

AN INVESTIGATION ON
SOME ASPECTS OF THE ECOLOGY AND BIOLOGY OF A
HILL-STREAM FISH, *GARRA LISSORHYNCHUS* (McCLELLAND)

ABSTRACT

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Thesis submitted in fulfilment of the requirements for the Degree of
DOCTOR OF PHILOSOPHY

to



**THE NORTH-EASTERN HILL UNIVERSITY
SHILLONG (MEGHALAYA) INDIA**

SEPTEMBER 1982

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A B S T R A C T

The lack of investigations on the biology and ecology of the fishes indigenous to the highlands of the North-Eastern Hill Regions of the country has led to a general paucity of scientific information which is necessary not only for academic purposes but also for the proper aquaculture management. Therefore, due to a virtual absence of such knowledge, a study has been undertaken to elucidate on the ecology and biology of the stone-licking torrential fish, Garra lissorhynchus (McClelland).

The study pertains to the specimens of the species collected from three different lotic systems viz.,

- (i) Umiam river - one of the major drainage systems of Meghalaya flowing by the western border of Shillong (25°5' Lat. and 91°9'E Long.) at 4,862 feet above sea level.
- (ii) Umkhras stream - a torrential hill stream flowing westwards and which for a major portion of its course passes through the town of Shillong, Meghalaya.
- (iii) Umshing stream - a torrential hill stream originating at Mampat village near Shillong and flowing in a somewhat north-westerly direction and approachable by road from near Umiam lake.

The results obtained during the present study have been presented in the present thesis entitled- "An investigation on some aspects of the ecology and biology of a hill-stream fish - Garra lissorhynchus (McClelland)".

The dissertation containing 243 pages inclusive of 34 tables and 41 figures has been divided into four chapters.

The first chapter deals with a general introduction pertaining to ecology of fish. The environment of the fish has been dealt with, in the second chapter which has been further divided into four sections. The first being an introduction of the limnological aspects with reference to work hitherto done on limnology in India, and a brief description of the study area. The second and the third sections share respectively the materials and methods applied for ecosystem analysis and results obtained on the abiotic factors viz., temperature, conductivity, pH, dissolved oxygen, free carbon-dioxide, alkalinity, phosphate, nitrate, silicate, calcium, magnesium, chloride, total hardness, calcium hardness and magnesium hardness and the biotic factors viz., periphytic algae and benthic organisms. Then follows the discussion on the abiotic and biotic factors along with their interrelationship.

The third chapter, which pertains to the study on the biology of Garra lissorhynchus has also been divided into four sections. The first section deals with an introduction to the biological studies on fishes with particular reference to the studies done so far in India on Garra. This is followed by diagnostic characters, taxonomic status and synonyms of the species. In the second section of the chapter, the materials and methods adopted for the biological studies of the fish have been presented. Then follows the third section dealing respectively with the results obtained on morphometric and meristic characters, length/mass relationship, condition factor, maturity and spawning, fecundity

and food and feeding habits of the fish. Then follows the fourth section in which discussion have been made reviewing the results obtained on the biology of the species.

In the fifth and final chapter, the summary and conclusion of the entire study has been presented. This is followed by the list of literature cited in the dissertation.

The following are the important results obtained during the present investigations and embodied in the thesis :-

(1) The water temperature varied from 12.2°C to 24.5°C and 12.5°C to 24.1°C respectively during 1979-80 in the Umiam and Umkhras systems. In 1980-81, their respective range of fluctuation was from 11.2°C to 24.5°C and 12.8°C to 23.5°C, while the Umshing system registered a range of 10.0°C to 22.8°C. The water temperature of all the systems showed a close affinity with the atmospheric temperature.

(2) The conductivity values ranged from 44.0 to 58.0 μ mhos/cm and 17.2 to 56.52 μ mhos/cm during 1979-80 in the Umiam and Umkhras systems respectively. During 1980-81, the respective range of values were from 42 to 59.0 μ mhos/cm and from 16.24 to 77.0 μ mhos/cm, while during the same period the range was from 26.0 to 52.0 μ mhos/cm in the Umshing system. The present study indicated that the conductivity values fluctuated widely in all the systems.

(3) The pH values too, have been observed to fluctuate widely ranging from 6.4 to 7.9 and 6.0 to 7.2 respectively in the Umiam

and Umkhrah systems in 1979-80. During 1980-81, the range was from 6.5 to 6.9 (Umiam) and from 5.9 to 7.2 (Umkhrah), while that of the Umshing stream was from 6.1 to 6.72. The pH values in all the three systems usually were found to be in the acidic range.

(4) Dissolved oxygen ranged from 6.4 to 9.28 mg/l and 5.6 to 11.4 mg/l respectively in 1979-80 in Umiam river and Umkhrah stream. In 1980-81, these values were found to range from 6.4 to 10.2 mg/l in Umiam river, 4.2 to 11.6 mg/l in Umkhrah stream, and 7.4 to 8.4 mg/l in Umshing stream. Dissolved oxygen showed an inverse relationship with temperature.

(5) The quantity of free carbon-dioxide varied from 1.3 to 5.0 mg/l and 3.5 to 9.5 mg/l in 1979-80 in the Umiam and Umkhrah systems respectively, whereas in 1980-81 the respective range was found to be 1.4 to 3.8 mg/l and 2.1 to 8.2 mg/l. During this period the fluctuations of free carbon-dioxide in the Umshing stream was from 2.8 to 4.0 mg/l.

(6) During 1979-80 the values of alkalinity in Umiam and Umkhrah systems varied respectively from 12.0 to 38.0 mg/l and 4.1 to 24.0 mg/l. In 1980-81, these values ranged from 16.0 to 26.0 mg/l and 4.1 to 28.0 mg/l respectively in the above systems while in the Umshing stream, the range was between 28.0 to 49.0 mg/l. Alkalinity values show an inverse relationship with free carbon-dioxide concentration.

(7) Phosphate content in Umiam and Umkhrah ranged from 0.32 to 0.9 mg/l and 0.118 to 0.89 mg/l respectively during 1979-80.

During 1980-81, the values fluctuated from 0.22 to 0.79 mg/l and 0.234 to 0.804 mg/l respectively in Umiam and Umkhras systems, while the range was from 0.26 to 0.87 mg/l in the Umshing stream. The concentration of phosphate in all the three systems were found to be quite poor.

(8) Low concentration of nitrate have been detected in all the three systems. In 1979-80, the values ranged from 0.06 to 0.68 mg/l and 0.02 to 0.5 mg/l in the Umiam and Umkhras systems respectively. The respective range of fluctuations during 1980-81 was 0.06 to 0.62 and 0.01 to 0.32 mg/l, while it was 0.08 to 0.62 mg/l in the Umshing stream. Nitrate showed an inverse relationship with oxygen content and temperature.

(9) The silicate content in Umiam and Umkhras during 1979-80 was recorded to range from 0.2 to 2.45 mg/l and 0.35 to 1.88 mg/l respectively. In 1980-81 their respective range of fluctuations varied from 0.15 to 2.125 mg/l and 0.14 to 2.0 mg/l, while it was 4.26 to 6.0 mg/l in the Umshing stream. In all the three systems, silicate was found to vary inversely with alkalinity. An inverse relationship between silicate content and free carbon-dioxide has been observed in the Umiam and Umkhras systems.

(10) During 1979-80, calcium values were found to vary from 4.775 to 2.70 mg/l and 1.3 to 4.6 mg/l respectively in Umiam and Umkhras. The respective fluctuations for the above two systems during 1980-81 were from 2.80 to 4.80 mg/l and 2.10 to 4.95 mg/l, while in the Umshing stream, it was from 2.0 to 4.8 mg/l.

(11) Magnesium values ranged from 1.2 to 2.15 mg/l and 0.7 to 1.6 mg/l respectively in Umiam and Umkhrach during 1979-80. In 1980-81 the respective ranges were 1.24 to 2 mg/l and 0.5 to 1.9 mg/l, while it was 1.42 to 3.3 mg/l in the Umshing stream.

(12) Chloride values in Umiam and Umkhrach varied from 0.32 to 0.95 mg/l and 0.28 to 0.68 mg/l respectively during 1979-80. In 1980-81 the respective chloride values ranged from 0.21 to 0.92 mg/l and 0.22 to 0.75 mg/l. During this period the range was found to be from 0.37 to 0.90 mg/l in the Umshing stream. Chloride content was found to be low in all the three systems.

(13) Total hardness levels during 1979-80 in Umiam and Umkhrach have been found to fluctuate from 14.5 to 36.0 mg/l and 8.4 to 22.0 mg/l respectively. Their respective range during 1980-81 was from 14.2 to 38.0 mg/l and 11.55 to 24.4 mg/l, while the Umshing stream waters showed a range of 18.4 to 26.34 mg/l during this period. Total hardness levels were comparatively poor in all the stations.

(14) During 1979-80, the levels of calcium hardness varied from 10.0 to 22.0 mg/l in Umiam and from 6.2 to 15.4 mg/l in Umkhrach. Their respective fluctuations during 1980-81 were from 10.1 to 21.0 mg/l and from 8.1 to 15.3 mg/l, while in Umshing stream it was from 14.36 to 20.98 mg/l.

(15) During 1979-80 the levels of magnesium hardness varied from 3.5 to 22.0 mg/l and from 1.67 to 11.0 mg/l in the Umiam and the Umshing systems respectively. The fluctuations of values during

1980-81 ranged from 2.2 to 20.0 mg/l and 1.0 to 10.8 mg/l respectively in the above two systems, while in the Umshing stream the levels of magnesium hardness fluctuations were from 3.59 to 5.81 mg/l. The peak levels of magnesium hardness were generally found to coincide with the peak levels of calcium and total hardness.

(16) In all the three systems true planktonic algae were scarce, but mostly were periphytic and their abundance has been observed to increase during the months of March to May.

(17) The benthic samples of the systems showed the presence of various insect groups.

(18) The factors found to affect the growth of periphytic algae are: temperature, pH, dissolved oxygen, free carbon-dioxide, alkalinity, phosphate, nitrate, silicate, calcium, magnesium and hardness of water.

(19) In the present study, morphological variations have been observed between three populations of G. lissorhynchus. A few of the morphological parameters viz., Fork length, Pre-dorsal length, Head width, Post-orbital distance, Diameter of the disc and Length of the caudal peduncle were found to be higher in the population of Umshing stream, whereas Least height of body, Inter-orbital width and Girth were observed to be higher in specimens from the Umkhrah stream. In the Umiam river population, parameters like Head length, Eye diameter, Body depth, Length of dorsal fin, Length of pelvic fin and Length of anal fin were found to be higher than other populations investigated. The regression

equations of the various parameters on the Standard length were found to differ from population to population.

(20) The length-weight relationship formulae of G. lissorhynchus from the three systems have been derived to be :-

$$\begin{aligned} \text{Log } W &= -4.957933 + 3.055714 \log TL \\ W &= 0.00001102 \quad \swarrow 3.0557 \\ r &= 0.994536 \end{aligned} \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} \text{(Umiam population)}$$

$$\begin{aligned} \text{Log } W &= -5.042796 + 3.125132 \log TL \\ W &= 0.000009061 \quad \swarrow 3.1251 \\ r &= 0.999446 \end{aligned} \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} \text{(Umkhrah population)}$$

and,
$$\begin{aligned} \text{Log } W &= -4.843737 + 2.997391 \log TL \\ W &= 0.00001433 \quad \swarrow 2.9974 \\ r &= 0.999128 \end{aligned} \quad \left. \begin{array}{l} \\ \\ \end{array} \right\} \text{(Umshing population)}$$

The regression equations of length-weight relationship for juveniles and adults from the three different populations have been worked out as has also been for length-weight of the populations during different seasons (viz. summer and winter). The regression and parabolic equations for males and females too, has been calculated.

