STUDIES OF THE ECOLOGY OF THE BLACKBASS, *MICROPTERUS SALMOIDES* (LACÉPÈDE) (PISCES:CENTRARCHIDAE) IN LAKE NAIVASHA, KENYA.

BY

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DECLARATION

I, PENINAH AKEYO ALOO, declare that the work presented in this thesis is the result of my own investigations and has neither been accepted nor is being submitted for any other degree.

Signature Aloo

Date 15|4|88

I, PROFESSOR STEPHEN DADZIE, declare that this thesis has been submitted for examination with my approval as University supervisor.

Signature

Date 15 - 4 - 88

DEDICATION.

To my parents, Mr. G. and Mrs. M. Aloo

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A B S T R A C T

The relative abundance, distribution, feeding ecology and the reproductive biology of the blackbass, Micropterus salmoides (Lacépède) in Lake Naivasha are described. Blackbass population is low as compared to that of the tilapiines in the lake. Depth is the major parameter affecting the distribution of the species, the numbers decreasing with increase in depth ($r= -0.89$. $P > 0.05$).

The food habits of the species changes with the size of the fish. In order of importance, juvenile blackbass feeds on corixids, chironomids, young crayfish, fish fingerlings and aquatic weeds while the adults feed on crayfish, fish fingerlings, corixids, frogs, chironomids, aquatic weeds and beetles. The frequency of occurrence of crayfish and fish fingerlings in the stomach of the adult was almost equal. There was a positive correlation between the size of the blackbass and the size of the prey eaten ($r = 0.900$, $P < 0.001$). M. salmoides is a diurnal feeder but shows increased feeding activity at dawn, around noon and towards dusk. Monthly variation in fullness index showed active feeding from August to February.

M. salmoides in Lake Naivasha has a single breeding period which extends from August to January. This period is characterized by the presence of highest numbers of mature male and female fish in monthly catches as well as high gonadosomatic index. The minimum size at sexual maturity for females occurred at a size-class of 30 - 34.9 cm while males mature at an early size-class of 25 - 29.9 cm. The numbers of males to females in

the population did not differ significantly from the expected 1:1 ratio (X^2 = 18.876, P < 0.100). Fecundity ranged from 1, 300 eggs to 3,524 eggs with a mean of 2,203 eggs. There was a positive correlation between fecundity and : (i) body weight (r = 0.92) and (ii) ovarian weight (r = 0.89). A negative correlation was observed between fecundity and: (i) body length (r = 0.06) and (ii) egg diameter (r = -0.98).

The equation for length - weight relationship revealed that growth in M. salmoides is allometric. Males showed better condition than females. Condition and feeding activity were highly correlated (r = 0.84). There was low incidence of nematode (Contracaecum sp) infestation in M. salmoides.

CHAPTER 1: INTRODUCTION

1.1 Blackbass in Lake Naivasha

The blackbass, *Micropterus salmoides* (Lacépède) is an exotic species having been introduced from its "home" in North America into Lake Naivasha in 1929.

Following a visit to Kenya during which sports fishing was found to be poor, Theodore Roosevelt in 1908 transported the blackbass, *M. salmoides* from North America to stock dams in Kiambu district. Later, the fish was introduced into Lake Naivasha. Before the introduction, apprehensions had arisen about the survival of this species in this entirely new environment due to the fact that the fish is an inhabitant of the temperate region. Never before, in the history of fish transplantation, had such elaborate preparations been made like those which preceeded the introduction of *M. salmoides* into Lake Naivasha-in 1925, *Tilapia nigra* (*Oreochromis niger*) was introduced into the lake, followed by the transplantation of *Tilapia zillii* from the ponds of the former Lake Victoria Fisheries Service in Kisumu. Finally, *Tilapia spilurus* (*Oreochromis spilurus* was also introduced into Lake Naivasha from the Athi river. These introductions were made with the intention that the transplanted fish would provide forage for the blackbass.

It was to be expected that after the painstaking measures which preceeded the introduction of *M. salmoides* into Lake Naivasha, considerable and sustained interest would be shown in the well-being of the fish in its new environment starting soon after the introduction. Nevertheless, this interest was not shown until 1974 - forty five years after the introduction when Malvestuto conducted limited studies on the gut contents, habitat preference and minimum size at sexual maturity in the species. He was followed three years later by Siddiqui (1977a) who also studied the gut contents and, in 1979, the same author reported the presence of M. salmoides in his studies of the fish species composition of Lake Naivasha.

In addition to the need for sustained research on the blackbass in Lake Naivasha, the present research is important also from the ecosystem point of view. In this regard, it is pertinent to note that the fish fauna of Lake Naivasha is unique as it consists of only three teleostean species, all of them introduced - two tilapiine species Oreochromis leucostictus (Trewavas) and Tilapia zillii (Gervais) and the blackbass, Micropterus salmoides (Lacepede). Considerable reports already exist on the tilapiine species - Elder and Garrod (1961), on the natural hybrids, Mann and Ssentongo (1969), on the population, Hyder (1970), on the patterns of reproduction, Malvestuto (1974), on some aspects of their biology, Malvestuto (1975), on the incidence of parasitism and Siddiqui (1977 a, b; 1979 a, b) on the food habits, reproductive biology and management.

From the point of view of limnology of Lake Naivasha, considerable information is also available from the works of Melack (1976a,b), Gaudet (1976 a; 1978; 1979), Muthuri (1980), Gaudet and Muthuri (1981) and Njuguna (1983).

On productivity of the lake, a fair amount of information is also available from the investigations of Gaudet (1976 a), Melack (1979), Mavuti and Litterick (1981), Mwaura (1982), Mavuti (1983) and Muthuri (1983).

From the foregoing, it becomes clear that the various components of the ecosystem of Lake Naivasha have received varying degrees of attention, the greatest being limnology and productivity. With regard to the fishes, the tilapiines have also had their fair share of treatment. The only species requiring detailed investigations in order to complete our knowledge on the ecological relationships of the inhabitants of Lake Naivasha and the aquatic environment is the blackbass, M. salmoides. The results of this study together with those already existing on the tilapiine species will provide the necessary information for the overall management of the fishery of Lake Naivasha.

It was against the above-elucidated background of the lack of sufficient biological knowledge on the blackbass, coupled with the need to provide information necessary for the management of this fish in Lake Naivasha that the present research was carried out.

1.2 Objectives of the research

The objectives of the above research were to study the following aspects of the ecology of M. salmoides in Lake Naivasha:

1.2.1 Relative abundance and distribution

1.2.2 Food and feeding habits

1.2.3 Reproductive biology

1.2.4 Length - weight relationship

1.2.5 Condition factor

1.2.6 Parasitism

1.3 Description of the Study area

Lake Naivasha (Fig. 1) lying at 0^{o} 45 S' and 36^{o} 20 E and at an altitude of 1890 m above sea level is a shallow equatorial lake in the eastern arm of the Rift Valley in Kenya. It is a small closed basin with a surface area of about 158 Km^2 and a mean depth of 6 m. The basin is roughly circular in shape and is made up of three water bodies viz: the main lake, the crescent lake and the Oloidien lake.

The basin is unique in being the only freshwater body in the eastern arm of the Rift Valley in Kenya (300 $\mu S\ cm^{-1}$). All the other lakes in the Kenyan Rift valley except Lake Baringo are saline to some extent. In relative terms, Lake Naivasha is large since it is the second largest lake in Kenya's Rift valley after Lake Turkana (7,200 Km 2).

The Naivasha basin receives water from the highest parts of the Rift Valley floor and the flanking escarpments. Three major rivers: Malewa, Gilgil and Karati enter the Jake to the north (Fig. 1). The Malewa river (1730 Km2 watershed) originates from the Nyandarua range and Kinangop plateau and contributes about 90% of the discharge into Lake Naivasha. Most of the remainder is provided by Gilgil river which drains the Bahati highlands.

In addition to the river flow, the lake receives water through seepage. Thompson and Dodson (1963) described Lake Naivasha as a "hydrographic window" because water passes freely through the extremely porous volcanic rocks which form 80% of the lake basin. Water input by seepage has been shown to occur in the North-eastern and North-western sections while water loss by seepage occurs to the south and South-eastern section of the lake (Gaudet and Melack, 1981).

The climate of the Naivasha basin is warm and semi-arid. The area receives 620 mm rainfall while evaporation is 1735 mm annually. Evaporation exceeds precipitation almost throughout the year. The rainfall has a muted bimodal distribution with a main peak in April and May and a minor peak in November (Melack 1976 a). Air temperatures are moderate with monthly means varying a little from 15.9°C to 18.5° C while water temperatures range from 19.5° C to 21.5°C near the bottom of the main lake (Anon, 1978).

The Naivasha basin has a maximum alkalinity of over 3.0 meq/l and a minimum of 20.0 meq/I (Milbrink, 1977) at low and high water levels respectively. The author also observed a conductivity range of 260 umohs cm^{-1} to 445 umohs cm^{-1} at high and low water levels respectively, while the Oloidien Lake had the highest conductivity of 615 umohs cm-1. Njuguna (1983) recorded a conductivity range of 300-350 umohs cm-1 in the main lake. The highest surface value of pH which has been recorded in the lake is 8.8 which is highly alkaline (Milbrink, 1977), while Harper and Muchiri (1984) reported Secchi disc readings in the basin ranging from 50-164 cm.

The basin has a very rich and diversified plant and animal life. Emergent macrophytes are mainly dominated by sedges of which Cyperus papyrus (L.) is the most important. Papyrus forms a fringing zone around the lake separating the surrounding farmed land from the water. In the open lake, the floating macrophyte community is dominated by Salvinia molesta (Mitch.) while Ceratophylum demersum (L.) dominate the submerged macrophyte community where it forms extensive beds on the shallow parts of the lake and lagoons (Muthuri, 1983).

This basin falls in the ecological zone IV of Gwyne, Pratt and Greenway (1966), a classification which refers to a zone in which upland Acacia woodland is predominant. The northern parts of the basin are bordered by submontane tropical evergreen forest dominated by Podocarpus spp. The slopes of the valley are covered by tropical Setaria spp. grassland which grades into Tarchonanthus camporatus (L.) bushland typical of valley floor. Along the Malewa river valley is a riverine forest dominated by Salix hutchinsii (Skan) which gives way to the papyrus swamp as the river enters the lake. Around the lakes of the Naivasha basin is an Acacia xanthophloea (Beth) which trees upto 35 m.

Lake Naivasha is famous for its varied bird life and is routinely included on the bird watchers itineraries. There are large concentrations of fish eagles, kingfishers, sacred ibises, pelicans, coots and ducks. On the surrounding plains are large herds of zebras, monkeys, kongoni, gazelles, impalas and dikdiks. In addition, large populations of hippopotami are found all over the lake.

Due to the wide variety of plant and wildlife the lake supports, it has become a great tourist attraction. For the tourists, the lake offers birdwatching, game watching and sports fishing. Tourism being a most important foreign exchange earner in Kenya, the value of this lake cannot be overstated.

CHAPTER 2: LITERATURE REVIEW

2.1 Ichthyofauna

Since the 1920s about 8-9 species of fish have been introduced into Lake Naivasha. These species established themselves well and supported a very good fishery during the 1950s and 1960s (Siddiqui, 1979 a). But in the recent years, reports have revealed that the species composition in the lake has changed and the yield has also declined considerably. Overfishing and Salvinia infestation seem to have contributed to these (Siddiqui, Op. cit.).

Leakey (1931) suggested that in the late pleistocene, during the Malkalian and the Nakuran - Post pluvial dry phase, Lake Naivasha probably dried up completely, at least once, in the history of the lake. This situation, coupled with the fact that the neighbouring lakes in the Rift Valley - Nakuru and Elementaita are highly saline, (Jenkin, 1931; 1936; Talling and Talling 1965), explains why the only recorded endemic species was the small tooth carp, Aplocheilichthyes antinorii (Richardson and Richardson 1972). This fish was reported to occur in large numbers and shoaled in surface waters (Elder et al, 1971) but by 1977 when Siddiqui was carrying out his investigations, it seemed to have disappeared. Two other Cyprinodontids, Poecilia sp. and Gambusia sp. which were introduced in the papyrus swamp to control mosquitoes are also no longer found in the lake (Siddiqui 1977). Elder and Garrod (1961) and Siddiqui (1977a; 1979b) have attributed the absence of these fish - A.

antinorii, Poecilia sp. and Gambusia sp. to predation by the blackbass. Occasionally rainbow trout, Salmo gairdneri have been taken in the lake (Elder et al 1971; Pers observation), probably as strays from the effluent river into which they were introduced. At present, Lake Naivasha contains only three introduced species: Oreochromis leucostictus, Tilapia zillii and Micropterus salmoides

2.2 General distribution and relative abundance

In Lake Naivasha, Malvestuto (1974) reported that the blackbass occurs mostly in the papyrus lagoon areas and very few are found in the littoral zone. On the contrary, Mavuti (1983) reported that the fish is predominantly in the littoral zone with a few occurring in the papyrus lagoons. Oluoch (Pers. comm.) also commented that during his research on the crayfish he noticed high populations of the blackbass in the Crescent lake and the Oloidien Lake. An interview of the Lake Naivasha fishermen revealed that the blackbass (" Chengu" as it is locally known) is a rare fish and that they have never come across its fry. Siddiqui (1979) only commented that the abundance of the fish has fluctuated since its introduction into the lake in 1929, and that the population has increased recently due to the introduction of the crayfish Procambarus clarkii on which it feeds.

As already mentioned, blackbass in Lake Naivasha is an introduced species from North America. Reports of successful introductions into tropical freshwaters are not available. However, Robbins and McCrimmon (1974) reported that unsuccessful attempts were made to introduce the species in Malawi in 1937, Zambia in 1944, Zaire in 1945, Mozambique in 1947, Mauritius in 1949 and Tunisia in 1966. In view of the failure of this species to establish itself in these tropical regions, there is no information on the distribution and the abundance of this fish in other tropical waters to serve as basis for review of the topic.

Even in its native North America, only scanty reports exist on the distribution of the blackbass. The juveniles tend to occur along the shoreline in shallower, more pretected areas than do the adults (Morgensen, 1982). Cady (1945) reported that M. salmoides in the Norris Reservoir remained in shallow water all the year round but concentrated at 10 to 20 feet depth (3.08 to 6.10 m). Temperature seem to play an important role in the distribution of the species as Dendy (1946) reported temperature preference of 80° F (27.9° C) by the blackbass.

In Lake Naivasha, M. salmoides seem to be gaining commercial importance (Table 1). From an annual catch of 10.4 tonnes in 1976, there was a consistent increase in catch until 1979 when the annual harvest stood at 32.5 tonnes. In 1980 there was a drastic drop in the harvest of the fish to 18.0 tonnes and this continued into 1981 when the lowest catch of 3.8 tonnes was recorded. From 1982 there has been a steady increase from 13.0 tonnes culminating in a record catch of 81.0 tonnes in 1986 (Govt of Kenya-Fisheries Department). Similarly, the contribution of blackbass to the total fish yield in the lake has also increased from 13.4% in 1976 to 17.0% in 1986 (Table 1).

3.3 Feeding ecology

Only scanty reports exist on the food and feeding habits of the blackbass in Lake Naivasha. Siddiqui (1977) studied the stomach contents of the blackbass and reported that the species is a carnivorous fish and that it feeds mainly on the crayfish, P. clarkii. Using the points analysis method of Hynes, the author reported that about 78% of the gut contents was made up of the crayfish while insects accounted for 15% and young tilapia 7%. Malvestuto (1974) reported that the food habits of the blackbass changes with age and size and that up to a length of 20 cm, invertebrates, mainly chironomids and Odonata, dominated in the stomach. From a length of 20 cm to 30 cm, crayfish became abundant and constituted 78% of the gut contents.

In North America which is the original "home" of the fish, a substantial amount of work has been done on its food and feeding habits. Rogers (1967) reported that blackbass fry feed primarily on copepods, cladocerans and rotifers. In Lake Washington, Stein (1970) reported that cladocerans and copepods were the primary foods of the young blackbass while Goodson (1965) observed that cladocerans made up to 26.2% of the diet composition of the blackbass fry.

Turner and Kraartz (1920) found that M. salmoides switches from a microcrustacean diet to an insect diet at a length of 5-10cm. According to Goodson (1965) the largemouthbass juveniles also feed on midge and mayfly larvae. In his findings, Stein (1970) reported that the frequency of occurrence of insects in the stomach of blackbass increased with increase in the size of the fish. Blackbass juveniles have also been known to take worms and insects as part of their diet (Singler and Miller, 1963). In Lake Mead, Morgensen (1982) reported that the blackbass have switched from a shad - insect diet to a centrarchid-crayfish - insect diet. Lewis et al. (1961) and Lewis and Helms (1964) found that the blackbass in small tanks preferred golden shiners to other forage organisms. However, in small ponds, bullfrog tadpoles, crayfish young black bullheads and green sunfish were preferred in that order.

Adult blackbass are omnivorous, eating almost anything small enough to be swallowed (Minckley, 1973). M. salmoides have been reported to take frogs, crayfish, mammals and young fish of their own kind (Singler and Miller, 1963). The adult blackbass in Lake Mead were observed to forage upon a number of food items such as young shad, blue gill, channel catfish, bass juveniles, crustacea and detritus (Espinosa and Deacons, 1973). In Lake Mohave, Johnson (1972) reported that threadfin shad were the primary forage fish, but were consumed less often than aquatic weeds. Other food items were crayfish and salamander. Stein (1970) reported that crayfish was the second most important food item of the adult blackbass in Lake Washington and that feeding activity was low during winter and spawning seasons but increased rapidly during summer months. During their research in West Point Lake, Tom and Pawaputanon (1980) noted that bluegills, gizzard shad and threadfin shad were the most common fishes consumed by the largemouth bass. According to Goodson (1965), threadfin shad constituted 72.5% of the diet of the blackbass in a steep sided Californian reservoir. Jonez and Summer (1954) found that black crappie comprised the bulk of blackbass forage during their study in Lake Mead. Bluegill and occasionally carp and channel catfishes were also found in bass stomachs. Goodson (1965) reported that sunfish and shad account for 90% of the largemouth bass diet in reservoirs. Prior to the introduction of threadfin shad into Lake Mead in late 1954, the main source of food utilized by the blackbass consisted of other centrarchids (Moffet 1943). According to Lawrence (1958), an adult blackbass can swallow a fish whose maximum depth is equal to the mouth-width of the blackbass.

Blackbass do not feed when they are spawning, or at water temperatures above 37° C or below 5° C (Markus, 1932). Even though small bass tend to feed at lower temperatures than adult blackbasses, (Markus, Op. cit.,), all sizes of the bass tend to feed very little during the winter at northern latitudes (Keast, 1968). Wright (1970) observed that as temperature decreases, the size of the forage organism consumed by the blackbass decreases. In support to the above observation, Hathaway (1927) reported that the species consume approximately three times the size of food at 20°C as at 10°C. If available, the size of food that blackbass eats increase with its size (Roggers, 1967; Lewis et al., 1974; Snow 1971; Schneider, 1971; Turner and Kraartz 1920.). In his finding, Snow (1961) observed that bass stops feeding when dissolved oxygen approaches 1 mg/l.

Prey selection by the largemouth bass is determined by prey availability and vulnerability as well as the size of the prey (Lewis et al., 1961; Lewis and Helms, 1964; and Snow, 1961). Blackbass does not bite off chunks of food from a prey organism but rather swallows a whole organism (Lawrence, 1958) while Goodyear (1972) reported that if a prey organism behaves unnaturally, predation by the bass increase.

M. salmoides is not a continuous feeder. When stomachs were collected using electro-fishing, it was common to find 50% of them to be empty (Zweiacker and Summerfelt, 1974; Dubets, 1954; Lewis et al., 1974). On the contrary, Moyle and Holzhauser (1978) reported that the species feeds throughout 24 hrs but most foods are consumed during the day while Lewis et al. (1974) reported that once a gizzard shad was ingested, the bass characteristically does not eat again for approximately 40 hrs. This, according to Snow (1971) and Lewis et al. (1974) apparently does not hold true when small forage fishes are being utilized.

Reports of food and feeding habits of other predatory fishes in various African water bodies are also available. In Lake Victoria, Corbet (1961) reported on the food habits of *Bagrus docmac* and observed that *Haplochromis* spp. dominated followed by aquatic insects, crustaceans and molluscs. Twenty years later, Okach (1981) confirmed the above finding that *B. docmac* in Lake Victoria prefers *Haplochromis* spp. to other forage organisms.

Elder (1961) reported that *B. docmac* locates its prey by chemotactile perception and that it feeds nocturnally when the fish prey are asleep. Okedi (197[illegible]a) reported that the foods and feeding habits of five small momyrid fishes in Lake Victoria fluctuated according to lunar phases.

On the transition in food habits, Moriarty *et al*. (1973) found that *Haplochromis* sp. changed to a piscivorous diet after being an opportunistic omnivore at fingerling stage. In *Lates niloticus*, Ogari (1984) observed that the juveniles are insectivorous but the feeding habits change, as large *Lates* become piscivorous. Coulter (1976) reported the sequence of transition of *Lates* from planktonic to insect larvae and finally to fish diet. Okach (1981) reported that the juveniles of *B. docmac* show preference for aquatic insects and crustaceans and that they change to a principally piscivorous diet at a length of 18 cm.

Zaret and Rand (1971) reported that the food items in the gut of the Nile perch, Lates niloticus change with the size of the predator in Lake Chad. On the other hand, Hamblyn (1966) reported that the size of the prey which can be captured, swallowed and retained in the stomach of Lates niloticus is determined by the size of the buccal cavity, the stomach capacity and available coelomic space. Hamblyn (Op. cit.), Gee (1968), Hopson (1972; 1975a) and Coulter (1976) noted a general increase in prey size with increase in predator size. Gee (Op. cit.) observed that the proportion of predator body length to prey body length was often in the region of 25% rarely exceeding 30% and his highest figure was 33%, whereas Okedi (1970) and Coulter (1976) reported the proportion to be 35.6% and 35% respectively. Hopson (1972, 1975a) however, observed that the maximum proportion between prey size and predator size was approximately 50%. In Lates niloticus Ogari (1984) reported that the size of prey which can be captured, swallowed and retained in the stomach was hardly more than a third of the predator size. The author observed that the type of prey item taken by the species is governed by the prey abundance and predator size.

Okach and Dadzie (1988) also reported on the increase in prey size with increase in predator size. These authors observed that B. docmac changes to piscivorous diet at a length of 18 cm - a size at which they started preying on Haplochromis spp. of 5 cm minimum size while the maximum size of prey taken by the juveniles was 3 cm.

2.4 Reproductive biology

2.4.1 General review of literature

In Lake Naivasha, the only reports available on the reproductive biology of the blackbass are the works of Malvestuto (1974) who reported that the breeding maxima of the fish occur from September up to November and the lowest breeding activity was observed in March. The author also observed the minimum size at sexual maturity to be 22.6 cm but Siddiqui (1977 b) observed this size at a length of 30.5cm

The foregoing, to date, are the only reports available on the reproductive biology of M. salmoides in Lake Naivasha. These limited efforts have, however, improved our knowledge on the subject but the paucity of information coupled with their equivocal nature, makes it difficult to arrive at any meaningful conclusions.

In North America, very scanty reports are also available on the reproductive biology of the species. The minimum size at sexual maturity for females was observed to be 25 cm while males matured at an early size of 22 cm (James,1942). Bishop (1968) reported that the ovaries of a ripe blackbass contain 2,000 - 145,000 eggs. The author also observed that the relative fecundity of the species appear to be directly related to the condition and the size of the fish. Snow (1972) reported that fecundity of the blackbass ranged from 5,000 to 43,000 eggs while Stein (1970) estimated fecundity to range from 7,635 -46,143 eggs and stated that fecundity may decrease after seven years. Sex ratio of the fish has also been a subject of study by a few authors. Cross (1951) reported the sex ratio of the blackbass less than 5 years to be 1:1. However, Bryant and Houser (1971) reported the female to male ratio up to six years of aged to be : 1:4 in the first year, 1:2 in the second year, 1:5 in the third year, 1:3 in the fourth year, 2:7 in the fifth year and 6:0 in the sixth year. They noted that at any given time there are usually more males than females in the spawning grounds.

On the spawning periodicity, Stein (1970) reported spawning of the blackbass to begin when water temperature approaches 60°F (20.9°C) and extends from about May 15th to the end of June.

Several investigators have reported some findings on the reproductive biology of different fish species in various water bodies:-

2.4.2 Morphology of the gonads.

The reproductive organs in fishes are internal and longitudinally placed within the body cavity from where they communicate with the outside via the genital openings. They originate as paired structures and remain so in most species. The size and colour of the reproductive organs vary according to the stage of sexual maturity. Most testis are creamy - white and smooth, and most ovaries are yellow to orange when ripe.

The general morphology of the gonads of fish has been a subject of investigation by a number of workers.

In Hilsa ilisha, the gonads are paired. The testis are elongated and dorso-ventrally compressed, whitish in colour during the the breeding season but translucent during off season (Nair, 1958). The ovaries are translucent and slightly pinkish in the off season but yellowish during breeding season (Nair, Op. cit.).

In Tilapia mossambica, Dadzie (1974) described the ovary as paired, usually equal in length and covered by a thin sheet of tissue. While Owiti (1986) described the testis of Clarias mossambicus as a paired, elongated dorso-ventrally compressed organ and the ovaries are also paired organs, suspended from the dorsal side of the peritoneal cavity by a thin mesovarium.

No description has been given by any worker on the morphology of the gonads in M. salmoides

2.4.3 Seasonal changes in gonadal development

The maturity stages of a fish designated, usually by Roman numericals, describes the phase of development of the most advanced germ cells in a fish gonad. From the morphology of the fish and their gonads, stages of maturation have been ascribed to individual fishes in a population. Maien (1939) was one of the pioneers in this field of investigation. Other reports include those of

Ghosh and Kar (1952), Nair (1958), Bagenal (1971) and Dadzie (1969, 1974). The above authors designated the maturity stages with Roman numericals 1 - V or 1- VI depending on species as follows:-

Stage 1 - Virgin juvenile fish which has not spawned before. Gonads are tiny transparent and undifferentiated. The sexes are not discernible macroscopically.

Stage II - Marks the quiescent stage when the gonad is differentiated but the sex products are faintly observed as minute white specks in both sexes but more pronounced in females. The gonads of both sexes loose their transparency and become translucent.

Stage III - In females, ripening eggs become discernible and a marked increase in the ovarian size is observed. The ovaries become slightly yellowish in colour, the coloration intensifying towards the end of this stage. The testis increases in translucency with thickened walls.

Stage IV - The oocytes attain maximum size and the yellow colour intensifies. The ovary occupies the greatest volume in the peritoneal cavity. The testis becomes milky white in appearance and occupies the full length of the peritoneal cavity. The belly becomes greatly distended. Application of slight pressure on the peritoneum results in the release of gametes towards the end of this stage.

Stage V - This is the "running" or spawning stage. There is a high accumulation of mesenteric fat and a slight pressure applied to the peritoneum results in the release of gametes.

Stage VI - This is the "spent" or post-spawning stage when the gametes have been released. The exhausted individual has little or no fats in the mesentery. After spawning, the ovary may return to either Stage II or III depending on the species and the type of spawning.

In Labeo victorianus, Candwalladr (1965) described the stages of maturity in terms of gonad weights and gonadosomatic indices. The author classified maturity stages for each sex into: resting, ripening, ripe and running. The males had low gonad weights ranging from 1.2 g in the resting stage to 1.0-12.0 g in the running stage with the corresponding GSI values ranging from 0.9% to 1.2-6.3%. In the females, the gonad weights ranged from 3.0 g in the resting stage to 4.0-95.5 g in the running stage with corresponding GSI values ranging from 1.4% to 4.9 - 34.3%.

The description of maturity stages in the horse mackerel, Trachurus trachurus in the North sea and English channel was based on external appearance of the testes and the ovaries as well as on histological observations of the ovaries (Macer, 1974). Nine maturity stages were recognised in both males and females. In the males, staging was based on colour, size and shape of the testes, length of body cavity occupied by testes and freeness of flow of milt. In the females it was based on colour, shape and size of the ovary in relation to that of the body cavity, size of the eggs as well as the number of different types of oocytes and stage of oogenesis distinguished in histological preparations.

In the haddock, Melanogrammus aeglefinus, seven maturity stages were distinguished in both sexes in a new form of description presented as follows: Stage I - immature, Stage II 1/4 ripe, Stage III - 1/2 ripe, Stage IV - 3/4 ripe, Stage V -ripe, Stage VI - running and Stage VII - spent (Robb, 1982). For each of these stages, the author described the macroscopic appearance of the gonad such as colour, size and visibility of the oocytes in the ovary to the naked eyes. Blay and Eyeson (1982) recognised five maturity stages in the male and four stages in the female shad, Ethmalosa fibriata in the coastal waters of Ghana.

To date there is no information on the maturity stages of the blackbass.

2.4.4 Minimum size at sexual maturity

The length at fist maturity of a fish is generally described as the minimum length at which 50% of the fish in a population are sexually mature (Rinne, 1980; Dadzie and Wangila, 1980; Nzioka, 1981; Okach, 1981; Geevarghese and John, 1983). El-Zarka (1961) indicated that the knowledge of size at first maturity is important in the determination of the minimum legal size that may be needed to secure potential reproductive stocks. In his report on Tilapia zillii, the author noted that males mature faster than females.

In Xenoclarias sp., (Rinne 1980) found the length at first maturity to be between 15-16 cm. The author only considered fish in Stage IV and above as mature for the purpose of this exercise. He further observed that both males and females mature at the same size. Nzioka (1981) reported that in the reef fish Scolopsis bimaculatus 50% population were mature at 16.5 cm. In his study, the author considered fishes in Stage III and above as mature. Lock (1975) reported that Bagrus bayad attains sexual maturity in their second year of life (from a fork length of 30 cm) and 50% of both sexes are mature at a fork length of 34 cm. In the Catfish, Bagrus docmac the males mature much earlier than the females (Okach, 1981). Geevarghese and John (1983) calculated the percentage occurrence of different stages of maturity in each length - group of male and female Oligolepsis acutipenis and found that the minimum size at first maturity in females was less than that of males.

To date, very scanty and equivocal reports are available on the minimum length at first maturity in M. salmoides in Lake Naivasha. Such an information is crucial in fishery management because it gives an idea as to the size of the fish at recruitment. With the latter information, it is possible to regulate the mesh size of fishing gear to ensure maximum sustainable yield.

2.4.5 Sex ratio

The ratio between total number of males to females of fish in a population is referred to as sex ratio. Mcleod (1975) found that the sex ratio of Lates longispinus varies with seasons. He reported that the species exhibit sexual congregation and segregation during and after spawning respectively. The females move to the deeper and shallower waters after a mid-water breeding activity.

Hopson (1975 a) reported an ontogenetic increase in the female preponderance among the Nile perch Lates niloticus. The author indicated lack of any males in samples of 140 cm and above. He attributed this state to a probable high male mortality at these sizes. Nikolsky (1962) reported fluctuation of male to female ratio in the common perch, Perca fluviatilis from 1:1 to 1:9 with female preponderance as they approach maturity.

In the Xenoclarias spp. in Lake Victoria, Gee (1975) reported that females generally outnumbered the males. But Rinne (1980) maintains that the females of the species outnumber the males by a ratio of 2:1 only during the spawning period and not throughout the year.

Nzioka (1981) found that in Scolopsis bimaculatus, the overall sex ratio of males to females was 1:1.7. The author however observed that the sex ratio did not differ significantly from 1:1 during the breeding season. Okach (1981) did not find significant variation (from the expected 1:1 ratio) in the sex ratio of B. docmac in the Nyanza gulf of Lake Victoria. The author observed that from fingerlings to the length of 45 cm, the sex ratio is almost 1:1 with a slight female preponderance. Females above 60 cm were absent from the population. This apparent absence of female B docmac at advanced ages has been reported also in B. bayad in Lake Turkana (Lock, 1975). No reasons, however, were ascribed to these observations.

Rinne and Wanjala (1983), during their study on the major catfishes of Lake Victoria observed that in Schilbe mystus, the females are more numerous than males in the ratio of 3:1, and in Synodontis victoriae, there is a 1.5:1 ratio of females to males. The sex ratio of B. docmac were almost 1:1.

Dadzie (1985) observed that in Lake Kamburu, the male Labeo cylindricus were more numerous than females from January to April. A ratio of 1:1 was recorded in the month of May. The author further observed that after May and throughout the spawning period, October to March, the sex ratio changed in favour of females. The overall sex ratio however was not significantly different from 1:1 according to the author.

Smith (1956) listed three possible causes of variability of sex composition in fish population. These are: segregation of sexes at different sizes and seasons and differences in fishing mortality caused by gear selectivity, the latter being a factor of body size and morphology.

No information is available on the sex ratio and its seasonal changes in M. salmoides.

2.4.6 Fecundity

Fecundity in this investigation is defined as the number of ripe eggs in the female ovary prior to the next spawning period (Bagenal, 1971). It is one of the best criteria for judging the reproductive capacity of a species. Bagenal (Op. cit.) reported that fecundity in fishes is proportional to the size of the adult female, to the size of the ovary and to the egg size. Different methods ranging from gravimetric through volumetric to actual physical counts of all the eggs have been used to determine fecundity in different species.

In her study of the fecundity of Tilapia species, Lowe (1955) found that the guarders were more fecund than the brooders. For example, the guarder T. zillii was found to produce many more eggs than any of the mouth brooding species. The maximum number of eggs produced by the guarder T. melanopleura was 7,277 while in the brooders the maximum number of eggs were as follows:

T. leucosticta	(Oreochromis leucostictus)	=	414 eggs
T. nilotica	(Oreochromis niloticus	=	705 eggs
T. karomo	(O. karomo)	=	65 eggs
and T. squamipinnis	(O. squamipinnis)	=	287 eggs

In T. aurea, Dadzie (1970) reported (from a study of seventeen mature females) a mean fecundity of 719 eggs and a maximum of 4,392 eggs in a fish measuring 19.8 cm.

In the genus Tilapia, evolution appears to have been directed towards a reduction in the number of eggs produced per female and the development of brooding adaptation (Lowe, 1955; Dadzie, 1970).

In Labeo victorianus, Candwalladr (1965) used a gravimetric method to determine fecundity. The maximum egg production determined in this species using this method was 162,525 in a fish measuring 24.7 cm standard length.

Fecundity of the bloater Coregonus hoyi, was estimated by the grid-count sample method (Emery and Brown, 1978). The authors reported that fecundity in this fish ranged from 3,230 in a 244 mm fish to 18,768 in a 305 mm fish.

In the stunted female Tilapia zillii, Dadzie and Wangila (1980) recorded a mean fecundity of 2,395 eggs and observed that the number of eggs per female increased with length, weight and depth of the fish. Similarly, Rinne and Wanjala (1983) observed that fecundity varied with length in B. docmac, Synodontis afro-fisheri, S. victoriae and Schilbe mystus.

Rounsenfell (1957) reported that fecundity also varied widely between different populations of the same species of North American salmonids.

Fecundity was found to be reciprocally related to egg size in Tilapia Spp. (Peters, 1963) while Rousenfell (1957) and Ross (1967) reported that the egg size of Salmo gairdnerii varies directly with body size and the nutritional condition of the adult.

In Acanthopagrus latus and A.curieri no intra-specific differences in potential fecundity were found in fishes within the same size range (Abu-Hakima, 1984). Fecundity estimates in these fishes were based on oocytes of size > 180 µm.

Bowmaker (1969) reported that Alestes macrophthalmus, inhabiting Lake Bangwelu are more fecund than those inhabiting adjacent swamps.

Ricker (1971) reported that the formula, Log F = log a + b log L, gives a linear relationship between fecundity and length of fish. He reported that fecundity may be related either to length or weight of a fish. If it is related to length, the value "b" is usually close to 3.0 but if to weight, then the value of 1.0 is found in most cases.

More reports on fecundity estimates are those on Esox lucius (Frost and Kipling, 1967), Bagrus docmac (Okach, 1981) Ethmalosa fimbriata (Blay and Eyeson, 1982) and Mugil spp. (Alvarez - Lajonchere, 1982). The authors observed that in general, fecundity is positively correlated with the lengths and weights of the fish species they studied.

Bagenal (1978) indicated that fecundity is best expressed as a function of length rather than weight of fish because the total weight of the fish is affected by the gonad weight.

Fecundity in M. salmoides in Lake Naivasha has not been a subject of investigation by any author.

2.4.7 Gonadosomatic index (GSL).

The gonadosomatic index (GSI = weight of gonad/weight of fish x 100) is an important indicator of the reproductive patterns and maturity stages of fish (Hickling and Ruttenberg, 1936).

GSI can be used as an index of either somatic growth or gonadal development and can give an accurate prediction of spawning period. In most fishes, the males and females have highest GSI values just before and at the onset of spawning. Comparisons of rate of either somatic or gonadal growth between species of different population or sizes can be computed from their GSI values (Dadzie, 1970; Gunstrom, 1968).

Turner (1919) observed that in the perch, Perca flavescence, the maximum weight attained by the ripe testis may be forty-five times the weight of the testis after spawning. He observed that in this species, the maximum weight of the testis was reached just before spawning in November.

