in agreement with that of Reed (1967) and Holden and Reed (1978); the only difference being that Reed (1967) arranged members of the genus Alestes in ascending order with the smallest species coming first while the biggest came last.

The total physical parameter values indicated in this study that A. nurse comes first while A. brevis and A. macrolepidotus come second and third respectively (TABLE X) in the taxonomic order. But in mean length and mean weight values A. brevis and A. macrolepidotus follow each other closely being the longest and heaviest, while A. nurse follow next. They also resemble each other closely in morphological appearance. Being the largest of the Alestes species, Holden and Reed (1978) put them first and second respectively while Reed(1967) placed them in the last positions for his arrangement was in ascending order for the Alestes species. The arrangement by Holden and Reed (1978) should be retained but A. nurse should occupy the third position after A. brevis and A. macrolepidotus. It would then be followed by A. baremose. A. leuciscus would then occupy the fifth position while Alestes "X" comes last in the taxonomic order of species examined in this study.

Reed (1967) and Holden and Reed (1978) agreed completely with each other in the arrangement of the Synodontis ~~species~~ they reported. In Holden and Reed (1978) S. schall was

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not included. The results obtained in this study agreed with those obtained by Reed (1967) and Holden and Reed (1970), the only difference being S. schall taking the place of S. clarias which moves to the third position while S. eupterus moves to the fifth position.

The taxonomic arrangement of the three available members of the genus Tilapia by Reed (1967) completely agreed with the physical parameter similarity values expressed as points in this study. In both cases T. zilli comes first which was followed by T. nilotica with T. galileae coming last.

5.5. EYE LENS PROTEINS

Variation in the protein composition of the eye lens nucleus in the fish species studied is consistent with findings in other species. Examples include Pacific albacore (Thunnus germon) (Smith, 1962); Ocean whitefish (Smith and Goldstein, 1967); mackere scad (Smith, 1969c) and three species of tuna (Smith, 1982).

In the aforementioned studies, interspecific variations in electrophoretic patterns were due to the nuclear lens proteins which migrated short distances (Smith, 1969c). This observation was also made in this study where the pattern variations were due to the proteins closest to the point of sample application. Nuclear lens protein patterns vary interspecifically in width, concentration, location and resolution.

The possibility that denaturation rather than genotype, accounts for this variability seems unlikely because nuclear lens proteins strongly resist breakdown (Smith, 1965).

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Since in the live animal the lens is an inert structure (Heyningen, 1962; Manski et al, 1964), even death would not directly cause changes in its proteins. Furthermore, denatured lens proteins produce electrophoretic patterns in which the lesser migrating fractions are more mobile, even to the extent of fusing with the farthest-migrating fraction so that only one band is observed (Sibley and Brush, 1967).

In this study, lenses were frozen at once after collection and where power failure persisted, lenses were discarded. With the poor performance of N.E.P.A. in those days, many valuable samples were lost. But samples were usually used as soon as possible when they were collected so that pattern variations due to denaturation would not be expected.

Proteins from two individuals of the same species revealed a high degree of similarity (Smith, 1969b). This great similarity between patterns of proteins from lenses of the members of the same species is a convincing indicator of the capability of the electrophoretic system to produce highly similar results where they are most expected. Having established the very low level of intra-specific variation the results were compared with current classification, and the latter used as a test against which to gauge the reliability of the former.

The eye lens protein electrophoretic results presented here have a high degree of congruence with published classifications. Closely related species have similar nuclear lens protein patterns and distantly related ones do not,

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The closeness of the relationship between species appears to be highly correlated with the nuclear lens protein electrophoretic similarity particularly below the family level.