(21) Condition factor varied from 0.9699 to 1.8994 in the Umiam river individuals and from 1.3372 to 1.7456 in the Umkhrah stream specimens. In the Umshing stream population, it varied from 1.2505 to 1.9034. Such variations have been attributed to different factors such as environmental conditions, food availability and gonadal maturity.

(22) Maturity studies indicated that G. lissorhynchus has one spawning season, i.e. from June to September. In all the populations, the ovaries of the species contained only one batch of maturing ova clearly demarcated from the immature stock.

It has been observed that 50% maturity (M_{50}) of specimens from Umiam and Umkhrah systems occur at the 60-64 mm length group, while the individuals of the Umshing stream attained M_{50} at the 55-59 mm length group.

(23) Gonado-somatic index (Gn.S.I.) calculations indicated that in G. lissorhynchus the spawning season lasts from June to September confirming the other results obtained for spawning season of the fish. It has also been observed that there is a tendency for Gn.S.I. to increase with the increase in total length of the fish.

(24) The fecundity of G. lissorhynchus has been found to range from 427 to 1898, 263 to 1410 and 210 to 1003 eggs in specimens from the Umiam, Umkhrah and Umshing systems respectively. The fecundity estimates suggest that the fish is highly fecund compared to other cyprinids of same size. Regression relationships between fecundity and various other parameters have been derived and presented in the text.

(25) Food items found in the digestive tracts of all the specimens examined have been demarcated in four broad groups :-

(a) Periphytic Bacillariophyceae (b) Chlorophyceae (c) Myxophyceae (d) Detritus. The major food of the species has been found to be periphytic algae belonging to the family of Bacillariophyceae.

Feeding intensity or G.S.I. was found to be higher in the individuals of smaller length groups in all the three populations. The relative length of the gut (R.L.G.) was found to range from 2.775 to 8.160, 2.663 to 8.050 and 2.550 to 5.850 in the individuals from Umiam, Umkhrak and Umshing systems respectively.

It may be inferred from the present investigation that unity of any fish and environment represents a system of adaptive relation between the species and the abiotic and biotic nature of their immediate environment. Hence, the successful existence and development of the fish depends on its adaptive interaction with its environment. The character of the interdependence of the fish to its environment, seems to be specific not only for various species, but also for different individuals of the same species. It is also clear that the dominant relations are not fixed, but are dependant on all other correlated factors of the system. They change during ontogenesis and may differ between populations of the same species.

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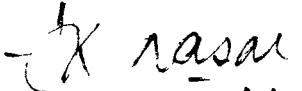
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I certify that the thesis entitled "AN INVESTIGATION ON SOME ASPECTS OF THE ECOLOGY AND BIOLOGY OF A HILL-STREAM FISH GARRA LISSORHYNCHUS (McCLELLAND)", submitted by Shri Sisir Kumar Shahoo for the Degree of DOCTOR OF PHILOSOPHY of the North-Eastern Hill University, Shillong (India), embodies the record of original investigations carried out under my supervision. He has been duly registered and the thesis presented is worthy of being considered for the award of a Ph.D. Degree. This work has not been submitted for any degree of any other University.

Dated Shillong,
The 30th Sept. 1982


(S.A.K. NASAR)

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DATED SHILLONG,
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(S.K. SHAHOO)

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CHAPTER I

General Introduction

GENERAL INTRODUCTION

It is an established fact that organisms cannot exist without the environment. Any population, species, or organism lives at the expense of its environment, and without this interaction it ceases to exist. The successful existence and development of any organism depends on its adaptive interaction with its environment. The system of adaptive interactions of fish with its environment is composed of interrelationships with the abiotic and the biotic environment. Any alteration in the nature of any fundamental biotic and or abiotic component in the environment of the fish, inevitably evokes a reconstruction not for the better, but normally for the worse of the entire system of relationships between the fishes themselves and their immediate habitat. The character of the interdependence of the fishes to its natural

environment, is known to be specific not only for the various species, but also for different individuals of the same species. The interaction of the fishes and the environment bears an adaptive character and every adaptation is specific. Adaptation is a property directed towards securing the preservation and flourishing of the species under which it lives and to which it adapted itself in the process of its evolution. Hence, it is obvious that the adaptation to the corresponding biotic and abiotic conditions should be related to morpho-physiological changes. A species is characterized by a relative morpho-physiologic-ecological stability, which is the result of adaptation to a particular environment under the conditions of which the species was formed and with which the species is in unity (Kaur, 1981). /

The features of the species reflect its adaptation to particular condition of existence. It must be emphasized that the character of the interaction of the fish with any particular element of its environment depends to a significant extent upon the condition of the fish itself, its stage of nourishment, fat content, the state of maturity of its gonads, and so on.

The individuals of any species do not reflect all of its properties. The species is a continually changing plurality, and the very character of this change i.e. the type of its population dynamics (time of spawning, life span and so on), are specific features. The variability is greater in species adapted to the more variable conditions. Populations of a species which live

under less stable conditions possess a greater amplitude of variation in those features which are adaptations to the varying factor of the environment, whereas populations of species which live under more stable conditions possess less variability. The amplitude of variability is also an adaptive property which ensures more favourable conditions of life for the population. The amplitude of variation of the features and properties of species with a restricted distribution is usually less than that of species with a wide distribution. Within limits of the distribution of the species, the amplitude of variation, like other species' properties, ensures the unity of the species with the environment.

The species has a definite area of distribution, within limits of which, the conditions correspond to its morpho-physiologo-ecological specificity. The morphological, physiological and ecological properties of the species are relatively stable in time. Changes within the species, apart from those connected with age and sex, bear a local character i.e., they are adapted to a particular habitat or to a definite geographical part of the range of distribution. This variability of group is a species adaptation, which ensures either that a greater variety of habitats are occupied or else a wider geographical distribution.

Population ecology is one of the most difficult aspects of fish biology to study, mostly because of the problems involved in sampling fish populations adequately. Nevertheless, population ecology is so important that fisheries research programmes have

tended to concentrate in this subject area. Much of this effort has been directed at determining sizes and fluctuations of exploited fish populations, and at examining age-structure and growth rates to arrive at some idea as to whether the population is declining, stable or increasing and the impact of fishing, upon that population. In particular, much effort has gone into examining the relationships between recruitment of fish and size of the parent stock. The first general model of this relationship was developed by Veber-ton and Holt (1957). Although this model was successfully applied to fisheries. Its application to many others was disastrous, while the study of relationships between stock and recruitment obviously is enormously important, it is also obvious that the reasons for such observed relationships need to be understood as well. This is particularly true since these relationships are seldom straight forward, primarily because many, if not most, factors affecting survival of larval fish are independent of the abundance of the larvae. The biological factors are ultimately regulated by environmental factors, including currents, upwelling and water temperature. As the importance of these relationships become apparent, more research is being devoted to mechanisms regulating growth and survival of fishes, but only a small number of species have been examined and still fewer are well understood. Even with more advanced life-history stages, much basic information is lacking on factors affecting population regulation for all but a handful of species (Moyle et al, 1979).

Views on various aspects of fish population dynamics are diverse, but the problem was of no general concern until the mid-nineteenth century. However, Ber (1954) was the founder of the modern progressive theory of productivity and of fish population dynamics. The theory of population dynamics is a division of the general theory of the development of life, which deals with the laws of reproduction, growth and the causes of death of living organisms (Nikolsky, 1969). The main laws of fish population dynamics as for other organisms are as follows. They are concerned with the continuous process of the replacement of generations in time, the birth of a generation, its growth and death. The details of the process are governed by specific adaptations and by the relationships of the fish with the environment.

According to Regier (1974), with very notable exceptions, fish biologists have tended to specialize at one particular level of organization, most at the organism, some at the population and fewer at the community level. The population dynamics of commercially valuable organisms is now primarily applied to the problem of providing their maximum yield. This entails a study of the productivity of the biosphere as a whole, which in turn involves the solution of various biological problems. The dialectical materialistic theory of development should be the basis of a progressive theoretical population dynamics for fish and other organisms, especially ideas such as the unity of an organism with its environment, the reality of a species, the adaptive significance of all species features, discontinuous continuity (stages) and so on.

It is well known that the unity of any organism and environment represents a system of adaptive relations between the organism and the biotic and abiotic parts of its environment. The dominant relations are not fixed but are dependent on all the other links in the system. They change during ontogenesis and may differ between populations of the same species.

All the relations with the environment affect the progress of development and are adaptive in nature. Adaptation is a feature that ensures the survival of the species under the conditions to which it is exposed (Nikolsky, 1969). Regier (1974) emphasised that a field ecologist intending to study fish is faced at the outset with the task of locating these creatures in an alien and largely opaque environment. Recently Kerr (1980) expressed that the niche concept provides a useful framework for analysis at the interface between organism and environment. By definition, all ecologists have a common interest in analysis at the level of biological organization. Fisheries ecology is no exception. Demonstrably, fisheries ecology has long possessed a theoretically sound, extremely developed and eminently practical niche concept which in all but name, anticipated and considerably antedates the contemporary views of theoretical ecology. Accordingly, it is convenient to distinguish an "academic" and a "fisheries" (applied) approach to niche analysis.

These same reasons had relatively little appeal for fisheries ecologists. In the first place, fisheries scientists are not often concerned with ultimate causes or equilibrium systems.

The immediacy and directness of the pressing problems in fisheries require proximate solutions, scaled in physiological or demographic time, rather than in evolutionary time. Secondly and perhaps more importantly, fisheries ecology already possessed a well developed approach to analysis at the interface between the organisms and environment. There was no record to adopt the relatively abstract and less practical approach of the theoretical ecologists.

The basic fisheries approach was set out in detail by Fry (1947) and later expanded and refined by him and others (Fry, 1957, 1971, 1976; Alderdice, 1972; Brett, 1979). Fry's approach has long since been the standard for analysis of environmental factors in fisheries and has found a wide range of applications, so much so that its origins are sometimes forgotten. Its essential characteristic is that it derives from autecology. It is primarily concerned with categorizing environmental factors according to their effects on the activities of organisms, as measured by standard physiological techniques.

Fry's method provides several useful advantages. It enables precise description of the lethal limits of a given factor to a specific organism. In Fry's terms, the zone within the "incipient lethal levels" of a given factor defines the "zone of tolerance" of the organism. Except that he did not explicitly extrapolate the zone of tolerance 'n-space' and called it a "niche". Additionally, Fry's methodology allowed precise definition of a "zone of resistance" surrounding the zone of tolerance, reflecting the time dependent capacities of organisms to survive levels of a factor

which would be lethal, if prolonged indefinitely. This provision and the ability to measure it precisely, is essential to many analysis of non-equilibrium situations, as for example Trout briefly penetrating the thermocline to feed beyond their incipient lethal temperature (Kerr, 1980).

Most significantly, Fry's approach enables useful analysis beyond mere survival. His approach recognizes the metabolic basis for the activities of organisms, providing the conceptual foundation for categorization and measurement of the effects of external factors on the capacities of organisms to function specifically. Fry (1957) defined the metabolic "scope for activities", which is the net metabolic latitude that an organism is able to expand, at a given conjunction latitude of environmental variables, beyond the basic prerequisites for its mere survival. That is, he provided a common measure, in units of energy expenditure of the capacities of organisms to mount useful activities at any point within their zones of tolerance. In effect, Fry provided a universal method for contending the niche hyperspace.