In the Indian shad, Hilsa ilisha, two peak values of GSI were observed, one in March and the other in August (Nair, 1958). After the first peak of gonadal activity, the testis expelled most of the spermatozoa, but in the case of the ovary, the majority of the ova instead of passing out, underwent atresia and resorption. Such high atresia rate has been reported recently in Clarias mossambicus (Owiti, 1986). The second peak of gonadal activity in August resulted in spawning in both sexes (Nair, 1958).

In Labeo victorianus, the GSI of the males and females increased just before the rains to a higher level of 6.3% in males and 32.3% in females at sexual maturation and at the time of maximum rains (Candwalladr, 1965).

In the pike, Esox lucius, Frost and Kipling (1967) reported that the GSI in females increased during October through March and that when the fish was ripe, this parameter increased to 18 - 20%. The authors however, did not indicate lower GSI level. In the males, the highest GSI of between 2% and 4% was reached by October. The GSI remained high till the height of the spawning activity in mid-April.

Hyder (1970) found that in Tilapia leucosticta in Lake Naivasha, gonadal development in both the males and females is closely related to high temperatures, maximal sunlight and low rainfall which occurs during the period of December to February and that sunlight and temperatures are the most important factors influencing gonadal development and subsequent breeding in Tilapia even under equatorial conditions. The author further suggested that rainfall as such is unrelated to gonadal development except initiating and (if heavy and sustained), in checking breeding.

In Acanthopagrus latus, the major spawning period, January to March is characterised by the highest GSI values in both sexes with peaks for males 5% and females 25% (Abu-Hakima, 1984).

Dadzie (1985), observed that in the African carp, Labeo cylindricus in Lake Kamburu, both the males and females had maximum GSI by the start of spawning period in October-November.

To date no information is available on the gonadosomatic index and breeding patterns of blackbass both in Lake Naivasha and in North America.

2.5 Length - weight relationship

The determination of length-weight relationship in fish is important both from practical and biological points of view. In fisheries work, lengths are much quickly and accurately determined under field conditions than weight. An equation for length-weight relationship therefore enables a worker to convert lengths into weights later in the laboratory. Another importance of length-weight relationship is that it enables one to obtain the expected weight-for-length of individual fish, which is used in the calculation of the relative condition factor. The following formula, first advanced by Le Cren (1951), has been generally accepted and widely used in the determination of length-weight relationships in fishes:

$W = a L^b$ where,

W = weight of fish

L = length of fish

a = a constant and

b = an exponent

The value of "b" usually lies between 2.5 and 4.0. This equation when transformed into logarithmic form is written as follows:

$$\text{Log } W = \text{Log } a + b \log L.$$

In the pike <u>Esox</u> <u>lucius</u>, Frost and Kipling (1967) found no significant difference between the regression lines for immature males and females as well between mature males and females. The position of the lines as determined by the parameter "a" were however, different in winter and summer individuals, being higher in the winter when the gonads were ripening.

Callander (1969) found from length-weight regression of fish from 398 populations that the value of "b" was close to 3.0. All the populations he studied came from temperate waters. In <u>Northobranchius</u> <u>guentheri</u>, Bailey (1972) found the value of "b" to be 3.34 in males and 3.76 in females.

The author concluded that in this species both sexes exhibit an allometric growth and that males grow larger than females.

Dadzie et al. (1979) studied length-weight relationship of four teleostean species in Lake Kamburu and found the following values of "b": 2.95 in Tilapia, 3.09 in Barbus, 2.6 in Labeo and 1.95 in Momyrus. From the above findings, the authors concluded that Tilapia, Barbus and probably Labeo grow isommetrically i.e their weights increase approximately as the cube of their lengths. However, the values of "b" for Barbus and Labeo departed too much from 3.0 for the conclusions to be correct.

In the African carp, Labeo cylindricus, monthly length-weight relationship was calculated for each sex (Dadzie, 1985). The author noticed considerable variations in length-weight relationships between the sexes even within the same months. For detailed analysis therefore, he calculated regressions for all the samples for the different months of the year. For the males, he found the values of "a" and "b" to be -1.57741 and 2.8986 respectively with the corresponding values of -1.5882 and 2.879 in the females. The values of "a" and "b" in a single regression for the combined sexes were - 1.5882 and 2.9021 respectively, indicating isometric growth in species.

Other reports on the length-weight relationship include those of Hopson (1975a; 1975b) in Lates niloticus and Alestes baremose, Siddiqui (1977) in Oreochromis leucostictus, Papageorgion (1979) in Rutilus rutilus and dadzie and Wangila (1980) in Tilapia zillii.

2.6 Condition factor

"Fulton's coefficient of condition" or simply, the condition factor (K) has often been used to investigate seasonal changes and habitat difference in the "condition", "degree of fatness" or "general well-being" of fish (Tesch, 1951).

Le Cren (1951) investigated the seasonal changes in the condition of the perch, Perca fluviatilis in Windermere and identified several factors that affect the condition of the species. High condition was recorded in summer and low condition at the end of winter. The author pointed out that the seasonal cycle in this parameter was related to age, size, feeding and reproductive condition of the fish.

Payne (1975) calculated the average monthly relative condition factor from total body weight without the gonads (somatic weight) for immature and mature Barbus liberiensis separately. The author also considered the effects of gonadal development, food availability and spawning behaviour on the condition of the fish and reported the lack of significant changes in the somatic conditions after spawning. Hopson (1975a) reported an increase in the condition factor with fish size in the Lake Turkana nile perch. The author compared the condition factor of the Lake Chad species and Lakes Kyoga and Victoria species and attributed the higher "K" value of the fish in Lakes Chad and Kyoga to high secondary productivity in the two lakes.

Dadzie et al. (1979) computed 'K' values for lacustrine species of Tilapia, Barbus, Labeo, and Momyrus according to size group and month of collection. In this way the authors were able to follow the monthly changes in the "well-being" of the fishes with size.

"Runted" Tilapia zillii under pond cultivation was found to be in surprisingly good condition with an almost uniform relative condition approaching unity, with no significant variation with respect to size (Dadzie and Wangila, 1980).

In the tropical glassy perchlet, Chanda (= Ambassis commersonii) a better 'K' was shown by the smaller, immature and first maturity stages, and larger, almost senile groups, while the actively breeding adults showed a uniform fall in 'K' (Nair et al., 1983). The authors observed that the 'K' cycle appear to follow a pattern of build up and loss of body resources, following, directly or indirectly, the breeding and feeding cycles.

The relative condition of Labeo cylindricus in Lake Kamburu shows monthly fluctuations without marked differences between the sexes (Dadzie, 1985). Both the males and females reach maximum condition at the beginning of th spawning period. Other recent information on relative condition included those of Ortega-Salas (1980) in the common dab Limanda limanda, Nzioka (1981) in Scolopsis bimaculatus, Okach (1981) in Bagrus docmac and Owiti (1986) in Clarias mossambicus.

No study has been carried out so far on the condition of Micropterus salmoides in lake Naivasha.

2.7 Parasitism

Lake Naivasha abounds in the parasitic nematode Contracaecum sp. It was therefore felt that a study of the incidence of parasitism in the blackbass would be interesting. If the incidence of infestation is high, management measures would be called for.

Parasitism in M. salmoides in Lake Naivasha is poorly documented. During his research in the lake, Malvestuto (1975) only reported on contracaecumosis in Oreochromis leucostictus. Elsewhere, reports by Hoffman (1967) revealed that blackbass is a host of a wide range of parasites viz: Protozoa, Nematoda, Cestoda, Trematoda, Hirudinea and Mollusca.

CHAPTER 3: MATERIALS AND METHODS

3.1 Fish sampling

Fleets of gillnets of mesh sizes 11 mm, 24 mm, 37 mm, 50 mm, 63 mm, 76 mm, 88 mm, 110 mm and 114 mm were used in catching M. salmoides. Each net had a mesh depth of 1.5 m and measured 45 m long. One fleet of gillnets was laid overnight at each of the sampling stations and the nets were examined the following morning starting from 5 a.m. till 11 a.m. Each fleet consisted of one representative from each of the mesh sizes mentioned above. With the help of an experienced fisherman the nets were laid parallel to the shore to trap fish as they move inshore to feed. Sampling was conducted once a week starting from October 1986 to September 1987. The sampling stations are depicted in Figure 1.

Gillnets were the main gear used in the study of the distribution of the blackbass. For the study of relative abundance and diurnal feeding activities of the fish, a seine net of 5 m deep and measuring 80 m long was employed. Hook and line was used for catching fish for diet composition studies as the food items in the stomach remained, in most cases, in undigested condition, unlike the gillnetted samples the stomach contents of which were almost always at various stages of digestion at the time of removal of the fish from the nets.

3.2 Relative abundance

The total catch from both the gillnets and the seine nets were used in elucidating the contribution of the blackbass to the total fish composition of the lake. From each haul, all the fish were grouped into genera except the blackbass which is represented in the lake by only one species. The percentage contribution of M. salmoides to the total catch was then calculated and histograms depicting monthly fluctuations in relative abundance of all the fish species in the lake presented.

3.3 Distribution of the blackbass

The objective of this study was to ascertain the influence of certain parameters/factors on the distribution of M. salmoides within the lake. The following parameters/factors were investigated with the above objective in mind:

a) Temperature

b) Conductivity

c) Water depth

d) Nature of substratum

e) Prey availability

Surface and bottom (maximum depth of 4.5 m) temperatures were measured using maximum and minimum thermometer from the different sampling stations and the mean determined. Monthly mean temperatures were used in studying the distribution of the blackbass in relation to temperature. The data on temperature was further pooled according to sampling stations and again the distribution of the fish in different stations investigated in relation to temperature.

The conductivity of the water was determined weekly using a dionic water tester (temperature compensating conductivity tube). Monthly means as well as pooled data from the sampling stations were used in the study of the distribution of M. salmoides in relation to this parameter.

For the study of the distribution of blackbass in relation to water depth, a pilot survey was carried out to investigate the depth profiles of the different sampling stations. A graduated string attached to an oxygen sampler was employed for this exercise. The results revealed differences in depth ranging from 0.5 m to 3.5 m between the sampling stations with a maximum depth of 4.5 m. The different sampling stations were therefore used to represent different depths within the sampled areas of the lake. Total catches of M. salmoides from these station, during the experimental period were correlated with water depth to give an indication of the distribution of blackbass in relation to depth.

An Ekman bottom grab was used to scoop out bottom particles to determine the nature of the substratum at the different sampling stations which were then related to the number of blackbass caught at the various substrata. The nature of the lake bed was categorized as follows:

a) Muddy - particles less that 0.5 mm in diameter

b) Sandy - particles ranging between 0.5 - 1.0 mm in diameter.

c) Pebbles - 1.0 - 10.0 mm

d) Rocky - greater than 10 mm in diameter.

An additional information on the nature of the substratum was gathered from the examination of sinkers attached to the gillnets. The sinkers, which were medium-sized stones, usually reached the bottom of the lake-hence on removal of the net, they scooped up bottom deposits which were then examined.

The crayfish, Procambarus clarkii has been reported to be the major food of the blackbass (Siddiqui, 1979). For this reason, the distribution of M. salmoides was studied in relation to this prey. To accomplish this task, cylindrical crayfish traps with funnel entrances at both ends, made of metal frames and bound with 4 mm nylon mesh were used in trapping the prey. Each of these traps measured 45 cm long with a diameter of 27 cm. On every sampling occasion, four of these traps baited with dead fish were set randomly at each of the five sampling stations. The number of crayfish trapped were removed and counted the following morning and live ones returned into the lake. Crayfish trapped in the gill nets were also counted and the total numbers of crayfish from both sources from the different sampling stations were used in determining the distribution of the blackbass in relation to its prey. In other words, the objective was to determine whether there was any association in the distribution of the predator and the prey or not.

3.4 Feeding Ecology.

For qualitative analysis of the stomach contents, samples of M. salmoides were dissected and the stomach removed, weighed and preserved in 4% formalin. The contents of each stomach were then emptied into a petri-dish and a small amount of water added to separate the organisms individually. Macroscopic food organisms were separated from the microscopic ones. The latter were examined under a microscope and identified, wherever possible, to the generic level. The macroscopic food organisms were identified with the unaided eyes. Since blackbass is basically a carnivorous fish and swallows its prey whole, the macroscopic method of identification was not difficult.

In the quantitative analysis of the stomach contents, the frequency of occurrence method of Hynes (1950) and Hyslops (1980) was employed. Using this method, the number of stomachs in which each food item occurred was recorded and expressed as percentage of the total number of stomachs examined.

The first exercise for which the frequency of occurrence method was employed involved the study of the diet of adult and juvenile M. salmoides. In this study, all the sampled fish were grouped into two-adults and juveniles. The stomach contents were then examined separately for each group and the percentage occurrence of each food item in the adults as compared to the juveniles was determined. The fish were then re-grouped into 4.9 cm length-classes and, the percentage occurrence of the food items, according to the length-classes also determined. Finally, the frequency of occurrence method was used to determine the monthly variations in the diet composition of *M. salmoides*.

Food selection in the blackbass was studied by comparing the quantity of the food items in the stomach of the fish with that in the environment. Five Ekman grab samples each from the five sampling stations were taken monthly. The samples were sieved and benthic organisms identified and counted. For pelagic food organisms, a tow net was used and ten tows were made for each sampling station on every sampling occasion. The food organisms from the ten tows were preserved in formalin for later identification and counting. Fish fingerlings were sampled using a mosquito net of 3.7 mm mesh size. The percentage of occurrence of each food item was determined. The percentage of the same food item in the stomach of *M. salmoides* was also determined. Food selection in the species in each sampling station was studied using the electivity index (E) of Ivlev (1961) which has the following formula:

$$E = \frac{Ri - Pi}{Ri + Pi}, \text{ where}$$

Ri = relative component of each food item in the stomach expressed as a percentage of the whole ration.

Pi = relative component of the same food item in the environment.

The degree of fullness of th stomach was studied using the index of fullness of Blegvad (1917) which has the following formula:

$$\text{Fullness index (FI)} = \frac{\text{Weight of stomach contents}}{\text{Total weight of fish}} \times 100$$

Monthly mean data on the fullness index of blackbass were used to describe variations in the intensity of feeding in the species throughout the year. The fullness index was also employed as the tool for studying the diurnal feeding patterns in M. salmoides. For this study, seining was carried out once a month at a two-hour interval over a 24-hour period. A total of 12 seines were made on every sampling occasion. The stomachs of individual fish caught were scored as 0,1,2,3, or 4 designated as empty, 1/4 full, 1/2 full, 3/4 full and full respectively. The results were used to determine the onset of, the variation in and the height of feeding activity during the 24-hour period. Predator-prey relationship in the blackbass was studied by relating the size of M. salmoides to the size of the reportedly main prey organism - the crayfish.

3.5 Reproductive biology

Determination of the sex of the fish using morphological characters was impossible since these characters are lacking in the blackbass. Dissection of the fish to expose the gonads was therefore necessary as an aid for ascertaining the sex to enable the sex ratio to be determined.

The gonads were carefully removed, weighed to the nearest 0.1 g using ordinary weighing balance and their lengths also measured using a metric rule. The monthly variation in the weight of the gonads were expressed as a percentage of body weight, also known as the gonadosomatic index (GSI) which has the following formula:

$$GSI = \frac{\text{Weight of gonads}}{\text{Total weight of fish}} \times 100$$

Monthly variations in the GSI of both sexes of fish were followed as indications of the cyclical activities taking place in the gonads in connection with maturation. The GSI was also followed in different size - class fish. This enabled the determination of the size-class at which maximum reproductive activity occur as well as the size-class at which reduced reproductive activity leading to senescence occurs. Finally, the GSI was also determined for fish inhabiting the different sampling stations with the view to investigating the intensity of reproduction in the different stations.

A comparison of the GSI and stomach fullness index (FI) was carried out for the sexes separately to establish whether there was any relationship between feeding and reproductive activities.

The stages of maturity of each fish was determined following the descriptions of Nikolsky (1963) and Dadzie (1969, 1974) and adapted to M. salmoides. Monthly variations in the maturity stages were progressively studied for all specimens collected. The data on the monthly fluctuations in the GSI and maturity stages were used in a complementary manner to elucidate the patterns of reproduction.

For the purpose of determining the minimum size at sexual maturity in M. salmoides, only fish with yolky oocytes (meant for the next spawning) were considered i.e those in Stage III and above. First, the fish were divided into males and females, and then separated further into length - groups. The number of fish at each maturity stage was then recorded. The size at the onset of maturity was then determined as the minimum length - group at which 50% of the individuals in the population were mature.

The testis once weighed, the length measured and the maturity stage determined were discarded but the ovaries were preserved for fecundity studies. The fecund ovaries were cut longitudinally and turned inside out before preserving in Gillson's fluid. Care was taken not to lose any eggs by performing this operation in a white tray so that any eggs that were spilled fell in the tray and were put back in the specimen jars.

The ovaries were preserved in Gillson's fluid for a period of 2-3 weeks. The specimen jars were vigorously shaken every two days to aid the release of oocytes from the ovarian tissues. Before counting the oocytes, they were poured in a petri-dish and those oocytes which had not been liberated from the ovarian tissue during the vigorous shaking were removed by teasing. The ovarian tissue free from oocytes was discarded and the oocytes were allowed to settle in the specimen jars. The Gillson's fluid was decanted and tap water added followed by subsequent settlement and decanting. This process was repeated several times to clean the oocytes. Each time water was decanted, the supernatant was checked under a dissecting microscope, lest tiny oocytes were thrown away.

The clean oocytes were poured into a one-litre capacity beaker and a known volume of water added. One difficulty was that sub-samples which contained sufficient number of oocytes to yield satisfactory diameter distributions contained several thousands of the smaller oocytes which also had to be measured and counted. It was therefore decided, in this work, to treat large and smaller oocytes separately. To accomplish this, an arbitrary division was made at 0.16 mm so that all oocytes above this size were large and those measuring 0.16 mm and below were treated as small oocytes. By adjusting the amount of water added, a 1ml sub-sample taken using a spring loaded micro-pipette could be made to contain a manageable number of oocytes. For sub-sampling the larger oocytes, the total volume was made up to 500 ml by addition of tap water. Three sub-samples were then collected using the micropipette to yield oocytes above 0.16 mm only; the smaller oocytes were ignored. For sub-sampling the smaller oocytes, the total volume was made up to 800 ml and three sub-samples collected yielding oocytes of 0.16 mm and below; the larger oocytes were ignored.

After the above procedure, the oocytes were carefully transferred into a squared perspex dish and then measured in Eye Piece Units (E.P.U.) using a graticule at a magnification of x 20 (30 E.P.U. = 1 mm). The diameter distribution of both large and small oocytes was then estimated and presented graphically.

In the estimation of fecundity, only yolky oocytes were counted. To accomplish this, a second arbitrary division was made at 10 E.P.U. (0.33 mm) and the total number of oocytes (N) in any size-class was estimated using the formula:

$$N = \frac{V}{VI} n, \text{ where}$$

n = number of oocytes in a given size-class in the subsample

V = Volume of sample

VI = Volume of the sub sample.

By averaging N, fecundity was estimated for each mature female. Logarithmic equations describing the relationship between fecundity and body weight, body length, ovarian weight and egg diameter were worked out and the data also presented graphically.

3.6 Length - weight relationship

The length - weight relationship in M. salmoides was calculated using the general equation of the form: $W = a\ L^b$ (Le Cren, 1951)

where W = weight of fish (g)

L = Length of fish (cm)

a = a constant

b = an exponent

The relationship was expressed graphically by plotting the observed lengths and weights as a dot diagram. The logarithms of the individual lengths and weights were obtained then a straight line representing the point for fish with the same length-weight relationship with some scatter due to individual variations was represented by the logarithmic form of the above equation as:

$$\text{Log } W = a + b \text{ Log } L.$$

3.7 Condition factor (K)

In the present study, the condition factor (K) was calculated from the formula:

$$K = \frac{100\ W}{L^3}$$ where W = weight of fish (g)

L = length of fish (cm)

3.8 Parasitism

During the dissection of the individual fish for feeding ecology and reproductive biology studies, the species was thoroughly inspected for any nematode (Contracaecum sp.). If found, the numbers were counted and recorded against the size of the fish. This exercise was carried out with the view to investigating the size of the blackbass at which the incidence of infestation by the nematode was intense.

CHAPTER 4: RESULTS

4.1 RELATIVE ABUNDANCE

The abundance of M. salmoides from the five sampling stations was compared to that of other fish species in the lake. From Table 2 and Figure 2 it is evident that the tilapiines dominate the fish species composition in the lake throughout the year followed by the blackbass and lastly the Barbus sp. which was least recorded during the research period. Results from the questionnaire method (Appendix I), also confirmed the findings that M. salmoides is less abundant in the lake as compared to the tilapiines.

4.2 DISTRIBUTION

4.2.1 Distribution in relation to water depth

The results of the present investigations have shown that depth is a major parameter affecting the distribution of M. salmoides in the lake, the numbers of fish decreasing with increase in depth ($r = -0.899$, $P > 0.05$).

The crescent island lake with an average depth of 1m seemed to harbour the greatest number of fish - 124 (Table 3, Fig.3). As the depth increased to 2 and 2.5 m at the Hippopoint and Safariland respectively, the numbers of fish caught at these depths reduced to 97 and 118 respectively. With increase in depth to 3 m at Korongo, the number of blackbass caught went down to 80. At Fisherman's camp which represented the deepest part of the lake (4.5 m), there was the lowest number of blackbass (56). The effect of depth on the distribution of adult and juvenile blackbass was also investigated. Table 4 shows that the numbers of adults decrease from shallow to deeper waters while juvenile numbers tended to increase from shallow to deeper waters, thus indicating a negative and positive correlations for adults and juveniles respectively ($r = -0.65$, $P > 0.1$ for adults and $r = 0.36$, $P < 0.01$).

4.2.2 Distribution in relation to water temperature.

In view of the small differences in the temperatures of the different sampling stations,it was difficult to assess the impact of this parameter on the distribution of M. salmoides from these areas (Table 5, Fig. 3). However, statistical analysis revealed that temperature has no effect on the distribution of this fish within the sampling stations ($r = -0.041$).

Monthly variations in water temperature were recorded and values correlated with the numbers of the blackbass caught in an attempt to find out whether fluctuations in monthly catches of the fish will be affected by fluctuating temperatures. The data presented in Table 6 and Fig. 4 do not seem to indicate any relationship between water temperature and the distribution of the blackbass and statistical analysis of the results revealed the lack of correlation between monthly variation in numbers of blackbass and temperature ($r = -0.16$. $p > 0.1$).

4.2.3 Distribution in relation to conductivity

The data on monthly variations in water conductivity against the number of *M. salmoides* caught are presented in Table 7 and Fig. 5 and they indicate no relationship whatsoever between these two parameters. These observations were confirmed by statistical analysis of the data ($r = 0.06$, $P > 0.1$).

4.2.4 Distribution and substratum.

Table 8 shows the relationship between the nature of the substratum and the numbers of blackbass caught. It is evident that *M. salmoides* in Lake Naivasha does not prefer any particular type of substratum as high and low numbers were recorded from both sandy and muddy substrata.

4.2.5 Distribution in relation to prey fish species

The numbers of *M. salmoides* caught was compared to those of the crayfish, *P. clarkii*, the supposed major food item of the blackbass. The presence of this prey had very little effect on the distribution of the blackbass (Table 9, Fig. 3), probably due to the fact that the fish has changed its feeding habits.

4.3 D i s c u s s i o n

The population of *M. salmoides* in Lake Naivasha is very low as compared to that of the tilapiines.

In North America, Cady (1945) reported that *M. salmoides* in Norris reservoir remained in shallow water all the year round but concentrated at 10 to 20 ft. depth (3 to 6.1 m). Malvestuto (1974) reported that in Lake Naivasha, blackbass occurs mostly in deep papyrus lagoons and very few are found in the littoral zone. On the contrary, Mavuti (1983) reported that the fish is predominant in the littoral zone with a few found in the papyrus lagoon.

The present work has revealed that the fish inhabits a depth range of 1 - 4.5 m with the majority of adults being encountered in shallow waters of 2.5 m deep and less. Morgensen (1982) reported that in North America, the juveniles of this fish occur in shallow sheltered areas while in Lake Naivasha, the juveniles were found in the deeper parts of the lake contrary to the occurrence of the juveniles in North America.

Relating the abundance of the fish to water depth in the different sampling stations, there is an indication that the Crescent Lake has the highest number of blackbass, followed by Safariland. Korongo ranks third, then Hippopoint and, finally Fisherman's Camp. Similar observations were made by Oluoch (1983) during his study on the ecology and the distribution of crayfish in Lake Naivasha.

There was low correlation between temperature and blackbass catches in Lake Naivasha during the present study. On the contrary Dendy (1946) reported that in the temperate regions, temperature seems to play an important role in the distribution of the species and that the fish prefers temperatures of about 80°F (27.9°C). This observation may be due to the sharp seasonality observed in the temperate North America.

There seems to be no reports available on the effects of conductivity on the distribution of the blackbass. The results of the present investigations, however, indicated no relationship between this parameter and blackbass numbers.

M. salmoides does not seem to prefer any particular type of substratum that was why in Lake Naivasha, the fish was found in various types of substrata. Unfortunately, no reports exist on this aspect of the ecology of the fish to afford comparisons.

Similar to the effects of conductivity, substratum and temperature on the distribution of the blackbass in Lake Naivasha, it was found, in the present study, that even the supposedly main diet of the fish, the crayfish did not have any influence on the distribution of M. salmoides. A part from Siddiqui (1977), who only reported the main food of the species as being the crayfish, no other report exist associating the numbers of the predator to the availability of the prey. That the distribution of the blackbass is not related to the distribution of the crayfish may be explained by the fact that the feeding habits of this fish has changed with time and now M. salmoides predates on a number of food items.

4.4 FEEDING ECOLOGY

4.4.1 Food habits

M. salmoides in Lake Naivasha is carnivorous and feeds on a wide variety of food items (Table 10, Fig. 6). In order of abundance, the diet of the adults consists of the following: Crayfish, Procambarus clarkii (Girard) 68.3%), fish juveniles (51.7%), corixids, Micronecta scutellaris (Stal.) (36.1%), frogs, Xenopus sp. (13.3%), chironomids Chironomus sp. (9.1%), aquatic weeds (8.6%) and beetles, Canthydrus notula (Er.) (2.6%). In the juveniles, corixids, M. scutellaris dominated the diet with an occurrence of 98.8%, followed by chironomids, Chironomus sp. with an occurrence of 31.4 %. Crayfish, P clarkii and fish juveniles had an occurrence of 14.5% and 1.8% respectively while aquatic weeds were rarely eaten by the juveniles (0.8%). Frogs, Xenopus sp. and beetles C. notula were never preyed upon by the young fish as it happens in the adults.

4.4.2 Changes in the diet in relation to the size of the fish.

The present research has revealed that the diet of M. salmoides changes with the size of the fish (Table 11, Fig. 7). Young fish of 5 - 9.9 cm size-range feed mainly on insect larvae and adult insects which made up to 64.7% and 28.1% respectively. At a size range of 10 - 14.9 cm, insects seem to be the only food item preferred by the young M. salmoides as evidenced by the occurrence of 90.6% of this item in the stomach. As the juveniles grow (15 - 19.9 cm), insects still dominate the diet with an occurrence of 75%. At this stage, the diet became more diversified since fish juveniles and crayfish appeared in the diet for the first time and accounted for 11% and 15% respectively. Blackbass of size range 20-24.9 cm became more piscivorous with fish juveniles being the dominant food item and accounted for 57%. Insects and insect larvae were also taken but in small quantities. At a size range of 25 - 29.9 cm, adult insects once again dominated the diet of the fish and made up to 56.9% of the diet. This was followed by fish juveniles which made up to 18.1%. The diet of adult blackbass of size range 30-34.9 and above was made up mainly of three food items viz: crayfish, fish juveniles and adult insects in that order.

4.4.3 Monthly variation in the diet composition of M. salmoides

Using the occurrence method of Hynes (1950), the monthly variation in the forage organisms consumed by the blackbass was analysed. The results depicted in Fig. 8 revealed that from September to December, crayfish dominated the diet of the species constituting 55%, 47.5%, 42% and 40% respectively in the stomach of M. salmoides. In January, fish fingerlings made up the highest percentage of 28.5 followed by crayfish with 22.5% occurrence. The trend changed in February when insects constituted the highest percentage (47%), followed by fish fingerlings (28.5%) and aquatic weeds which were least eaten (2.25%). Insects continued dominating the diet in March (51.5%), this was followed again by fish fingerlings and crayfish with percentage occurrences of 20 and 13.5 respectively. The dominance of insects continued into April when they constituted 29% of the diet, followed by crayfish with an occurrence of 29% and fingerlings only constituting up to 11.5% of the diet. In May, the occurrence of fish fingerlings reduced drastically to 2.5% while crayfish also decreased over the April value and constituted 17.5%. On the other hand, the occurrence of insects increased to 47.5%. Insects continued to dominate the diet of this fish in June, July and August, constituting 46%, 44% and 35% respectively. The frog, Xenopus sp. was only encountered in the stomach of the fish from July to December, probably due to the scarcity of other food items.

From the above observations it was concluded that the diet of M. salmoides varies with seasons. During the dry and sunny months lasting from September to December, crayfish dominated the diet. January which is neither wet nor cold saw a high consumption of fingerlings. Insects were preyed upon during wet months lasting from February to June.

4.4.4 Food selection

The results of analysis of food selection in M. salmoides presented in Table 12 and Fig 9 reveal that in Station 1 Table (12(a), Fig. 9(a)), blackbass shows preference for fish fingerlings (E = 0.85) in spite of the fact that fingerlings were present in low quantities in the environment (1.03%). This was followed by Xenopus sp. and P. clarkii which were also present in low quantities in the environment (0.39% and 3.6% respectively) and had electivity indices of 0.52 and 0.50 respectively. Chironomus sp. and M. scutellaris which were abundant in this environment (57.6% and 32.3% respectively) both had negative electivity indices of -0.04 and -0.3. This means that they were never selected by the fish despite their abundance in the environment. However, the beetle, C. notula was both scarce in the environment and was not selected as food (E - -0.2).

The trend changed in Station 2 (Table 12(b), Fig. 9(b)) where P. clarkii became the most preferred food item (E = 0.58) with an occurrence of 4.6% in the environment. This was followed by Xenopus sp. with E value of 0.39 and an occurrence of only 0.37% in the environment. M. scutellaris ranked third (E = 0.26) and a relatively high occurrence in the environment (7.9%). Chironomus sp. which was most abundant (78.04%) was never selected by the fish (E = 0.03) and fish fingerlings were not only present in low quantities in the environment (4.5%) but were also not selected by the fish (E = -0.45).

Similar patterns in food selection were observed in Stations 3 and 4. In the former (Table 12 (c), Fig. 9(c)), fingerlings which were the least represented in the environment (1.16%) were the most preferred food item with an electivity index of 0.88. This was followed by Chironomus sp. which had an abundance of 26.1% in the environment and E value of 0.24. The third position was taken by P. clarkii with an abundance in the environment and electivity index of 11.6% and 0.1 respectively. M. scutellaris which was the most abundant food item in the lake (42.9%) was not sought by the fish (E = -0.40); the same case applied to C. notula with an abundance of 12.7% in the environment and E of -0.55. The frog Xenopus sp. were very few in the environment and were at the same time rejected by the fish. In Station 4 (Table 12(d), Fig.9(d)), fingerlings were still preferred by the fish (E = 0.89). This time M. scutellaris ranked second with E value of 0.57 and third position taken by C. notula (E = 0.47). Xenopus sp. and P. clarkii which were the most abundant in the environment (62.9% and 20.7% respectively were not eaten by the fish at all (E = -1 and -0.03) while Chironomus sp. not only had a low percentage in the environment (3.7%) but were also not sought by the fish.

Station 5 however, depicted a unique picture. Here surprisingly, C. notula was the most preferred food item (E = 0.44) although it was not abundant in the environment (6.15%). This was followed closely by Chironomus sp. with an electivity index of 0.34. P. clarkii was the third preferred food item with an E value of 0.12. The most abundant food item in the environment was M. scutellaris but it was never eaten (E = 0.05) while both Xenopus sp. and fingerlings were also negatively sought by the fish (E =-1). It is probable that the last two food items were not taken by the fish in Station 5 because during this research, the fish caught in this station were mainly juveniles.

From the above results, it was concluded that blackbass does not prey on whatever is abundant in its environment but selects its food items.

4.4.5 Diurnal feeding habits

The results of investigations carried out to elucidate the feeding patterns of the blackbass revealed that M. salmoides is a diurnal feeder but shows increased feeding at dawn, around noon and towards dusk (Table 13, Fig. 10). During this study it was noted that most of the feeding activity takes place at daytime i.e 1600 hrs, 1800 hrs, 0600 hrs and 12 noon when the highest fullness indices of 3.3, 5, 4.3 and 3 were recorded respectively. The species feeds mostly at daytime probably due to poor visibility at night hence takes advantage of the sunlight in its predatory manoeuvres.

4.4.6 Seasonal variation in the feeding activity

Table 14 and Fig. 11 show the monthly variations in the fullness index (FI) potraying the feeding activity of M. salmoides throughout the study period.

From these results, it was observed that the maximum feeding activity occurred in September when the highest FI of 2.91 was recorded. The active feeding continued into October through to February with fullness indices of 2.35 in October, 2.0 in November, 1.92 in December, 2.1 in January and 1.93 in February. The trend changed suddenly in March and April when the least fullness indices were recorded (0.27 and 0.46 respectively). The fullness index showed an increase in May (2.04) reflecting a resurgence in feeding activity, and this continued into June (FI = 2.38). A slight drop in FI was observed in July (1.92) but it quickly picked up again in August (2.0) and culminating in the September maxima.

The observation on monthly variations in the feeding activity was further complemented with monthly records of the numbers of empty stomachs (Table 15, Fig. 12). These results supported the observations made using the fullness index to elucidate seasonal variations in feeding activity. Specifically, March and April had the highest percentage of empty stomachs (62.7% and 65.9%) indicating reduced feeding. June, September and October which had the highest fullness indices were marked by low percentages of empty stomachs (11.53, 12.0 and 15.78 respectively), suggesting active feeding.

4.4.7 Predator - prey relationship

An attempt was also made to relate the size of the blackbass to the size of its main prey organism - the crayfish. It is worth noting here that the sample size for this particular work was small because it was difficult to find in the stomach whole food organisms whose total lengths could be measured.

The results presented in Table 16 and Fig. 13 show a high positive correlation between the size of the predator and that of its prey ($r = 0.90$, $P < 0.001$). The relationship between the size of the predator and that of its prey can be described by the equation:

$$\bar{Y} = -3.22 + 0.376\,\bar{X}, \quad \text{where,}$$

$\bar{Y}$ = mean prey length

$\bar{X}$ = mean predator length

The data was further analysed by calculating 95% confidence limits (C.L) for the mean prey size (7.4 ± 1.5), the sizes of P. clarkii eaten by M. salmoides ranged between 1.5 and 13.4 cm ($P < 0.05$).

4.5 Discussion

Nine years after the last study on the food of the blackbass in Lake Naivasha, considerable changes seem to have taken place in this aspect of the ecology of the species. During his investigations, Siddiqui (1977) observed that about 78% of the gut contents of M. salmoides was made up of the crayfish while insects accounted for 15%

and young tilapia 7% - these were the broad categories of the food upon which the species fed at that time. Presently in addition to the afore-mentioned food categories, frogs and aquatic weeds have been added to the diet. Not only has the blackbass included additional food in its diet, it has also changed the proportions of the food items it consumes.

In the present study, crayfish constituted only 28% of the food in the stomach - a considerable reduction from the 78% observed by Siddiqui (1977). The fish diet of the species as reported by Siddiqui (Op. cit.) consisted only of tilapia and it accounted, as already indicated, for only 7% of the stomach contents. In the present work, apart from tilapia, the young of blackbass itself and also some Barbus constituted the fish diet which in total formed a substantial 24%. The presence of the young blackbass in the stomach of this species indicates a tendency towards cannibalism. Insects constituted only 15% of the stomach contents in Siddiqui's observation while in this research they make up the highest percentage of the diet (38%). The present investigation has also revealed that blackbass feeds on three kinds of insects viz: corixids, M. scutellaris chironomids, Chironomus sp. and the beetle C. notula. Among the three however, corixids were observed to be the most preferred by both juveniles and adults.

On the changes of food habits with size, the only report available is that of Malvestuto (1974). The author observed that up to a length of 20 cm, invertebrates, mainly chironomids and Odonata dominate in the stomach. From a length of 20 to 30 cm, crayfish became abundant and constituted 78% of the gut contents. The present work has revealed the changes in food habits with length up to 49.9 cm. In these results, the juveniles up to a length of 9.9 cm feed mainly on chironomid larvae and corixids. At a length group of 15 - 19.9 cm, the diet of the fish became dominated by corixids while between 20 and 30 cm, fish fingerlings were the major food item taken by the fish. Above 30 cm, the adult blackbass had a varied diet made up of crayfish, corixids, fingerlings and frogs. From the above results, it becomes evident that thirteen years since Malvestuto's observations, even the various sizes-classes of the blackbass have diversified their diet. This general diversification in the diet of the blackbass and the preference of fish of different length groups for particular food types may be seen as an adaptation for maximum utilization of food resources.