5.5.1. SEX AND SIZE DIFFERENCES

There is little information in the literature about fish size in relation to lens protein polymorphism. A few authors (Tsuyuki et al, 1968; Eckroat and Wright, 1969; Eckroat, 1971, Saunders and Mckenzie, 1971; Blake, 1976) noted no such relationship. This is in agreement with the results obtained in this study. Other authors (Barrett and Williams, 1967; Haen and O'Rourke, 1969; Petterson and Shehadeh, 1971; Benz, 1980; Leenen and de Jong, 1981) reported the existence of such a relationship. In some of the studies, electrophoretic patterns of some lens proteins from different individuals of the same species arranged in order of size show irregular, and sometimes abrupt differences. Such variations, if considered to reflect a developmental pattern within a single fish with growth, would represent an unusual form of post-synthetic protein modification. This modification as thought to occur in the lens (Harding, 1976; Bloemendal, 1977; Banroques et al, 1978; Ohrloff et al, 1980; Zigler et al,1981) is expected to produce smooth and continuous changes (Harding, 1973, 1976) not irregular and sometimes abrupt ones. These non-graded protein variation may have other, non-developmental causes, for example, (1) inclusion in the fish series of one or more individuals from a different population(s) or (2) technical manipulation that produce this

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type of variation as an artifact.

Smith and Gilman (1982) working on a number of fish species showed that majority of the fishes they used showed some degree of protein polymorphism between small and large individuals of the same species. They made the observation that polymorphism involves some proteins to varying degrees in certain species and is absent in other species.

No information was found about fish sexual dimorphism in relation to lens protein polymorphism in the literature. In this study sexual differences in relation to this protein was not observed.

The fact that electrophoretic patterns of the eye lens protein from a small and a large fish and from a male and a female fish of the same species do not show protein polymorphism opens a clear way for the use of this proteins as sources of fresh water fish taxonomic information. One can take any size or sex of the same fish species, carry out electrophoretic studies on the eye lens protein and utilize the protein pattern in a taxonomic study without the fear of sex or size interference.

The results obtained from the lens nuclear protein electrophoretic patterns have indicated that the eye lens protein has great potential as a source of taxonomic information.

Although the electrophoretic and physical parameter data are presented here in isolation, an exercise which might be quite valid under some circumstances, it might be more suitable to integrate the electrophoretic and physical

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parameter evidences with that from other characters in any investigation of specific taxonomic problems.

5.6 PHYSICAL PARAMETERS VS ELECTROPHORESIS

When results obtained from physical parameters were compared with those obtained from electrophoresis, it would be observed that the electrophoretic results would be more reliable. This is because there are many factors that can bring about changes in weight and lengths in fishes (Lagler, 1972). These changes therefore make physical parameter values unreliable. On the other hand the electrophoretic results are observed not to be influenced by sex or size variation.

The lens nucleus in the live animal is an inert structure, so that death would not directly cause changes in the proteins of the nucleus and in addition the nuclear lens proteins are highly resistant to denaturation. The electrophoretic patterns of the lens proteins would not produce the observed pattern changes had it been that the proteins were denatured; neither are the pattern variations caused by technique, as the uniformity of many patterns demonstrates the reliability of the procedure, and the genetic basis of the patterns.

5.7. PROBLEMS AND AREAS OF FURTHER INVESTIGATIONS

The protein extraction method employed in this study takes a long time to accomplish and depends very much on cooling the system to a temperature of about $8^{o}C$. The use of another buffer solution for extraction may reduce

the length of time for the extraction.

The resolution of fractions may be improved by using another stain instead of ponceau S stain. Further investigations could be carried out using another buffer system and another stain to see if more protein fraction bands can be visible.

6. SUMMARY AND CONCLUSION

The potentials of physical parameters and eye lens proteins were investigated as tools in fish taxonomy.

The mean values of length and weight are species specific and so could be used as tools in fish taxonomic information.

Slopes of regression lines and the correlation coefficient values got from regressing length against length, length against weight and weight against length are also species specific.

The condition factor which is a measure of the physiological robustness of fishes shows variations in its values in different fish species.

Fish taxonomic orders could be rearranged by the help of physical parameter similarity values which were expressed as points.

Fish length and weight can be affected by many factors and as such care must be taken in area of fish collection.

Electrophoretic separation of proteins from the lens nucleus effectively identifies molecular differences which reflect genetic variation among the different species of fishes.

This method in comparison with those utilizing blood proteins, muscle proteins, enzymes, etc, avoids oversensivity and is less complex.

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