Given these tools, it is understandable that fisheries ecologists failed to embrace the more recent and less utilitarian alternatives offered by the academic theoreticians. In fact, the academic and applied approaches outlined above are not in opposition. Apart from failure to equate "zone of tolerance" with "niche", the two schools differ chiefly in that the fisheries approach is more usefully quantifiable in standard units of energy expenditure, as opposed to the various measures that have been

applied by the academics. However, it seems reasonable to conclude that fisheries and academic ecologists have independently developed parallel and compatible methods of analysis at the organism environment interface.

In the first place, ecology differs from many scientific disciplines in that it simply does not possess a coherent and comprehensive theoretical base, recent progress notwithstanding. Thus, there is less disciplinary pressure to link the applied with the theoretical, allowing the various sub-disciplines of ecology to develop with greater independence than in many other scientific disciplines. Moreover, much existing ecological theory was formed under the evolutionary paradigm that now tends to dominate academic thought. As discussed previously, their approach often appears remote and un-realistic to the fisheries analyst, typically concerned with perturbed systems, often far from equilibrium, which require proximate scales of analysis. For these and many associated reasons, fisheries and academic ecology have tended to develop independently. Unfortunately so, because many instances could be cited of intellectual wheels having been unnecessarily reinvented by one or the other sub-disciplines. More seriously, one can only guess at the missed theoretical and analytical opportunities that might have been realized from a close coupling of academic with fisheries ecology. Principles of fisheries management must obviously rest ultimately on sound ecological theory. On the surface, then it would seem that fisheries and academic ecologists should be interested in similar problems.

Bardach (1978) argued that the application of fisheries science and limnology to aquaculture has been late in arriving, because these sciences themselves had to develop specific technical and conceptual tools in population biology, fish physiology and analysis of nutrient dynamics in water and the like. It is this growth of scientific approach of aquaculture, which may eventually develop into applied scientific disciplines.

Since fishes are both poikilothermic and live permanently immersed in water, they are very directly and quickly affected by changes in their ambient medium. It is well known that since fish affect the trophic status of other organisms in their environment and alter the condition of water in various ways especially when their population density is high, the relation between organisms and environment are far from unidirectional. A study of biology in fish, offers an ecologist many opportunities to enquire into the dynamic balance and the states of change in aquatic ecosystems. Weatherley (1972) stressed that most studies of fish population dynamics and growth, have been restricted to determining responses of a population to changes in certain features of the environment. A limited number of investigations, have however, taken the view that every fish population is a part of an ecosystem, affected by chemical and physical factors while functioning within the system through biotic, especially, trophic interrelationships.

It is becoming increasingly clear that wise management of fishery requires a consideration of the total aquatic ecosystem

in a given region, since the components of the system interact and the fishery for one species may affect abundance and distribution of other species. Hence, there is a need to determine the basic distribution, abundance and the habitat requirements of the fishes in a particular system.

Fishes have great significance in the life of mankind, being an important natural source of protein and providing certain other useful products as well as in the economy of many nations, particularly in a developing country like ours. Fresh-water fishes too, form a vital part of the diets of people throughout the tropics. The fact that the world catch of fish, which was increasing until recently, has now started declining at an alarming rate, mainly due to over-exploitation and other factors. However, today almost all the inland water bodies are undergoing eutrophication, in other words, a step prior to pollution, particularly due to our burgeoning population, growing advancement in the cultural activities etc. This lays emphasis on the urgent need to develop these resources fully and to achieve this, we need to understand the factors governing fish production.

The application of fisheries sciences and limnology to aquaculture has been late in arriving, because these sciences themselves had to develop specific technical and conceptual tools in population biology, fish physiology and analysis of abiotic and biotic component along with nutrient dynamics in water. It is this, the growth of scientific approach of aquaculture, which may eventually develop into an applied scientific discipline.

A basic information on the length-weight relationship, morphological variations, condition factor, maturity, spawning, food and feeding habits etc., in relation to their abiotic and biotic environment is indispensable, as no organism can live as isolated units and the activities which comprise their lives are dependent upon and closely controlled by chemical conditions in which they live and the populations of other organisms with which they interact. Hence, on a virtual absence of information and lacuna in our present day knowledge on the ecology and biology of hill stream fishes viz., Garra lissorhynchus, Channa punctatus, Channa stewartii, Channa orientalis, Danio sp., Nemacheilus sp. etc. which are commonly found in the highland of the North-Eastern part of India.

The North-Eastern Hilly Regions of India are mostly inhabited by tribal people and most of them are meat eaters having inadequate sources to fulfill the great protein deficiencies. Moreover, it is well known that the tribals of the hilly areas in Meghalaya (Khasis, Jaintias and Garos) have less land for agriculture, but 85% of the population subsists on agriculture. Apart from animal husbandry and mining of silliminite, coal etc. there are no industries in Meghalaya. There is, however, plenty of rain and sufficient water bodies to grow fish in this part of the country. Hence, introduction of fish farming in these highlands would certainly help to grow a new occupation which will raise the economic status of small farmers. There is however, hardly any practical information available on the structure and function

of freshwater ecosystems and on the biology of fish that naturally grows in this region.

There is a paucity of information on the biology and ecology of the fishes indigenous to the highlands of the North-Eastern part of India and knowledge of these is of utmost importance, not only from the academic point of view, but its utility in increasing the technological efficiencies of the fishery entrepreneurs for evolving judicious management measures in culture operations of these fishes. Hence, on a virtual absence of scientific knowledge on these aspects, prompted to undertake the present investigations. It is therefore, earnestly hoped that the information embodied in this dissertation, apart from academic importance, it would have application and relevance to the socio-economic development of these areas of the country.

These hilly areas of the North-east India are rich in its freshwater resources ranging from very small ephemeral pools to big perennial ponds, lakes, streams, thermal springs and rivers, spread all over the region, in a wide range of climatic conditions. An extensive survey on the Ichthyo-fauna of this region reveals that the lotic ecosystems in Shillong region abound with Garra lissorhynchus along with other less commercially important fish species.

Keeping in view the basic necessity to have a knowledge on the structure of lotic ecosystems and on the biology of G. lissorhynchus adapted in such systems, a study has been

undertaken on some aspects of the ecology and biology of the above mentioned species.

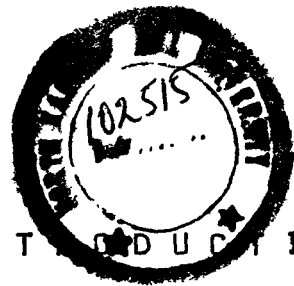
The study pertains to the specimens of fish collected from a river and two streams situated in and around Shillong (India), with emphasis on the following :-

- (a) The structure of the lotic system from the limnological standpoint and impact of the abiotic and biotic factors on the biology of G. lissorhynchus.
- (b) An intraspecific comparison on some important biological parameters of the species.

The dissertation has been divided into two broad chapters. The first deals with the environment of the fish and the second with their biology.

CHAPTER II

Environment Of The Fish



I N T R O D U C T I O N

An ecosystem is traditionally regarded to be a self-contained complex system to which energy is supplied in the form of radiation. This energy passes through a series of trophic levels converting inorganic substance into organic materials which subsequently returns to their original forms. However, such a similar trend does not apply to the ecosystem of running waters, where anything released into solution by metabolism tends to go downstream and has little opportunity of being recycled at the spot. The unidirectional flow of streams set their waters off from lentic habitats. The water current is a salient feature of streams and therefore, there is little or no opportunity for retention of ions and compounds in streams except by addition due to runoff from shores (Reid, 1961).

Winberg (1963) implied that the most important goal of limnology is to study the circulation of materials and especially of organic substances in a body of water. Biotic and abiotic phenomena are, of course, interrelated and the concept of balance is a major part of this interrelationship. Thus, the aim of limnological investigations are to comprehend and calculate the whole of productive and destructural processes that are involved in the energy flow. In brief, it is the science of inland waters concerned with all the factors that influence living populations within those waters. Thus, the study of abiotic environment is of utmost importance as the seasonal and diurnal variations in the physico-chemical properties, from the substructure upon which the whole framework of biological productivity rests (Nasar, 1980b).

Inland waters are ecologically diverse and only a few have been intensively studied. Although streams outnumber the units of standing water investigation of the running waters, particularly from limnological standpoint, had lagged behind that of lakes and ponds. In few instances extensive researches in relation to pollution has been reported by Gaufin and Tarzwell, 1956; Garmer et al, 1936; Causton, 1948; Patrick and Ruth, 1950; Mohr, 1952; Klein, 1956; Butcher, 1964; Hannan and Young, 1974; and Hannan and Broz, 1976.

Studies relating to Indian freshwaters extend back to the latter half of the last century and were in the nature of presenting species lists and descriptions of taxa new to the then Indian sub-continent (Baird, 1859; Anderson, 1889; Bhatia, 1936; Arora,

1931; Prasad, 1916; Edmondson and Hutchinson, 1934; Brehm, 1936, 1950; Hauer, 1936, 1937a,b). Some of the significant monographs on algae are those of Desikachary (1959) on Cyanophyta, Philipose (1959, 1967) on Chlorococcales, Venkataraman (1961) on Vaucheriaceae and of Ramanathan (1964) on Ulotrichales containing extensive bibliographies on the subject.

After about three decades extensive research was carried out by numerous Indian workers on different freshwater organisms, particularly the zooplankton. These were on Protozoa (Naidu, 1962, 1966, 1967), on Rotifers (Donner, 1949; George, 1961a; Pasha, 1961; Arora, 1962, 1963a,b, 1965, 1966; Nayar, 1965a, 1970; Nayar and Nair, 1969; Michael, 1966, 1973; Naidu, 1967; Wycliffe and Michael, 1968; Wulfert, 1966; Vasisht and Gupta, 1967; Vasisht and Dawar, 1968; Vasisht and Bhattish, 1969, 1970, 1971a,b; Rajendran, 1971; Dhanapati, 1973, 1974, 1975, 1976a,b, 1978; Das and Akhter, 1976; Sharma, 1976, 1977, 1978, 1979; Nasar, 1973; Leal and Nasar, 1977; Tiwari and Sharma, 1977; Patil, 1978); on Cladocerans (Biswas, 1964; Nayar, 1971; Michael, 1973; Nasar, 1977d); on Ostracods (Deb, 1972; Nasar and Deb, 1975; Nasar, 1977b; Deb and Nasar, 1977); and other Branchiopods (Nayar, 1965b; Malhotra and Duda, 1970; Royan, 1972).

The primary attempts on the seasonality of Indian freshwater plankton were that of Sewell (1935) on the fauna of a tank (pond) in the Indian Museum Compound, Calcutta. Earlier, Prasad (1916) and Pruthi (1933) described the seasonal changes of the physical and chemical characteristics of the water in the same

system. Following this, there were a long series of hydrobiological studies of freshwater impoundments mostly in ponds and reservoirs in different parts of the country. Many of these were initiated to obtain baseline information of plankton and water chemistry to be of use in fishery practices since it was pointed out that such a gap proved to be a serious handicap to Indian fishery workers (Hora, 1951; Job, 1951).