Munro (1967) reported the seasonal changes in the diet of a clariid catfish, <u>Clarias gariepinus</u> in Central Africa. The author suggested a fluctuating seasonal availability of food supply as one of the possible causes of this tendency. Okedi (1971 b) reported that the food and feeding habits of five small momyrid fishes in Lake Victoria fluctuated according to the lunar phases while Ogari (1984) observed irregular pattern of foods and feeding habits of Lates niloticus in Lake Victoria. However, in the present work, it has been observed that although blackbass selects its food, it is also a seasonal feeder. Crayfish was mostly abundant in the diet of the fish during the dry months lasting from September to December. Insects made up the highest percentage of food items taken during wet months (February to June). The above results were attributed to the variation in the composition of these food items in the aquatic environment during the different seasons. Despite the diversification in the food habits of M. salmoides just discussed, the study of food selection has revealed that, in Lake Naivasha, the species actually selects its food even from the food items that have been recognised as the materials habitually eaten. The most surprising observation from these studies concern the negative selection for fish fingerlings realized in Station 2 and 5. With regard to Station 5, the negative selection was most probably due to the fact that all the 56 blackbass caught from this station, during the entire duration of the research, were juveniles (see Tables 3 and, 4) and as it has already been established in this research, juvenile blackbass rarely include fish fingerlings in their diet. So far as the negative selection in Station 2 is concerned, it is difficult to explain because adult blackbass were present in the sampling zone in appreciable numbers (73) and fish fingerlings were also available at higher levels in the environment (22.05%).

Summarizing the food selection data presented in Table 12, the overall picture of food selection by M. salmoides in Lake Naivasha may be presented as follows: Out of the different food items upon which blackbass feeds in the lake, Chironomus sp. is present in the greatest quantities followed by M. scutellaris, Xenopus spp., P. clarkii, C. notula and fingerlings in that order. However M. salmoides selects the crayfish first, followed closely by fish fingerlings, chironomids, beetles and corixids are least sought while frogs are negatively selected.

Few authors have reported on the diurnal feeding patterns in fish in tropical waters. Elder (1961) reported that Bagrus docmac locates its feeds at night while the fish prey are asleep. In the same species, Okach (1981) reported that the fish exhibits diurnal feeding habits and that it feeds mainly in the evenings and early mornings. The present research has revealed that the blackbass is a diurnal feeder but shows increased feeding at dawn (at around 6 a.m.), around noon and towards dusk (at around 6 p.m.). The results of this work are in general agreement with those of Moyle and Holzhauser (1978) that M. salmoides feeds throughout the 24-hour period but most foods were consumed during the day.

Studies of monthly variations in the feeding activity revealed that the species feeds actively throughout the year except in March and April, the months which also correspond to minimum spawning. The period from August to January were observed to be the maximum feeding months and it coincided with the period of maximum breeding activity, hence it was concluded that the fish feeds actively during breeding. This active feeding throughout the year was attributed to the probable availability of food items in the aquatic environment all year around.

Many authors have reported on the predator-prey relationship in fish. Hamblyn (1966), Gee (1969), Hopson (1972, 1975a) and Coulter (1976) noted a general increase in predator size. Gee (1969) observed that the proportion of predator body length to prey body length in Lates niloticus was often in the region of 25%, rarely exceeding 30% and possibly, a maximum of 33%. Okedi (1970) in the momyrid fishes and Coulter (1976) in L. niloticus, however, reported the proportion to be 35.6% and 35% respectively. Hopson (1972, 1975a) in L. niloticus, on the other hand, observed that the maximum proportion between prey size and predator size was approximately 50%. In the present work except for one individual fish, the proportion ranged from 20% to 33.7% (Table 16) which does not deviate much from the observations made by the previous authors in other predatory fishes.

The orientation by the fish to prey size which it can handle has been attributed by Hyatt (1979) to upper and lower limits of prey size within which visually - oriented predators will detect and respond to positively. The author reported that a large mouth appear to be an excellent way to increase the size of the prey ingested. Keast and Webb (1966) further suggested that the mouth of fishes is the structure which dictates the size and the structure of the prey taken in. The same authors observed that the shape and the position of the mouth have the potential to influence the quantity and the quality of prey that may be ingested. Reports on the blackbass indicated that the fish can swallow a prey whose maximum depth is equal to the width of the mouth of the species (Lawrence, 1958). The present observation generally agrees with results of the previous workers that as the predator size increases, the size of its prey also increases. This simultaneous increase in size of predator and prey is attributed to the increase in the gape of the mouth as blackbass grows. It was also observed in this work from the limited samples that the size range of P. clarkii at which there was the greatest impact of predation by M. salmoides was 5.8 cm to 8.6 cm.

4.6 REPRODUCTIVE BIOLOGY

4.6.1 Morphology of the testis

The testis of M. salmoides are paired elongated organs in the posterior - dorsal part of the body cavity, lying against the ventral wall of the swim bladder. They are fused posteriorly and a duct leads to the urogenital opening. Anteriorly, they are connected to the swim bladder with two mesorchia. Each testis is covered with connective tissue that extends into the organ on the ventral side.

The immature testis is transparent and ribbon-like but this structure becomes more prominent and turgid during breeding season. The colour of this organ changes to cream with maturation - when the lobes become filled with sperms.

4.6.2 Morphology of the ovary

The female reproductive organs of M. salmoides consist of paired, bilobed ovaries, elongated, nearly circular in cross section.

In immature virgins, the ovary is transparent but it soon becomes translucent and orangish in colour. This organ occupies only a small portion of the dorsal part of the body cavity, but as it matures, it becomes elongated and ventrally placed, pushing the gut and its associated organs dorsally and anteriorly. A fully mature ovary occupies 70 - 80% of the peritoneal cavity. In a mature ovary, the ova are seen through the tunica with unaided eyes.

In M. salmoides, the two lobes of the ovary are usually slightly unequal in size, the left is usually bigger than the right one.

4.6.3 Maturity stages in the male M. salmoides

The process of development of the testis in M. salmoides can be divided into a series of maturity stages based on morphological observations as follows:

Stage 1: Virgin

The testis in this stage is a pair of ribbon-like organ with smooth edges. At this stage, sex differentiation is impossible macroscopically but the male organs are more thread like. The organ occupies about a quarter of the length of the body cavity.

Stage II: Developing virgin

The testis becomes translucent - white and more enlarged than those in Stage 1. At this stage, the sex products are slightly discernible as minute whitish specks. The sex is more discernible in the females than in males.

Stage III: Ripening

The testis at this stage is enlarged, opaque and cream in colour. The organ occupies about half of the body cavity. There is little flow of milt but only with application of considerable pressure to the peritoneum.

Stage IV: Ripe

The testis becomes turgid and very cream in colour. The whole organ becomes greatly enlarged with a distended outer membrane. The organ increases in weight and occupies about two-thirds of the body cavity. It becomes swollen and twisted. At this stage, there is free flow of milt with slight application of pressure on the belly. The organ becomes thick cream in colour and can be stripped easily from the peritoneum. Considerable amount of mesenteric fat become evident.

Stage V: Running/Spent

The testis at this stage is large and flabby. There is free flow of milt even without application of pressure on the belly. There is reduction in mesenteric fat and the individuals show signs of exhaustion. After spawning, the testis of *M. salmoides* returns to Stage II.

4.6.4 Maturity stages in the female *M. salmoides*

The ovarian growth and maturation in the centrarchid *M. salmoides* can be divided into a series of maturity stages described below:

Stage I: Virgin

The ovary at this stage is colourless to translucent. It occupies the posterior quarter of the body cavity. Sex differentiation in these individuals is possible due to the slight thickness of the ovaries compared to the thread like nature of the testis.

Stage II: Developing virgin

At this stage, the ovary becomes translucent and yellowish-brown in colour. It increases in size and individual cells are recognised as white specks within the ovarian cavity. Capillary network surrounding the organ becomes evident.

Stage III: Maturing

The ovaries become opaque, brownish to yellow in colour and occupy more than half of the peritoneal cavity. The capillary network increase and the eggs increase in size.

The whole organ continues to increase in size and becomes distended with thickened walls. This is the beginning of yolk deposition in the eggs. However, no eggs are released even with application of considerable pressure.

Stage IV: Mature (ripe)

At this stage, the ovary attains its maximum size and occupies more than 90% of the peritoneal cavity. The yellow colouration of the organ intensifies and the eggs run out with slight pressure on the belly and the ovarian weight is at its maximum. The ovary becomes surrounded by a heavy network of capillaries.

Stage V: Running/Spent

The ovarian weight decreases, the organ becomes loose and flabby. The ovaries still contain a few residual ova which flow out freely without pressure. The individuals show signs of exhaustion, there is loss of mesenteric fat and vigour. After spawning, the ovaries of M. salmoides return to Stage II and the cycle is repeated.

4.6.5 Seasonal changes in the maturation of the gonads

To gain an insight into the seasonal changes in the reproductive cycle of M. salmoides, the numbers of males and females at each maturity stage in monthly samples were counted and recorded (Table 17). The results which gave a quantitative reflection of frequencies of males and females at various maturity stages throughout the year were used in plotting histograms (Figure 14) depicting those changes.

a) Males

Out of the 18 males caught in October, the majority were in Stage IV (35%) followed by Stage III (22%) while 16.6% of the males in the population were in Stage II and the lowest number (6.6%) were in Stage I. Spent fish were also encountered and they constituted 19.6% of the males in the population. In November, no virgin males (Stage I) were caught, the majority of fish encountered (31%) being in Stage III. The number of spent fish increased in the catches up to 25% and ripe fish (Stage IV) continued to be present though in reduced numbers (18.8%). Stage III males continued to dominate up to December when 42.8% was recorded. During this time, the Stage II males showed a slight increase up to 28.7% while the Stage IV fish reduced slightly to 14.3% which was equal to the Stage V males although for the latter, it represented a considerable drop from the November peak of 25%. Stage I fish dominated the population for the first time in January when they accounted for 26% of the males caught, followed by Stage III males (17.3%) and lastly Stage V males (13.9%). The sudden appearance of Stage I fish in January suggests spawning which might have taken place in earlier months. February showed a turn of events when there was no maturing, mature or spent fish-males, in the population i.e. males in Stages III, IV and V respectively. Majority of fish caught in this month were in Stage II (50%) and the virgin Stage I (37.5%). The virgin males continued to dominate the population in March (66.6%). There were no developing virgins (Stage II) or mature males (Stage IV) while very few males were in Stage III and V (9.1% and 4.5% respectively). The same trend continued in April where 69.2% of the population were virgin males, 15.4% were developing virgins, 3.8% were maturing and 11.5% were spent. No mature males (Stage IV) were encountered in April. In May, the number of virgins went up (75%) while 15% were developing virgins and only 5% were maturing. Again mature and spent fish were absent. This pattern was repeated in June with 45.5% of the males in the population being virgins. Developing virgins, maturing and spent fish were present in equal numbers (33% both), maturing males were absent while mature and spent males were equal (16.7% both). There was another rise of virgin males in August (50%) with equal numbers of developing virgins and mature males (13.6% both). Maturing males were very few (4.5%) while spent males accounted for 18.2 % of the population. In September, the pattern changed completely. Only 2.5% of the population were virgins, developing virgins being absent. Maturing males made up the highest percentage (67.5%), mature fish were present in low numbers (2.5%) while spent fish accounted for 25% of the population.

b) Females

The fluctuation in numbers of female M. salmoides in various maturity stages follows almost the same pattern as that of the males. Out of the 20 females caught in October, 50% were virgins, followed by spent fish which constituted 30% of the females in the population. Maturing and mature females were also encountered and they constituted 5.5% and 14% respectively while developing virgins were absent in the population. The presence of virgin females in this month indicate spawning which might have started in earlier months. In November very few virgin females were encountered (8.8%). The highest group was spent females which constituted 38.7% of the population, followed by developing virgins (23%) while maturing and mature females were present in equal numbers (15% each). In December, spent fish and developing virgins dominated the population. There was an increase in the number of virgins in January to 31% while developing virgins decreased to the same level (31%). The number of spent females dropped drastically equaling the maturing ones (5.2% each) while mature ones constituted 15.8% of the population. In February virgin females dominated the population constituting 40%, followed by developing virgins which accounted for 37.5% of the population and maturing females made up only 15.3% while mature and spent fish were absent. Stage I fish continued their dominance in March constituting 66.7% of the population, followed by very few developing virgins (4.2%) while maturing, mature and spent females were absent. The same trend continued into April when virgin and developing virgins still dominated the population constituting 55.6% and 33.3% respectively. The Stage II fish showed a sudden rise as compared to the 4.2% in the previous month. Mature females reappeared after their disappearance in February constituting 11.1% of the population. No maturing and spent females were encountered in this month. The population of blackbass in May was made up of only virgins and developing virgins constituting 75% and 20% respectively. The dominance of virgins continued into June where they made up 60% of the population followed by developing virgins which constituted 27% while maturing and mature females each made up 6.6% of the population. In July, virgins, developing virgins and maturing females dominated the population in that order constituting 50%, 20% and 15% of the population respectively. Spent fish were also encountered and made up only 5% of the population. All the maturity stages were represented in August. Spent fish were the majority (50%) indicating the beginning of spawning. This was followed by virgins and mature females (15% each) while maturing and developing virgins were also present in equal numbers (5% each). In September, there were no virgins, mature females were the majority (42%) followed by maturing females (28%) while spent and developing virgins both constituted 7.1% of the female population during this month.

From the foregoing, it was concluded in this work that the maximum spawning season of _M. salmoides_ in Lake Naivasha starts around August and continues up to January. March and April appear to be the minimum spawning months.

4.6.6 Minimum size at sexual maturity

From Table 18 and Figure 16, it can be seen that all males up to 14.9cm were immature. Mature males (1.4%) first appeared in the population at a size range of 15-19.9cm. 19.1% of the males were mature at a size range of 20-24.9cm. At a size range of 25-29.9cm, exactly 50% of the male fish in the population were mature. The latter size class was therefore taken to be the minimum size at maturity in the male M. salmoides. All the males beyond 40cm were mature.

In the females (Table 19 and Figure 15), no mature individuals were also encountered up to a size of 14.9cm. At 15-19.9cm size class, 4.5% of the females were mature. 11.5% and 41% of the females in the population were mature at size classes of 20-24.9cm and 25-29.9cm respectively. At a length-class of 30-34.9cm, 50.1% of the females were mature. This size was therefore considered to be the minimum size at sexual maturity in female M. salmoides. All females beyond 45cm were mature.

4.6.7 Seasonal changes in the gonadosomatic index

The seasonal changes in the maturation of the gonads were studied through the analysis of the monthly variations in the gonadosomatic index (GSI) in both sexes throughout the year (Table 20, Figures 16 and 17).

a) Males

The above results show that the lowest GSI in males (0.19) was observed in March suggesting the beginning of the reproductive cycle. A gradual increase followed up to June when a GSI of 1.01 was recorded. After a small drop to 0.71 in July, a sharp increase was observed in August to 2.0. From August, gradual increases were observed up to November when the peak GSI of 2.4 was realized. From December, the GSI started decreasing but it was still quite high (1.5), indicating that spawning was still continuing and lasted till January. The lowest GSI of 0.59 in the male was recorded in February indicating the spent condition.

b) Females

Female M. salmoides showed, qualitatively similar trend in the changes of the GSI to that observed in the males. The only difference were in the actual values. The lowest GSI of 0.35 was also recorded in March while the highest value (2.7) was observed in November as in the males. The lowest GSI of 0.35 recorded in March was followed by a gradual rise up to June when a value of 1.32 was recorded. July saw a small drop to 0.9 followed by a sharp increase in August (2.35). From August through to November, there was gradual but consistent increase in the GSI culminating in a maximum of 2.70. After November, the GSI started decreasing but the December value of 2.0 was still high enough to suggest continuation of spawning until January. February was probably the spent stage with the lowest GSI of 0.66. Overall, the females showed a higher GSI than the males throughout the study period.

4.6.8 Size of maximum reproductive capacity

An attempt was also made to determine the mean annual gonadosomatic index of different length-groups of M. salmoides with the view to elucidating the size of maximum reproductive capacity in both sexes (Table 21, Figures 18 and 19).

In the female M. salmoides, the lowest GSI (0.18) was recorded among the virgins of 5-9.9cm size-class. As the fish entered the developing stage, the GSI increased gradually in the 20-24.9cm size-range fish with a GSI of 1.1. The 25-29.9cm size-class with a GSI of 0.52 was also in the developing stage. As the fish matures i.e. size ranges from 30-34.9cm and 35-39.9cm, the GSI also increased from 1.38 to 3.03. At a size-class of 40-44.9cm, the highest GSI of 6.2 was recorded and these are also ripe fish. The GSI then decreased from 6.2 to 3.22 at a size range of 45-49.9cm, this size range included ripe as well as spent fish. From both the table and the graph, it becomes evident that the size of maximum reproductive capacity for females lies in the size class of 40-49.9cm. As the females increase in size beyond 45-49.9cm, the reproductive capacity also goes down, leading to senescence.

The male M. salmoides followed almost the same pattern of GSI changes as that observed in the females. The virgins (5-9.9cm) had the lowest GSI of 0.2. As the fish enters maturing stage, the GSI increases gradually in the size range of 25-29.9cm. The sharp rise in the GSI up to 1.47 at a size-class of 30-35.9cm was found in the spawning adults. This was therefore considered as the size of maximum reproductive capacity in the males. As the fish increases in size beyond 30-44.9cm size-class, the reproductive capacity goes down as evidenced by the consistently low gonadosomatic index starting from 35-39.9cm length-class.

4.6.9 Breeding grounds

Table 21 and Figure 20 show variations in the gonadosomatic index between sampling stations, a study which was undertaken with the view to determining the breeding grounds of M. salmoides.

The high gonadosomatic indices of 2.67 and 2.04 recorded at stations 1 and 3 respectively for females and 0.64 and 0.57 respectively for males suggest that these two Stations could be the breeding grounds for blackbass.

4.6.10 The relationship between gonadosomatic index and fullness index.

This study was carried out to establish whether there was any relationship between feeding activity and reproduction. (Tables 23 (a & b) and Figures 21 (a & b)).

In the male M. salmoides, it was observed that there was a relatively high positive correlation between GSI and FI ($r=0.79$ $p<0.005$). The lowest GSI of 0.19 recorded in March corresponded to the lowest FI of 0.98. This was followed by a gradual increase in GSI up to September when a value of 2.2 was recorded and this corresponded to the highest FI of 2.0. In October there was a slight drop in GSI but it quickly picked up in November when the highest value of 2.4 was recorded which corresponded to a relatively high FI value of 1.92. The high values in both variables from August to January coincided with maximum spawning period hence it was concluded that the male M. salmoides feeds actively during spawning. Both variables went down during February which is the end of the reproductive cycle, just before the minimum values in March which marks spent/resting stage.

The female M. salmoides followed qualitatively the same pattern in the relationship between FI and GSI. Statistical analysis revealed a higher correlation between these variables than in the males ($r=0.86$, $p<0.001$). The lowest value in both variables was observed in March just like in the males. This was followed by a gradual increase in both the variables up to June when a GSI of 1.32 corresponded to an FI of 2.0. The latter months were considered to be preparatory months when the fish was accumulating energy reserves through feeding and getting ready for spawning. In July there was a slight drop in both variables but they quickly picked up in August up to November when the highest GSI value of 2.7 corresponded to a relatively high value of FI (2.05). Both variable went down in December and January but they were still high enough to suggest spawning. February values were low just before the minimum values in March.

4.6.11 Sex ratio

The analysis of the ratio of males to females in monthly samples of M. salmoides in Lake Naivasha presented in Table 24 revealed that overall, the ratio of males to females in the population of 1:1.05 did not differ significantly from the expected 1:1 ratio (X^2=18.87, d.f.=11 p<0.1)

From Table 25, it is clear that even between sampling stations, the ratio did not differ significantly from the expected 1:1 ratio (X^2=15.13, d.f.=4, p<0.01).

Table 26 also revealed no significant differences in the ratio of males to females relative to size groups (X^2=21.76, d.f.=9, p<.01).

4.6.12 Fecundity

In order to make accurate fecundity estimates, it was first necessary to identify oocytes that were at different developmental stages. This was established by analysing the oocyte diameter frequency distribution for all the maturity stages of M. salmoides. Figure 22 shows the oocyte diameter frequency distribution for all the maturity stages. From this exercise, it was observed that Stage I show unimodal distribution of oocytes since all are at the same stage of development. In Stage II, there is some tendency of bimodal distribution because the oocytes are in the process of development (developing virgins) with residual ones in the ovary. In Stage III, there is a multimodal distribution and this was attributed to the fact that these are maturing fish hence the presence of oocytes at various stages of development, viz: residual oocytes, small-size developing oocytes, middle-size developing oocytes and large-size developing oocytes. The bimodal nature of oocyte distribution typical of ripe ovaries is clearly depicted in Stage IV, which contains only modes of small and large size oocytes with very few intermediate sizes. In Stage V, a unimodal distribution was observed again, typical of spent fish.

In Figure 23, the oocyte frequency distribution of four Stage IV (mature) fish is illustrated. It became evident that these Stage IV oocytes had intermediate size oocytes missing altogether leaving large and small oocytes separated by a gap. These are the two modes which were depicted in the previous figure.

In M. salmoides a small variation in fecundity was observed among fishes of almost the same sizes. The lowest fecundity estimated was 1,300 eggs and was found in a female measuring 28.4cm and weighing 371 g while the highest fecundity of 3,524 eggs was recorded in a fish with a length of 33cm and a weight of 550 g. The mean fecundity from 18 females was 2,203 eggs (Table 27).

The relationship between fecundity and: (i) total body length (cm) (ii) body weight (g) (iii) ovarian weight (g) (iv) egg diameter (mm) are depicted in Figure 24 (a, b, c and d). The corresponding logarithmic equations describing these relationships can be expressed as follows:

(i) $LogF = 4.4 - 0.7468\ LogL$ ($r=0.06$, $p>0.1$)

(ii) $LogF = 2.966 + 0.018\ LogW$ ($r=0.92$, $p<0.001$)

(iii) $LogF = 2.337 + 0.714\ LogOW$ ($r=0.89$, $p<0.001$)

(iv) $LogF = 3.27 - 0.91\ LogED$ ($r=0.-98$, $p<0.001$)

Where,

F = Fecundity

L = Length (cm)

W = Weight (g)

OW = Ovarian weight (g)

ED = Egg diameter (mm)

M. salmoides shows a unique relationship between fecundity and body length. In this species there was no relationship between these variables, fecundity decreasing slightly with increase in length (r=0.06). However, there was a high correlation between fecundity and body weight (r=0.92) as well as a high correlation between fecundity and ovary weight (r=0.89). A negative correlation was again observed between fecundity and egg diameter (r=-98), and this was attributed to the fact that the ovaries of this fish contain oocytes at different developmental stages.

4.6.13 Discussion

In the present studies, both sexes of M. salmoides were classified into five maturity stages. After spawning, the gonads of the species return to Stage II. The observations made on the monthly variations in maturity stages revealed that the greatest numbers of mature and spent fish appear in the population from August and lasted until December. In January mature and spent fish were still present but their numbers underwent considerable reduction. The results are further supported by complimentary studies of the monthly variations in the gonadosomatic index in both sexes. The data clearly show an increased GSI from August to December. The January values although relatively low, were still slightly higher than the pre-spawning values in both sexes. The observations strongly suggest that in M. salmoides, August to December represents the period of maximum spawning which probably continues until January. February represents the spent stage after which, after a resting stage in March, the fish goes through a recovery stage beginning from April which characterises the onset of the next cycle of reproduction.

During his investigations, Malvestuto (1974) observed spawning in the species in Lake Naivasha to occur from September to November i.e. within three months. This observation which differs slightly from what has been made in the present study and also different from reports from North America, makes it possible for some comparisons to be made and some general conclusions to be drawn regarding the spawning rhythm in the species from different regions.

In North America, Stein (1970) reported that spawning of M. salmoides is accomplished from about the middle of May to the end of June i.e. within one and a half months, with increasing water temperature. In the tropics, where water temperatures are relatively higher, especially in the spawning months reported by Malvestuto (1974), the author observed an increase in the spawning duration up to three mohths. But this was observed during the "early" stage after introduction of blackbass into Lake Naivasha. Some 13 years after Malvestuto's study, it has been observed that the spawning duration of M. salmoides in the lake has increased further to six months.

At this stage, it may be inferred that the duration of spawning of blackbass in its natural environment as compared to the tropics is dictated by water temperature which is closely linked to the season of the year. In North America with clear-cut differences in seasons, the duration of spawning in M. salmoides is short (1.5 months) and it coincides with the period of increased water temperature in the spring. In Lake Naivasha, the favourable spawning temperature starting from 21°C and increasing gradually to 25.5°C (See Table 6) probably remains stable for a long time - hence, the increased spawning duration observed.

That temperature and sunny conditions are the triggering mechanism for breeding in blackbass in the tropics was observed in the present work. August to February are sunny and warm months in Naivasha area, these months were characterised by warm temperatures recorded during the sampling period (Table 6). The maximum breeding months (August - January) characterised by high GSI falls within the dry and sunny months, hence the conclusion that extended sunlight and temperature play an important role in influencing breeding in the blackbass. Hyder (1970) working on the cichlid fish, *Tilapia leucosticta* (*Oreochromis leucostictus*) also observed that sunlight and temperatures are the most important factors influencing gonadal development and subsequent breeding in the species in Lake Naivasha.

Favourable temperature has been established as a positive stimulus for breeding in sub-tropical and temperate fish species. There appeared to be total cessation of spawning activity in the Nile perch *Lates niloticus* from December to February, the winter period in Lake Chad (Hopson, 1972). Spawning activity in *Tilapia zillii* in Lake Quarun is controlled by and limited to 5 months during summer temperatures of 31°C (El-Zarka, 1961). From the above studies, the important role played by temperature and sunlight in influencing breeding in both tropical and temperate fish species is evident.

From the foregoing, it may be concluded that the main difference in the reproductive pattern of *M. salmoides* in its natural environment as compared to its relatives introduced into Lake Naivasha, is in the duration of spawning which, in the latter, has increased to six months as compared to 1.5 months in the former. Increasing water temperature and sunny conditions probably serve as the factors triggering spawning in the species in Lake Naivasha.

The minimum size at sexual maturity in M. salmoides has been a subject of considerable controversy. Thirteen years ago, Malvestuto (1974) observed the size at first maturity to be 22.6cm. Three years later, Siddiqui (1977) reported that the minimum size at sexual maturity in the blackbass was 30.5cm. These authors reported their findings indiscriminate of the sexes and not taking into account the variations in the rate of maturation in males and females. The present work however, has revealed that the minimum size at sexual maturity for females fall in the size-class of 30-34.9cm while males mature at a smaller size of 25-29.9 cm. Similar observations were made by James (1942) in North America where females were observed to mature at 25cm while males matured at a smaller size of 22cm. From these investigations, it can be seen that with time, M. salmoides in Lake Naivasha is maturing at a bigger size. This observation has a dual significance - management and economics. Fishing from the proper management point of view, will have to be done soon after spawning when the fish available to the fishery have attained large marketable size with high economic returns.

Studies of variations in the gonadosomatic index with the size of the fish revealed that the size of maximum reproductive capacity in the female M. salmoides lies in the size-class of 40-44.9cm. Beyond this size-class, the reproductive capacity went down as was indicated by the fall in the gonadosomatic index leading to senescence. The male M. salmoides was observed to attain maximum reproduction at a smaller size-class of 30-34.9cm beyond which there was a reduction in the gonadosomatic index leading to senescence. Unfortunately no reports exist on this aspect of the reproductive biology to afford comparisons.

The breeding grounds of M. salmoides in Lake Naivasha has not been established in this work. This is due to the fact that most ripe adults were caught at Crescent Island Lake and Safariland while fingerlings were found towards the northern end of the lake. Crescent Island is a rocky area while Safariland has a muddy substratum. Towards the northern end of the lake, Hippopoint is rocky while Fisherman's camp is muddy (see Table 8). It therefore remained a mystery as to the type of substratum that blackbass prefers for spawning.

Markus (1932) reported that M. salmoides does not feed during spawning since most of the spawners had empty stomachs. Contrary to the above observation, the present work has revealed that there is increased feeding activity during spawning as evidenced by the high gonadosomatic index and the fullness index in both sexes although females showed a higher correlation than males. Ogari (1984) also observed that in the tropical species, Lates niloticus, feeding activity increased during spawning season as evidenced by the high percentage of full stomachs during spawning months.

It is probable that feeding activity increased before and during spawning to accumulate and ensure the availability of energy for the on-coming activity (spawning) and also to replace the energy lost during spawning.

In the present work, the monthly variations in sex ratio, sex ratio within length-classes and sex ratio between habitats did not differ from the expected 1:1. However, Bryant and Houser (1971) reported the preponderance of males over females as the blackbass advances in age. The authors noted that at any given time there were usually more males than females on the spawning grounds.

On fecundity, Bishop (1968) reported that in North America, the ovaries of ripe blackbass contain 2,000 to 145,000 eggs. The author also observed that fecundity appeared to be directly related to condition of the fish. In his paper on the study of the largemouth bass population in Lake Washington, Stein (1970) estimated fecundity to range from 7,365 to 46,143 eggs - and stated that fecundity may decrease after seven years. In Lake Naivasha, the present work has revealed that fecundity only ranged from 1,300 - 3,524 eggs with a mean of 2,203 eggs.

From the above observations, it is evident that equatorial species of the blackbass have very low fecundity as compared to that of their temperate counterparts. This is probably due to the effect of latitude, the temperate species growing slowly and attaining sexual maturity at sizes much larger than their equatorial relatives, hence higher fecundity in the temperate species as compared to the equatorial ones.

In this work fecundity showed negative correlation with body length which agrees with the observation of Stein (1970) that fecundity decreases with age. However, there was a high correlation between fecundity and body weight as well as fecundity and ovarian weight but fecundity and egg diameter showed a negative correlation.

4.8 Length-Weight relationships

Table 28 (a and b) and Figure 25 (a and b) illustrate the logarithmic length-weight relationship of *M. salmoides* on monthly basis. The two graphs illustrate essentially similar growth patterns for both sexes. The linear regression equations describing these relationships are as follows:

(i) Females

$$\text{Log}W = -2.15 + 3.243\ \text{Log}L\ (r=0.86,\ n=231)$$

(ii) Males

$$\text{Log}W = -2.491 + 3.420\ \text{Log}L\ (r=0.83,\ n=219)$$

Appendix 2 shows analysis of variance table for the above results.

4.9 Discussion

From the expected results of regression coefficients in length-weight relationships in fishes (Le Cren, 1951; Frost and Kipling, 1967; Bagenal, 1978), pointed out that an ideal fish change their shape as they grow (Martin, 1949) and so a cube relationship between length and weight would hardly be expected.

Bailey (1972) found out that in Northobranchius guentheri, the value of "b" was 3.34 in the males and 3.76 in the females. The author concluded that in this species both sexes exhibit an allometric growth and males grow larger than females. In the present study, the value of "b" for the males was 3.243 and for the females was 3.420. It was therefore concluded that both male and female M. salmoides exhibit allometric growth and that the two sexes grow at almost the same rate.

4.10 Condition factor (K)

4.10.1 Monthly variation in condition factor

The mean monthly variation in the condition factor of M. salmoides in Lake Naivasha show almost the same pattern of fluctuation for both sexes (Table 29, Figures 26 and 27).

In females, the lowest 'K' value of 1.10 was observed in July. This was followed by a gradual rise from August up to December, with the maximum value of 1.80 recorded in November. In January there was a sudden drop to 1.23 and this was followed by a slight rise in February (1.47). A gradual decrease followed again up to May with a sudden rise in June (1.43), just before the lowest value in July.

Male M. salmoides exhibited a similar pattern of fluctuation as that of females (Figure 28). The lowest 'K' value of 1.35 was also recorded in July. This was again followed by a gradual rise up to December when the highest value of 1.83 was recorded. From January, the trend of rise and fall was similar to that of females.

On the whole, males showed a higher value of 'K' (mean=1.53) than females (mean=1.42) hence males were in better condition than females. It was noted that both sexes showed high 'K' values during spawning months (August - December). However, the difference in mean 'K' value between males and females was not significant ($p<0.1$).

4.10.2 The Relationship between condition factor and gonadosomatic index

An attempt was made to relate condition factor to GSI with the view to elucidating whether the condition of the fish affects its reproductive capacity or vice versa (Table 30 a & b and Figures 28 & 29). It was surprising that males which were generally in better condition showed low correlation between GSI and 'K' factor ($r=0.59$, $p<0.05$) while females showed a higher correlation ($r=0.72$, $p<0.01$), indicating that at the pre-spawning stage, females seemed to be in better condition than males.

4.10.3 The relationship between condition factor and fullness index

High condition factor is usually associated with active feeding (Le Cren, 1951). This study was therefore carried out to investigate any relationship between condition factor and the nutritional status of the fish. The present work confirms observations made by Le Cren (Op. cit.) that good condition means active feeding (Table 31, Figure 31). The results showed a high positive correlation between 'K' factor and FI ($r=0.84$, $p<0.001$).

4.10.4 Discussion

Most fish species have been reported to exhibit fluctuating cycle of condition which, apart from reflecting the reproductive state of the fish also reflect its feeding state (Le Cren, 1951; Frost and Kipling, 1967; Hopson, 1975; Dadzie and Wangila, 1980 and Nair *et al*., 1983). Le Cren (op. cit.) pointed out that the seasonal cycle in condition factor was related to age, size, feeding and reproductive condition of the fish. Hopson (1975) reported an increase in the condition factor with fish size in Lake Turkana nile perch while Dadzie (1985) reported that the relative condition of *Labeo cylindricus* in Lake Kamburu shows monthly fluctuations without marked differences in sexes. The author further observed that both males and females reach maximum condition at the beginning of the spawning season.

In the present study, the monthly fluctuations in condition factor of male and female *M. salmoides* followed the same pattern. Both sexes were observed to reach maximum condition during the spawning season. However, males showed better condition than females throughout the study period.

The relationship between condition factor and reproductive cycle showed low correlation in males but a higher correlation in females. Female M. salmoides attain a higher condition during spawning than males. Feeding activity and condition factor were highly correlated in this work, confirming the observation made by Le Cren (1951) that good condition means active feeding.

4.11 Parasitism

The parasitic nematode, Contracaecum sp. has been reported to infest mainly Oreochromis leucostictus (Malvestuto, 1975). During the execution of this study, this nematode was observed also in M. salmoides although the rate of infestation was low. During the survey period, only about 15.5% of the total numbers of fish examined were infested (Table 32). Station 3 (mean depth 2.5±1) had the highest incidence of infestation (27.1%). This was followed by Station 2 (mean depth 2.0±0.6) with 18.6% infestation while Station 5 (mean depth 4.5±1.9) had no cases of Contracaecum. This led to the conclusion that the rate of infestation was higher in shallow than in deeper waters.

A noteworthy point in this investigation was that the parasite was observed only around the gastric lining of the stomach and not in the gills like was observed in Oreochromis (Malvestuto op. cit.).

Table 33 and Figure 30 show the relationship between the size of the fish and the rate of infestation. The table shows that young blackbass were not infested by the parasite but as the fish grows, the rate of infestation increases.

Statistical analysis confirmed this observation ($r=0.84$, $p<0.01$). It was concluded that young blackbass are not infected since they do not feed on young tilapia. The adults get the infection through feeding on young tilapia which are bottom feeders and are infected with the eggs of this nematode (Muchiri, 1987). Besides, the rate of infestation was observed to be high between the size-classes of 20-24.9cm to 35-39.9cm, sizes at which the fish was found to be more piscivorous.

4.12 Discussion

The rate of infestation of M. salmoides by the nematode Contracaecum sp. in Lake Naivasha is very low as compared to that of Oreochromis leucostictus (Malvestuto, 1975). This is due to the fact that although M. salmoides is not a bottom feeder, it nevertheless gets infected when it feeds on the tilapia bottom-feeding juveniles which are infected. This fact was supported by the observation that M. salmoides was infected only around the lining of the stomach and not the gills like Oreochromis.

The rate of infestation by nematode was observed to be highly correlated with the size of the fish. This was attributed to the fact that the juveniles are not piscivorous but as they grow, young tilapia are consumed as part of their fish diet.

CHAPTER 5: GENERAL CONCLUSIONS

1. Blackbass population in Lake Naivasha is very low as compared to that of tilapiines.

2. *M. salmoides* has a narrow area of distribution in the lake and it is found between depths of 1 - 4.5m in the shallow, warmer waters.

3. Depth is the major parameter determining the distribution of the fish in the lake, the numbers decreasing with increase in depth.

4. The young blackbass (juveniles) feed mainly on corixids and chironomid larvae while adults feed on a wide range of food items viz: insects, crayfish, fish fingerlings, frogs and aquatic weeds.

5. *M. salmoides* is a diurnal feeder but shows increased feeding activity at dawn, around noon and towards dusk.

6. *M. salmoides* showed increased feeding from August to February.

7. Blackbass in Lake Naivasha is an annual spawner with breeding maxima extending from August to January.

8. Males mature at a smaller size of 25-29.9cm length-class while females mature at a larger size of 30-34.9cm length-class.

9. Males and females are generally present in a ratio of 1:1 throughout the year.

10. Mature fish of both sexes ranging between 25.0cm and 49.9cm lengths are characterised by the highest gonadosomatic index, indicating the size of maximum reproductive capacity.