It was around this time that many general limnological surveys and studies of somewhat regional nature were published from various parts of the country. Of these many were from central and northern regions (Das, 1961, 1970; Das and Srivastava, 1956, 1959; Das et al., 1969, 1970; George, 1961b, 1966a; Pahuwa and Mehrotra, 1966; Krishnamurthy and Visweswara, 1965; Khan and Qayyum, 1966; Vasisht, 1968; Vyas and Kumar, 1968; Sahai and Sinha, 1969; Unni, 1971; Grover et al., 1978; Vaas and Zutshi, 1979; Swerup and Singh, 1979; Yousuf, 1979), some from southern India (Ganapati, 1940, 1941, 1943, 1949, 1955, 1960; Chacko and Krishnamurthy, 1954; Philipose, 1959; Zafar, 1959, 1964a, 1966; Subbarao and Govind, 1964; Sreenivasan, 1964a, 1968, 1970, 1971; Seetharamaiah, 1966; Hussainy, 1967; Munawar, 1970; Seenayya, 1971) while the rest are from eastern India (Michael, 1965, 1969; Moitra and Bhattacharya, 1965; Moitra and Mukherji, 1972; Saha et al., 1971; Nasar and Munshi, 1974, 1975; Jana, 1973a; Nasar and Kaur, 1981), and western India (Patil, 1978).

Apart from the above general works, there have been specific studies on zooplankton ecology (George, 1966a; Bernice, 1970,

1971a, 1972a; Nayar, 1970; Moitra and Bhowmick, 1968; Michael, 1968; Nasar, 1977a, 1979), cyclomorphosis (Nayar, 1965c; Arora, 1966b; George, 1966b; Sharma, 1976) diurnal variations (Krishnamurthy and Visweswara, 1965; Michael, 1966; Verma, 1967; Sumitra, 1971; Nasar, 1977a) and on biochemical aspects (Bernice and Srinivasagam, 1967; Michael and Chandran, 1967; Bernice, 1971b, 1972b; Khan and Siddique, 1971a,b). Certain works on the ecology of the aquatic insects has also been attempted (Sen, 1979).

General works on the weed fauna are by Michael (1968) and on benthos by Mandal and Moitra (1975). In recent years few studies on the aquatic macrophytes and their production were conducted (Kaul, 1971; Unni, 1971a,b; Nasar and Munshi, 1971, 1976, 1978; Rai and DattaMunshi (1979) and Rai et al (1980). A comparative account of soil-water relationship in three tropical ponds was described by Sumitra (1971) and on Indian thermal springs by Jana (1970, 1973b), Jana and Sarkar (1971a,b) and Saha and Datta Munshi (1980). There lacks a total information at the decomposer level except a preliminary report by Nasar and Munshi (1980).

After the functional aspects, primary productivity and energy flow studies are the two largely attempted areas of research and are based on the well known light-dark bottle techniques and their theoretical computations respectively (Sreenivasan, 1963, 1964a,b, 1968; Hussainy, 1967; Ganapati and Sreenivasan, 1970; Kaul, 1971; Khan and Siddique, 1971a; Sumitra, 1971; Nasar and Munshi, 1975; Michael and Anselem, 1978; Nasar and Sharma, 1980; and Nasar, 1980a). The effect of certain organochlor

insecticides on primary production has been recently studied by Nasar (1979b). An outstanding effort to review the limnological knowledge in India was made by Nasar (1980b).

A good deal of limnological work has been carried out in India but most of the available literature on tropical freshwaters is incomplete as it portrays either (a) a momentary picture of the physico-chemical and biological conditions, or (b) are mere records of occurrence without adequate descriptions of the relative abundance of individual organisms of each species, or (c) are confined to a single tank, pond or lake of some particular geographic region. Very few attempts have been made to determine the exact and comparative relationships amongst various components of the ecosystems during different seasons of a yearly cycle. The majority of these investigations have mainly dealt with the abiotic factors and few biotic factors without paying much attention to fishes, which have great significance in the life of mankind and which, apart from being an important natural source of protein and certain other useful products also has the immense potential to contribute to the economics of many nations.

Realising these possibilities, limnological studies in general have been the object of research for many Indian Scientists during the last few decades. However, few have studied the freshwater ecosystems from higher altitudes and, as a matter of fact, practically no such work has been attempted from the highlands of the North-Eastern Region of the country and hence the present study was undertaken to elucidate certain important abiotic

aspects of three lotic systems namely Umiam, river and Umkhrak and Umshing streams situated in the vicinity of Shillong (Figs.1 & 2), together with the biotic factors with special reference to the fish, Garra lissorhynchus (McClelland) which is commonly found in these water bodies, and are greatly relished as food by the local populace. The aim of this study is to obtain basic informations on the physico-chemical factors of the freshwater ecosystems of the highlands of Shillong, which will, apart from the academic view-points, be useful not only in understanding the environmental conditions where such fishes thrive but also help in gathering information for the proper propagation and management of aquaculture.

STUDY AREA

The city of Shillong (Fig. 1), capital of the State of Meghalaya is situated at an altitude of 4,862 feet above the sea level and falls at an intersection of 25°5'N latitude and 91°9'E longitude.

The Meghalaya region is a pre-cambrian table-land which is the eastward extension of the massive block of the Indian peninsular shield from which it has been separated by the Garo-Rajmahal gap as a result of denudational and tectonic forces. The Shillong hills towering above Shillong contain the highest peneplaned surfaces trending E.S.E. to W.N.W. of the central portion of the plateau proper, over which streams meander before plunging into the deep valleys of the Umiam and the Umkhen. The presence of many rapids and waterfalls in the neighbourhood of Shillong indicates that this region has a youthful topography perhaps due to a recent uplift.

Climate of Shillong :- Locational and physiographic factor have greatly influenced the climatic characteristics of Shillong. The climate of this region differs from that of the Brahmaputra valley chiefly due to its high relief which, in general, makes the climate very salubrious. Shillong experiences very cold nights in winter, when the temperature goes down to about 1.7°C. The temperature seldom rises above 26°C in any part of the year. During winter (December-January) one usually experiences frost although snowfall is unknown to this region. The most interesting climatic characteristic of this part is very high rainfall with an average

annual of 7,196 mm which distinguishes this area climatically from other parts of the Meghalaya. However, there is a great variation of rainfall within this region from South to North. This is primarily because the higher part i.e. the Central Upland Zone having an E-W alignment rendering a rain shadow effect on the areas lying to the north. Consequently, the rainfall in Cherrapunji which is located in the structural platform on the south is as high as 12,033 mm while Shillong being located only 50 km to the north with a rain shadow effect gets only 2,296 mm. This is due to the fact that south-west monsoon laden with great amount of moisture from the Bay blows over Bangladesh and is suddenly cut off by the cliffs of the table-land in the south with an average elevation above 1,200 m which juts out like a peninsula into the surrounding gorges about 600 m deep on either side and as a result, the monsoon having reached the heads of the gorges ascends vertically upwards and causes heavy rainfall, whereas, Shillong experiences a rain shadow effect as mentioned earlier.

Meteorological condition of the Study Area :- Data on certain meteorological factors for the year 1979-81 have been tabulated in Table-1 and graphically presented in Fig. 4. The meteorological data have been obtained from the Meteorological Station, Upper Shillong situated about 10-25 kms from the different study sites.

During the period of investigation, the study areas experienced heavy rainfall (408.9-315.9 mm) from June, 1980 to September, 1980 and from May, 1981 to August, 1981 (401-539.4 mm). The relative humidity always remained above 40 during the two years except in one instance (November, 1979) when it dropped to 31.4 (Table-1).

FIG.1:
MAP OF SHILLONG
AND ADJOINING AREAS
SHOWING STUDY SITES

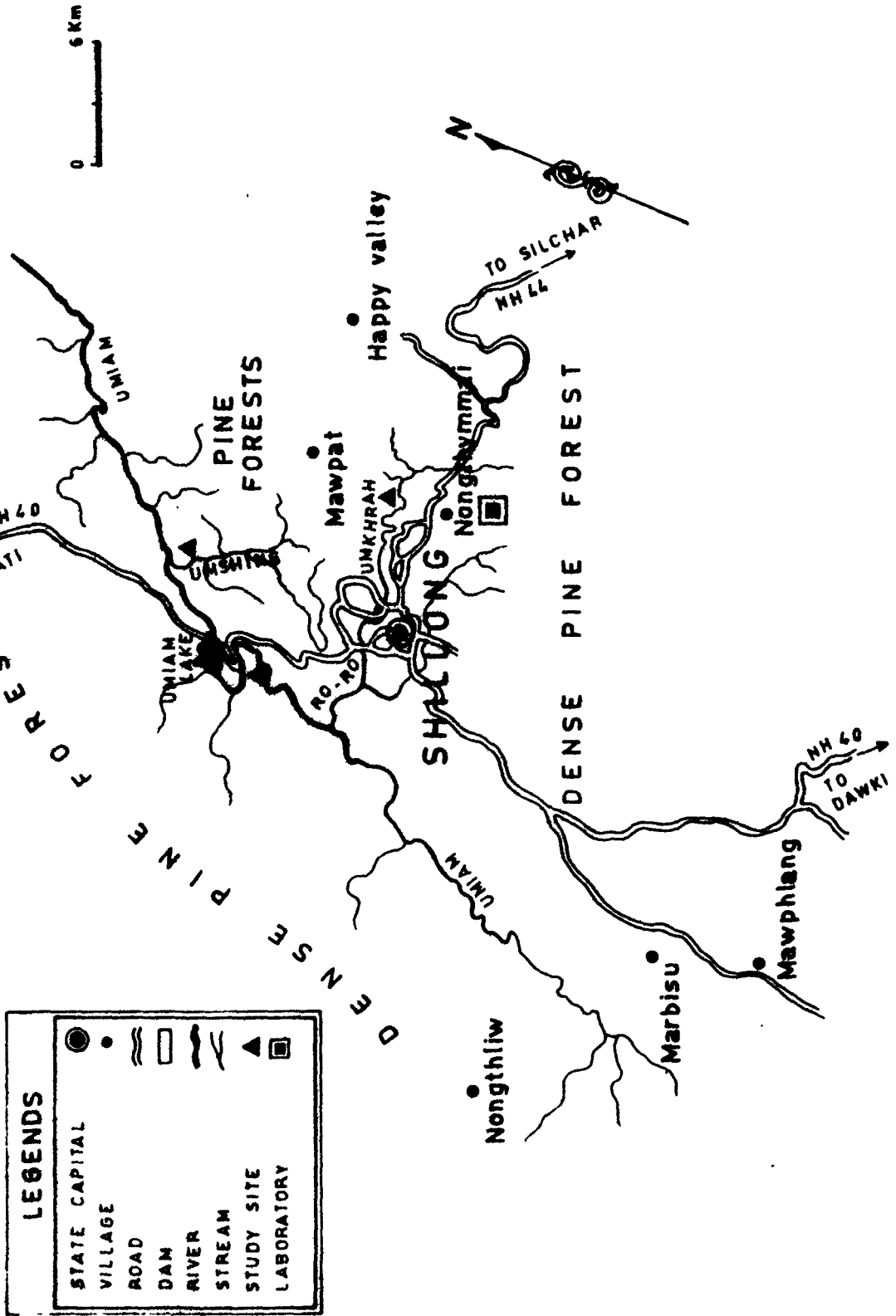


TABLE-I

METEOROLOGICAL CONDITIONS OF SHILLONG (MEGHALAYA) DURING 1979-81

MONTHS	TEMPERATURE °C (Mean)		HUMIDITY % (Mean)	TOTAL RAIN- FALL (mm)
	Maximum	Minimum		
<u>1979</u>				
SEP	23.4	16.8	87.5	253.8
OCT	20.2	15.1	79.5	192.1
NOV	20.2	11.6	31.4	11.3
DEC	15.9	3.9	61.2	35.8
<u>1980</u>				
JAN	13.3	5.1	73.5	Tr.*
FEB	17.8	7.5	62.5	32.5
MAR	20.2	11.2	60.5	34.7
APR	25.1	15.2	66.0	80.4
MAY	22.6	14.6	79.5	261.8
JUN	23.6	17.4	88.0	408.9
JUL	23.7	18.2	87.5	312.9
AUG	24.2	17.6	86.0	218.5
SEP	22.6	16.7	88.0	315.9
OCT	20.5	13.6	81.5	224.3
NOV	10.7	10.3	71.5	-
DEC	13.7	7.9	77.5	7.5
<u>1981</u>				
JAN	14.2	5.9	50.0	34.5
FEB	17.2	7.4	69.0	20.1
MAR	20.0	10.7	40.5	45.9
APR	20.5	12.0	68.5	192.0
MAY	18.9	14.4	84.5	401.0
JUN	23.4	17.1	85.0	263.4
JUL	23.1	17.7	88.0	586.1
AUG	23.8	17.6	86.5	539.4

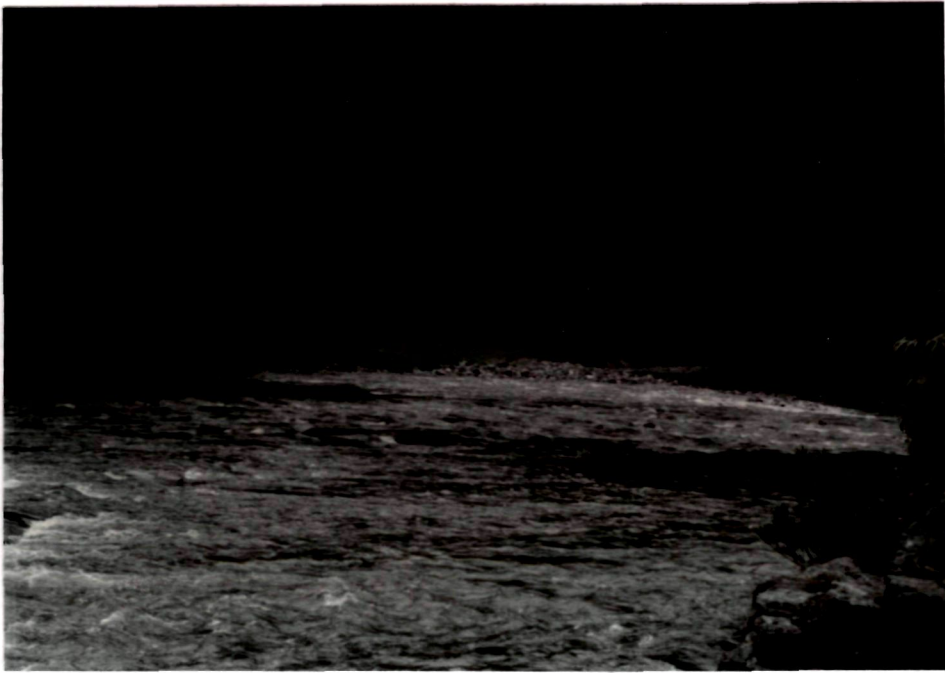
* Tr. = Trace

Fig. 2 : Photographs of the study sites.

(A) Umiam river

(B) Umkhras stream

(C) Umshing stream



A



B



C

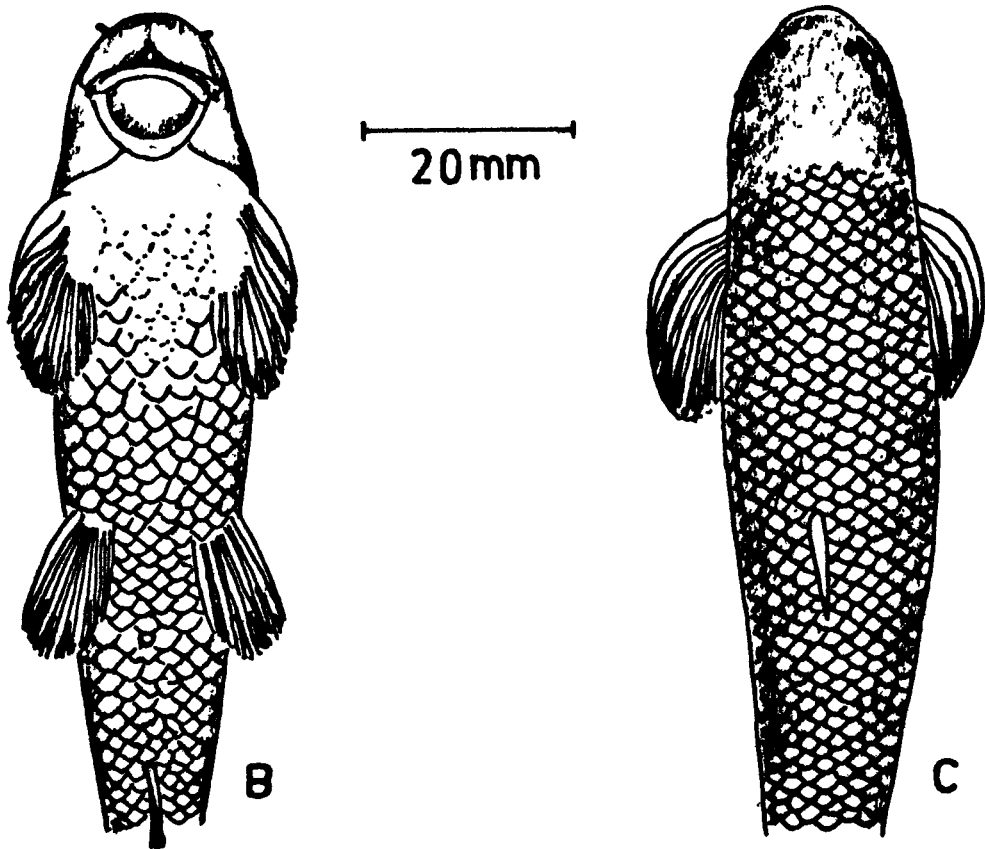
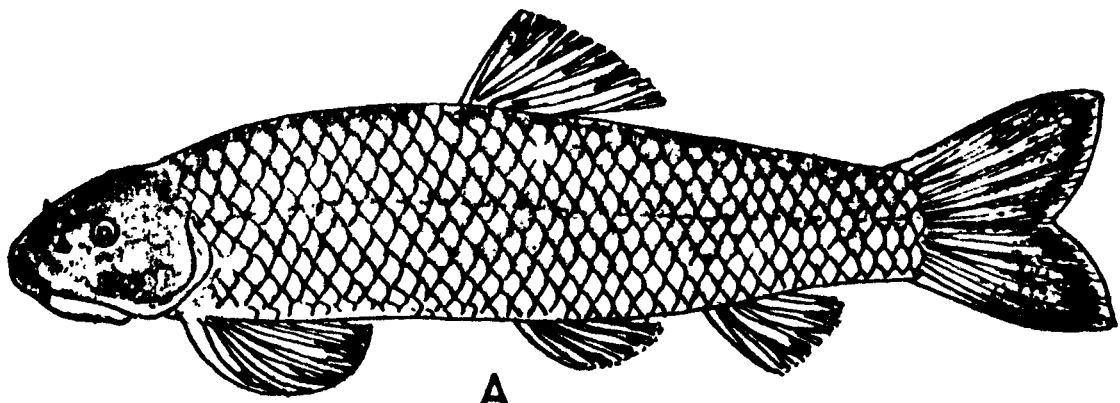


Fig. 3 Garra lissorhynchus (McClelland)
A = Lateral view, B = Ventral view
C = Dorsal view

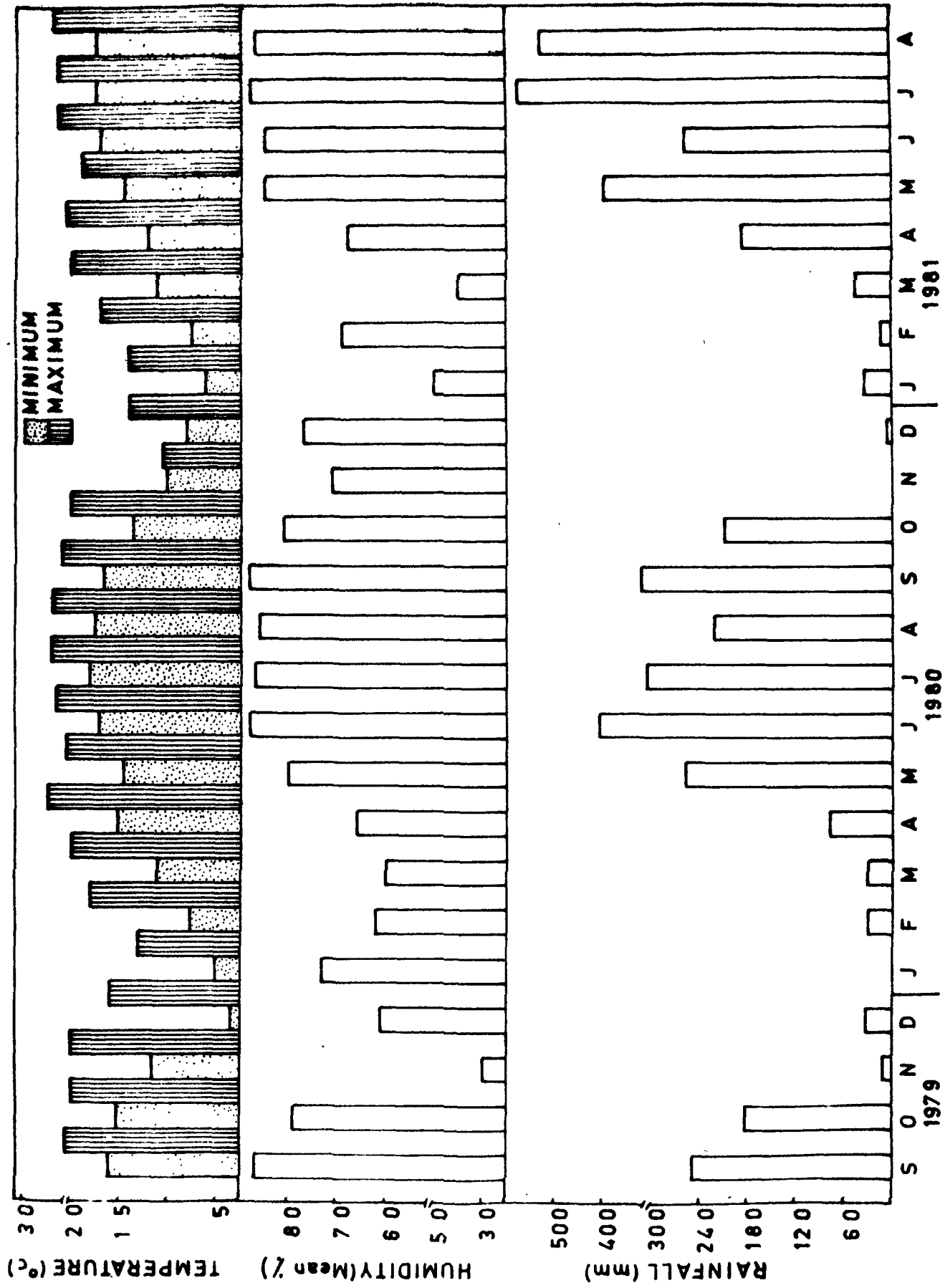


Fig. 4: Climatic conditions of Shillong region

The average minimum temperature varied between 3.9°C to 18.2°C during September, 1979 and August, 1980, while in September, 1980 and August, 1981 it fluctuated between 5.9°C to 17.7°C. The average maximum temperature varied from 13.3°C in January, 1980 to 25.1°C in April, 1980 and from 10.7°C in November, 1980 to 23.8°C in August, 1981 (Table-1).