11. Blackbass in Lake Naivasha feeds during the spawning period but females feed more actively than males.

12. Fecundity in the species ranged from 1,300 eggs to 3,524 eggs with a mean of 2,203 eggs and it correlated positively with body weight and ovarian weight but negatively with body length and egg diameter.

13. The equation for the length-weight relationship revealed that growth in both sexes of M. salmoides is allometric.

14. Male M. salmoides showed generally better condition than females.

15. There was a higher correlation between GSI and condition factor in females than in males.

16. 'K' factor and feeding activity also showed a high positive correlation.

17. There was low incidence of nematode, Contracaecum sp. infestation in M. salmoides.

18. The rate of infestation increased with fish size and they were mainly infested around the gastric wall.

TABLES

Table 1. Lake Naivasha annual fish productions (metric tonnes)

Year	Oreochromis/ Tilapia	M. salmoides	Contribution of M. salmoides to total fish yield
1976	67.2	10.4	13.4
1977	48.4	23.0	32.2
1978	225.4	29.5	11.6
1979	450.3	32.5	6.7
1980	452.5	18.8	3.8
1981	265.1	3.8	1.4
1982	339.1	13.0	3.7
1983	534.6	41.0	7.1
1984	212.7	64.2	23.2
1985	146.8	58.1	28.4
1986	398.2	81.1	17.0

Data from Government of Kenya - Fisheries Department.

Table 2. Relative abundance of blackbass

Month	Percentage contribution: Tilapiines		Blackbass		Barbus	
October	72	(114*)	19	(38)	9	(18)
November	75	(119)	24	(38)	1	(2)
December	87	(339)	10	(39)	3	(12)
January	83.5	(220)	16	(42)	0.5	(1)
February	82	(167)	17.5	(36)	0.5	(1)
March	90	(644)	9.5	(68)	0.5	(4)
April	74	(125)	26	(43)	0	(0)
May	75	(104)	25	(36)	0	(0)
June	82	(118)	18	(26)	0	(0)
July	79	(60)	21	(16)	0	(0)
August	71.1	(104)	28.9	(42)	0	(0)
September	80.5	(103)	19.5	(25)	0	(0)

*Figures in parentheses indicate the number of fish.

Table 3. Distribution of *M. salmoides* in relation to water depth.

Station	Depth (m) ± SD	No. of blackbass
Crescent Lake	1.0±1.6	124
Hippopoint	2.0±0.6	97
Safariland	2.5±0.1	118
Korongo	3.0±0.4	80
Fisherman's Camp	4.5±1.9	56

Table 4. The effect of depth on the distribution of adult and juvenile blackbass.

Station	Depth (m) ± SD	No. of adults	No. of juveniles
Crescent Lake	1.0±1.6	114	10
Hippopoint	2.0±0.6	73	24
Safariland	2.5±0.1	100	18
Korongo	3.0±0.4	58	22
Fisherman's Camp	4.5±1.9	-	56

Table 5. Variation of blackbass numbers with temperature.

Station	Mean temp (^{o}C) $\pm$ SD	No of blackbass
Crescent Lake	21.0 $\pm$ 0.65	124
Hippopoint	21.75 $\pm$ 0.10	97
Safariland	22.5 $\pm$ 0.85	118
Korongo	21.0 $\pm$ 0.65	80
Fisherman's Camp	22.0 $\pm$ 0.35	56

Table 6. Monthly variations in blackbass numbers with variation in water temperature

Month	Mean temp(°C) ± SD	No of blackbass
October	25.5 ± 3.0	38
November	25.0 ± 2.5	38
December	23.5 ± 1.0	39
January	24.75± 2.25	42
February	23.2 ± 0.7	36
March	19.5 ± 3.0	68
April	21.5 ± 1.0	44
May	21.6 ± 1.9	36
June	22.0 ± 0.5	26
July	20.5 ± 3.0	16
August	21.1 ± 2.4	42
September	22.5 ± 0.0	25

Table 7. Monthly variations in blackbass numbers with variation in conductivity.

Month	Mean conductivity(umohs) ± SD	Numbers of blackbass
October	380 ± 11.25	38
November	390 ± 1.25	38
December	380 ± 11.25	39
January	400 ± 8.75	42
February	410 ± 18.75	36
March	415 ± 41.25	68
April	350 ± 21.25	44
May	380 ± 11.25	36
June	400 ± 8.75	26
July	415 ± 23.75	16
August	400 ± 8.75	42
September	420 ± 28.75	25

Table 8. Relationship between the nature of substratum and blackbass numbers.

Station	Nature of substratum	Number of blackbass
Crescent Lake	Sandy	124
Hippopoint	Sandy	97
Safariland	Muddy	118
Korongo	Muddy	80
Fisherman's Camp	Sandy	56

Table 9. Distribution of the blackbass in relation to prey availability.

Station	Number of blackbass	No. of crayfish
Crescent Lake	124	59
Hippopoint	97	44
Safariland	118	98
Korongo	80	158
Fisherman's Camp	56	100

Table 10. The mean percentage frequency of occurrence of different food items in the stomach of *M. salmoides*

Food item	Percentage occurrence ± SD	
	Adults	Juveniles
Crayfish, *P. clarkii*	68.3 ± 37.4	14.5 ± 6.5
Fish fingerlings	51.7 ± 25.3	1.82 ± 19.3
Corixids, *M. scutellaris*	36.1 ± 9.9	98.0 ± 77.9
Chironomids, *Chironomus* sp.	9.1 ± 17.3	31.4 ± 10.3
Beetles, *C. notula*	2.6 ± 23.4	0.0 ± 21.1
Frogs, *Xenopus* sp.	13.3 ± 13.1	0.0 ± 21.1
Aquatic weeds	8.6 ± 17.8	0.8 ± 20.3

Table 11. The changes in food habits of *M. salmoides* in relation to size.

		Percentage occurance of food items					
Length class	No. of fish	Crayfish	Finger-lings	Aquatic weeds	Insects	Frogs	Insect larvae
1 - 4.9	0	0	0	0	0	0	0
5 - 9.9	69	-	-	-	28.1	-	64.7
10 - 14.9	66	-	-	8.3	90.6	-	-
15 - 19.9	23	15.0	10.6	-	75.0	-	-
20 - 24.9	47	-	57	-	10.3	-	11.2
25 - 29.9	71	18.1	56.9	-	20.1	-	-
30 - 34.9	47	42.5	19.0	-	23.0	-	-
35 - 39.9	68	50	37.0	-	11.9	-	-
40 - 44.9	41	42	35	-	-	8.4	-
45 - 49.9	57	23	-	10.1	5.0	-	-

Table 12. Food selection by blackbass from different sampling stations.

Note: E = Electricity Index.

a) Station 1.

Food item	% in the gut	% in the environment	E.
Procambarus clarkii	11	3.59	0.50
Micronecta scutellaris	18.34	32.29	-0.27
Fingerlings	12.84	1.027	0.851
Canthydrus notula	3.66	5.13	-0.16
Xenopus sp.	0.92	0.385	0.519
Chironomus spp.	53.21	57.55	-0.039

b) Station 2.

Food item	% in the gut	% in the environment	E.
Procambarus clarkii	17.09	4.61	0.575
Micronecta scutellaris	13.67	7.90	0.26
Fingerlings	1.70	4.45	-0.45
Canthydrus notula	5.98	4.98	0.091
Xenopus spp.	0.85	0.37	0.39
Chironomus spp.	60.68	78.04	0.03

c) Station 3.

Food item	% in the gut	% in the environment	E.
Procambarus clarkii	15.17	11.64	0.13
Micronecta scutellaris	19.64	46.70	-0.40
Fingerlings	18.75	1.16	0.88
Canthydrus notula	3.75	12.67	-0.55
Xenopus spp.	0	1.68	-1
Chironomus spp.	42.85	26.13	0.24

d) Station 4.

Food item	% in the gut	% in the environment	E.
Procambarus clarkii	19.23	20.7	0.04
Micronecta scutellaris	36.53	9.88	0.57
Fingerlings	15.38	0.87	0.89
Canthydrus notula	5.76	2.04	0.47
Xenopus spp.	0	62.88	-1
Chironomus spp.	23.07	3.73	-0.46

e) Station 5.

Food item	% in the gut	% in the environment	E.
Procambarus clarkii	4.16	5.26	0.116
Micronecta scutellaris	33.3	37.63	-0.05
Fingerlings	0	22.05	-1
Canthydrus notula	12.5	6.51	0.44
Xenopus spp.	0	4.51	-1
Chironomus spp.	50.0	24.08	0.34

Table 13. Diurnal changes in the feeding habits of blackbass.

Time (hrs)	No. of fish	Full	Stomach 3/4	fullness 1/2	index 1/4	Empty
1400	40	-	20	40.9	-	31.1
1600	27	5.9	64.7	-	23.5	5.9
1800	49	77.5	20.4	2.0	-	-
2000	34	-	57.1	28.6	-	-
2200	55	-	-	-	20	80
2400 (midnight)	21	-	-	18.2	-	81.8
0200	45	-	-	6.7	-	86.6
0400	50	-	20	15.8	40	19.7
0600	38	67	20.3	2.8	7.7	2.8
0800	23	15.4	7.4	15.7	7.1	55.6
1000	28	-	-	5	5	90
1200 (noon)	19	51	-	24.8	10	14.2

Table 14. Monthly variations in the feeding activity of the blackbass.

Month	FI* ± SD
October	2.35 ± 0.5
November	2.0 ± 0.15
December	1.92 ± 0.07
January	2.10 ± 0.25
February	1.93 ± 0.08
March	0.27 ± 1.58
April	0.46 ± 1.93
May	2.04 ± 0.19
June	2.38 ± 0.53
July	1.92 ± 0.07
August	2.0 ± 0.15
September	2.91 ± 1.06

*FI = Fullnes index

Table 15. Monthly variations in the percentage of empty stomachs.

Month	No. of fish	No. of empty Stomachs	% No. of empty Stomachs
October	38	6	15.78
November	38	8	21.05
December	39	4	10.25
January	42	10	23.8
February	36	7	19.4
March	68	32	47.08
April	44	29	65.9
May	36	8	22.2
June	26	3	11.53
July	16	5	31.25
August	42	12	28.6
September	25	3	12.0

Table 16. The relationship between the size of the blackbass and the size ofits prey (crayfish).

Size of blackbass (cm)	Size of prey (cm)	Proportion of predator to prey size
14	1.5	10.7
15	3.0	20
21	5.8	27.6
24	6.0	25
25	6.2	24.8
29	8.0	27.5
31	8.6	27.7
34.5	11.0	31.8
35	11.8	33.7
34	7.5	22.2
28	5.0	17.9
37	8.5	22.9
40	13.4	33.5

Table 17. Monthly variations in the number of *M. salmoides* at different maturity stages.

Month	Sex	Maturity stages (%) I	II	III	IV	V	Number of fish
October	M	6.6	16.6	22.2	35	19.6	18
	F	50	-	5.5	14	30	20
November	M	-	25	31	18.8	25	13
	F	8.8	23	15	15	38.7	25
December	M	-	28.7	42.8	14.3	14.3	17
	F	20	40	-	-	40	22
January	M	26	17.3	21.7	17.3	13	23
	F	31	31	5.23	15.8	5.23	19
February	M	37.5	50	-	-	-	20
	F	40	37.5	15.3	-	-	16
March	M	66.6	-	9.09	-	4.5	22
	F	66.6	4.2	-	-	-	46
April	M	69.2	15.4	3.8	-	11.5	26
	F	55.6	33.3	-	11.1	-	18
May	M	75	15	5	-	-	16
	F	75	20	-	-	-	20
June	M	45.5	9.09	9.09	18.2	9.09	15
	F	60	27	6.6	6.6	-	11
July	M	33	33	-	16.7	16.7	10
	F	50	20	15	-	5	6
August	M	50	13.6	4.5	13.6	18.2	22
	F	15	5	5	15	50	20
September	M	2.5	67.5	2.5	25	-	14
	F	-	7.1	28	42	7.1	8

Table 18. Distribution of male M. salmoides of different sizes into maturity stages.

Size class	No. of fish	I	II	III	IV	V
1 - 4.9	0	-	-	-	-	-
5 - 9.9	34	100	-	-	-	-
10 - 14.9	32	76.5	33.4	-	-	-
15 - 19.9	11	54.5	44.1	1.4	-	-
20 - 24.9	17	33.6	47.3	19.1	-	-
25 - 29.9	25	-	31.3	27.6	16.3	6.1
30 - 34.9	24	-	25	2.	15	40
35 - 39.9	48	-	4.8	24.2	37.1	27.9
40 - 44.9	20	-	-	34.1	10.7	52.2
45 - 49.9	8	-	-	27.2	30.5	42.3

Table 19. Distribution of female M. salmoides of different sizes into maturity stages.

Size class	No. of fish	Percentage number of different maturity stages				
		I	II	III	IV	V
1 - 4.9	0	-	-	-	-	-
5 - 9.9	35	100	-	-	-	-
10 - 14.9	34	67.3	32.1	-	-	-
15 - 19.9	12	56.6	38.9	4.5	-	-
20 - 24.9	19	-	89.9	11.5	-	-
25 - 29.9	46	-	60.0	31.5	6.0	-
30 - 34.9	23	-	48.5	20.1	20.8	9.6
35 - 39.9	20	-	-	47.6	22.1	10
40 - 44.9	21	-	5	-	45	50
45 - 49.9	10	-	-	72.8	-	27.2

Table 20. Monthly variations in the gonadosomatic indices of male and female M. *salmoides*

Month	Females GSI±SD	Males GSI±SD
March	0.35±1.14 (20)*	0.19±0.78 (18)*
April	0.50±0.99 (25)	0.31±0.91 (13)
May	0.95±0.54 (22)	0.79±0.43 (17)
June	1.32±0.17 (19)	1.01±0.21 (23)
July	0.90±0.59 (16)	0.71±0.51 (20)
August	2.35±0.86 (46)	2.00±0.78 (22)
September	2.41±0.92 (18)	2.20±0.98 (26)
October	2.57±1.08 (20)	2.00±0.78 (16)
November	2.70±1.21 (11)	2.40±1.18 (15)
December	2.00±0.51 (6)	1.50±0.28 (10)
January	1.26±0.23 (20)	1.01±0.21 (22)
February	0.66±0.83 (8)	0.59±0.63 (14)

* Figures in parenthesis indicate the number of fish sampled.

Table 21. Mean annual gonadosomatic index between length groups of *M. salmoides*.

Size class (cm)	Gonadosomatic index ± SD Males	Females
1 - 4.9	-* (0)	- (0)
5 - 9.9	0.20±0.40 (34)**	0.18±1.90 (34)**
10 - 14.9	0.33±0.27 (32)	0.25±1.84 (34)
15 - 19.9	0.56±0.04 (11)	0.40±1.68 (12)
20 - 24.9	0.47±0.13 (17)	1.10±0.98 (30)
25 - 29.9	0.50±0.10 (25)	0.52±1.58 (46)
30 - 34.9	1.47±0.87 (24)	1.38±0.70 (23)
35 - 39.9	0.95±0.35 (48)	3.03±0.95 (20)
40 - 44.9	0.82±0.22 (20)	6.20±4.12 (21)
45 - 49.9	0.66±0.06 (8)	3.22±1.14 (10)

* - means that data for 1 - 4.9 length class was not included since this represents young virgin fish the sex of which is difficult to ascertain.

** - Figures in parenthesis indicate number of fish sampled.

Table 22. Variations of GSI of M. salmoides between sampling stations

Sampling Station	Gonadosomatic index ± SD Males	Females
1	0.64±0.28 (50)*	2.67±1.13 (68)*
2	0.21±0.17 (45)	0.70±0.16 (30)
3	0.57±0.19 (58)	2.04±0.50 (64)
4	0.32±0.06 (30)	1.01±0.53 (49)
5	0.19±0.19 (36)	0.29±1.25 (20)

* - Figures in parenthesis indicate number of fish sampled.

Table 23(a). A comparison of the mean monthly gonadosomatic index and fullness index in the male M. salmoides.

Month	GSI±SD	FI±SD
October	2.00±0.78 (36)*	1.14±0.30
November	2.40±1.18 (26)	1.92±0.48
December	1.50±0.28 (16)	1.73±0.29
January	1.01±0.21 (42)	1.10±0.34
February	0.59±0.63 (25)	1.01±0.43
March	0.19±0.78 (38)	0.98±0.46
April	0.31±0.92 (38)	1.05±0.39
May	0.79±0.43 (39)	1.25±0.19
June	1.01±0.21 (42)	1.61±0.17
July	0.71±0.51 (36)	1.70±0.26
August	2.00±0.78 (68)	1.82±0.38
September	2.20±0.98 (44)	2.00±0.56

* Figures in parenthesis indicate the number of fish sampled.

Table 23(b). A comparison of the mean monthly gonadosomatic index and fullness index in the female *M. salmoides*.

Month	GSI±SD		FI±SD
October	2.57±1.08	(36)*	2.29±0.41
November	2.70±1.21	(26)	2.05±0.17
December	2.00±0.51	(16)	2.10±0.22
January	1.26±0.23	(42)	1.90±0.02
February	0.66±0.83	(25)	1.44±0.44
March	0.35±1.14	(38)	1.04±0.84
April	0.50±0.99	(38)	1.31±0.57
May	0.95±0.54	(39)	1.80±0.08
June	1.32±0.17	(42)	2.00±0.12
July	0.90±0.59	(36)	1.94±0.06
August	2.35±0.86	(68)	2.34±0.46
September	2.41±0.92	(34)	2.40±0.52

* Figures in parenthesis indicate the number of fish sampled.

June Table 24. Monthly variation in the sex ratio of *M. salmoides*

Month	Males	Females	Ratio (M:F)	X^2
October	18	20	1.0 : 1.1	0.105
November	13	25	1.0 : 1.9	3.590
December	17	22	1.0 : 1.3	0.640
January	23	19	1.2 : 1.0	0.381
February	20	16	1.3 : 1.0	0.449
March	22	46	1.0 : 2.0	8.471
April	26	18	1.4 : 1.0	1.455
May	16	20	1.0 : 1.3	0.444
June	15	11	1.4 : 1.0	0.615
July	10	6	1.7 : 1.0	1.000
August	22	20	1.1 : 1.0	0.095
September	14	8	1.8 : 1.0	1.636
	219	231	1.0 : 1.05	18.876

Table 25. Sex ratio in relation to habitats (Sampling stations)

Sampling Station	Males	Females	Ratio (M:F)	X^2
1	58	64	1.0 : 1.3	0.290
2	45	30	1.4 : 1.0	3.000
3	50	68	1.0 : 1.4	2.741
4	31	49	1.0 : 1.63	4.560
5	36	20	1.8 : 1.0	4.572
	219	231	1.0 : 0.98	15.130

Table 26. Sex ratio in relation to size-classes of *M. salmoides*

Size class (cm)	Males	Females	Ratio (M:F)	χ^2
1 - 4.9	0	0	0	0
5 - 9.9	34	35	1.0 : 1.02	0.028
10 - 14.9	32	34	1.0 : 1.06	0.060
15 - 19.9	11	12	1.0 : 1.09	0.040
20 - 24.9	17	30	1.0 : 1.76	3.590
25 - 29.9	25	46	1.0 : 1.84	6.200
30 - 34.9	24	23	1.04: 1.0	0.040
35 - 39.9	48	20	2.4 : 1.0	11.520
40 - 44.9	20	21	1.0 : 1.05	0.048
50 - 49.9	8	10	1.0 : 1.25	0.220
	219	231	1.0 : 1.10	21.760

Table 27. The relationship between fecundity and: (i) body-length (ii) body-weight (iii) ovarian-weight (iv) egg-diameter.

Serial No. of fish	Total body length (cm)	Body weight(g)	Mean egg diameter(mm)	Ovarian weight(g)	Fecundity
1	36.5	710	0.64	25.8	1573
2	39.0	955	0.81	20.6	1463
3	33.0	1550	0.63	46.7	3524
4	29.0	1335	0.49	35.0	2882
5	30.1	1038	0.58	28.5	2821
6	37.2	716	0.64	29.0	2090
7	29.5	1486	0.53	39.5	3215
8	28.4	371	0.51	9.5	1300
9	30.0	1413.5	0.52	31.0	2983
10	28.5	460	0.53	13.5	1634
11	31.0	1200	0.50	27.0	2375
12	28.0	1375	0.54	38.2	3186
13	27.5	1170	0.51	24.0	2625
14	32.5	630	0.51	14.8	1369
15	37.2	750	0.74	21.0	1988
16	31.5	472	0.71	18.4	1600
17	34.5	675	0.72	16.0	1571
18	27.0	460	0.46	15.0	1450

Table 28(a). Monthly length-weight relationship of male *M. salmoides*.

Month	No. of fish	Mean length ± SD (cm)	Mean weight(g)	Log a intercept	b regr. coeff.	r correlation
October	18	23.1±4.2	563.5	-2.470	3.502	0.991
November	13	29.5±2.2	492	-1.648	2.925	0.988
December	17	28.3±0.98	401.6	-2.322	3.380	0.871
January	23	27.1±0.26	329.4	-2.143	3.218	0.995
February	20	25.2±2.12	457.7	-2.751	3.642	0.998
March	22	26.1±1.2	583.1	-2.728	3.649	0.994
April	26	28.2±0.9	648.2	-2.492	3.461	0.997
May	16	29.9±2.6	581.5	-2.614	3.631	0.982
June	15	26.8±0.5	606.4	-2.808	3.664	0.995
July	10	26.5±0.8	428.3	-2.564	3.491	0.986
August	22	27.3±0	407.1	-2.877	3.069	0.988
September	14	29.8±2.5	539.0	-2.493	3.451	0.990

Table 28(b). Monthly length-weight relationship of female *M. salmoides*.

Month	No. of fish	Mean length ± SD (cm)	Mean weight(g)	Log a intercept	b regr. coeff.	r correlation
October	20	25.9±0.4	294.2	-1.755	2.978	0.957
November	25	26.5±0.2	418.7	-2.422	3.491	0.981
December	22	30.05±3.75	455.2	-1.282	2.663	0.990
January	19	29.5±3.2	425.5	-3.196	4.014	0.986
February	16	25.5±0.8	472.9	-0.360	3.356	0.994
March	46	24.5±1.8	250.4	-1.753	2.934	0.980
April	18	24.8±1.5	283.5	-1.559	2.820	0.953
May	20	24.4±1.9	288.2	-2.326	3.372	0.969
June	11	25.8±0.5	391.4	-2.041	3.196	0.992
July	6	23.6±2.7	226.8	-2.373	3.296	0.995
August	20	26.1±0.2	446.2	-2.589	3.381	0.994
September	8	28.8±2.5	451.9	-2.331	3.357	0.990

Table 29. Monthly variations in condition factor of *M. salmoides*.

Month	Condition factor ± SD: Males	Condition factor ± SD: Females
October	1.68±0.15 (18)*	1.52±0.1 (20)*
November	1.66±0.13 (13)	1.80±0.38 (25)
December	1.83±0.3 (17)	1.70±0.28 (22)
January	1.49±0.04 (23)	1.23±0.19 (19)
February	1.40±0.13 (20)	1.47±0.05 (16)
March	1.59±0.06 (22)	1.33±0.09 (46)
April	1.45±0.08 (26)	1.26±0.16 (18)
May	1.36±0.17 (16)	1.28±0.14 (20)
June	1.56±0.03 (15)	1.43±0.01 (11)
July	1.35±0.18 (10)	1.10±0.32 (6)
August	1.38±0.15 (22)	1.46±0.04 (20)
September	1.64±0.11 (14)	1.52±0.1 (8)

* - Number of fish analysed ~~are~~ is indicated by figures in parentheses

Table 30 (a). The relationship between Condition factor ("K") and GSI in female *M. salmoides*.

Month	"K"- factor ± SD	GSI ± SD
October	1.52±0.1	2.57±1.08
November	1.80±0.38	2.70±1.21
December	1.70±0.28	2.00±0.51
January	1.23±0.19	1.26±0.23
February	1.47±0.05	0.66±0.83
March	1.33±0.09	0.35±1.14
April	1.26±0.16	0.50±0.99
May	1.28±0.14	0.95±0.54
June	1.43±0.01	1.32±0.17
July	1.10±0.32	0.90±0.59
August	1.46±0.04	2.35±0.86
September	1.52±0.1	2.41±0.92

Table 30 (b). The relationship between Condition factor ("K") and GSI in male *M. salmoides*

Month	"K"- factor ± SD	GSI ± SD
October	1.68±0.15	2.0±0.78
November	1.66±0.13	2.4±1.18
December	1.83±0.30	1.5±0.28
January	1.49±0.04	1.01±0.21
February	1.40±0.13	0.59±0.63
March	1.59±0.06	0.19±1.03
April	1.45±0.08	0.31±0.91
May	1.36±0.17	0.79±0.43
June	1.56±0.03	1.01±0.21
July	1.35±0.18	0.71±0.51
August	1.38±0.15	2.0±0.78
September	1.64±0.11	2.2±0.98

Table 31. The relationship between Condition factor (K) and fullness index (FI) in *M. salmoides*

Month	"K"- factor ±	GSI ± SD
October	1.60±0.12	2.35±0.5
November	1.73±0.25	2.0±0.15
December	1.76±0.28	1.92±0.07
January	1.36±0.12	2.10±0.25
February	1.43±0.05	1.93±0.08
March	1.46±0.02	0.27±1.58
April	1.35±0.13	0.46±1.93
May	1.32±0.16	2.04±0.19
June	1.49±0.01	2.38±0.53
July	1.22±0.26	1.92±0.07
August	1.42±0.06	2.0±0.15
September	1.58±0.1	2.91±1.06

Table 32. Variation in the rate of nematode infestation in <u>M. salmoides</u>

Sampling Station	No. of Fish examined	No. of Fish infected	% of Fish infected
1	124	20	16.12
2	97	18	18.6
3	118	32	27.1
4	80	10	12.5
5	56	—	----

Table 33. Variation in the incidence of infestation of <u>M. salmoides</u> within length-classes

Length class	No. of Fish examined	No. of Fish infected	% of Fish infected
1 - 4.9	0	0	0
5 - 9.9	69	0	0
10 - 14.9	66	0	0
15 - 19.9	23	5	20.7
20 - 24.9	47	16	36.0
25 - 29.9	71	25	38.3
30 - 34.9	47	15	31.2
35 - 39.9	68	21	30.8
40 - 44.9	41	6	14.6
45 - 49.9	18	2	11.1

F I G U R E S

Fig. 1. Map of Lake Naivasha showing the sampling stations (1-5). After Gaudet (1977a). Survey of Kenya, Kenya Government.

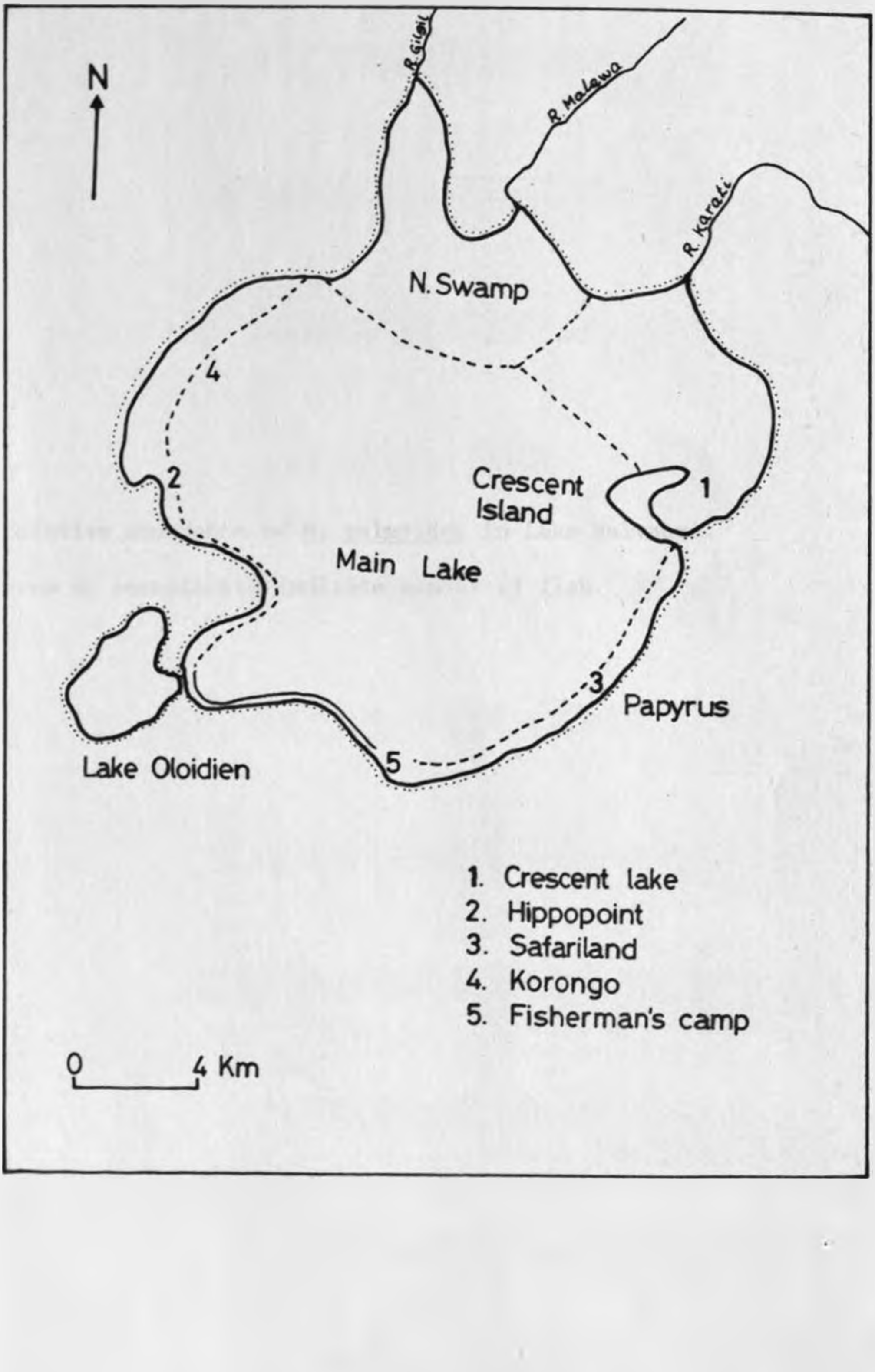
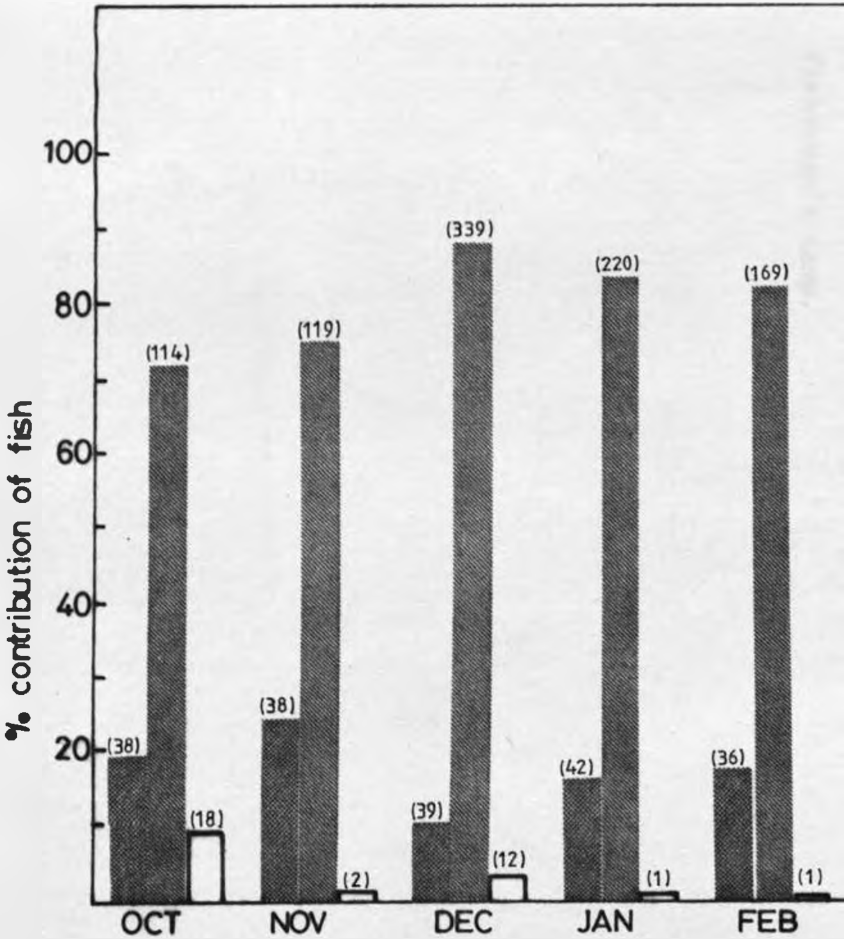
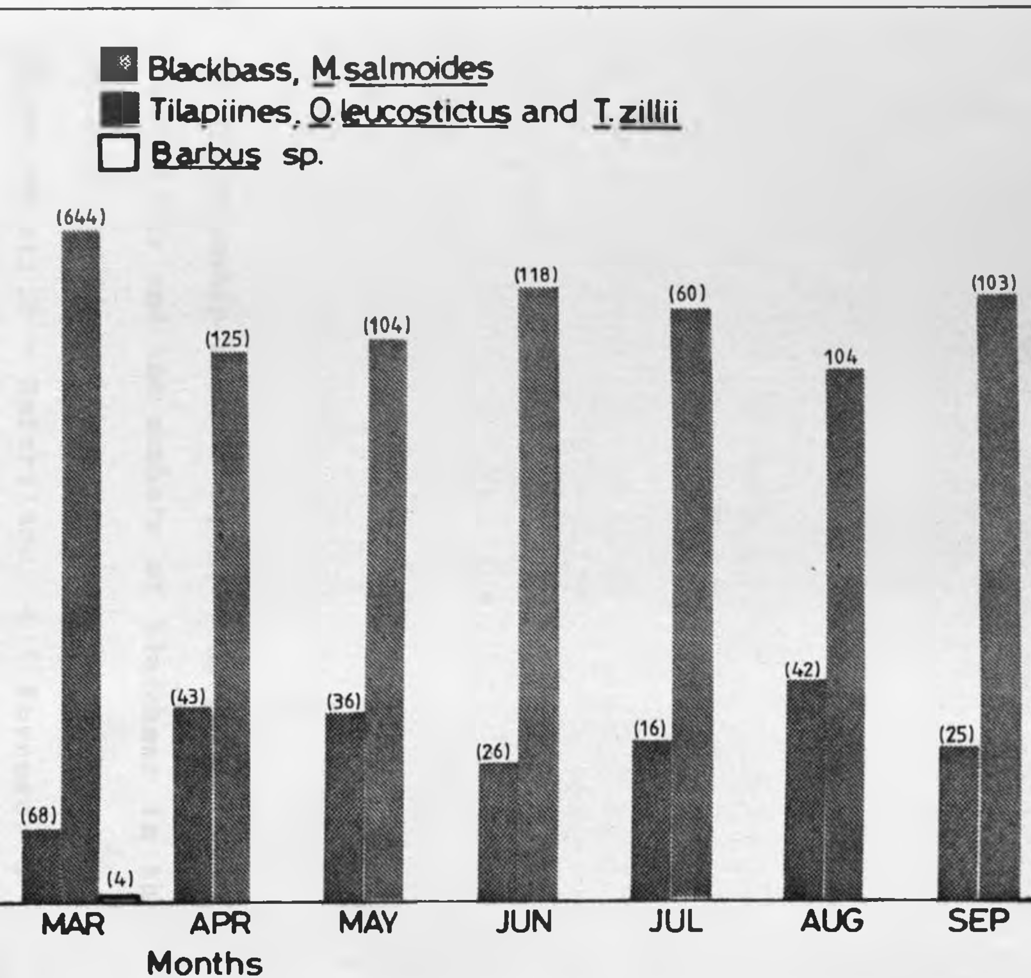

N
R. Gilgil
R. Malewa
R. Karati
N. Swamp
4
2
Crescent
Island
1
Main Lake
3
Papyrus
5
Lake Oloidien
1. Crescent lake
2. Hippopoint
3. Safariland
4. Korongo
5. Fisherman's camp
0
4 Km

Fig. 2. The relative abundance of M. salmoides in Lake Naivahsa.

*Figures in parenthesis indicate number of fish.

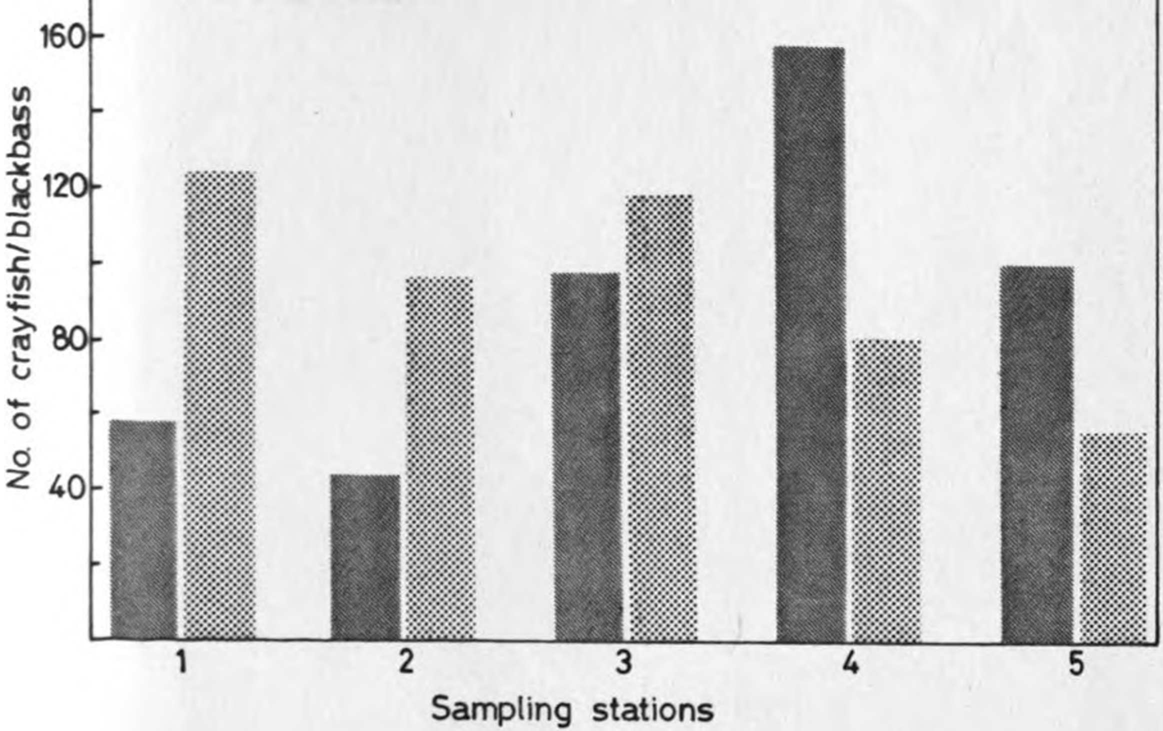


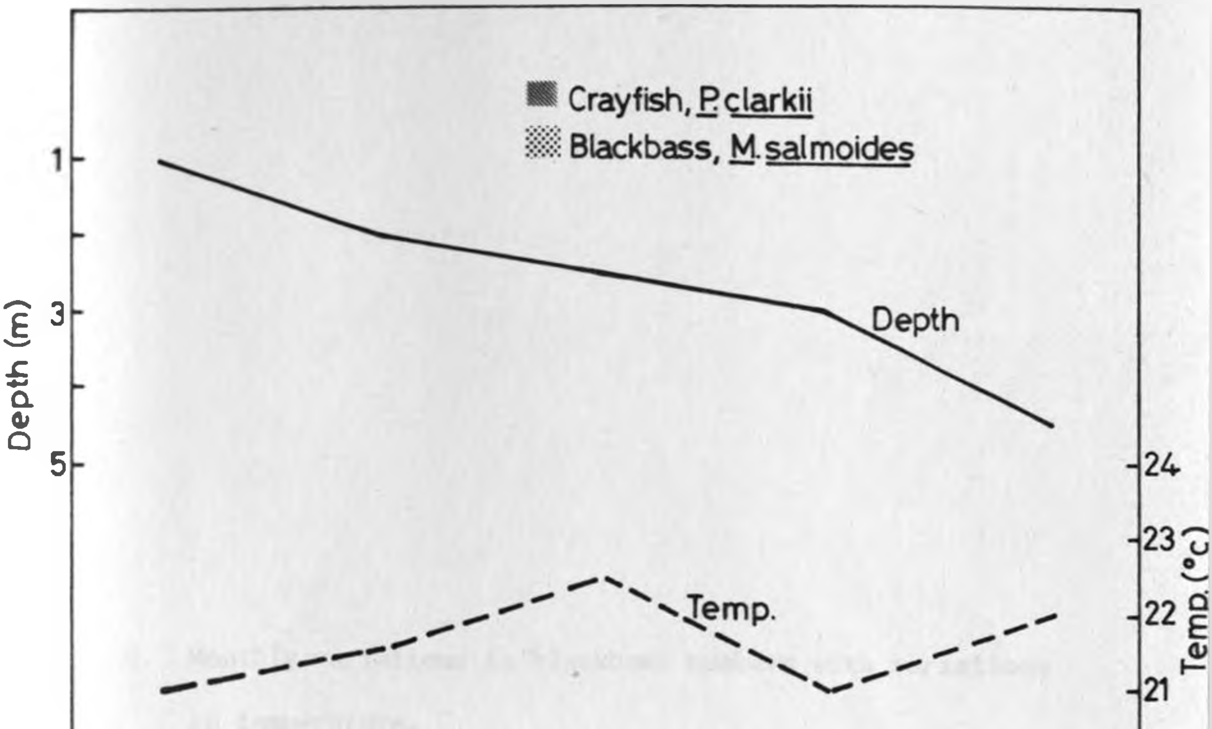
% contribution of fish
100
80
60
40
20
(38)
(114)
(18)
(38)
(119)
(2)
(39)
(339)
(12)
(42)
(220)
(1)
(36)
(169)
(1)
OCT
NOV
DEC
JAN
FEB



Blackbass, M.salmoides
Tilapiines, O.leucostictus and T.zillii
Barbus sp.
(644)
(68)
(4)
(125)
(43)
(104)
(36)
(118)
(26)
(60)
(16)
104
(42)
(103)
(25)
MAR
APR
MAY
JUN
JUL
AUG
SEP
Months

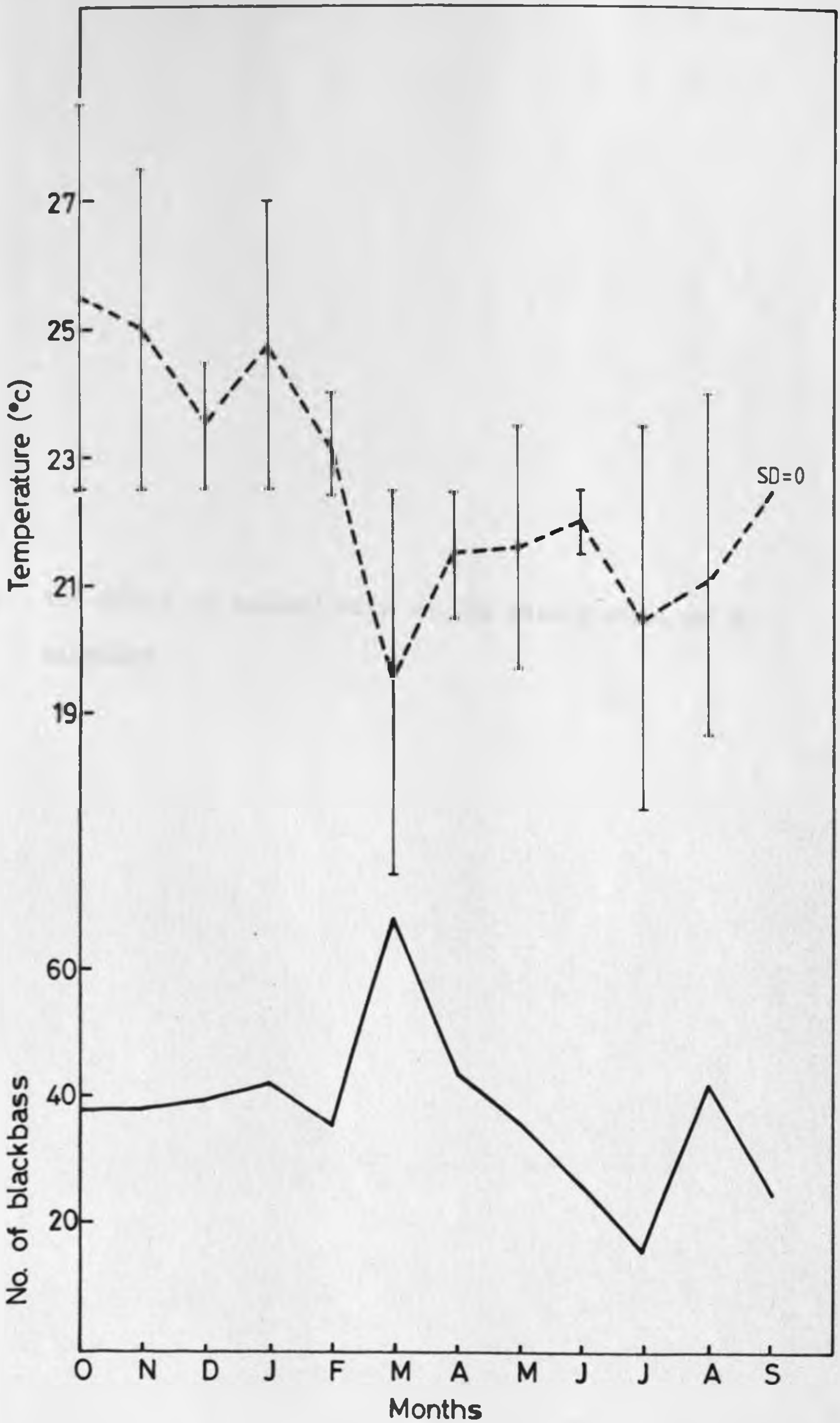
Fig. 3. The relationship between depth, temperature, prey availability and the numbers of blackbass in the different sampling stations: 1 - Crescent lake; 2 - Hippo point; 3 - Safariland; 4 - Korongo; 5 - Fisherman's camp.


No. of crayfish/blackbass
40
80
120
160
1
2
3
4
5
Sampling stations



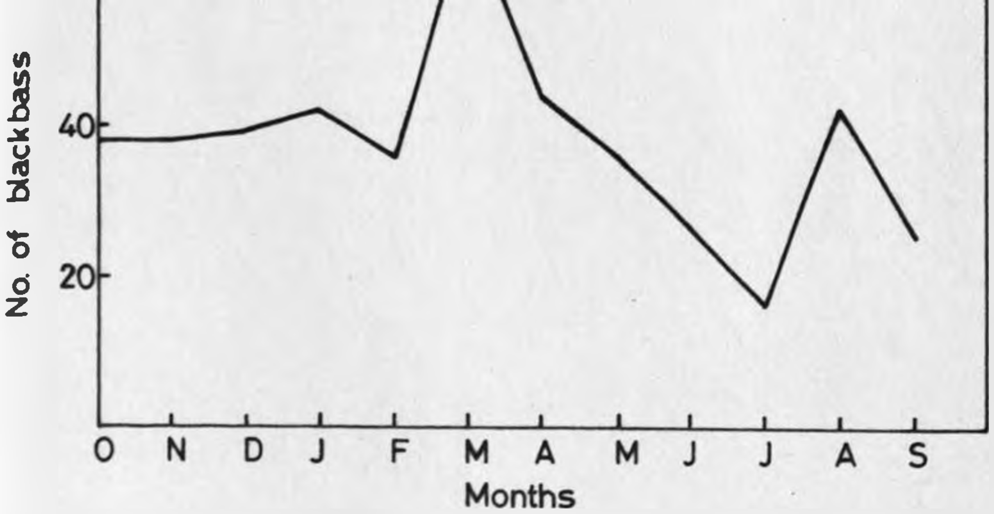
Crayfish, P. clarkii
Blackbass, M. salmoides
Depth (m)
1
3
5
Depth
Temp.
24
23
22
21
Temp. (°c)

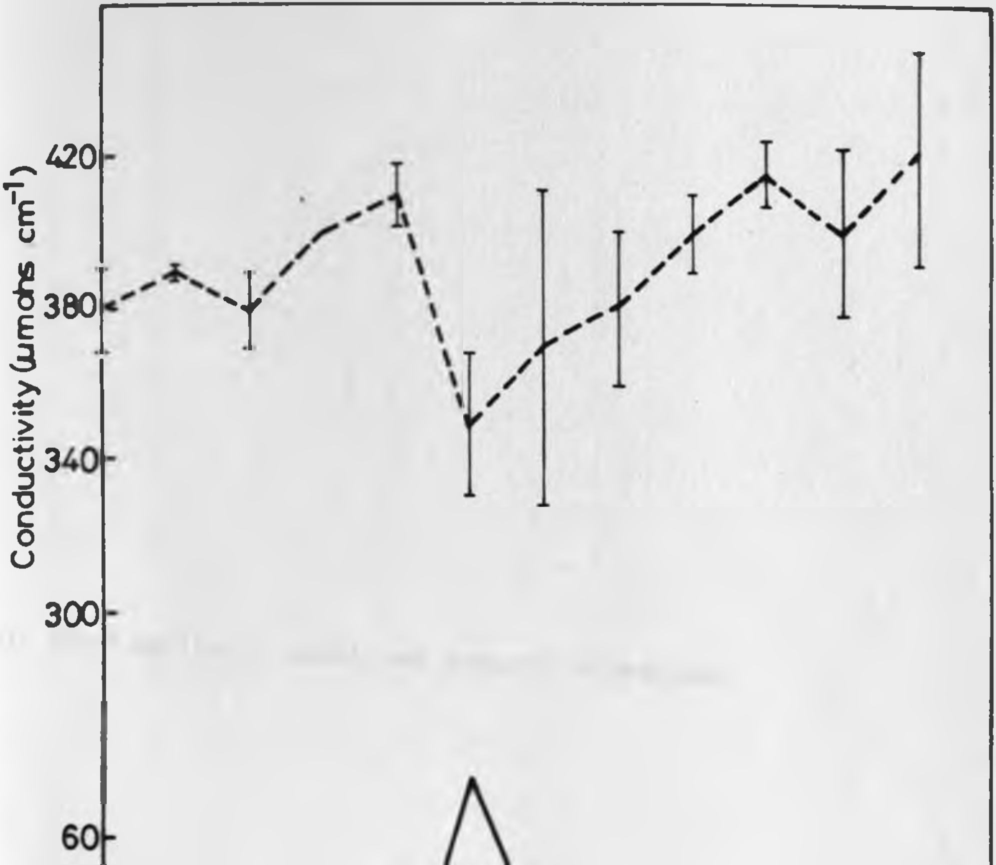
Fig. 4. Monthly variations in blackbass numbers with variations in temperature.



Temperature (°c)
27
25
23
21
19
SD=0
No. of blackbass
60
40
20
O
N
D
J
F
M
A
M
J
J
A
S
Months

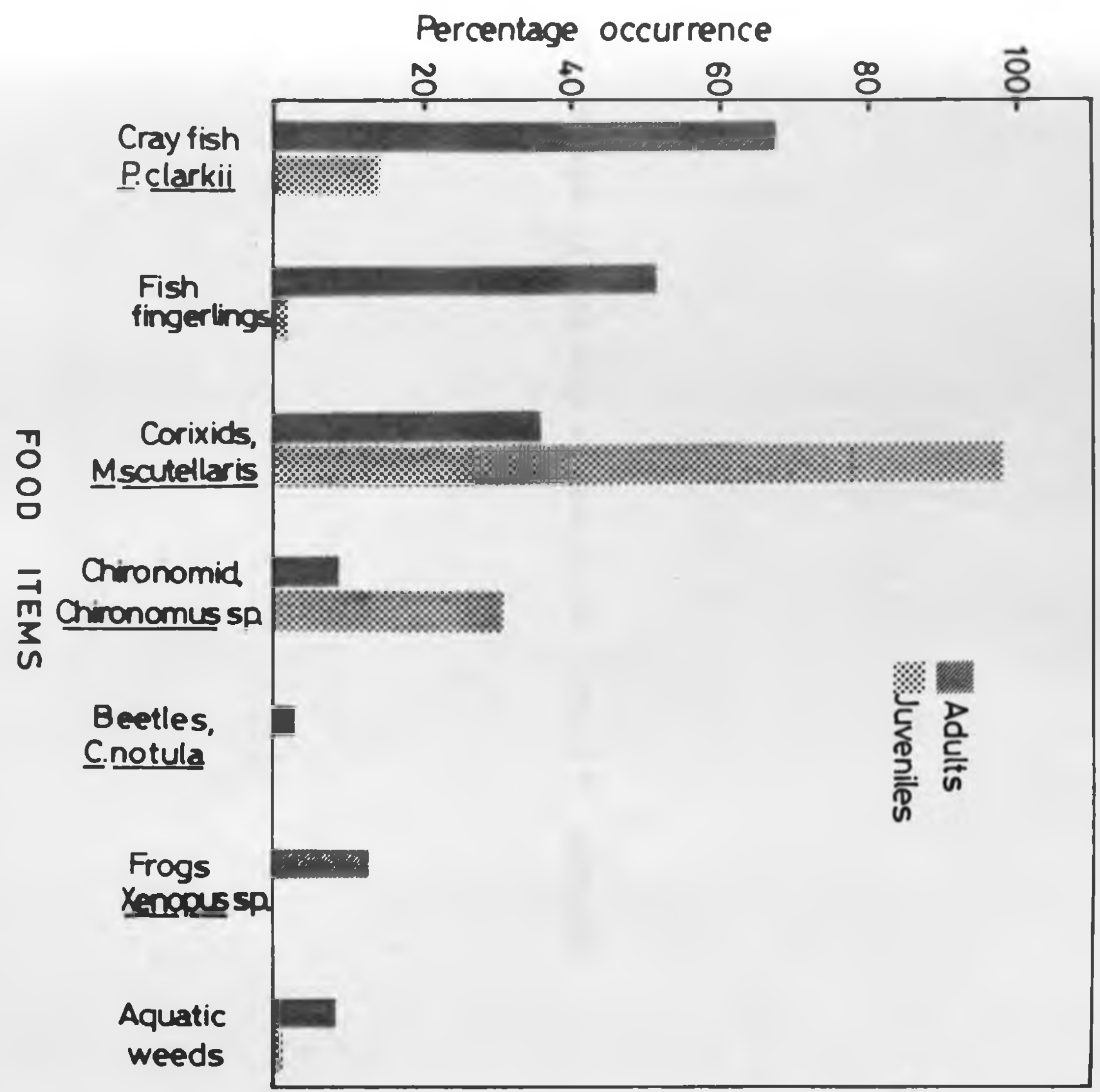
Fig. 5. The effect of conductivity on the distribution of ***M. salmoides***


No. of blackbass
40
20
O
N
D
J
F
M
A
M
J
J
A
S
Months



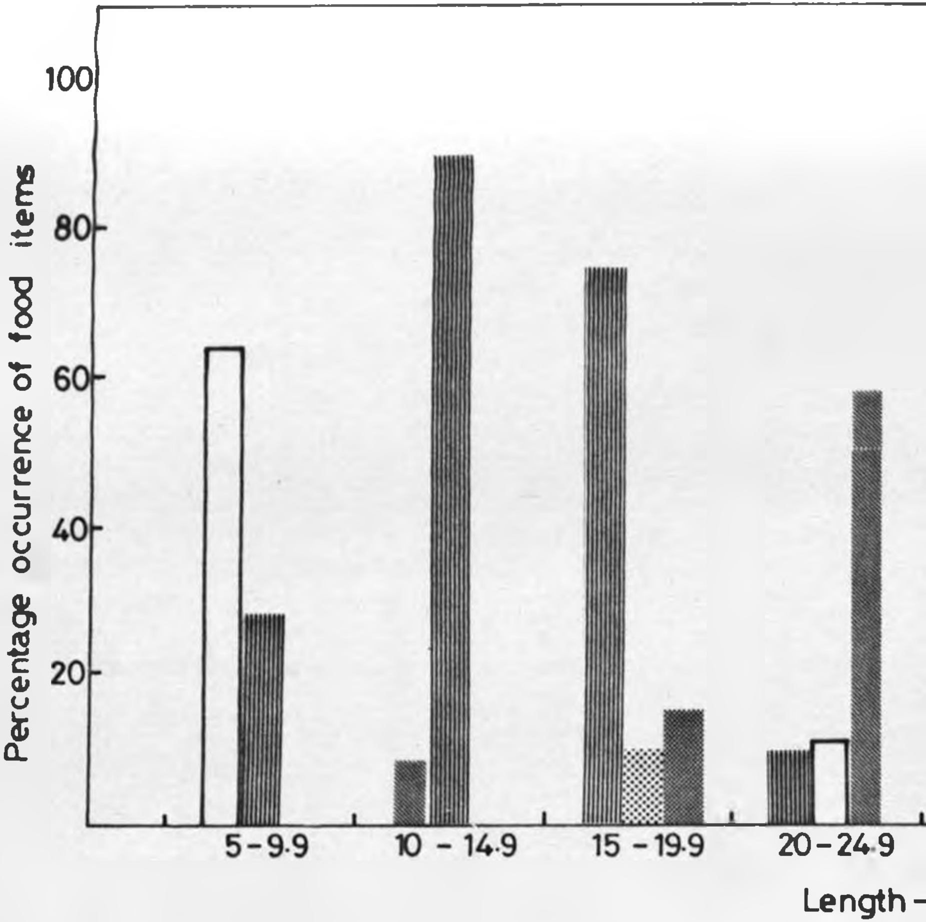
Conductivity (μmohs cm⁻¹)
420
380
340
300
60

Fig. 6. Food habits of adult and juvenile blackbass.

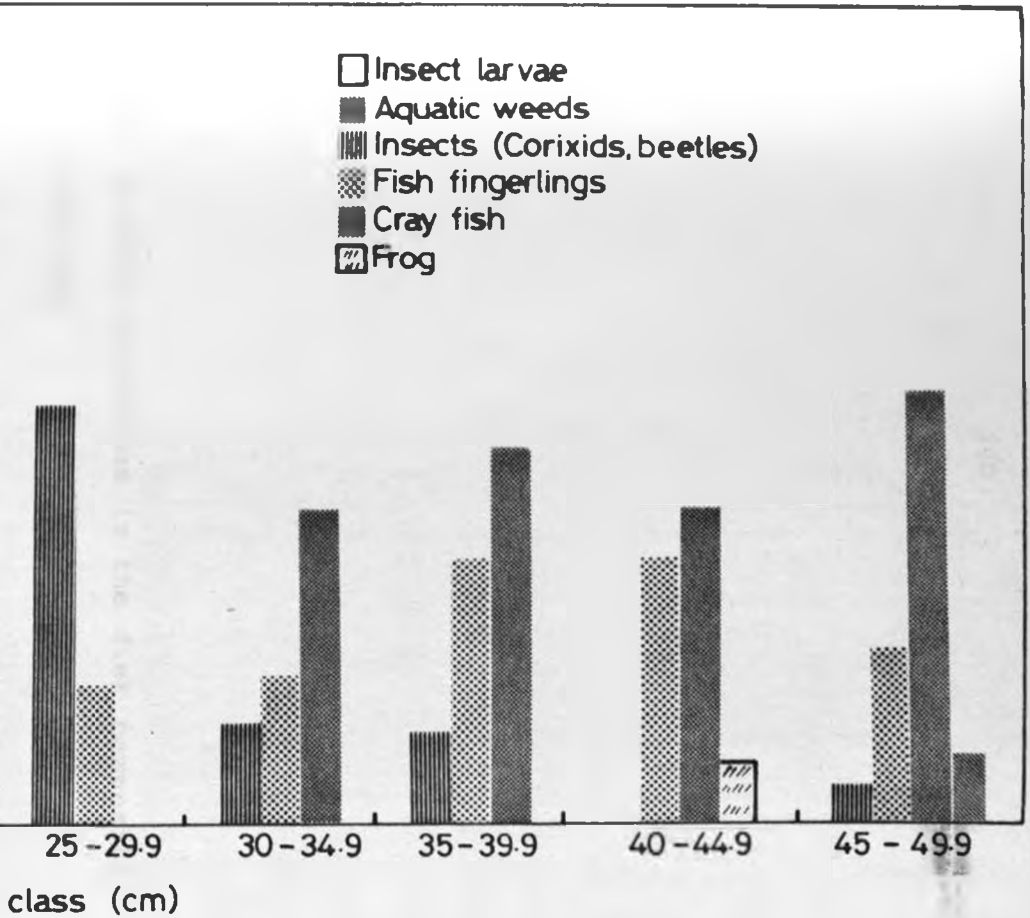


Percentage occurrence
20
40
60
80
100
FOOD ITEMS
Cray fish
P. clarkii
Fish
fingerlings
Corixids,
M. scutellaris
Chironomid,
Chironomus sp.
Beetles,
C. notula
Frogs
Xenopus sp.
Aquatic
weeds
Adults
Juveniles

Fig. 7. Changes in diet with changes in the size of M. salmoides

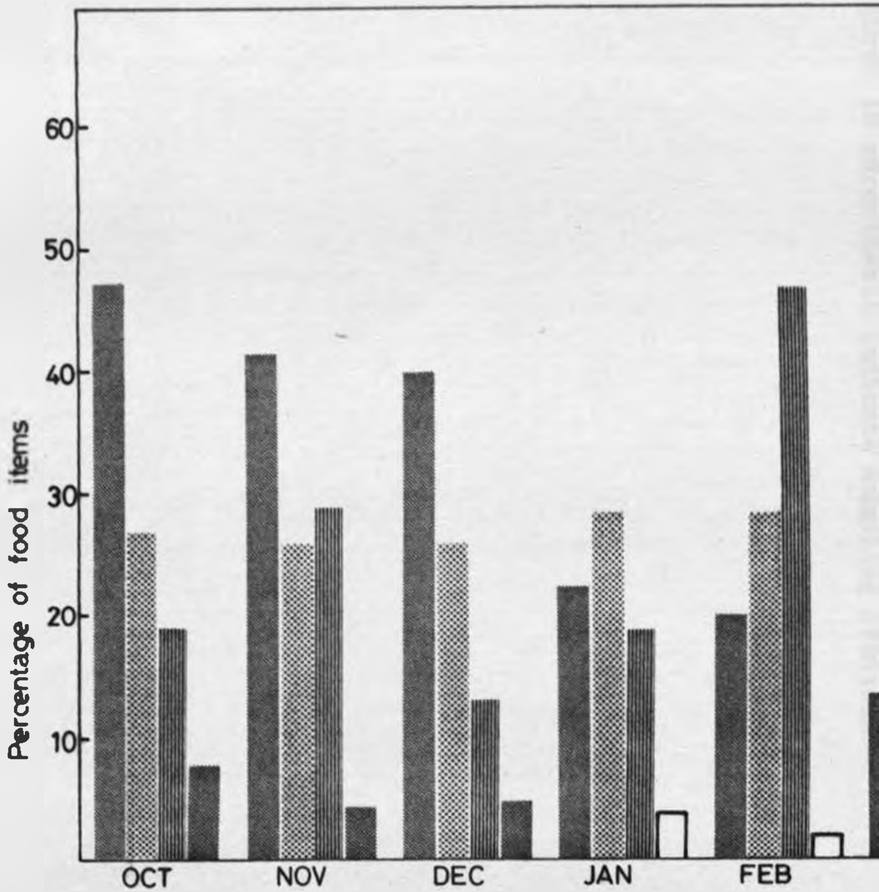


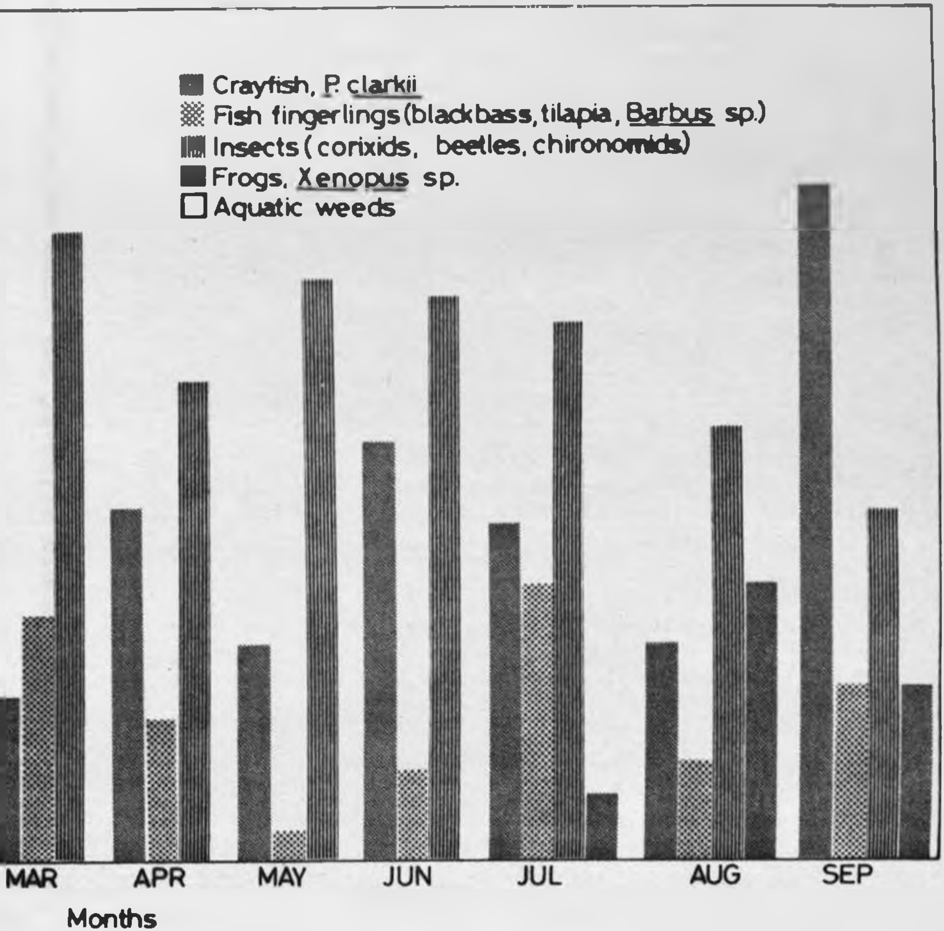
100
80
60
40
20
Percentage occurrence of food items
5-9.9
10 - 14.9
15 - 19.9
20-24.9
Length -



Insect larvae
Aquatic weeds
Insects (Corixids, beetles)
Fish fingerlings
Cray fish
Frog
25 - 29.9
30 - 34.9
35 - 39.9
40 - 44.9
45 - 49.9
class (cm)

Fig. 8. Monthly variations in the diet composition of *M. salmoides*.


60
50
40
30
20
10
Percentage of food items
OCT
NOV
DEC
JAN
FEB



Crayfish, P. clarkii
Fish fingerlings (blackbass, tilapia, Barbus sp.)
Insects (corixids, beetles, chironomids)
Frogs, Xenopus sp.
Aquatic weeds
MAR
APR
MAY
JUN
JUL
AUG
SEP
Months

Fig. 9. Food selection by adult and juvenile blackbass.

NOTE: Figures in parenthesis indicate sampling stations

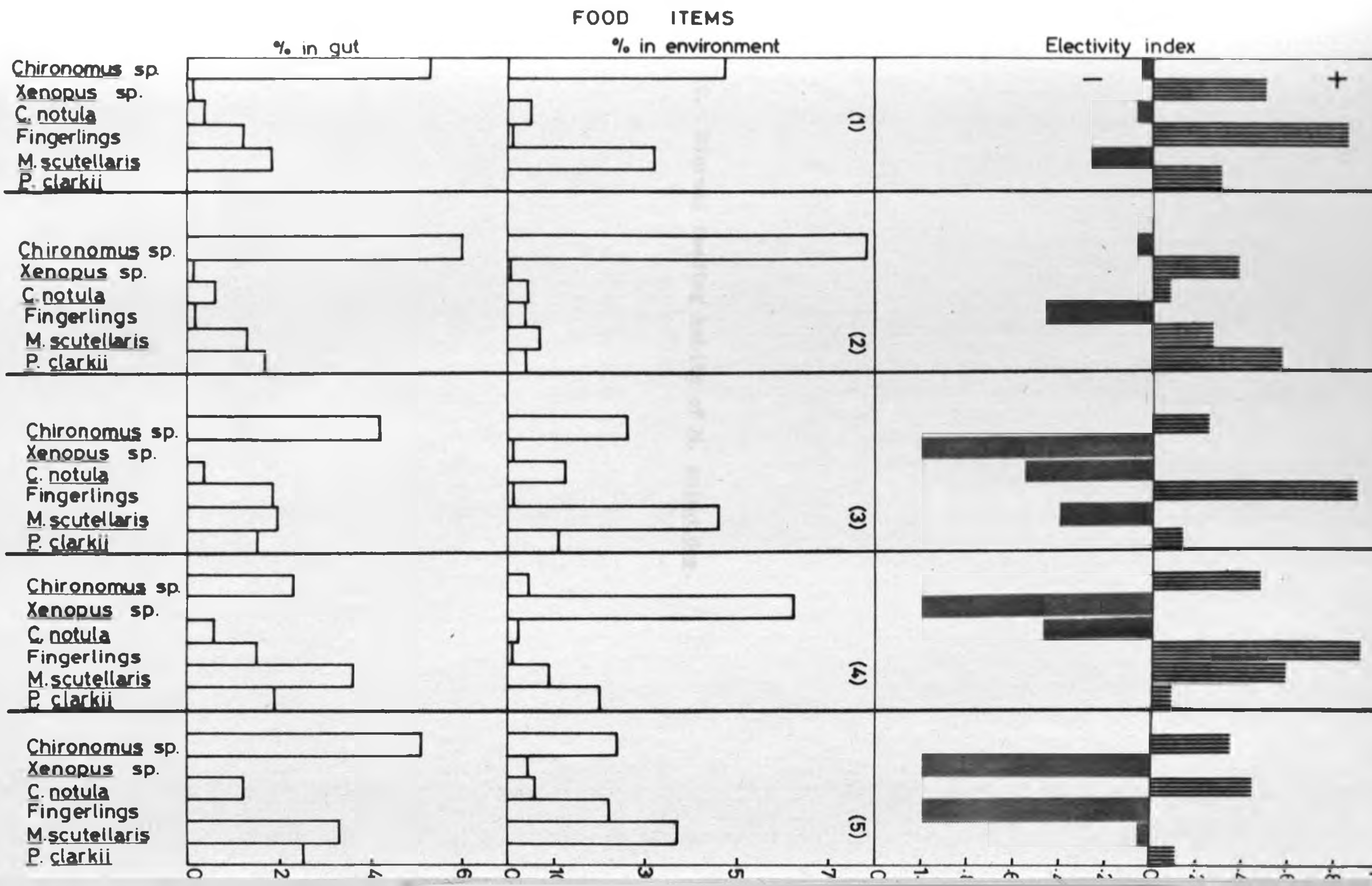
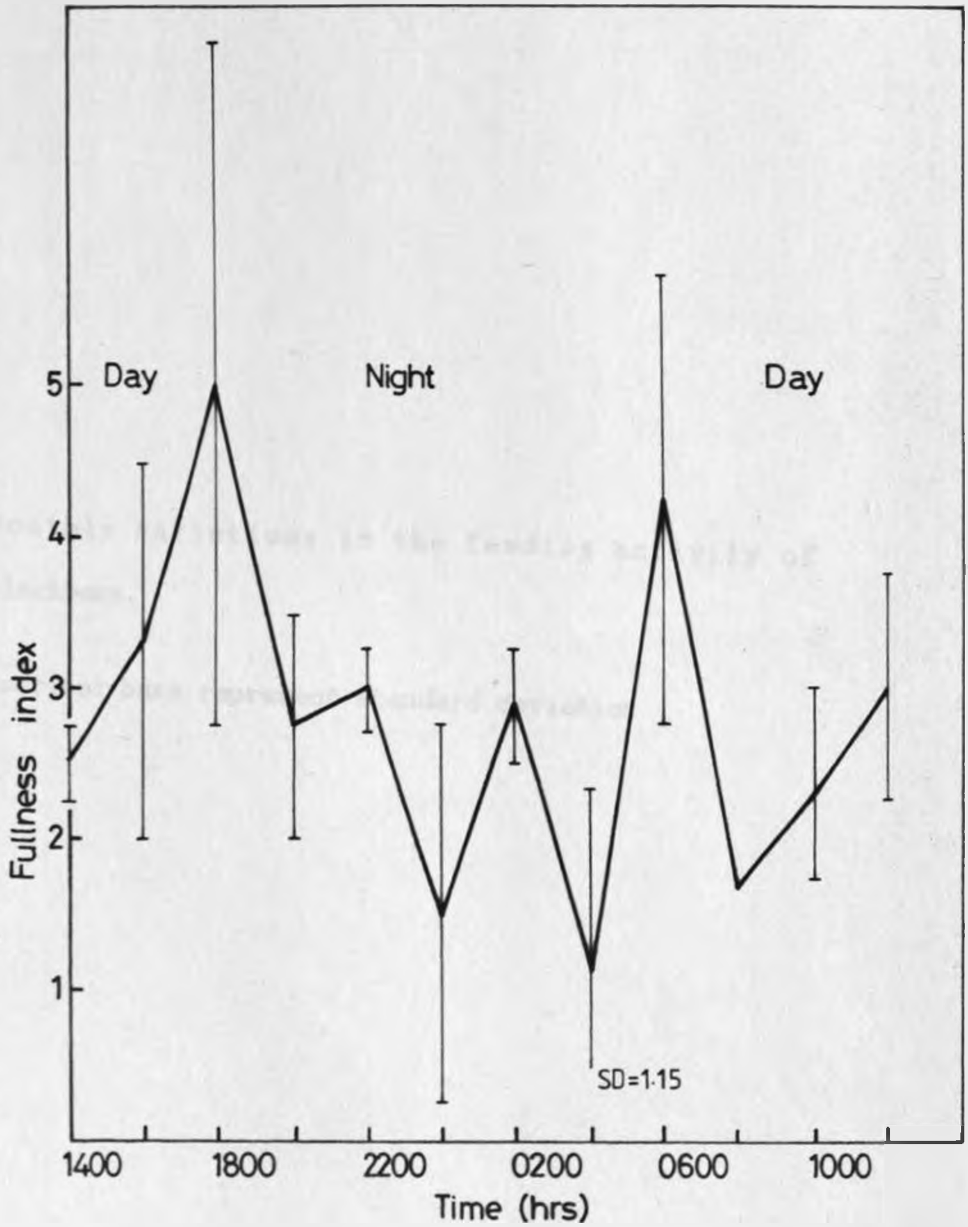

FOOD ITEMS
% in gut
% in environment
Electivity index
Chironomus sp.
Xenopus sp.
C. notula
Fingerlings
M. scutellaris
P. clarkii
(1)
(2)
(3)
(4)
(5)
−
+

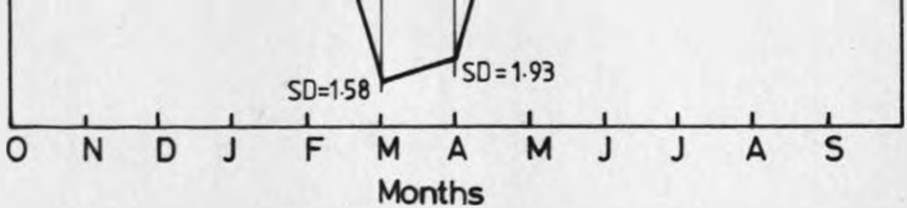
Fig. 10. Diurnal feeding habits of M. salmoides.