Description of the sites :- Three lotic systems viz., Umiam, Umkhras and Umshing (Fig. 1) were selected for the present investigation in and around Shillong (25°5'N latitude and 91°9'E longitude) situated at an altitude of 4,862 feet above sea level.

Umiam River :- This is one of the important drainage systems of Meghalaya. The width of this torrential river ranges from 20 feet to more than 30 feet at places in the lower reaches with a varying depth upto 3 metres. The bed of the river is made of rocks and medium size boulders. Rooted vegetation is present on its banks. The river traverses through deep valleys covered with thick pine forests (Fig. 2A).

Umkhras Stream :- This is a hilly torrential stream which is moderately narrow with a varying depth of 0.5 to 1.0 metres. The water current is however, not as swift as that of the Umiam river. The stream bed is composed of sand and large and medium sized rounded boulders. The density of pines in its catchment area is sparse when compared to that of the Umiam river. Rooted vegetation is present on the banks for a major part of the year (Fig. 2B).

Umshing Stream :- The hill stream is nearly of the same width and depth as that of the Umkhrak stream, but water current is lesser. The stream bed is composed of sharp edged medium sized stones. The banks are covered with tall grasses, shrubs and bushes. Here, too, the density of pines in the catchment area is less (Fig. 2C).

M A T E R I A L S A N D M E T H O D S

Samples for the physico-chemical analysis of water and periphytic algae samples were collected at fortnightly intervals from Umiam river and Umkhrah stream, during the period from September, 1979 to August, 1981 and from Umshing stream from September, 1980 to August, 1981. The following abiotic parameters were taken into consideration in the present study. Temperature (air and water), Conductivity, Hydrogen-ion concentration, Dissolved oxygen, Free Carbon-dioxide, Alkalinity, Phosphate, Nitrate, Silicate, Calcium, Magnesium, Chloride, Total hardness, Calcium hardness and Magnesium hardness. The methods for the above parameters adopted for the present study are as follows :-

The temperature were measured with the help of an ordinary mercury thermometer graduated upto 110°C. For measuring the

conductivity and pH, a portable Water Quality Analyser (Make-ELICO, Model PE-132) has been used. The dissolved oxygen content of the water has been determined as per the modified Winkler's Method (A.P.H.A., 1965).

Carbonate and bicarbonate alkalinity were estimated by titration with N/50 Sulphuric Acid using Phenolphthalein and Methyl Orange as indicators (A.P.H.A., 1965). Further differences of alkalinities due to hydroxide, normal carbonate and bicarbonate were calculated as per the method recommended by Welch, 1948.

Phosphate has been determined following the methods as outlined in A.P.H.A. (1965). 2 ml of the sample has been taken in a test tube and 1 ml of Ammonium Molybdate and 0.4 ml of Stannous Chloride solution were added. Colour developed in about 15 minutes and this was compared with the reagent blank at 650 nm. Similarly, standard phosphate solution was pipetted out in different test tubes ranging from 0.1 to 1.0 ml. The volume was equalized with distilled water and 1 ml of Ammonium Molybdate and 0.4 ml of Stannous Chloride (SnCl_2) were added. Colour was allowed to develop at room temperature and optical density read off at 650 nm. By plotting the optical density, a standard graph has been plotted from which the amount of phosphate in the sample was calculated (A.P.H.A., 1965).

Nitrate levels have been estimated after A.P.H.A. (1965) as follows :-

50 ml of the sample was evaporated to dryness. To the residue, 2 ml of Phenol-di-sulphonic acid was added. After 10 minutes, 40 ml

of distilled water and 2 ml of Magnesium Sulphate solution were added followed by 40% Sodium Hydroxide, which was added drop by drop until Magnesium Hydroxide precipitated. The Magnesium Hydroxide precipitate was removed by filtration through Whatman No.42 Filter Paper. The hydroxide removed by absorption any coloured organic matter which would otherwise interfere with the colour match. The filtrate has been measured in a Colorimeter at 410 nm, against a reagent blank. Similarly, the standard Nitrate solution was treated and a standard graph plotted, taking the concentrations on the X-axis. The amount of Nitrate in the sample was calculated from the standard graph thus prepared.

Silicon content has been determined spectrophotometrically by reduction of silicomolybdate (Mackereth, 1957). 20 ml of the sample was taken in a 50 ml graduated stoppered volumetric flask, to which 3 ml of Acid Molybdate reagent was added and mixed. After 10 minutes, 15 ml of the reducing agent was added and the volume equalized with distilled water. It was allowed to stand for 3 hours and then the extinction read at 812 nm against a blank. Silicon content was found out from a standard graph prepared by using known amounts of silicon.

Calcium was estimated following the method described by Golterman (1970). 20 ml of the sample was put in a 250 ml stoppered volumetric flask. Added in succession were 2 ml of buffer solution (10 gm of NaOH + 10 gm of $\text{Na}_2\text{B}_4\text{O}_7$ in one litre distilled water), 1.0 ml of glyoxalbis-(2-hydroxyanil) reagent and 20 ml of Ethanol-n-butanol solvent mixture (Ethanol:n-butanol=1:1). The

contents were shaken after each addition, the extinction of the sample : compared with the reagent blank after 25 minutes at 520 nm, and the calcium content read off from a calibration curve prepared from samples containing known concentration of calcium.

Magnesium in the systems has been detected by the method described in the IBP Handbook No.8 (Goltherman, 1970). 50 ml of the sample water was poured into a 100 ml volumetric flask. Added in succession was 1.0 ml of 0.1N H_2SO_4 , 1 ml of $Ca^{2+}-Al^{3+}$ soln. (1.5 gm of $Al_2(SO_4)_3 \cdot 18 H_2O$ in 500 ml distilled water), 5 ml of starch solution (1.0 gm of soluble starch in 50 ml of distilled water), 4 ml of 5N NaOH and 10.0 ml of Brilliant yellow solution (10 μ g of Brilliant yellow in 100 cc of distilled water). The entire content of the volumetric flask was then diluted to the 100 ml mark. The extinction of the blanks and samples were measured after 15-20 minutes at 540 nm and compared with a standard curve prepared with known concentrations of magnesium.

Estimations of chloride was done titrametrically as per "Standard Methods for Examination of Water and Wastewater" (APHA, 1971). To 100 ml of filtered sample, 0.1 ml of Methyl orange indicator solution was added. This was titrated with 0.2N sulphuric acid till the indicator colour just changed to orange. To this, 0.5 ml of 5% Potassium Chromate indicator was added and the resultant titrated with 0.02N Silver Nitrate solution until a reddish brown tinge was observed. The entire process was repeated for the preparation of a blank using distilled water in place of the sample, and concentrations were calculated by :-

$$\text{Cl (mg/l)} = \frac{(\text{Sample Blank}) \text{ ml Silver Nitrate } 0.02\text{N} \times 709}{\text{ml sample}}$$

Total Calcium and Magnesium hardness were estimated titrimetrically following the procedures outlined in "Standard Methods for Examination of Water and Wastewater" (APHA, 1971). For the estimation of Total hardness, 2 ml of Ammonia Buffer solution (BDH) and 1(one) total hardness indicator tablet (BDH) was added to 100 ml of sample in an Erlenmeyer flask. The resultant was titrated with Ethylenediaminetetra-acetic acid (EDTA) 0.02N solution (BDH) until all traces of red colour was lost.

$$\text{mg/l Total hardness} = \frac{\text{ml EDTA } 0.02\text{N} \times 1000}{\text{ml sample}}$$

Calcium hardness level estimates were made by adding 1.0 ml of 4N NaOH solution and 1(one) Calcium hardness indicator tablet (BDH). The solution was titrated with EDTA 0.02N solution (BDH) until a stable violet colour was attained.

$$\text{Ca hardness (mg/l)} = \frac{\text{ml EDTA } 0.02\text{N} \times 1000}{\text{ml sample}}$$

Magnesium hardness was estimated from the difference between the total hardness and calcium hardness.

A preliminary study revealed that the majority of the algae are periphytic in nature generally as in torrential lotic systems of tropical environments. The periphyton were collected by scraping the rocks and boulders of mixed sizes and from a cross-section of current conditions at each site according to Bishop (1973). Periphyton scrapings were then preserved in 5% formalin at the spot itself and brought to the laboratory for subsequent analysis.

R E S U L T S

The data on the physico-chemical parameters of Umiam river and Umkhrah and Umshing streams have been tabulated in Tables-2, 3 & 4 and illustrated in Figs. 5-15.

PHYSICAL CONDITIONS

AIR TEMPERATURE :

The air temperature at the Umiam river varied from 17°C (January) to 26°C (June) during the period of 1979-80. During 1980-81 the temperature fluctuated from 16.5°C (December) to 25.5°C (August). The factor ranged from 11.3°C (January) to 28.9°C (August) during 1979-80, while during 1980-81 the range of fluctuation was from 12.5°C (January) to 27.8°C (June and July) in the Umkhrah stream (Tables-2 & 3). The Umshing stream air

temperature was recorded at a minimum of 10.5°C (January) and a maximum of 26.8°C (March) during 1980-81 (Fig. 6A).

WATER TEMPERATURE :

During the period of 1979-80, the water temperature of the Umiam and Umkhras varied from 12.2°C (January) to 24.5°C (June), and 12.5°C (January) to 24.1°C (May) respectively. Fluctuations during the period 1980-81 ranged from 11.2°C (December) to 24.5°C (June) in Umiam, and from 12.8°C (January) to 23.5°C (May) in the Umkhras stream (Fig. 5A). In the Umshing stream, water temperature ranged from 10.0°C (December) to 22.8°C (March) during 1980-81 (Fig. 6A).

CONDUCTIVITY :

The conductivity values during 1979-80 fluctuated between 44.0 μ mhos/cm and 58 μ mhos/cm in Umiam and from 17.2 μ mhos/cm to 56.52 μ mhos/cm in the Umkhras stream (Fig. 5B). The values ranged from 36.0 μ mhos/cm (February) to 52.0 μ mhos/cm (May) in Umshing stream (Table-4) during 1980-81, while the respective range of fluctuation in the Umiam and Umkhras was from 42.0 to 59.0 μ mhos/cm and 16.24 to 77.00 μ mhos/cm.

HYDROGEN-ION CONCENTRATION :

In 1979-80, pH of the water of Umiam river ranged from 6.4 (January) to 7.9 (May) and in the Umkhras stream the range was between 6.0 (January) and 7.2 (April), whereas in 1980-81, the pH values of Umiam and Umkhras ranged from 6.5 (January) to 6.9 and from 5.9 (June) to 7.2 respectively (Tables-2 & 3). pH of Umshing stream was acidic and varied between 6.1 (March) and 6.72 (January) during 1980-81 (Fig. 6B).

CHEMICAL CONDITIONS

DISSOLVED OXYGEN :

Dissolved oxygen values ranged from 6.4 mg/l (September) to 9.28 mg/l (December), and 5.6 mg/l (March) to 11.4 mg/l (January) respectively in Umiam and Umkhrah (Fig. 8A). The oxygen values for the two system ranged from 6.4 (September), to 10.2 mg/l (December) and 4.2 (March) to 11.6 mg/l (December). In Umshing stream, the values (Fig. 9C) fluctuated between 7.4 (October) and 8.4 mg/l (September) during 1979-80.

FREE CARBON-DIOXIDE :

In Umiam and Umkhrah the quantity of free CO₂ varied from 1.3 (December) to 5.0 mg/l (July) and 3.5 (January) to 9.5 mg/l (May) respectively during the period 1979-80 (Fig. 8B). For the same systems the respective values varied during 1980-81 from 1.4 (November) to 3.8 mg/l (April) and from 2.1 (October) to 8.2 mg/l (May). During 1980-81, the free CO₂ values ranged from 2.80 (January) to 4.0 mg/l (March) in Umshing stream (Fig. 9A).