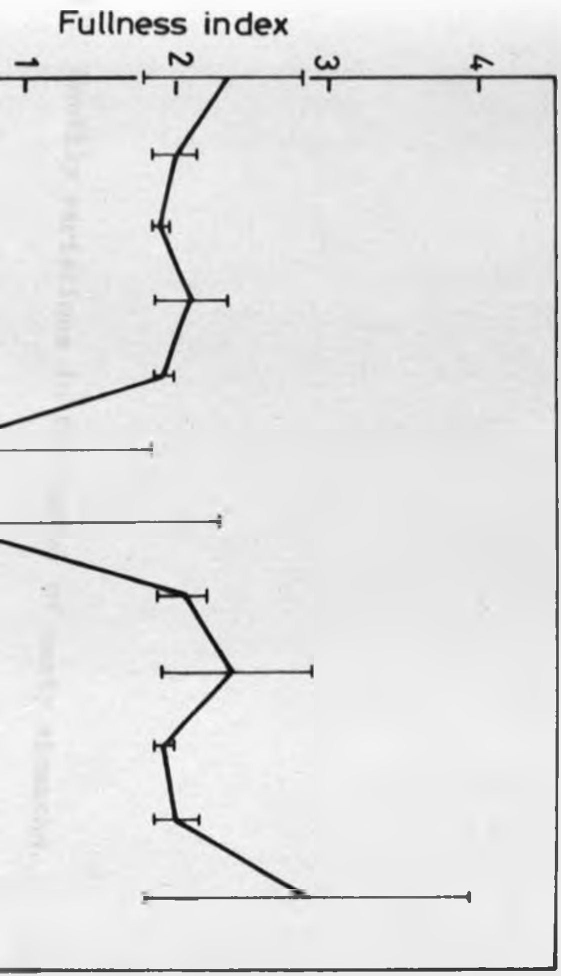


Day
Night
Day
Fullness index
5
4
3
2
1
SD=1·15
1400
1800
2200
0200
0600
1000
Time (hrs)

Fig. 11. Monthly variations in the feeding activity of blackbass.

NOTE: Vertical bars represent standard deviation


SD=1·58
SD=1·93
O N D J F M A M J J A S
Months



Fullness index
1
2
3
4

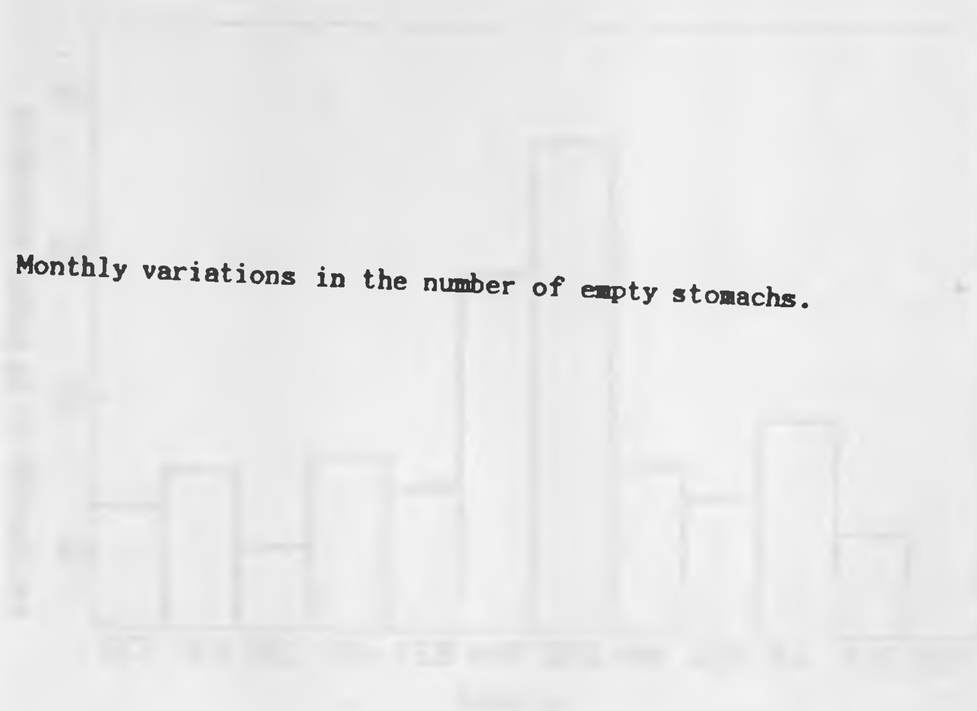


Fig. 12. Monthly variations in the number of empty stomachs.

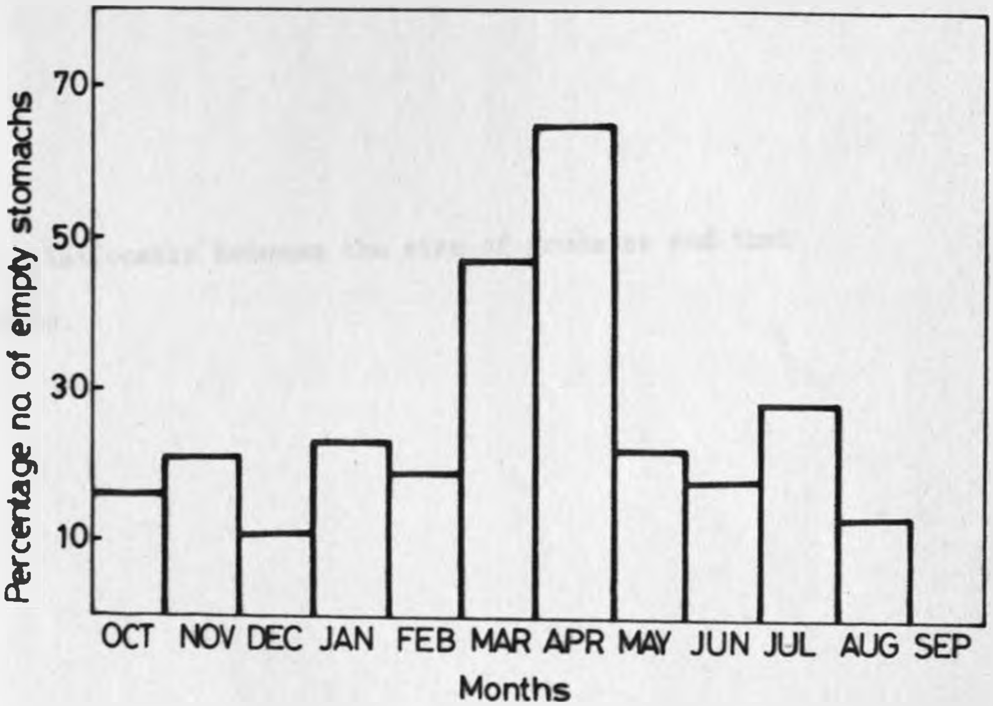
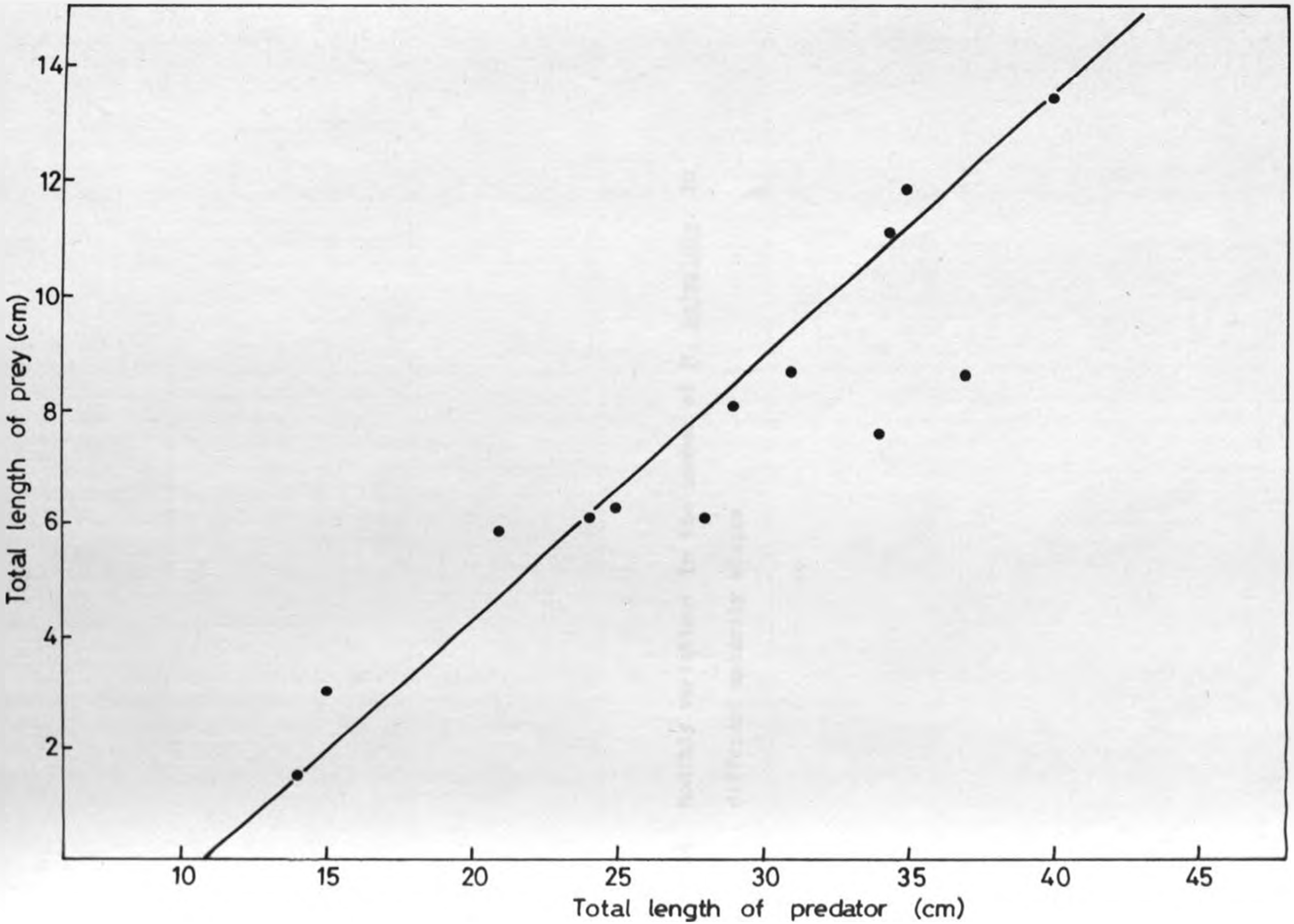

Percentage no. of empty stomachs
70
50
30
10
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Months

Fig. 13. The relationship between the size of predator and that of prey.



14
12
10
8
6
4
2
Total length of prey (cm)
10
15
20
25
30
35
40
45
Total length of predator (cm)

Fig. 14. Monthly variations in the number of M. salmoides. in different maturity stages.

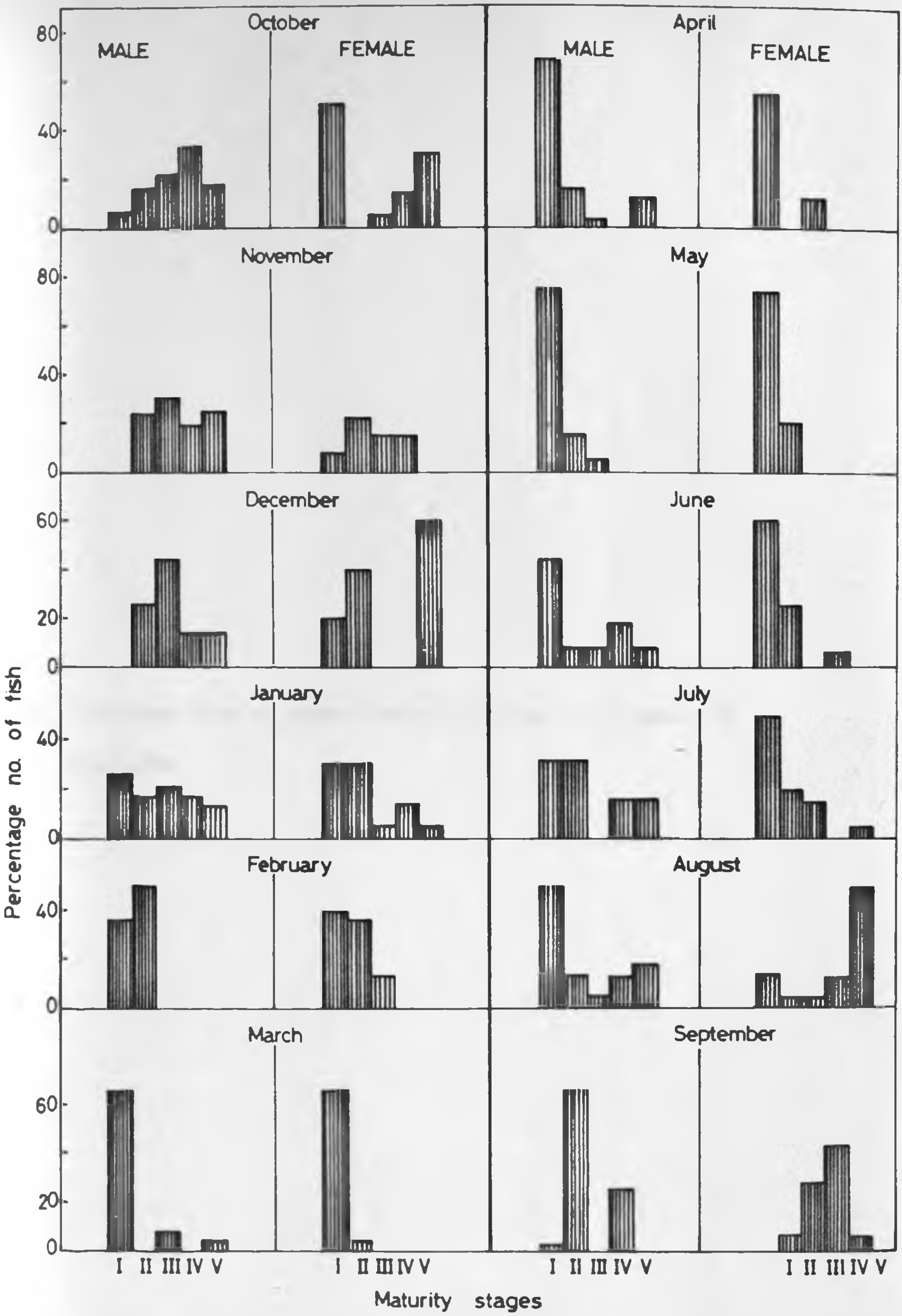
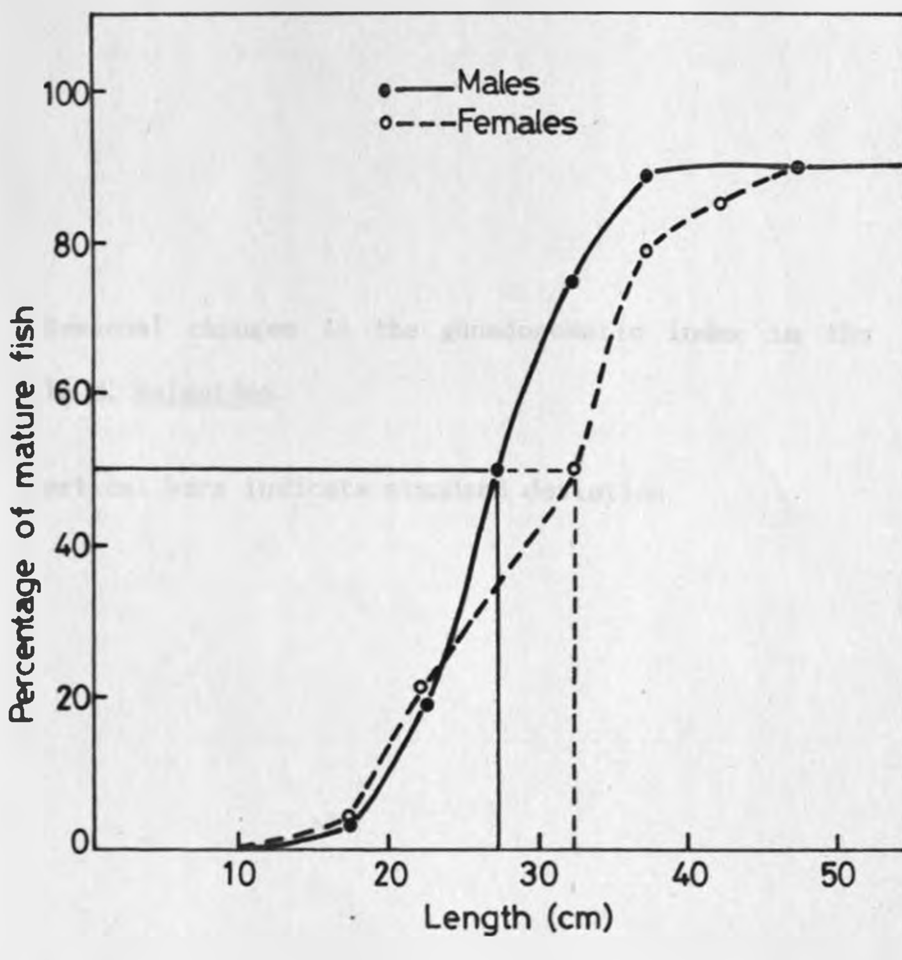

October
MALE
FEMALE
April
MALE
FEMALE
November
May
December
June
January
July
February
August
March
September
0
20
40
60
80
I II III IV V
Percentage no. of fish
Maturity stages

Fig. 15. Minimum size at sexual maturity in male and female *M. salmoides*.



Males
Females
Percentage of mature fish
0
20
40
60
80
100
10
20
30
40
50
Length (cm)

Fig. 16. Seasonal changes in the gonadosomatic index in the male *M. salmoides*.

NOTE: Vertical bars indicate standard deviation

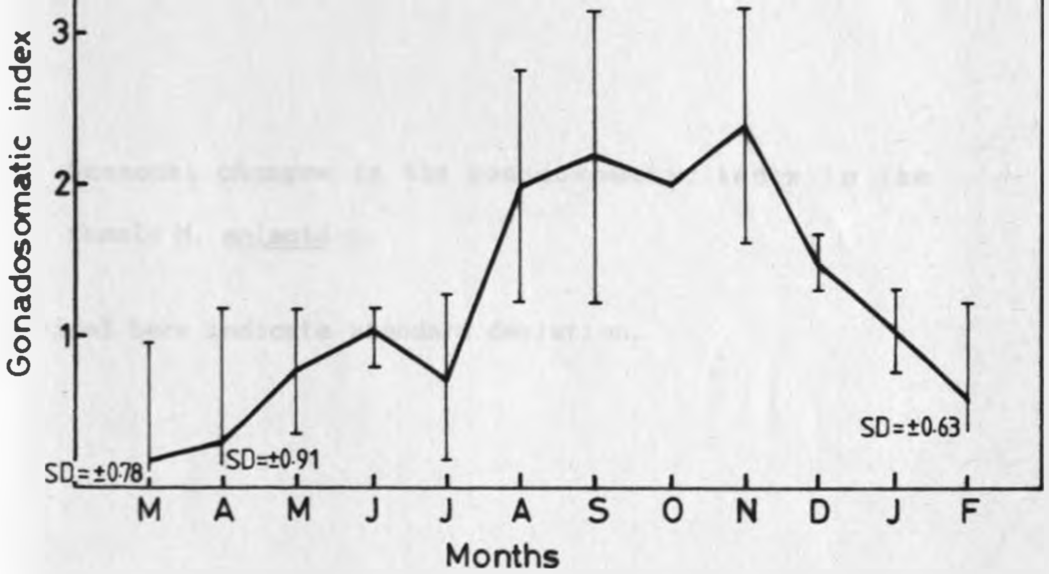
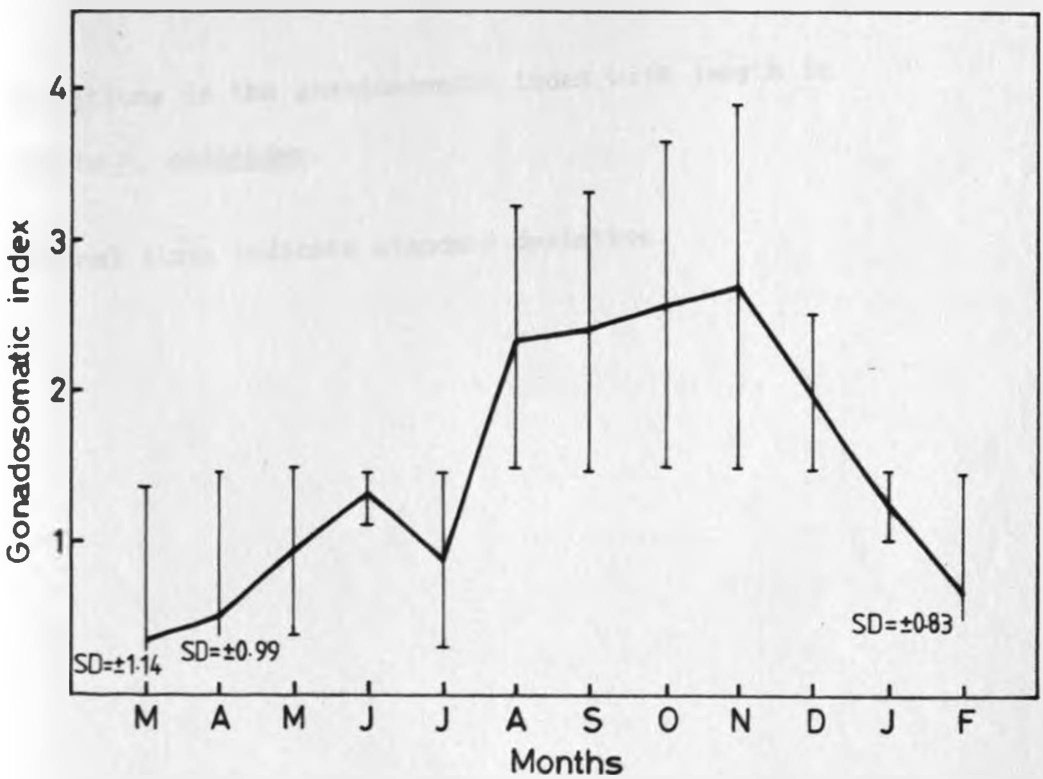

Gonadosomatic index
3
2
1
SD=±0.78
SD=±0.91
SD=±0.63
M A M J J A S O N D J F
Months

Fig. 17. Seasonal changes in the gonadosomatic index in the female *M. salmoides*.

Vertical bars indicate standard deviation.



Gonadosomatic index
4
3
2
1
SD=±1·14
SD=±0·99
SD=±0·83
M A M J J A S O N D J F
Months

Fig. 18. Variations in the gonadosomatic index with length in female *M. salmoides*.

NOTE: Vertical lines indicate standard deviation.

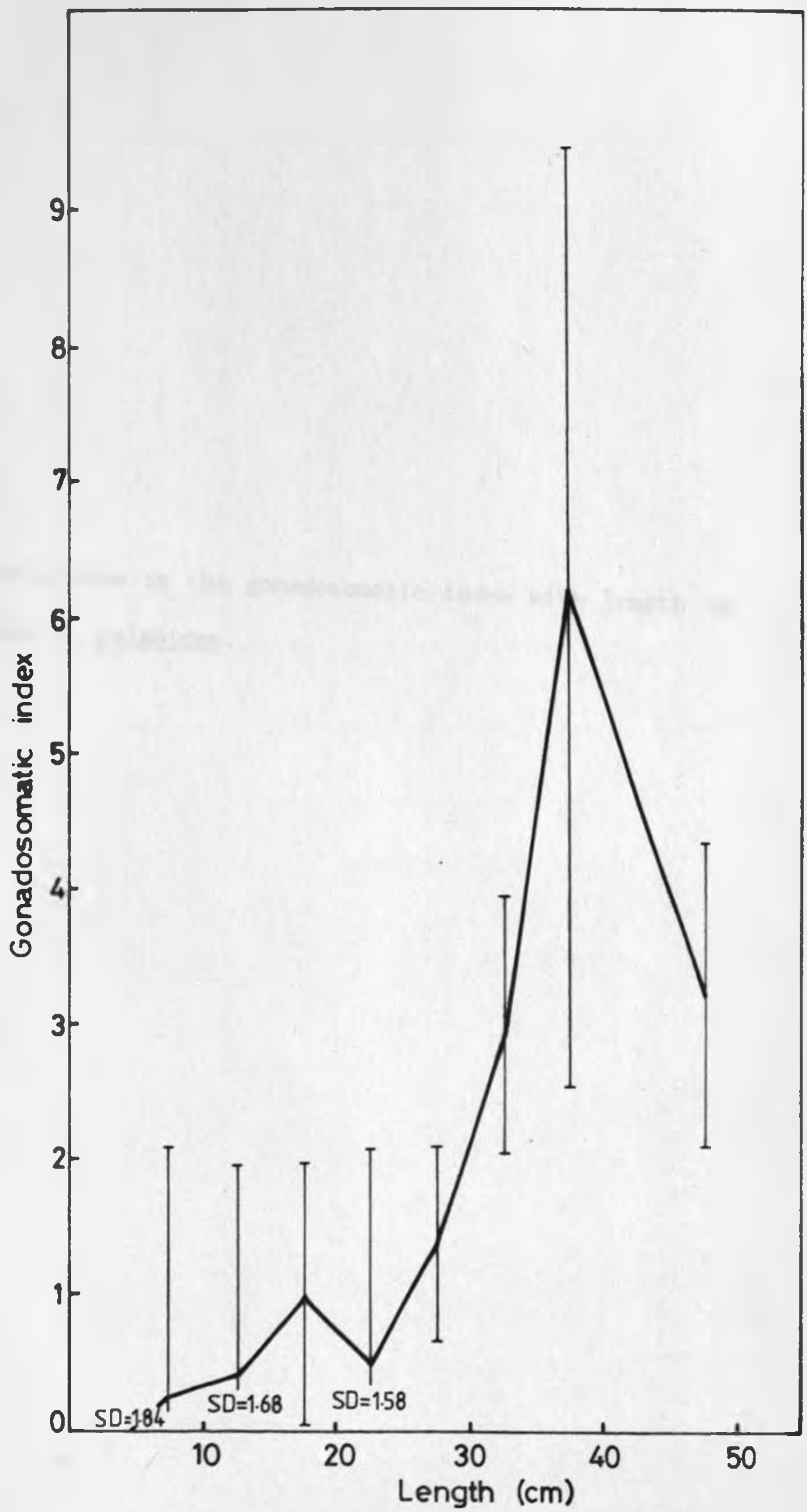
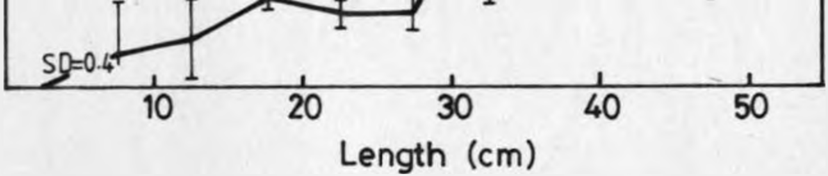

Gonadosomatic index
0
1
2
3
4
5
6
7
8
9
10
20
30
40
50
Length (cm)
SD=1·84
SD=1·68
SD=1·58

Fig. 19. Variations in the gonadosomatic index with length in male _M. salmoides_.


SD=0.4
10
20
30
40
50
Length (cm)

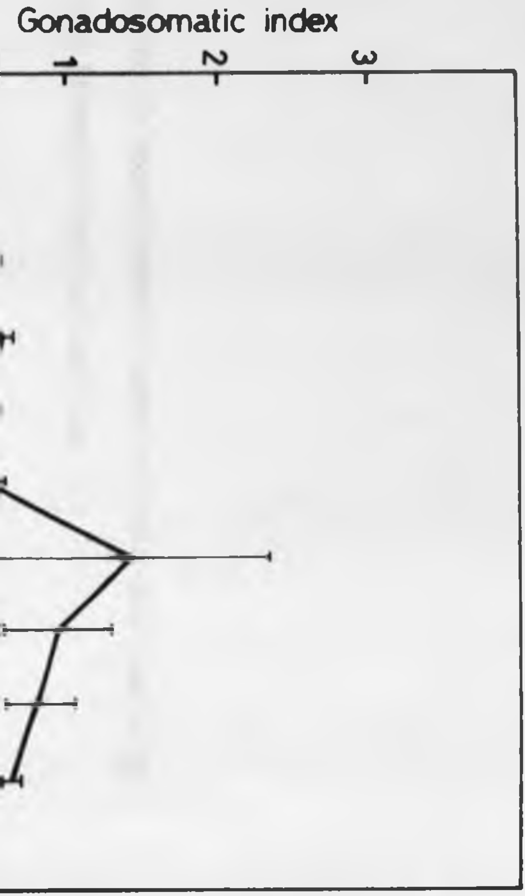

Gonadosomatic index
1
2
3

Fig. 20. Variations in gonadosomatic index of male and female M. salmoides between sampling stations.

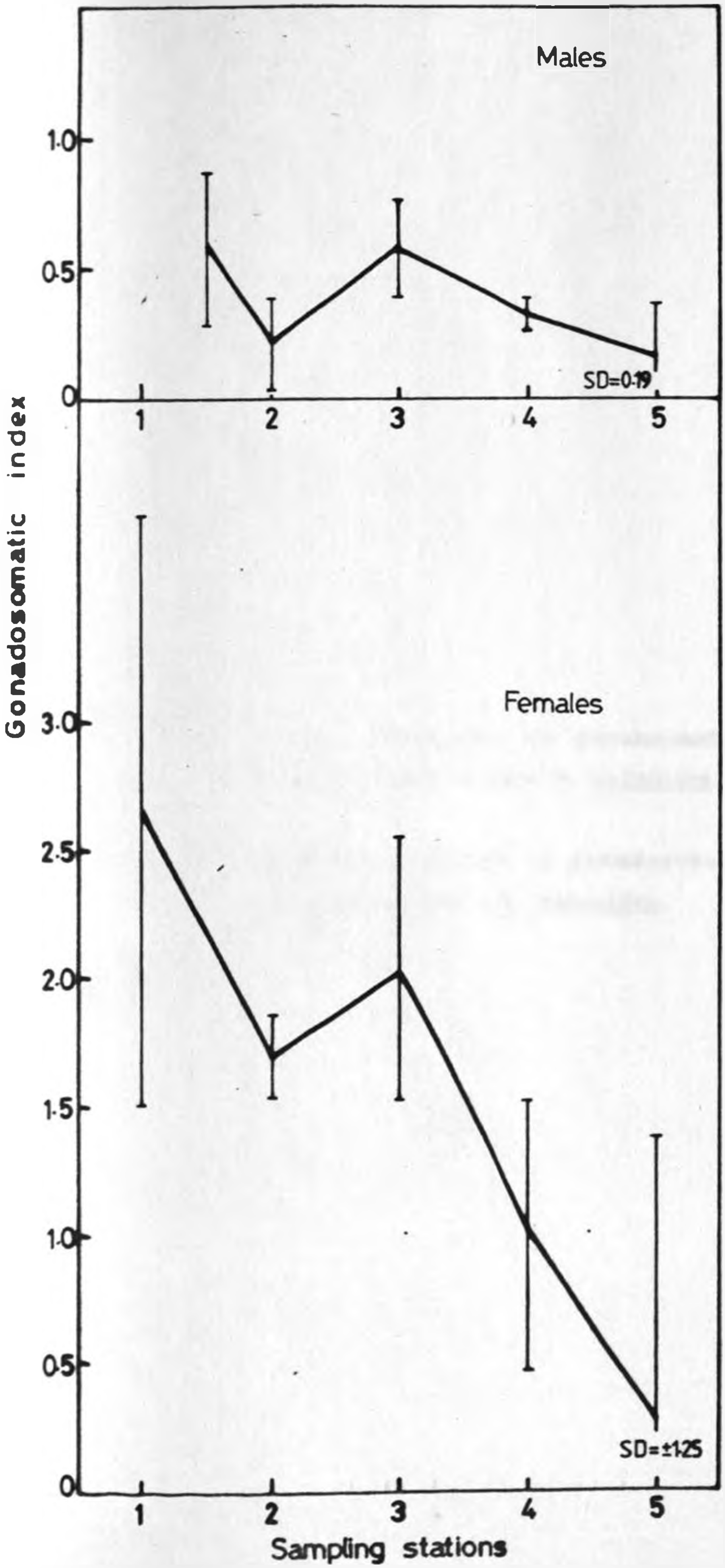

Males
1.0
0.5
0
SD=0.19
1
2
3
4
5
Gonadosomatic index
Females
3.0
2.5
2.0
1.5
1.0
0.5
0
SD=±1.25
1
2
3
4
5
Sampling stations

Fig. 21 (a). Monthly variations in gonadosomatic index and fullness index in male M. salmoides.

Fig. 21 (b). Monthly variations in gonadosomatic index and fullness in female M. salmoides.

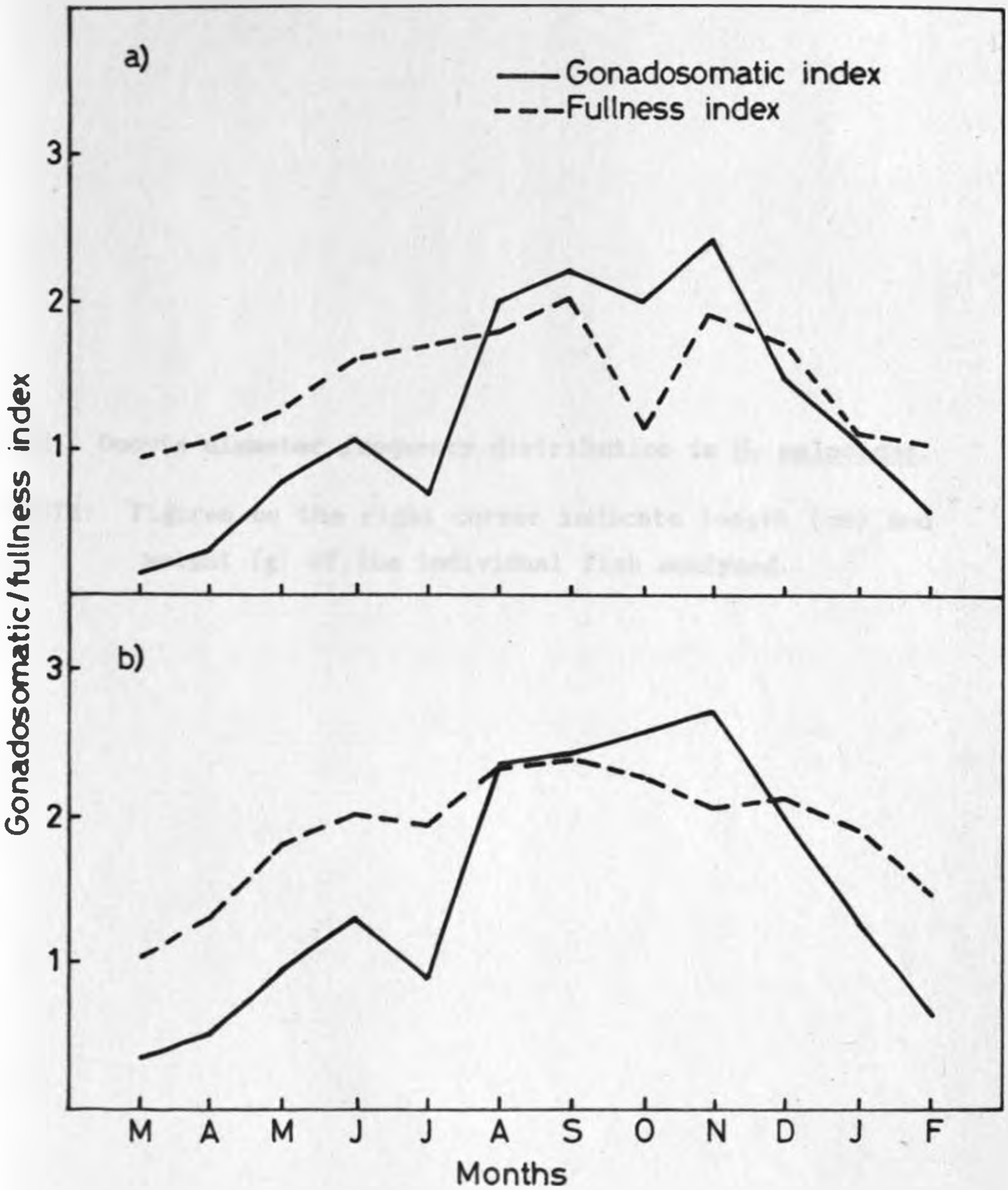
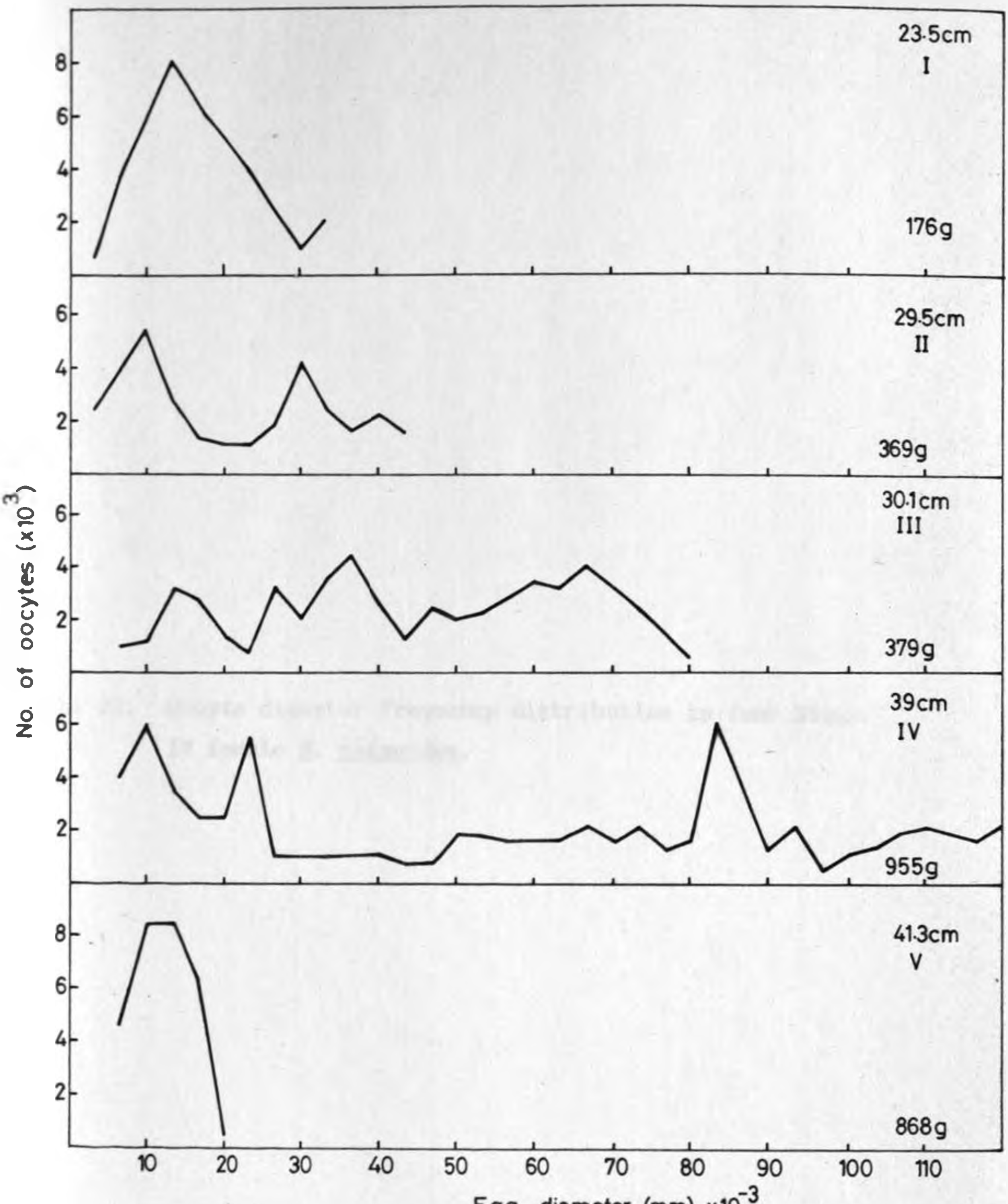

a)
Gonadosomatic index
Fullness index
b)
3
2
1
Gonadosomatic/fullness index
M
A
M
J
J
A
S
O
N
D
J
F
Months

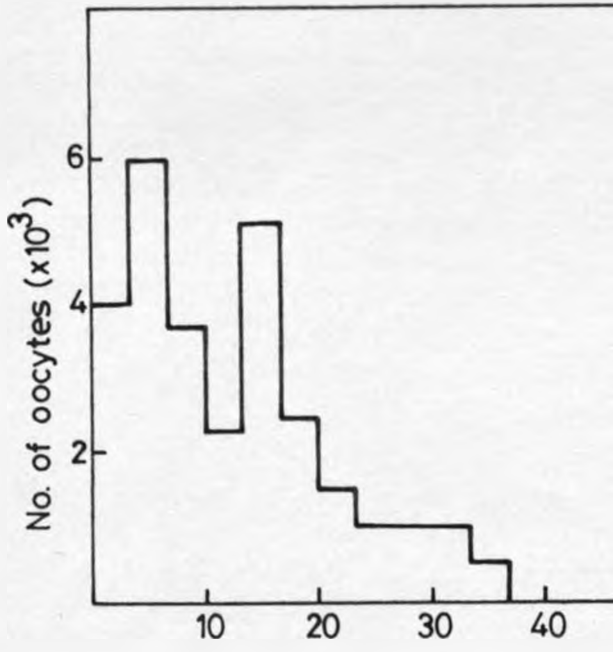
Fig. 22. Oocyte diameter frequency distribution in M. salmoides.

NOTE: Figures on the right corner indicate length (cm) and weight (g) of the individual fish analysed.



23·5cm
I
176g
29·5cm
II
369g
30·1cm
III
379g
39cm
IV
955g
41·3cm
V
868g
No. of oocytes ($\times 10^{3}$)
Egg diameter (mm) $\times 10^{-3}$

Fig. 23. Oocyte diameter frequency distribution in four Stage IV female *M. salmoides*.



No. of oocytes (x10^3)
6
4
2
10
20
30
40

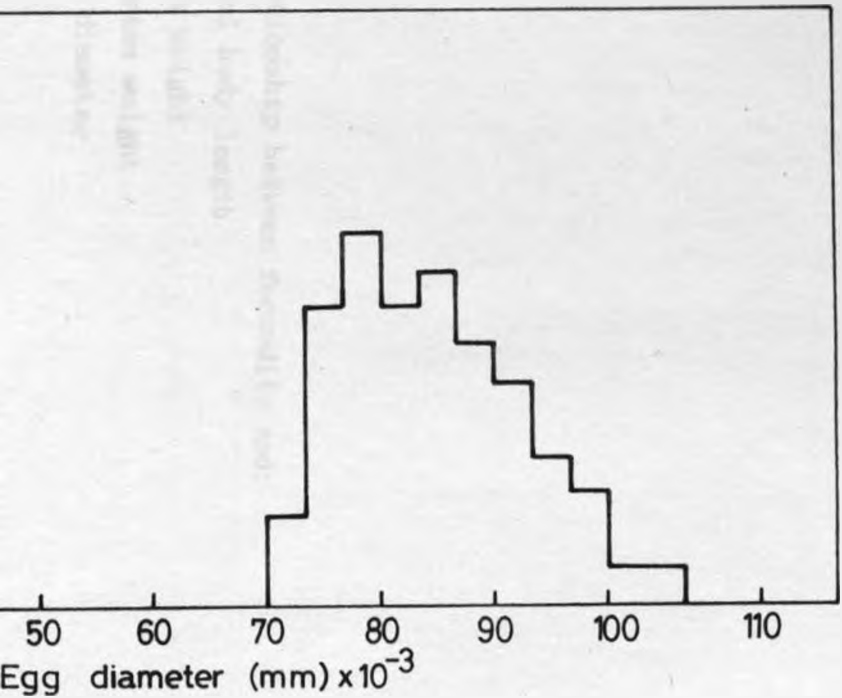

50
60
70
80
90
100
110
Egg diameter (mm) x 10⁻³

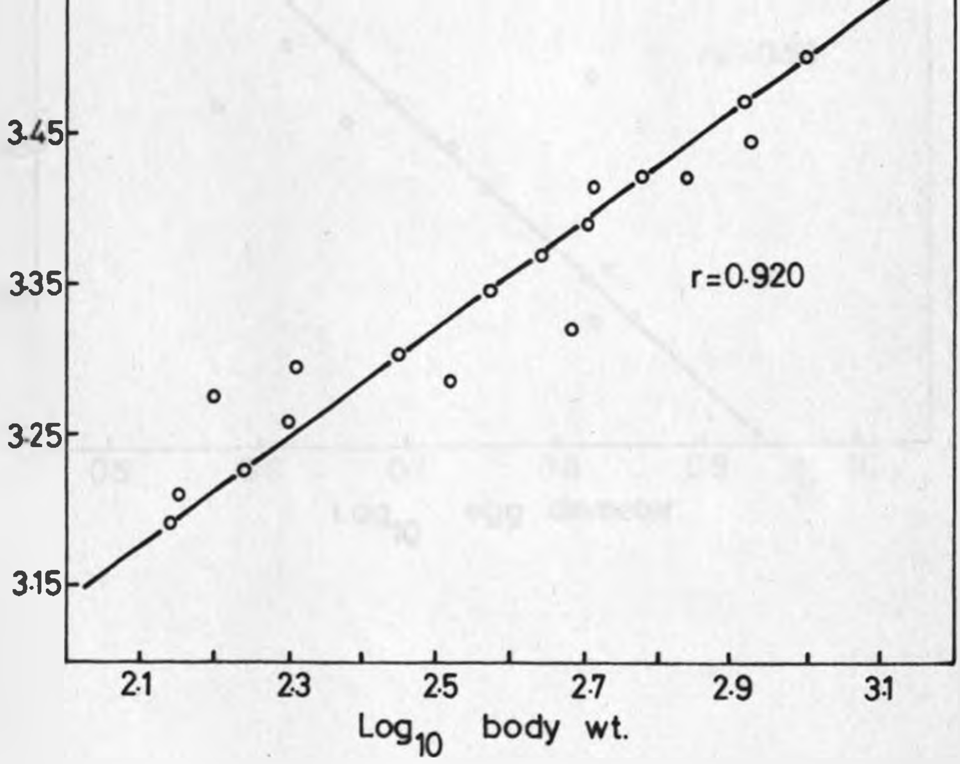
Fig. 24. The relationship between fecundity and:

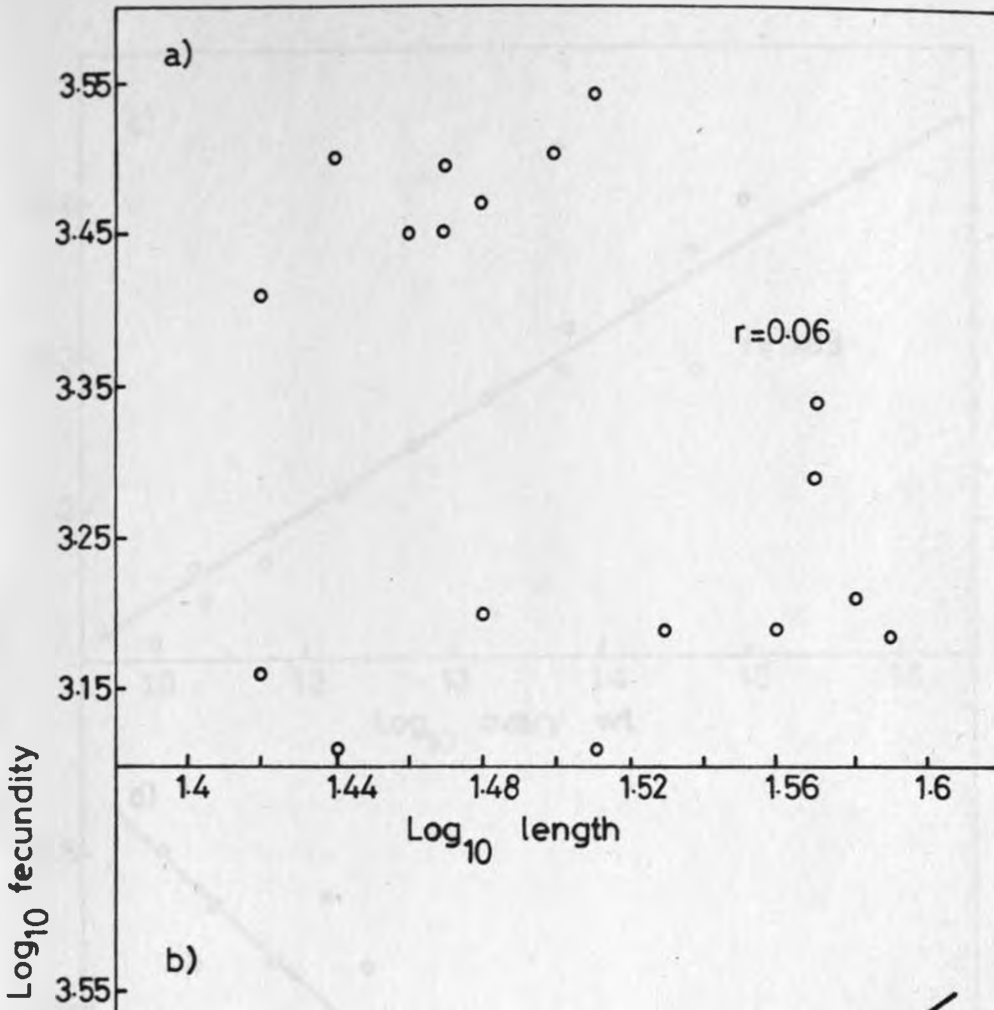
(a) Total body length

(b) Body weight

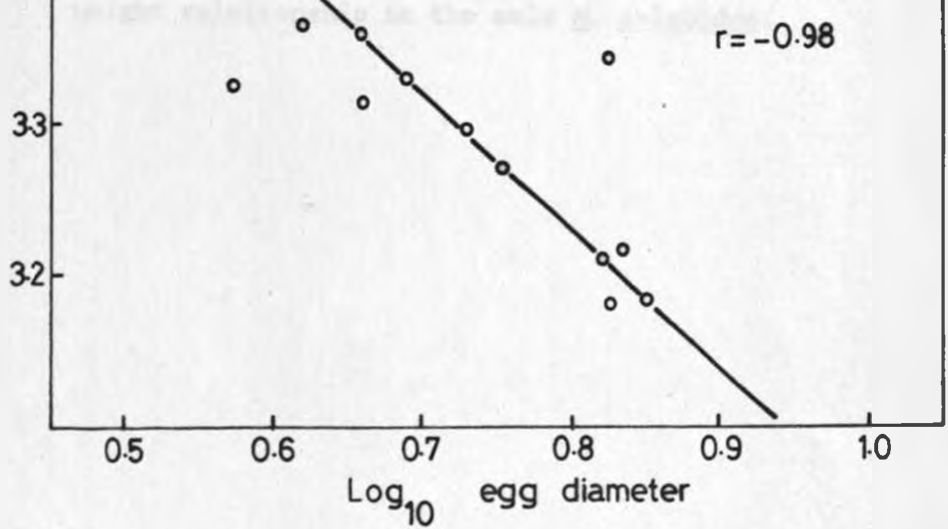
(c) Ovarian weight

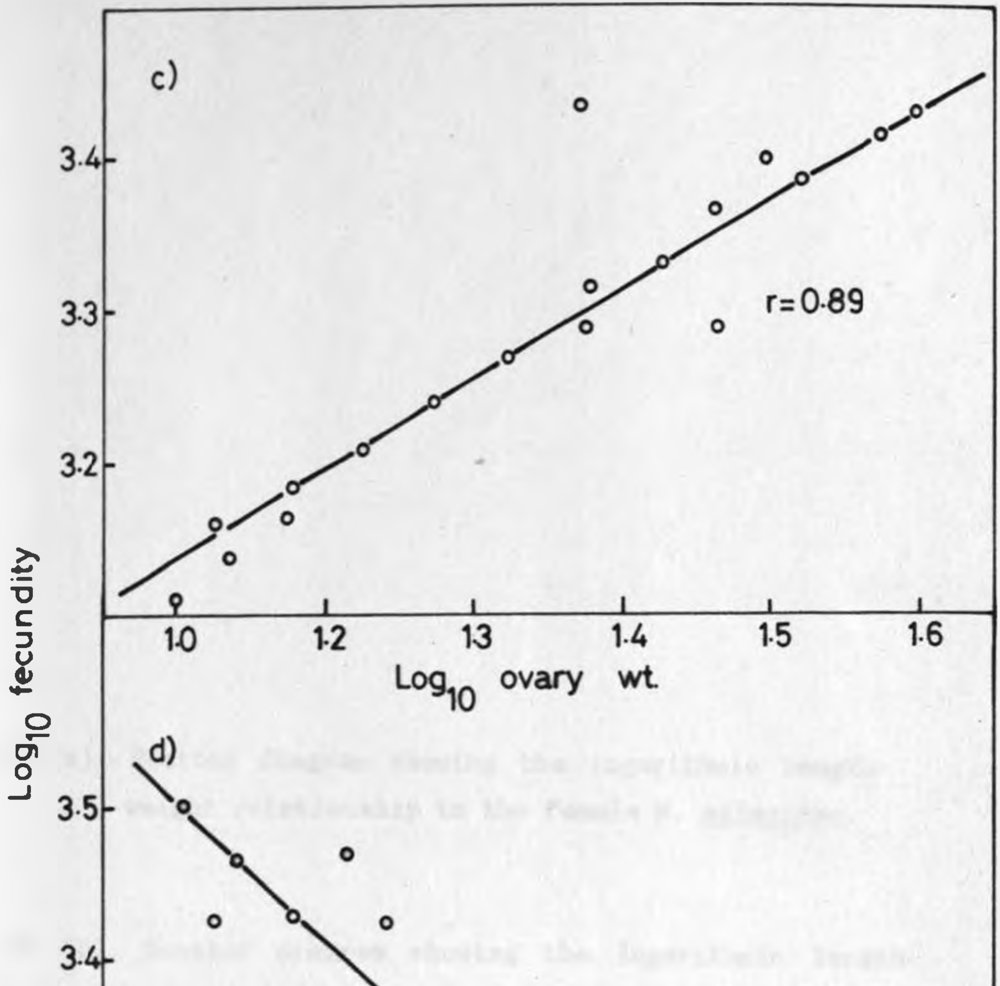
(d) Egg diameter


3·45
3·35
3·25
3·15
r=0·920
2·1
2·3
2·5
2·7
2·9
3·1
Log10 body wt.



a)
r=0·06
3·55
3·45
3·35
3·25
3·15
1·4
1·44
1·48
1·52
1·56
1·6
Log10 length
Log10 fecundity
b)
3·55


r= -0.98
3.3
3.2
0.5
0.6
0.7
0.8
0.9
1.0
Log10 egg diameter



c)
r=0.89
Log10 fecundity
3.4
3.3
3.2
1.0
1.2
1.3
1.4
1.5
1.6
Log10 ovary wt.
d)
3.5
3.4

Fig. 25 (a). Scatter diagram showing the logarithmic length-weight relationship in the female *M. salmoides*.

Fig. 25 (b). Scatter diagram showing the logarithmic length-weight relationship in the male *M. salmoides*.

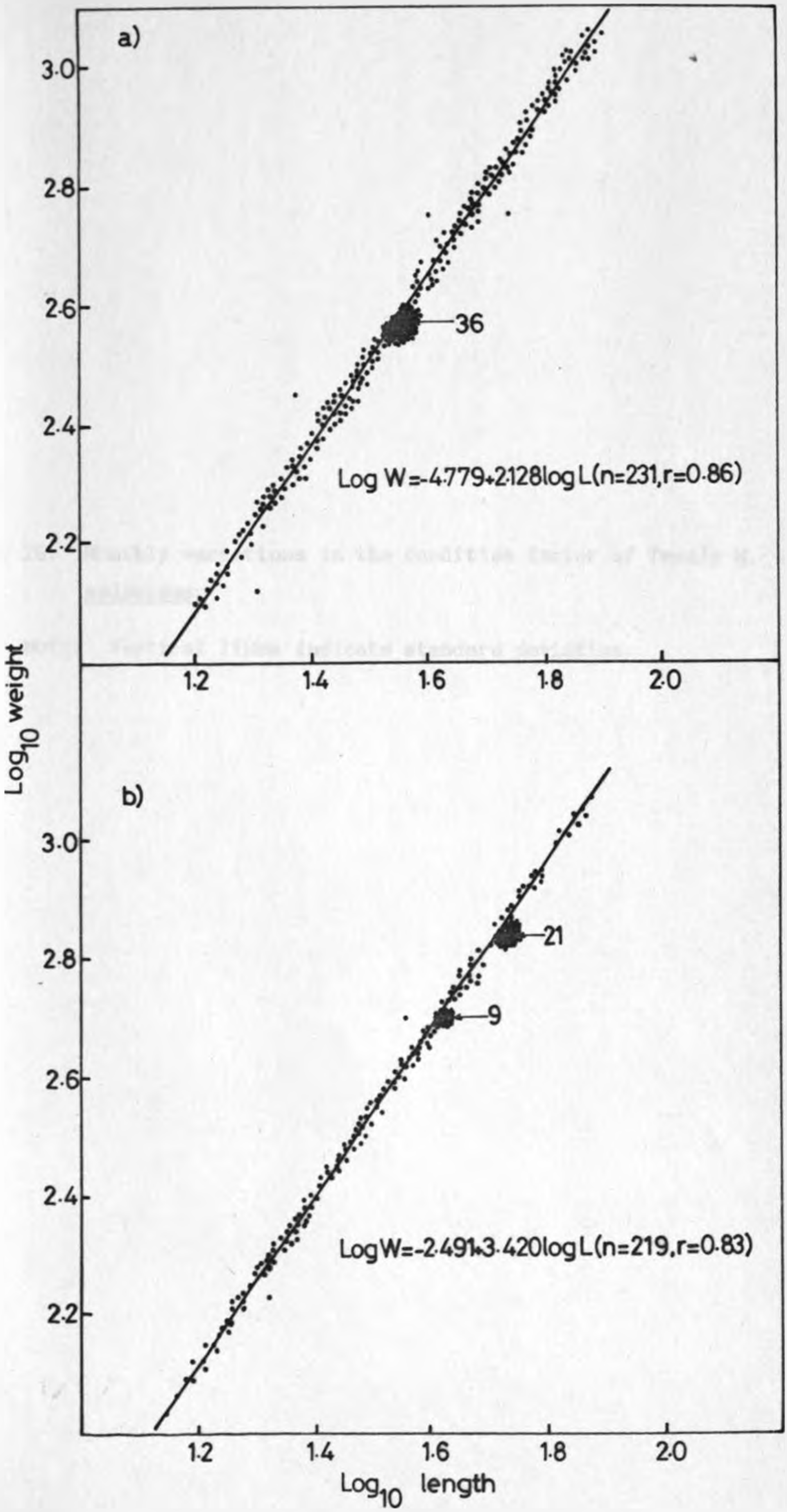
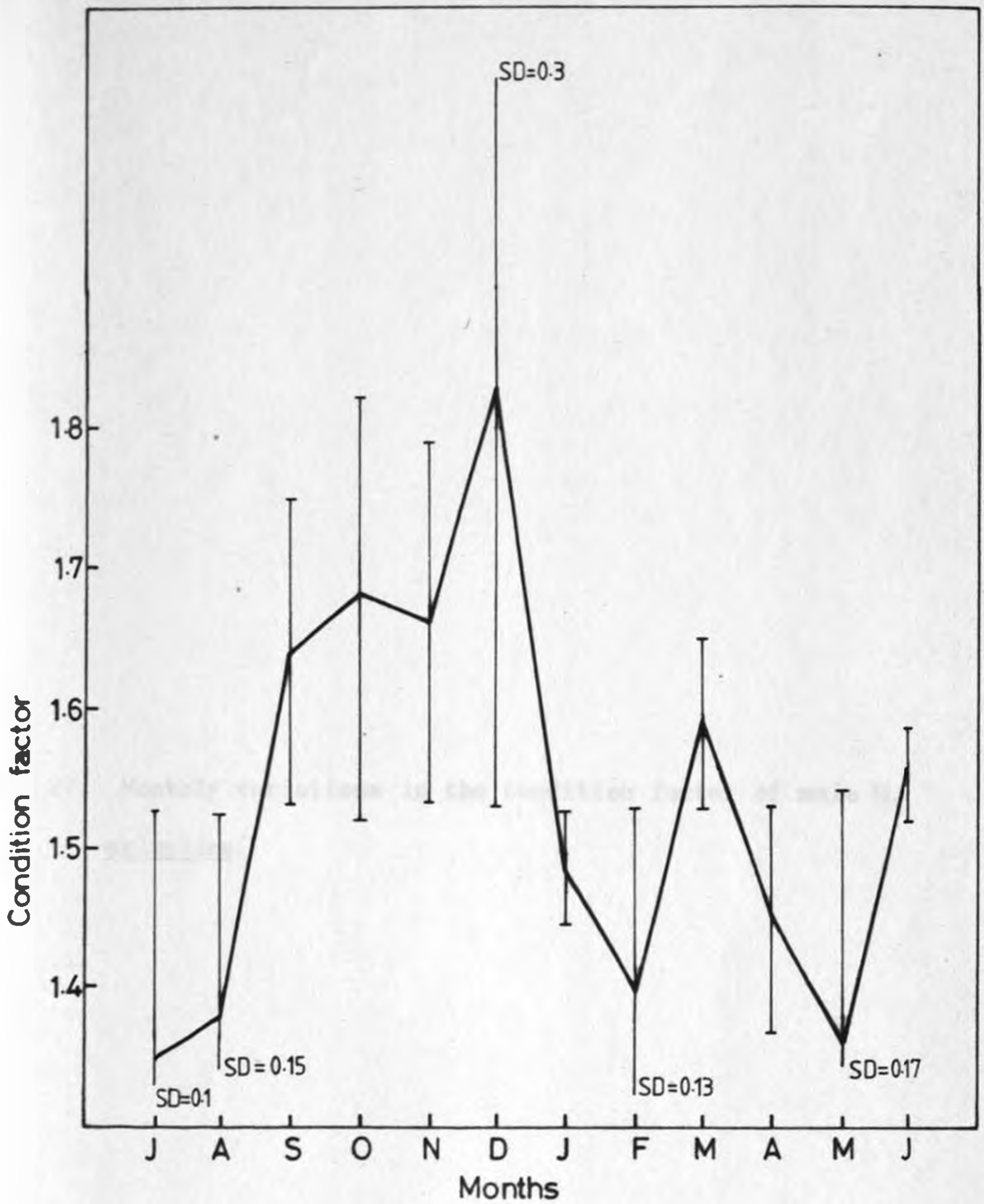

a)
3·0
2·8
2·6
2·4
2·2
36
Log W=-4·779+2·128log L(n=231,r=0·86)
1·2
1·4
1·6
1·8
2·0
b)
3·0
2·8
2·6
2·4
2·2
21
9
Log W=-2·491+3·420log L(n=219,r=0·83)
1·2
1·4
1·6
1·8
2·0
Log10 weight
Log10 length

Fig. 26. Monthly variations in the condition factor of female _M. salmoides_.

NOTE: Vertical lines indicate standard deviation.


Condition factor
1·4
1·5
1·6
1·7
1·8
SD=0·1
SD = 0·15
SD=0·3
SD=0·13
SD=0·17
J
A
S
O
N
D
J
F
M
A
M
J
Months

45. Gwyne, M.D.; Pratt, D.J. and Greenway, P.J. (1964). A classification of East African rangeland with an appendix on terminology. J. Appl. Ecol. 3: 369-382.

46. Hamblyn, E.L. (1966). The food and feeding habits of nile perch, Lates niloticus (Linn.). (Pisces: Centropomidae). Rev. Zool. Bot. Afr. 74: 1-28.

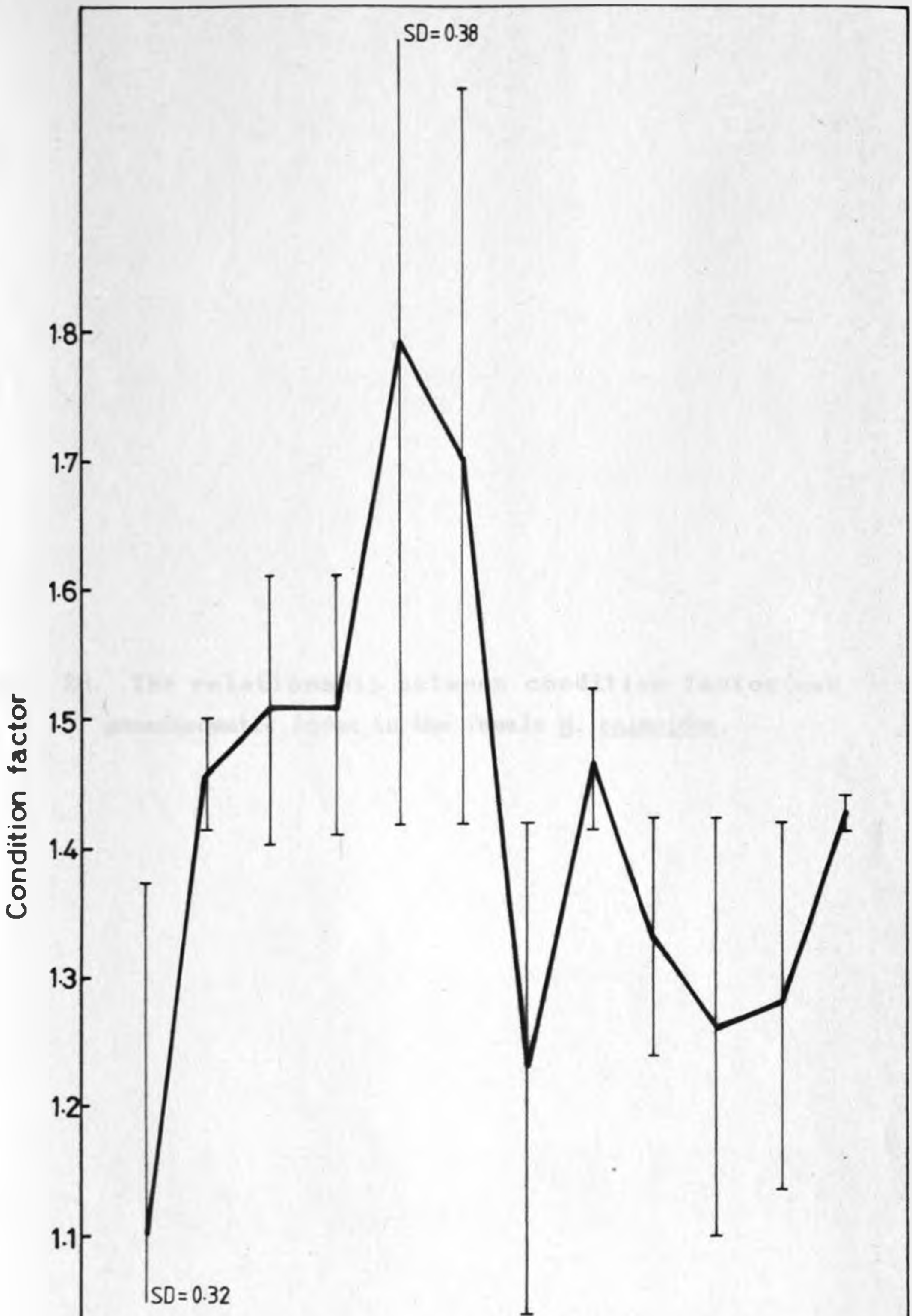
47. Harper, D and Muchiri, S.M. (1984). The ecology of Lake Naivasha - Introduction and historical review In Final report to Kenya Government, May 1987.

48. Hathaway, E.S. (1927). The relation of temperature to the quantity of food consumed by fishes. Ecol. 8(4): 428-434.

49. Hicking, C.F. and Ruttenberg, E. (1936). The ovary as an indicator of spawning period of fishes. J. Mar. Biol. Ass. U.K. 21: 311-317.

50. Hoffman, G.L. (1967). Parasites of North American fresh-water fishes. Los Angeles, University of California Press. 486 p.

51. Hopson, A.J. (1972). A study of the nile perch Lates niloticus (L.) in Lake Chad. Foreign and Commonwealth office. Overseas Res. Pub. 19, 93, London: HMSO.



SD = 0·38
SD = 0·32
1·8
1·7
1·6
1·5
1·4
1·3
1·2
1·1
Condition factor
J
A
S
O
N
D
J
F
M
A
M
J
Months

Fig. 28. The relationship between condition factor and gonadosomatic index in the female M. salmoides.

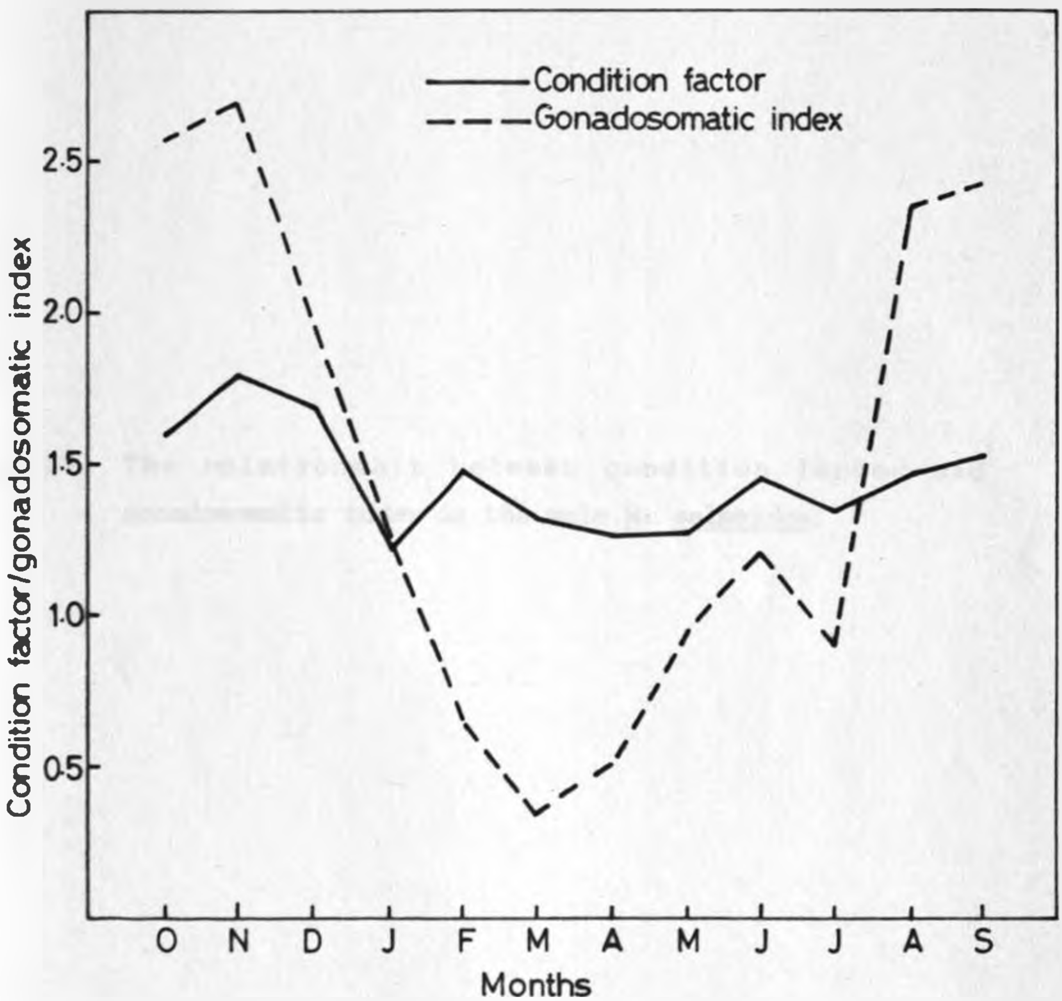

Condition factor
Gonadosomatic index
Condition factor/gonadosomatic index
2·5
2·0
1·5
1·0
0·5
O
N
D
J
F
M
A
M
J
J
A
S
Months

Fig. 29. The relationship between condition factor and gonadosomatic index in the male *M. salmoides*.