ALKALINITY :

The alkalinity values in Umiam water ranged from 12.0 mg/l in July to 38.0 mg/l in April during 1979-80. During the same period, the alkalinity values in Umkhrah waters fluctuated between 4.1 mg/l (August) and 29.0 mg/l (October). In 1980-81, the alkalinity for the stations at Umiam and Umkhrah ranged from 16.0 mg/l (July) to 26.0 mg/l (March) and 4.1 mg/l (June) to 28.0 mg/l (April) respectively (Fig. 7B). During this period, the alkalinity values of Umshing stream (Fig. 9B) ranged between 28.0 mg/l (November) and 49.0 mg/l (January).

TABLE-2

PHYSICO-CHEMICAL CONDITIONS OF THE UMIAM RIVER WATER

MONTHS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1979																
SEP	24.5	22.0	45.00	7.20	6.40	1.80	16.0	0.410	0.36	0.20	4.650	1.45	0.72	29.0	18.0	11.0
OCT	25.7	22.5	45.66	7.30	7.20	1.90	20.0	0.400	0.16	1.41	4.250	1.60	0.65	34.2	22.0	12.2
NOV	26.0	23.5	50.00	6.80	9.20	1.40	21.0	0.374	0.40	1.46	4.125	1.92	0.52	24.0	15.0	9.0
DEC	22.0	18.5	55.00	6.72	9.20	1.30	22.0	0.840	0.32	0.90	4.300	2.15	0.92	28.0	19.0	9.0
1980																
JAN	17.0	12.2	58.00	6.40	8.80	3.50	26.0	0.410	0.12	1.75	4.725	1.35	0.75	34.0	12.0	22.0
FEB	20.0	15.0	52.00	7.20	6.80	4.00	17.0	0.400	0.12	1.75	4.250	1.50	0.32	36.0	14.0	12.0
MAR	22.0	18.0	44.00	6.80	6.40	3.90	19.0	0.320	0.64	0.55	4.000	1.52	0.52	32.0	19.0	13.0
APR	26.0	22.0	49.35	7.20	7.20	3.50	24.0	0.380	0.68	0.66	4.145	1.15	0.66	32.0	19.0	13.0
MAY	24.5	22.0	44.10	7.90	8.40	1.50	26.0	0.900	0.34	0.23	4.300	1.40	0.91	30.0	21.0	9.0
JUN	26.0	24.5	50.40	7.40	9.20	2.50	38.0	0.720	0.32	0.26	4.775	1.60	0.88	28.0	20.0	8.0
JUL	22.0	21.0	39.90	6.80	6.40	5.00	12.0	0.660	0.24	0.30	2.700	1.32	0.94	14.5	10.0	4.5
AUG	25.0	22.5	48.30	7.20	9.60	1.80	20.0	0.680	0.06	2.45	4.650	1.20	0.84	18.0	14.5	3.5
SEP	23.0	21.5	42.53	6.80	6.40	1.90	23.0	0.560	0.10	2.10	4.800	1.24	0.65	21.0	15.8	5.2
OCT	23.7	21.0	46.32	6.30	8.80	1.80	24.0	0.420	0.13	1.80	4.050	1.95	0.72	14.2	12.0	2.2
NOV	24.5	22.0	50.00	6.90	9.84	1.40	22.0	0.340	0.32	1.63	4.260	2.00	0.56	26.0	17.0	9.0
DEC	16.5	11.2	52.00	6.50	10.20	1.60	23.0	0.500	0.16	0.45	2.800	1.80	0.83	30.0	18.0	12.0
1981																
JAN	19.0	18.2	59.00	6.50	9.60	2.00	24.0	0.240	0.10	1.88	4.500	1.80	0.68	38.0	18.0	20.0
FEB	21.5	18.0	46.00	7.10	8.40	3.00	18.0	0.220	0.06	2.13	4.100	2.26	0.48	31.0	11.0	20.0
MAR	24.0	22.5	50.00	7.10	9.20	3.20	26.0	0.560	0.13	1.80	3.350	1.95	0.58	25.0	18.0	7.0
APR	25.0	23.0	45.00	6.70	5.60	3.80	18.0	0.398	0.62	0.42	4.600	1.32	0.78	34.0	18.0	16.0
MAY	23.0	21.5	43.05	7.10	7.60	1.90	18.0	0.790	0.58	0.55	4.750	1.60	0.21	27.2	10.1	17.1
JUN	25.5	24.5	53.00	6.90	8.80	2.00	17.0	0.760	0.24	0.30	4.750	1.80	0.92	31.5	16.0	15.5
JUL	22.0	19.2	42.00	6.90	8.40	2.00	16.0	0.580	0.19	0.45	3.380	1.49	0.85	32.0	21.0	11.0
AUG	25.5	23.0	51.00	7.00	7.60	1.90	18.0	0.530	0.13	0.15	3.500	1.86	0.91	28.0	14.0	14.0

1 = Air Temperature (°C)
 2 = Water Temperature (°C)
 3 = Conductivity (Amhos/cm)

4 = pH (unit)
 5 = Oxygen (mg/l)

6 = Free Carbon dioxide (mg/l)

7 = Alkalinity (mg/l)

8 = Phosphate (mg/l)

9 = Nitrate (mg/l)

10 = Silicate (mg/l)

11 = Calcium (mg/l)

12 = Magnesium (mg/l)

13 = Chloride (mg/l)

14 = Total Hardness (mg/l)

15 = Calcium Hardness (mg/l)

16 = Magnesium Hardness (mg/l)

TABLE-3

PHYSICO-CHEMICAL CONDITIONS OF THE UMKHRAH STREAM WATER

MONTHS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1979																
SEP	25.5	23.0	55.20	6.70	6.00	5.20	24.0	0.288	0.16	1.250	1.30	0.80	0.58	8.40	6.2	2.20
OCT	23.2	22.6	25.32	6.80	8.40	6.00	29.0	0.470	0.02	1.630	2.55	1.30	0.55	12.80	6.3	6.50
NOV	19.2	17.6	55.23	5.80	10.00	4.50	28.0	0.400	0.22	1.500	3.35	1.60	0.56	16.80	8.4	8.40
DEC	14.5	15.3	56.52	7.10	10.20	4.20	17.0	0.730	0.42	0.350	2.70	1.00	0.38	13.80	9.4	4.40
1980																
JAN	11.3	12.5	28.00	6.00	11.40	3.50	12.5	0.320	0.50	1.880	2.40	0.71	0.28	22.00	11.0	11.00
FEB	14.3	15.6	34.00	6.80	9.28	5.10	13.0	0.250	0.04	1.680	3.00	0.70	0.35	15.18	9.4	5.78
MAR	22.8	20.0	49.35	6.70	5.60	3.40	11.0	0.178	0.10	1.280	3.30	0.95	0.53	16.50	9.9	6.60
APR	23.2	21.5	52.00	7.20	6.00	7.20	24.0	0.118	0.26	0.400	3.75	1.40	0.68	18.50	15.2	3.30
MAY	26.2	24.1	34.00	6.40	6.08	9.50	13.2	0.890	0.02	1.250	4.60	1.60	0.65	20.80	15.4	5.40
JUN	26.8	22.4	72.00	6.10	7.24	6.10	3.8	0.344	0.16	0.450	2.95	0.92	0.52	14.80	10.3	4.50
JUL	27.8	23.4	17.20	6.50	8.40	4.20	17.2	0.344	0.18	0.425	2.55	1.00	0.53	12.87	11.2	1.67
AUG	28.9	22.4	45.20	5.20	8.80	4.10	4.1	0.400	0.04	0.125	2.35	0.65	0.65	11.80	7.2	4.60
SEP	24.0	22.5	45.52	6.30	6.60	4.50	26.0	0.280	0.18	1.275	2.80	0.62	0.75	14.00	8.1	5.90
OCT	23.6	21.5	16.24	6.10	10.00	2.10	22.0	0.400	0.16	1.480	2.75	0.60	0.69	20.20	9.4	10.80
NOV	18.1	16.5	58.40	6.20	11.20	4.20	31.0	0.344	0.02	1.240	3.05	1.80	0.52	15.10	10.2	4.90
DEC	14.5	14.0	77.00	6.00	11.60	4.50	15.0	0.680	0.32	0.425	2.10	0.60	0.75	17.00	11.0	6.00
1981																
JAN	12.5	12.8	31.00	6.20	9.20	4.20	15.8	0.324	0.01	1.300	4.70	0.65	0.35	23.10	15.3	7.80
FEB	16.4	15.5	36.10	6.50	10.24	4.20	18.0	0.260	0.04	2.000	3.30	0.50	0.22	16.80	11.2	5.60
MAR	19.4	17.2	47.00	6.80	4.20	5.50	2.6	0.238	0.12	1.640	2.55	0.75	0.41	12.80	10.4	2.40
APR	24.5	22.2	49.00	7.20	10.80	6.20	28.0	0.804	0.30	0.375	3.25	0.50	0.62	16.17	12.4	3.77
MAY	25.8	23.5	42.00	6.10	6.48	8.20	15.3	0.680	0.28	0.875	4.95	1.90	0.42	24.40	14.3	10.10
JUN	27.8	23.1	69.00	5.90	7.16	5.20	4.1	0.484	0.16	0.390	3.85	1.00	0.73	19.10	15.3	3.80
JUL	26.9	22.2	42.10	6.90	7.90	3.90	19.4	0.236	0.12	0.445	2.75	0.60	0.64	13.50	12.5	1.00
AUG	27.8	21.2	51.30	4.90	10.00	2.20	21.0	0.380	0.02	0.140	2.30	0.90	0.69	11.55	8.2	3.35

- 1 = Air temperature (°C)
- 2 = Water temperature (°C)
- 3 = Conductivity (µmhos/cm)
- 4 = pH (unit)
- 5 = Oxygen (mg/l)
- 6 = Free Carbon-dioxide (mg/l)
- 7 = Alkalinity (mg/l)
- 8 = Phosphate (mg/l)
- 9 = Nitrate (mg/l)
- 10 = Silicate (mg/l)
- 11 = Calcium (mg/l)
- 12 = Magnesium (mg/l)
- 13 = Chloride (mg/l)
- 14 = Total Hardness (mg/l)
- 15 = Calcium Hardness (mg/l)
- 16 = Magnesium Hardness (mg/l)

TABLE-4

PHYSICO-CHEMICAL CONDITIONS OF THE UMSHING STREAM WATER

MONTHS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1980																
SEP	24.00	19.00	51.00	6.30	8.40	3.85	34.0	0.87	0.38	5.15	4.00	2.50	0.80	20.32	15.01	5.31
OCT	25.00	18.50	49.00	6.40	7.40	3.20	30.0	0.65	0.32	5.00	3.20	2.20	0.72	21.46	16.42	5.04
NOV	16.50	15.50	48.00	6.50	7.60	3.15	28.0	0.48	0.47	4.65	3.00	1.80	0.56	18.72	14.57	4.15
DEC	12.50	10.00	50.00	6.60	7.80	3.10	38.0	0.52	0.46	4.26	2.00	1.60	0.82	19.31	14.58	4.73
1981																
JAN	10.50	11.20	43.20	6.72	7.60	2.80	49.0	0.44	0.25	4.28	2.20	1.95	0.42	21.51	15.79	5.72
FEB	23.20	22.00	36.00	6.30	8.00	3.60	43.5	0.26	0.08	5.22	3.10	2.20	0.37	26.34	20.53	5.81
MAR	26.80	22.80	40.00	6.10	7.90	4.00	42.0	0.49	0.12	4.96	2.20	2.00	0.51	25.06	20.98	4.08
APR	20.00	16.50	47.50	6.20	7.85	3.62	39.0	0.62	0.38	5.30	2.85	1.95	0.64	24.70	20.98	3.72
MAY	19.50	18.00	52.00	6.25	7.60	3.70	36.0	0.83	0.53	5.40	3.30	1.42	0.82	18.14	14.38	3.76
JUN	22.00	18.20	46.00	6.30	7.45	3.90	30.0	0.84	0.62	5.50	3.75	2.20	0.90	19.63	16.04	3.59
JUL	24.20	19.50	40.00	6.25	7.60	3.72	31.0	0.80	0.51	6.00	4.00	2.60	0.82	19.47	15.44	4.03
AUG	26.20	21.50	43.00	6.30	7.80	3.75	32.0	0.82	0.34	5.30	4.80	3.30	0.81	18.50	14.36	4.14