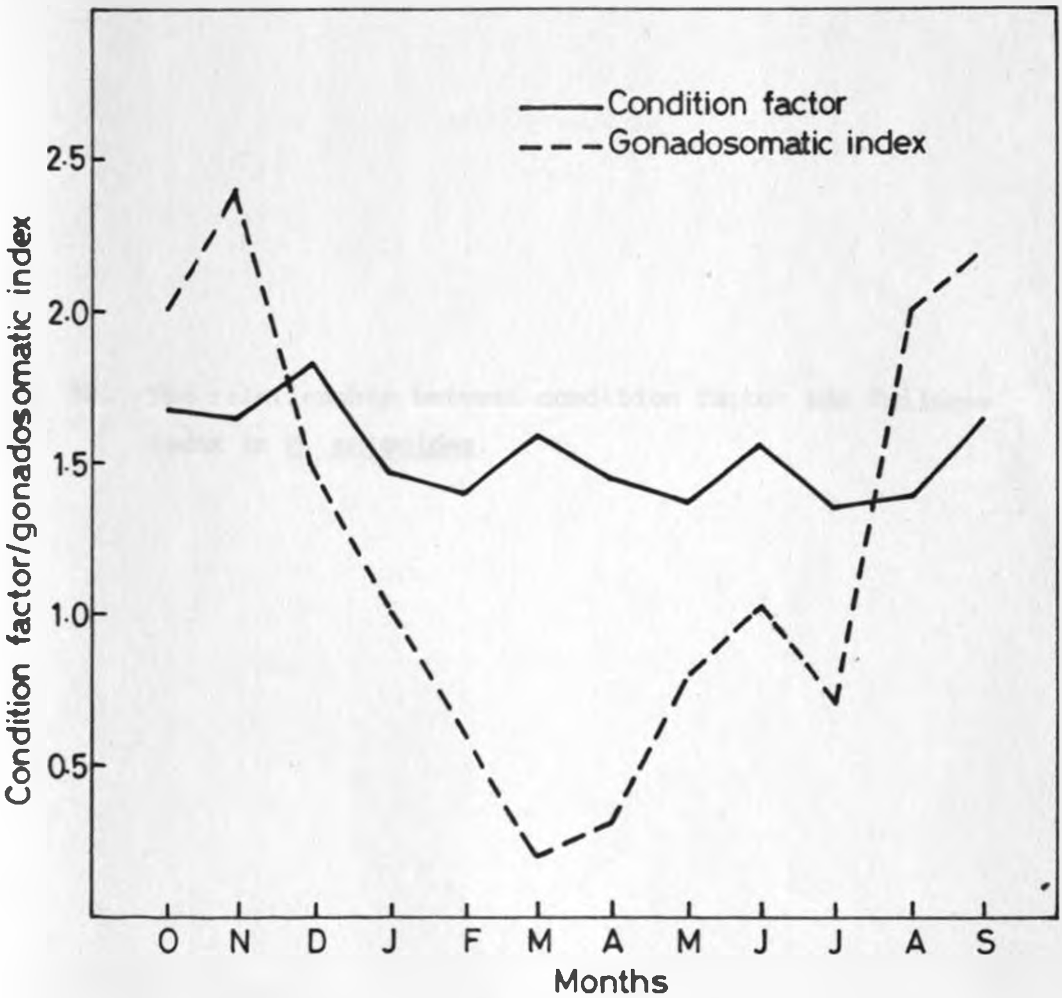

Condition factor
Gonadosomatic index
Condition factor/gonadosomatic index
2.5
2.0
1.5
1.0
0.5
O N D J F M A M J J A S
Months

Fig. 30. The relationship between condition factor and fullness index in M. salmoides.

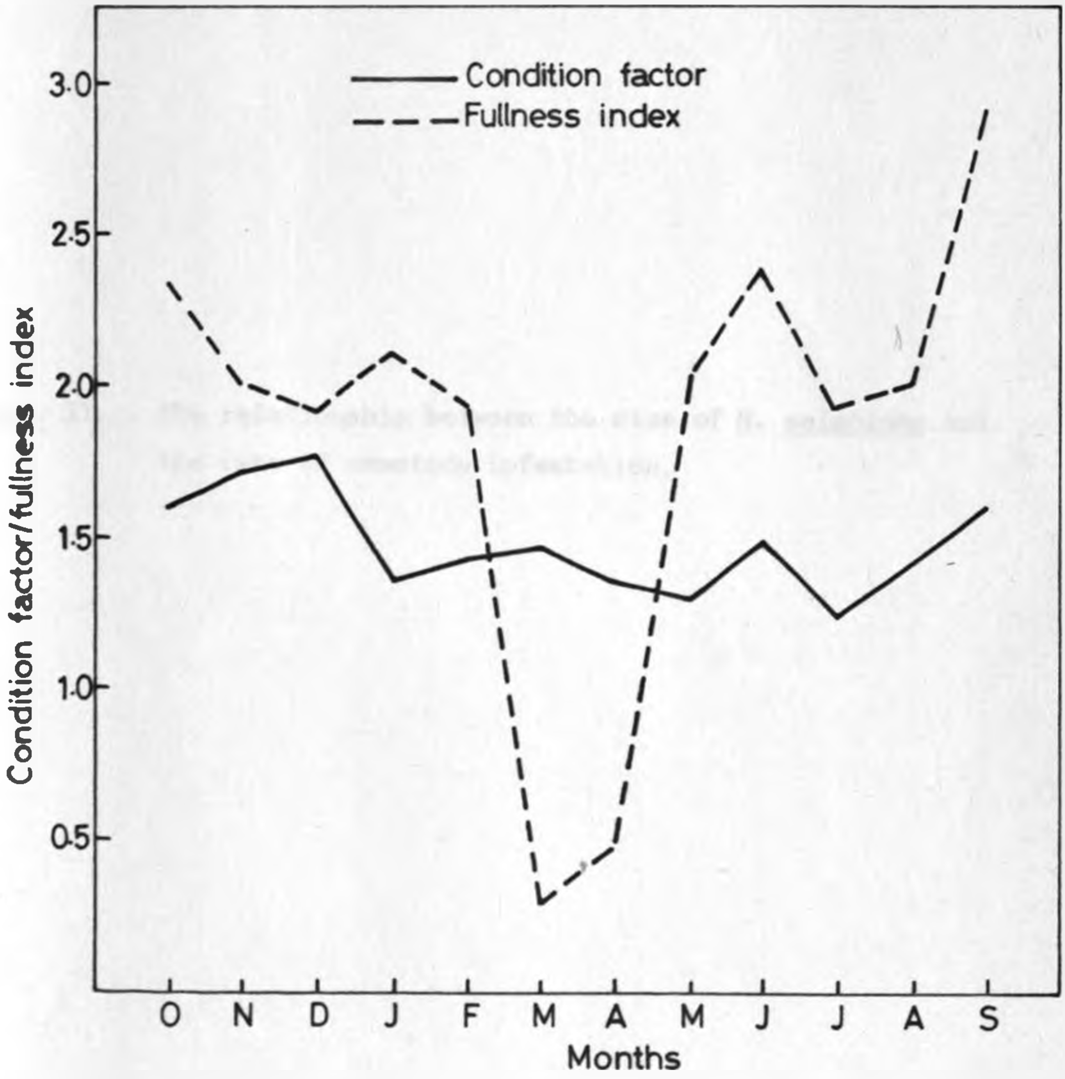
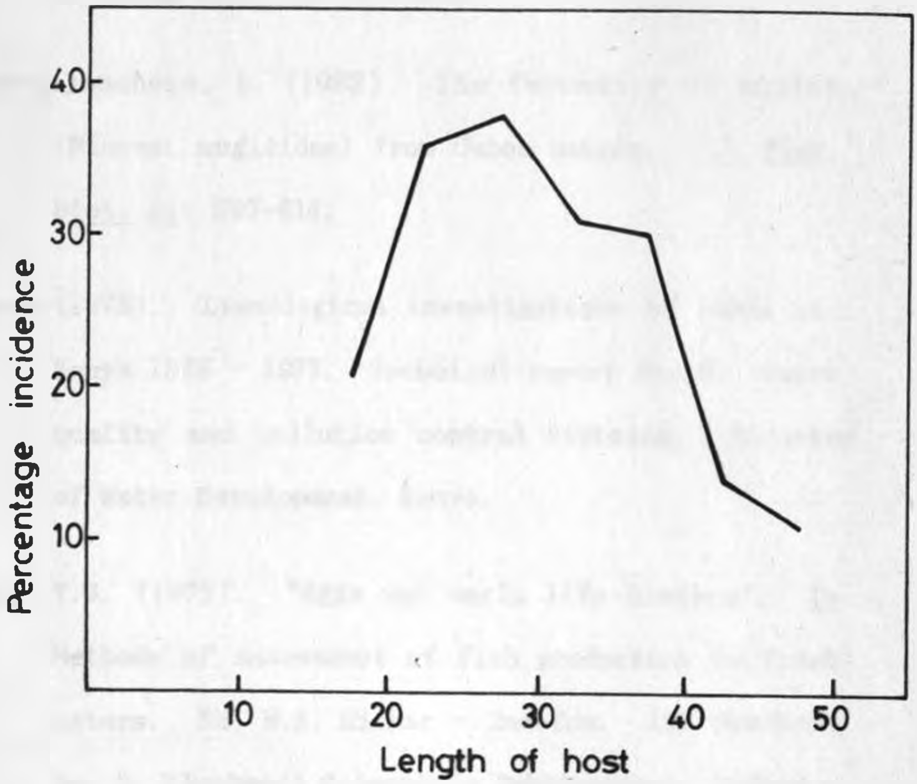

Condition factor
Fullness index
Condition factor/fullness index
3.0
2.5
2.0
1.5
1.0
0.5
O
N
D
J
F
M
A
M
J
J
A
S
Months

Fig. 31. The relationship between the size of M. salmoides and the rate of nematode infestation.


Percentage incidence
40
30
20
10
10
20
30
40
50
Length of host

BIBLIOGRAPHY

1. Abu-Hakima, R. (1984). Some aspects of the reproductive biology of Acanthopagrus spp. (Family: Sparidae). J. Fish. Biol. 25: 515-526.

2. Alvarez-Lajonchere, L. (1982). The fecundity of mullet (Pisces: mugilidae) from Cuban waters. J. Fish. Biol. 21: 607-614.

3. Anonymous (1978). Limnological investigations of lakes in Kenya 1976 - 1977. Technical report No. 6. Water quality and pollution control Division. Ministry of Water Development, Kenya.

4. Bagenal, T.B. (1971). "Eggs and early life history". In Methods of Assessment of fish production in fresh waters. Ed. W.E. Ricker - 2nd Edn. IBP Handbook No. 3, Blackwell Scientific Publication. Oxford - London pp 167-179.

5. Bagenal, T.B. (1978). Methods of Assessment of fish production in fresh waters. Ed. W.E. Ricker - 3rd Edn. IBP Handbook No. 3.

6. Bailey, T.B. (1972). Observation on the biology of Northobranchus guentheri (Cyprinodontidae) an annual fish from coastal region of East Africa. Afr. J. Trop. Hydrobiol. Fish. I: 33-34.

7. Bishop, H. (1968). Largemouth bass culture in the Southwest. In Proceedings of North Central warmwater fish culture workshop. Ames, Iowa P. 24 - 27

8. Blay, J. Jr and Eyeson, K.N. (1982). Observations on the reproductive biology of shad, Ethlamosa fibriata (Bodwich) in coastal water of Cape Coast, Ghana. J. Fish. Biol. 21: 485-496.

9. Blegvad, H. (1917). On the food of fishes in the Danish waters with skaw. Rep. Den. Biol. Stn. Vol. 24: 17-72.

10. Bowmacker, A.P. (1969). Contribution of the knowledge of the biology of Alestes macrophthalmus (Pisces: Characidae). Hydrobiologia 33: 302-341.

11. Bryant, H.E. and Houser, A. (1971). Population estimates and growth of largemouth bass in Beaver and Bull shoals reservoirs. Spec. Publ. Am. Fish. Soc. 8: 349-357.

12. Cady, E.R. (1945). Fish distribution, Norris Reservoir, Tennessee (1943). (1). Depth distribution of fish in Norris Reservoir. J. Tenn. Acad. Sc. 20(1): 103-114.

13. Callander, K.D. (1969). Handbook of fresh water fishery biology Vol. I. University Press. Iowa State.

14. Candwalladr, D.A. (1965). Notes on the breeding biology and ecology of Labeo victorianus Blgr. (Cyprinidae) in Lake Victoria. Revue. Zool. Bot. Afr. Vol. 72: 100-134.

15. Corbet, P.S. (1961). The food of non-cichlid fishes in Lake Victoria basin, with remarks on their evolution and adaptation to lacustrine conditions. Proc. Zool. Soc. Lond. Vol. 136: 1-101.

16. Coulter, G.W. (1976). The biology of Lates species (Nile Perch) in Lake Tanganyika and the status of the pelagic fishery for Lates species and Luciolates stappersii (Blgr.). J. Fish. Biol. 9: 235-259.

17. Cross, F.B. (1951). Early limnological and fish population conditions of Canton Reservoir, Oklahoma with special references to the Carp, Channel catfish, largemouth bass, green sunfish and bluegill and fishery management recommendations. Ph.D. thesis. Oklahoma Agricultural and Technical College, Still Water. 92p.

18. Dadzie, S. (1969). Spermatogenesis and stages of maturation in the male cichlid fish, Tilapia mossambica. J. Zool. Lond. 159: 139-403.

19. Dadzie, S. (1970). Laboratory experiment on fecundity and frequency of spawning in Tilapia aurea. Bamidgeh 22: 14 - 18

20. Dadzie, S. (1970a). Growth, maturation and pituitary activity in Tilapia species. Ph.D. thesis. University of Stirling

21. Dadzie, S. (1974). Oogenesis and stages of maturation in female cichlid fish Tilapia mossambica. Ghana J. Sc. 14: 23-31.

22. Dadzie, S. (1985). Seasonal changes in the length-weight relationship, reproduction and condition of the African carp, Labeo cylindricus (Peters) in a tropical man-made lake, Lake Kamburu, Kenya J. Sc. Techn. (B)(2): 79-88.

23. Dadzie, S.; Odingo, R.S. and Ongoma A. (1979). Aquatic ecology and Fisheries. In "African Dam: Ecological Survey of the Kamburu/Gitaru Hydroelectric dam area, Kenya". (R.S. Odingo Ed.). Ecol. Bull. (Stockholm (1979) 29:65 - 84.

24. Dadzie, S. and Wangila, B.C.C. (1980). Reproductive biology, length-weight relationship and relative condition of pond raised Tilapia zillii (Gervais). J. Fish. Biol. 17: 243-253.

25. Dendy, J.S. (1946). Further studies on depth distribution of fish, Norris Reservoir, Tennessee. J. Tenn. Acad. Sc. 21(1): 94: 134-104.

26. Dubets, H. (1954). Feeding habits of the largemouth bass as revealed by a gastroscope. Prog. Fish. Cult. 16: 134-136.

27. Elder, H.Y. and Garrod, D.J. (1961). A natural hybrid of *Tilapia nigra* and *T. leucosticta* from Lake Naivasha, Kenya. Nat. Lond. Soc. 191: 722-724.

28. Elder, H.Y.; Garrod, D.J. and Whitehead, T. (1971). A natural hybrid of *T. nigra* and *T. leucosticta* from Lake Naivasha, Kenya. Biol. J. Linn. Soc. 3: 103-106.

29. El-Zarka, S. (1961). III. Maturity, spawning and sex ratio of *Tilapia zillii* (Gerv.) in Lake Quaran. Notes and memoirs No. 67. Alexandria Inst. Hydrobiol.

30. Emery, L. and Brown, E.H. Jr (1978). Fecundity of the bloater, *Coregonus hoyi* in Lake Michigan. Trans. Am Fish. Soc. 107: 785-789.

31. Espinosa, F.A. Jr and Deacon, J.E. (1973). The preference of largemouth bass, *Micropterus salmoides* (Lacepede) for selected bait species under experimental conditions. Trans. Am. Fish. Soc. 102: 355-362.

32. Fisheries department: Statistical data 1976-86.

33. Frost, W.E. and Kipling, C. (1967). A study of reproduction, early life, length-weight relationship and growth of pike, Esox lucius in Windermere. J. Anim. Ecol. 9: 105-118.

34. Gaudet, J.J. (1978). Effects of a tropical swamp on water quality. Vern. Intern. Veren. Limm. 20: 2202-2206.

35. Gaudet, J.J. (1979). Seasonal changes in nutrients in a tropical swamp, North Swamp, Lake Naivasha - Kenya. J. Ecol. 67: 953-981.

36. Gaudet, J.J. and Melack, J.M. (1981). Major ion chemistry in a tropical African lake basin. Fresh. Wat. Biol. 11: 309-333.

37. Gaudet, J.J. and Muthuri, F.M. (1981). Nutrient relationships in shallow water in an African lake, Lake Naivasha. Oecol. (Berl.). 49:109-118.

38. Gee, J.M. (1968). A comparision of certain aspects of the biology of Lates niloticus (Linn.) in endemic and introduced environments in East Africa, in man made lakes: The Accra Symposium. Ed. L.E. Obeng. Ghana Univ. Press. pp 251-259.

39. Gee, J.M. (1975). The genus Xenoclarias, (Pisces, Siluriformes) in Lake Victoria with a re-description of Xenoclerias eupogon and notes on the biology of the species. J. Zool. Lond. 175: 201-217.

40. Geevarghese, C. and John, P.A. (1983). Biology and spawning of gobiid fish, Oligolepsis acutipenis (Cur. and Val.) from the south west coast of India. J. Fish. Biol. 23: 611-624.

41. Goodson, L.F. Jr (1965). Diets of four warm water game fishes in a fluctuating, steep-sided, California reservoir. Calif. Fish. and Game 51(4): 259-269:

42. Goodyear, C.P. (1972). A simple technique for detecting effects of toxicants or other stresses on predatory-prey interaction. Trans. Am. Fish. Soc. 11: 367-370.

43. Gosh, A. and Kar, A.N. (1952). Seasonal changes in the gonads of the common Indian Catfish, Heteropneustes fossilis. Proc. Zool. Soc. Bangau Vol. 5: 29-50.

44. Gunstrom, G.K. (1968). Gonad weight/body weight ratio of mature Chinook salmon males as a measure of gonad size. Prog. Fish. Cult. 30: 23-25.

45. Gwyne, M.D.; Pratt, D.J. and Greenway, P.J. (1964). A classification of East African rangeland with an appendix on terminology. J. Appl. Ecol. 3: 369-382.

46. Hamblyn, E.L. (1966). The food and feeding habits of nile perch, Lates niloticus (Linn.). (Pisces: Centropomidae). Rev. Zool. Bot. Afr. 74: 1-28.

47. Harper, D and Muchiri, S.M. (1984). The ecology of Lake Naivasha - Introduction and historical review In Final report to Kenya Government, May 1987.

48. Hathaway, E.S. (1927). The relation of temperature to the quantity of food consumed by fishes. Ecol. 8(4): 428-434.

49. Hicking, C.F. and Ruttenberg, E. (1936). The ovary as an indicator of spawning period of fishes. J. Mar. Biol. Ass. U.K. 21: 311-317.

50. Hoffman, G.L. (1967). Parasites of North American fresh-water fishes. Los Angeles, University of California Press. 486 p.

51. Hopson, A.J. (1972). A study of the nile perch Lates niloticus (L.) in Lake Chad. Foreign and Commonwealth office. Overseas Res. Pub. 19, 93, London: HMSO.

52. Hopson, A.J. (1975a). Preliminary observation on the biology of Lates niloticus in Lake Rudolf. Proc. Symp. Hydrobiol. Fish of Lake Rudolf Molo, May 1975.

53. Hopson, A.J. (1975b). Preliminary observation on the biology of Alestes seramere in Lake Rudolf. Proc. Symp. Hydrobiol. Fish of Lake Rudolf Molo, May 1975.

54. Hyatt, K.D. (1979). Feeding strategy. In Fish Physiology, edited by W.S. Hoar, D.J. Randall and J.R. Brett. Vol. 3: 71-121.

55. Hyder, M. (1970). Gonadal and reproductive patterns in Tilapia leucosticta (Teleostei: Cichlidae) in an equatorial lake, Lake Naivasha, Kenya. J. Zool. Lond. 162: 179-195.

56. Hynes, H.B.N. (1950). The food of the freshwater sticklebacks, Gasterosteus aculeatus and Pygosteus pungitis with a review of the methods used in studies of the foods of fishes. J. An. Ecol. 19: 36-58.

57. Hyslops, E.J. (1980). Stomach content analysis - Review of methods and their analysis. J. Fish. Biol. 17: 411-429.

58. Ivlev, V.S. (1961). Experimental ecology of the feeding of fishes. Yale Univ. Press. New Haven.

59. James, M.F. (1942). Histological changes in the gonads of the bluegill, Lepomis macrochinis (Rafinesque) and of the largemouth bass Micropterus salmoides (Lacepede) accompanying seasons, age and condition. Ph.D. thesis. University of Illinois, Urbana, 86 p.

60. Jenkin, P.M. (1931). Biology of lakes in Kenya. Nature 124: 574.

61. Jenkin, P.M. (1936). Reports on the Percy Sladen expedition to some Rift Valley lakes in Kenya 1929. An. Mag. Nat. Hist. (Ser. 10) 18: 133-181

62. Johnson, L. J. (1972). Investigation of food habits of largemouth bass in Lake Mohave Nev. Dept. of Fish. and Game 6p (Unpubl.)

63. Jonez, A. and Summer, R.C. (1954). Lake Mead and Lake Mohave investigation. A comparative study of an established reservoir as related to a newly created impoundment. Nev. Fish and Game Comm. Final rep. D-J Proj F-I-R 185 p.

64. Keast, A. (1968). Feeding of some Great Lakes fishes at low temperatures. J. Fish. Res. Board. Can. 25(6): 1199-218.

65. Keast, A. and Webb, D. (1966). Mouth and body form relative to the feeding ecology in the fish fauna of a small lake, Lake Opinicon, Ontario. J. Fish. Res. Board. Can. 23: 1845-1867.

66. Lawrence, J.M. (1958). Estimated sizes of various forage fishes largemouth bass can swallow. Proc. Ann. Conf. South East Ass. Game and Fish. Comm. (1957): 220-225.

67. Leakey, L.S.B. (1931). East African lakes. Geogrl. J. 77: 497-514.

68. Lewis, W.M. Jr, Summerfelt, R. and Bender, M. (1961). Food choice of largemouth bass as a function of availability and vulnerability of food items. Trans. Am. Fish. Soc. 90(3): 277-280.

69. Lewis, W.M. Jr and Helms, D.R. (1964). Vulnerability of forage organisms to largemouth bass. Trans. Am. Fish. Soc. 93(3): 315-8.

71. Le Cren, E.D. (1951). The length-weight relationship and seasonal cycle in gonad weight and condition in perch, Perca fluviatilis. J. An. Ecol. 20: 201-229.

72. Lock, J.M. (1975). Preliminary report of the biology of Lake Rudolf catfish, Bagrus bayad. Symp. on Lake Rudolf, Molo 1975.

73. Lowe, (McConnell) R.H. (1955). Fecundity of Tilapia species. E. Afr. Agr. J. 21: 45-50.

74. Macer, C.T. (1974). The reproductive biology of the horse mackerel, Trachurus trachurus (L.) in North Sea and English Channel. J. Fish. Biol. 6: 415-438.

75. Maien, V.A. (1939). On the question of annual cyclical changes in the ovaries of bony fishes. Dok, Akad. Nauk. U.S.S.R. 3.

76. Malvestuto, S. (1974). The fishes of Lake Naivasha, their biology, exploitation and management. Mimeo report to Kenya Govt.

77. Malvestuto, S. (1975). Contracaecumosis of Oreochromis leucostictus in Lake Naivasha - Kenya. MSc. thesis, Univ. Nairobi.

78. Mann, R.H. (1976). Observation on age, growth, reproduction and food of the Pike, Esox lucius (L.) in two rivers in Southern England. J. Fish. Biol. 8: 179-197.

79. Mann, M.J. and Ssentongo, G.W. (1969). A note on the Tilapia populations of Lake Naivasha in (1968). Rep. E. Afr. Fresh Wat. Fish. Res. Org. 1968. pp (28-33).

80. Markus, H.C. (1932). The extent to which temperature changes influence food consumption in the largemouth bass, Micropterus salmoides. Trans. Am. Fish. Soc. 62: 202 - 210

81. Martin, W.R. (1949). The mechanics of environmental control of body form in fishes. Univ. Toronto Stud. Biol. 58. (Publ. Ont. Fish. Res. Lab. 70). 1-91.

82. Mavuti, K.M, (1983). Studies on the community structure population dynamics and production of the limnetic zooplankton in a tropical lake (Naivasha - Kenya). Ph.D. thesis, Univ. Nairobi.

83. Mavuti, K.M, and Litterick, M.R. (1981). Species composition and distribution of zooplankton in a tropical lake, Lake Naivasha, Kenya. Arch. Hydrobiol. 93: 52-58.

84. McLeod, A.A.O. (1975). Some results in the investigation of the biology of Lates longispinus. Proc. Symp. Hydrobiol. Fish. of Lake Turkana, Molo, May 1975.

85. Melack, J.M. (1976a). Limnology and dynamics of phytoplankton in equatorial African lakes. Ph.D. thesis, Univ. Duke, Durham, N.C. 453 p.

86. Meleck, J.M. (1976b). Photosynthetic rates in four African fresh waters. Fresh. Wat. Biol. 9: 555-571.

87. Milbrink, C. (1977). On the limnology of two alkaline lakes (Nakuru and Naivasha) in East Rift Valley system in Kenya. Int. Revue. ges Hydrobiol. 62: 1-17.

88. Minckley, W.L. (1973). Foods of buffalo fishes genus Ictiobus in Central Arizona reservoirs. Trans. Am. Fish. Soc. 103: 130-134.

89. Moffet, J.E. (1943). A preliminary report on the fishery of Lake Mead. Trans. 8th North American Wildl. Conf. 8: 179-186.

90. Morgensen, S.A. (1982). The status of the blackbass fishery in Lake Mead and a programme towards restoration and enhancement (1981. U.S. Bur. Rec. Contract No. 7-07-30-X0028. 115 p.

91. Moriarty, D.J.W, Darlington, J.P.E.C, Dunn, I.G, Moriarty, C.M and Tervin, M.P (1973). Feeding and grazing in Lake George, Uganda. Proc. Roy. Soc. Lond. Vol. 184 (pp 389 - 414).

92. Moyle, P.B. and Holzhauser, N.J. (1978). Effects of the introduction of Mississippi silverside, (Menidia audiens) and Florida largemouth bass (Micropterus salmoides) on the feeding habits of young-of-the year largemouthbass in clear Lake California. Trans Am. Fish. Soc. 107(4): 574-582.

93. Muchiri, S.M. (1987). Pers. Comm.

94. Munro, J.L. (1967). "The food of a community of East African Freshwater fishes". Proc. Zool. Soc. Lond. Vol. 151 (pp 389 - 415).

95. Muthuri, F.M. (1980). Nutrient relationships in the shallow water of Lake Naivasha - Kenya. MSc. thesis, Univ. Nairobi.

96. Muthuri, F.M. (1983). The primary productivity of papyrus, (*Cyperus papyrus* L.) in relation to environmental variables. Ph.D. thesis, Univ. Nairobi.

97. Mwaura, F.B. (1982). Investigations of microbial nitrogen fixation in the papyrus swamps of Lake Naivasha. MSc. thesis Univ. Nairobi.

98. Nair, P.V. (1958). Seasonal changes in the gonads of *Hilsa ilisha*. Hamilton Philip. J. Sc. 87: 256-287.

99. Nair, J.R.; Nair, N.B. and Balasubramenien, N.K. (1983). Condition and relative condition cycles in tropical glassy perchiet, *Chanda* (=*Ambasis*) *commersonii* (Cur and Val). (Pisces: Centropomidae). Proc. Indian Acad. Sc. (Anim. Sc.) 92: 415-422.

100. Nikolsky, G.V. (1962). "On some adaptations to the regulation of population density in fish species with different types of stock structures. In E.D. Le Cren and Holgate (E. Eds). The exploitation of natural animal populations. Blackwell, Oxford pp 265-282.

101. Nikolsky, G.V. (1963). The ecology of fishes. Academic press, London and New York. 352pp.

102. Njuguna, S.G. (1983). Nutrient productivity relationships in tropical Naivasha basin lakes - Kenya. Ph.D. thesis, Univ. Nairobi.

103. Nzioka, R.M. (1981). Biology and fishery of the reef fish, Scolopsis bimaculatis (Rupfell) (Moncleo: Bream) in Kenya. MSc. thesis, Univ. Nairobi.

104. Okach, J.I.O. (1981). Reproductive biology and feeding ecology of predatory siluroid catfish, Bagrus docmac Forskal (Pisces: Bagridae) in Winam Gulf of Lake Victoria, East Africa. MSc. thesis, Univ. Nairobi.

105. Okach, J.I.O. and Dadzie, S. (1988). The food, feeding habits and distribution of a siluroid catfish, Bagris docmac (Forsscal) in the Kenya waters of Lake Victoria. J. Fish. Biol. Vol. 32: 85 - 94.

106. Okedi, J. (1970). A study of fecundity of some momyrid fishes from Lake Victoria, E. Afr. Agr. For. J. 35: 436-442.

107. Okedi, J. (1971a). Maturity, sex ratio and fecundity of the lungfish Protopterus aethiopicus from Lake Victoria. Report: E.A.F.F.R.O. Ann. Report 1970 17-20.

108. Okedi, J. (1971b). The food and feeding habits of small momyrid fishes of Lake Victoria. E.A. Afr. J. Trop. Hydrobiol. Fish. Vol. 1 (1-2).

109. Ogari, J. (1984). The biology of Lates niloticus (Linn.) in the Nyanza gulf of Lake Victoria, (Kenya) with special reference to the food and feeding habits. MSc. thesis, Univ. Nairobi.

110. Oluoch, A.O. (1983). A study of some aspects of the distribution, biology, ecology and fishery of crayfish, Procambarus clerkii (Girard) population in Lake Naivasha. MSc. thesis, Univ. Nairobi.

111. Ortega-Salas, A.A. (1980). Seasonal changes in the common dab Limanda limanda in the Isle of Man waters. J. Fish. Biol. 16: 75-82.

112. Owiti, D.O. (1986). Cyclical changes in the histology of the gonads and the biology of Clarias mossambicus (Peters) in the Nyanza gulf of Lake Victoria. MSc. thesis, Univ. Nairobi.

113. Papageorgion, N.K. (1979). The length-weight relationship, age, growth and reproduction in Rutilus rutilus (L.) in Lake Volvi. J. Fish. Biol. 14: 529-538.

114. Payne, A.I. (1975). The reproductive cycle, condition and feeding in Banbus liberiensis, a tropical stream dwelling cyprinid. J. Zool. Lond. 174: 247-269.

115. Peters, H.M. (1963). Fecundity, egg weight and oocyte development in tilapias (Cichlidae: Teleostei). ICLARM Translations 2, 28 pp.

116. Richardson, J.L. and Richardson, A.E. (1972). History of an African Rift Valley lake and its climatic implications. Ecol. Monographs 42: 499-534.

117. Ricker, W.E. (Ed) (1971). Methods for Assessment of fish production in fresh waters, IBP Handbook No. 3, 2nd Edn, Oxford, Blackwell. pp. 348.

118. Rinne, J.N. (1980). Notes on the occurrence and biology of Xenoclarias (greenwood) (Siluliriformes: Clarriidae) in Lake Victoria, East Africa. J. Nat. Hist. 14: 579-587.

119. Rinne, J.N. and Wanjala, B. (1983). Maturity, fecundity and breedings of major catfishes (Suborder: Silurioidae) in Lake Victoria, East Africa. J. Fish Biol. 23: 357 - 368.

120. Robb, A.P. (1982). Histological observations on the reproductive biology of the haddock, Melanogrammus aeglefinus (L.). J. Fish. Biol. 20: 397-408.

121. Roggers, W.A. (1967). Food habits of young largemouth bass, Micropterus salmoides in hatchery ponds. Proc. of 21st Ann. Conf. of S.E. Ass. of Game and Fish. Comm. 8p.

122. Robbins, W.H. and McCrimmon, H.R. (1974). The blackbass in America and overseas. Ontario, Canada, Biomanagement and Research enterprise, 196 pp.

123. Ross, V.B. (1967). Fecundity of steelhead trout, Salmo gairdneri from Alsea River, Oregon. J. Fish. Res. Bd. Canada Vol. 24(5) pp 917-926.

124. Rounsenfell, G. (1957). Fecundity of North American Salmonidae, U.S. Fish and Wildl. Service. Fishery Bulletin 122 Vol. 57: 451-468.

125. Schneider, J.C. (1971). Characteristics of a populations of warm water fishes in a Southern Michigan lake 1964-69. Dev. Rep. Mich. Dep. Conserv. 236: 158

126. Siddiqui, A.O. (1977a). Lake Naivasha (Kenya, East Africa). Fishery and its management together with a note on the food habits of fishes. Biol. Cons. 12: 217-227.

127. Siddiqui, A.O. (1977b). Reproductive biology, length-weight relationship and relative condition of Tilapia leucosticta (Trewavas) in Lake Naivasha - Kenya. J. Fish. Biol. 10: 251-60.

128. Siddiqui, A.O. (1979a). Reproductive biology of T. zillii (Gerv.) in Lake Naivasha, Kenya. Env. Biol. Fish. 4(3): 257-262.

129. Siddiqui, A.Q. (1979b). Changes in fish species composition of Lake Naivasha - Kenya. Hydrobiol. 64: 131 - 138.

130. Singler, K. and Miller, P. (1963). The taxonomy and life history of some freshwater fishes. Utah State Univ. Dept. Wildl. Mgt. Mimeo.

131. Smith, S. (1956). The life history of the lake Herring of greenbay, Lake Michigan. Fish. Bull. No. 109 Vol. 151: 138.

132. Snow, H.E (1971). Harvest and feeding habits of largemouth bass in Murphy flowage, Wisconsin. Tech. Bull. Wisc. Dept. Nat. Resour. 50: 25p.

133. Snow, J.R (1972). Controlled Culture of largemouth bass fry. Proc. Ann. Conf. Southeast Assoc. Game Fish. Comm. 26: 392 - 398.

134. Stein, M.J (1970). A study of the largemouth bass population in Lake Washington. Ph.D thesis Univ. Washington.

135. Talling, J.F. and Talling, I.B (1965). The chemical composition of African waters. In. Revue. ges. Hydro. 50: 421 - 463.

136. Tesch, F.W (1951). Age and growth. In "Methods of Assessment of fish production in fresh waters". (W.E. Ricker Ed.). 2nd Edn. PP. 28 - 31. Oxford, Blackwell.

137. Thompson, A.O. and Dodson, R.G (1963). Geology of Naivasha area. Report No. 55. Geological survey of Kenya.

138. Tom, J.T. and Pawaputanon, O (1980). Relative size relationship in prey selection by largemouth bass in West-point lake, Alabama-Georgia. Presented at 34th Ann. Meeting of Southeastern Assoc. of Game and Fish Agencies. (Unpubl.).

139. Turner, C.L (1919). The seasonal cycle in the spermery of the perch. J. Morph. 32: 681 - 719.

140. Turner, C.L. and Kraartz, W.C (1920). Food of the young largemouth bass in some Ohio waters. Trans. Am. Fish. Soc.

141. Wright, L.D (1970). Forage size preference of the largemouth bass. Prog. Fish. Cult. 32(1): 39 - 42.

142. Zaret, T.M. and Rand, A.S (1971). Competition in tropical stream fishes: Support for the competitive exclusion principle. Ecol. 52: 336 - 342.

143. Zweiacker, P.L. and Summerfelt, R.C (1974). Seasonal variation in food diet periodicity in feeding of Northern largemouth bass, Micropterus salmoides (Lacepede) in an Oklahoma reservoir. Proc. Ann. Conf. 27 (1973): 579 - 591.

Appendix I: Blackbass population compared to that of the tilapiines in Lake Naivasha

Fishermans No.	Area Fished	No. of blackbass	No. of Tilapia
1	Korongo	1	75
2	Malewa	10	120
3	Hippo	3	20
4	Fisherman's	-	50
5	Safariland	12	167
6	Crescent	9	84
7	Hippo	14	112
8	Korongo	8	41
9	Safariland	27	138
10	Korongo	15	81
11	Crescent	12	58
12	Fisherman's	4	121
13	Hippo	15	118
14	Safariland	11	92
15	Crescent	8	47
16	Safariland	32	102
17	Crescent	11	90
18	Korongo	16	108
19	Hippo	22	79
20	Crescent	14	168
21	Crescent	5	70
22	Safariland	12	110
23	Fisherman's	8	62
24	Korongo	24	98
25	Crescent	10	54
26	Hippo	19	66
27	Safariland	20	72
28	Korongo	2	35
29	Crescent	13	80
30	Fisherman's	4	114

Appendix 2: Analysis of variance for length-weight relationship in males and females

(a) Females:

Correlation matrix

	18	19
Log mean wt	19	1.00
Log mean length	19	r = 0.86

Analysis of Variance

	DF	Sum of Squares	Mean Squares	F-ratio	P
Regression	1	0.53010	0.53010	27.90	0.0004
Residual	10	0.18994	1.8994		
Total	11	0.72005			

b) Males:

Correlation matrix

	14	15
Log mean wt	14	1.000
Log mean length	15	r = 0.83

Analysis of Variance

	DF	Sum of Squares	Mean Squares	F-ratio	P
Regression	1	0.48011	0.48011	25.9400	0.0038
Residual	9	0.15694	1.5694		
Total	10	0.15724			