1 = Air Temperature (°C)
 2 = Water Temperature (°C)
 3 = Conductivity (µmhos/cm)
 4 = pH (Unit)
 5 = Oxygen (mg/l)

6 = Free carbon-dioxide (mg/l)
 7 = Alkalinity (mg/l)
 8 = Phosphate (mg/l)
 9 = Nitrate (mg/l)
 10 = Silicate (mg/l)

11 = Calcium (mg/l)
 12 = Magnesium (mg/l)
 13 = Chloride (mg/l)
 14 = Total Hardness (mg/l)
 15 = Calcium Hardness (mg/l)
 16 = Magnesium Hardness (mg/l)

PHOSPHATE :

The dissolved phosphate in Umiam and Umkhras ranged during 1979-80 from 0.32 mg/l in August to 0.9 mg/l in May and 0.118 mg/l in April to 0.89 mg/l in May (Fig. 10A). During 1980-81, phosphate values of the above two systems fluctuated from 0.22 mg/l (February) to 0.79 mg/l (May), and 0.234 mg/l (January) to 0.804 mg/l (April). Phosphate content of the Umshing stream during 1980-81 varied from 0.26 mg/l in February to 0.87 mg/l in September (Fig. 11c).

NITRATE :

During the period of 1979-80, Nitrate values in Umiam and Umkhras was recorded to fluctuate from 0.06 mg/l (August) to 0.68 mg/l (April), and 0.02 mg/l (May and October) to 0.5 mg/l in January (Fig. 10B) respectively. In 1980-81, the values ranged from 0.06 (February) to 0.62 mg/l (April) in Umiam and from 0.01 (January) to 0.32 mg/l in December. In the Umshing stream, nitrate values were found to vary from 0.08 mg/l in February to 0.62 mg/l in June (Fig. 11B) during 1980-81.

SILICATE :

The silicate content in 1979-80 in Umiam and Umkhras was recorded to range from 0.2 (September) to 2.45 mg/l (August), and 0.35 (December) to 1.88 mg/l (January) respectively. In 1980-81, the values for the above two systems varied from 0.15 (August) to 2.125 mg/l (February) and 0.14 (August) to 2.0 mg/l in February (Fig. 10C). The silicate values in Umshing stream fluctuated between 4.26 (December) and 6.0 mg/l in July during 1980-81 (Fig. 11A).

CALCIUM :

During 1979-80, calcium values were found to vary from 4.775 mg/l (June) to 2.70 mg/l (July) and 1.3 (September) to 4.6 mg/l (May) respectively in Umiam and Umkhrah. The respective fluctuations for the above two systems during 1980-81 were from 2.80 mg/l (December) to 4.80 mg/l (September), and 2.1 mg/l (December) to 4.95 mg/l in May (Fig. 12A). The maximum and minimum values of dissolved calcium during this period in Umshing stream was 2.0 mg/l in December and 4.8 mg/l in August respectively (Fig. 13A).

MAGNESIUM :

In 1979-80 the range of fluctuation of magnesium content in Umiam and Umkhrah was from 1.2 (August) to 2.15 mg/l (December), and 0.7 (February) to 1.6 mg/l (May and November) respectively. The respective range during 1980-81 in the two water systems was from 1.24 (September) to 2.0 mg/l (November) and 0.5 mg/l (February and April) to 1.9 mg/l in May (Fig. 12B). The values during this period in Umshing was recorded to range from 1.42 in May to 3.3 mg/l in August (Fig. 13B).

CHLORIDE :

Chloride values in Umiam and Umkhrah varied from 0.32 (February) to 0.94 mg/l (July), and 0.28 (January) to 0.68 mg/l (April) respectively during 1979-80. During the next twelve months, the chloride values of the respective streams have been found to fluctuate from 0.21 (May) to 0.92 mg/l (June), and 0.22 (February) to 0.75 mg/l in September and December (Fig. 12C). The values during this period varied from 0.37 mg/l (February) to 0.90 mg/l (June) in the Umshing stream (Fig. 13C).

TOTAL HARDNESS :

The level of total hardness during 1979-80 in Umiam and Umkhrah have been found to fluctuate from 14.5 mg/l (July) to 36.0 mg/l (February), and 8.4 mg/l (September) to 22.0 mg/l (January) respectively. The respective values for the same stations were recorded to vary in 1980-81 from 14.2 (October) to 38.0 mg/l (January), and 11.55 (August) to 24.4 mg/l in May (Fig. 14A). The level of total hardness in Umshing stream fluctuated between 18.4 (May) and 26.34 mg/l (February) during 1980-81 (Fig. 15C).

CALCIUM HARDNESS :

During 1979-80, the level of calcium hardness varied from 10.0 mg/l in July to 22.0 mg/l in October (Umiam), and 6.2 mg/l in September to 15.4 mg/l in May (Umkhrah). During 1980-81, the fluctuations were from 10.1 (May) to 21.0 mg/l (July) in Umiam and 8.1 (September) to 15.3 mg/l (January and June) in Umkhrah (Fig. 14B). The values in Umshing stream during 1980-81 were found to vary from 14.36 (August) to 20.98 mg/l during March and April (Fig. 15B).

MAGNESIUM HARDNESS :

In Umiam and Umshing the level of magnesium hardness during 1979-80 varied from 3.5 (August) to 22.0 mg/l (January), and 1.67 (July) to 11.0 mg/l (January) respectively. The respective ranges of values during 1980-81 were from 2.2 (October) to 20.0 mg/l (January and February) and 1.0 (July) to 10.8 mg/l in October (Fig. 14C). During this period the fluctuations in magnesium hardness level in the Umshing stream was between 3.59 mg/l in June and 5.81 mg/l in February (Fig. 15A).

PERIPHYTON

In all the three streams under study, true planktonic algae were scarce and mostly all the algal flora recorded were benthic or periphytic in nature. The density of such periphytic algae has been observed to be generally more during March to May in all the systems studied. Apart from that periphytic algae displayed greater abundance in the Umiam river than in the Umkhras stream. Such quantitative abundance was observed to be the least in the Umshing stream. A list of the periphytic and also the non-periphytic algae recorded from the three stations under study has been presented in Table-5. In all the streams Bacillariophyceae was found to be the most dominant group, both qualitatively and quantitatively. Altogether a total of 31 genera have been recorded.

UMIAM RIVER : The dominant diatoms recorded in this river were Meridion, Cymbella, Fragillaria, Synedra, Navicula, Gomphonema, Diatoma, Eunatia and Mastogloia belonging to Bacillariophyceae, which were distributed particularly in the riffles. The riffles also showed the presence of Oedogonium and Spirogyra. Bacillariophyceae formed the most dominant group, being 14 out of 24 genera recorded in this system.

UMKHAHRAH STREAM : The periphytic algal flora recorded in this stream was almost similar to that in Umiam river except for the absence of Pinnularia sp. and presence of Frustulia sp. In this system, the majority of the non-periphytic diatoms (Table-5) were found to be present mostly in the riffles, where presence of Oedogonium and Spirogyra were also recorded. Other members of Chlorophyceae, along

TABLE-5

THE ABUNDANCE OF ALGAL POPULATION IN THE UMIAM, UMKHRAH
AND UMSHING LOTIC SYSTEMS

	UMIAM	UMKHRAH	UMSHING
<u>BACILLARIOPHYCEAE</u>			
Surirella	-	-	++
Meridion	+++++	+++++	+++
Cymbella	+++	+++	+
Amphora	++	++	++
Nitzschia	++	++	++
Fragillaria	+++	++	+++
Tabellaria	++	+++	++++
Synedra	+++	++++	+++
Navicula	+++++	+++++	+++++
Pinnularia	++	-	+++
Bacillaria	++	++	++
Gomphonema	+++	+++	+++++
Diatoma	+++	+++	+++
Eunatia	+++	+++	++
Kirchneirella	-	++	++
Mastogloia	++++	++++	+++
Frustulia	-	+	-
Hantzschia	-	-	+
<u>CHLOROPHYCEAE</u>			
Scenedesmus	-	+	-
Tribonema	+	+	-
Ulothrix	++	+++	+
Microspora	+	+	+
Spirogyra	++	+++	+++
Oedogonium	++	++	+
Coelastrum	-	+	-
Closterium	+	+	+
Eudorina	-	+	-
<u>MYXOPHYCEAE</u>			
Anabaena	++	+	+
Oscillatoria	+	+	-
<u>EUGLENOPHYCEAE</u>			
Euglena	+	+	+
<u>CHRYSDOPHYCEAE</u>			
Synura	+	+	+

(-) indicates absence while (+) indicates presence.

with some Myxophyceae, Euglenophyceae and Chrysophyceae were present in the stagnant zones. Out of the 28 algal genera recorded from the stream, 15 belonged to Bacillariophyceae, 9 to Chlorophyceae, 2 to Myxophyceae and one each to Euglenophyceae and Chrysophyceae. Among the various Bacillariophyceae recorded in the system, Meridion, Cymbella, Tabellaria, Synedra, Navicula, Gomphonema, Diatoma, Eunatia and Mastogloia and among Chlorophyceae, Ulothrix and Spirogyra were the most common.

UMSHING STREAM : Altogether 25 genera of algae were recorded in this system out of which 17 belonged to Bacillariophyceae, 5 to Chlorophyceae and one each to Myxophyceae, Euglenophyceae and Chrysophyceae. Among Bacillariophyceae, Frustulia could not be recorded but Hantzschia sp. and Surirella sp. were present. The most abundant forms of Bacillariophyceae were found to be Meridion, Fragillaria, Tabellaria, Synedra, Navicula, Pinnularia, Gomphonema, Diatoma sp. and Mastogloia sp.

Among Chlorophyceae, only Spirogyra was found to be comparatively common. Myxophyceae, Euglenophyceae and Chrysophyceae were recorded to be represented by one genera each.

The benthic samples also showed the presence of some insect groups among which are Ephimerates and Dipterans followed by caddisflies (Trichoptera) and stone-flies (Plecoptera). A few genera of Hemiptera and Coleoptera were also encountered. Some genera of dragonfly nymphs (Odonata) were recorded near the water banks and slow moving parts of the water systems, whereas the faster moving portions showed the presence of Megalopterans. A few genera of Planerians (Order: Tricladida) and crustaceans have been recorded.

D I S C U S S I O N

It is an established fact that water has a two-fold effect on the life within it, (a) through its physical properties, a medium for the locomotion of plants and animals, and (b) through its chemical properties, a bearer of nutrients producing organic from inorganic, a basis of primary production of the plant kingdom setting a sequence of chain reactions.

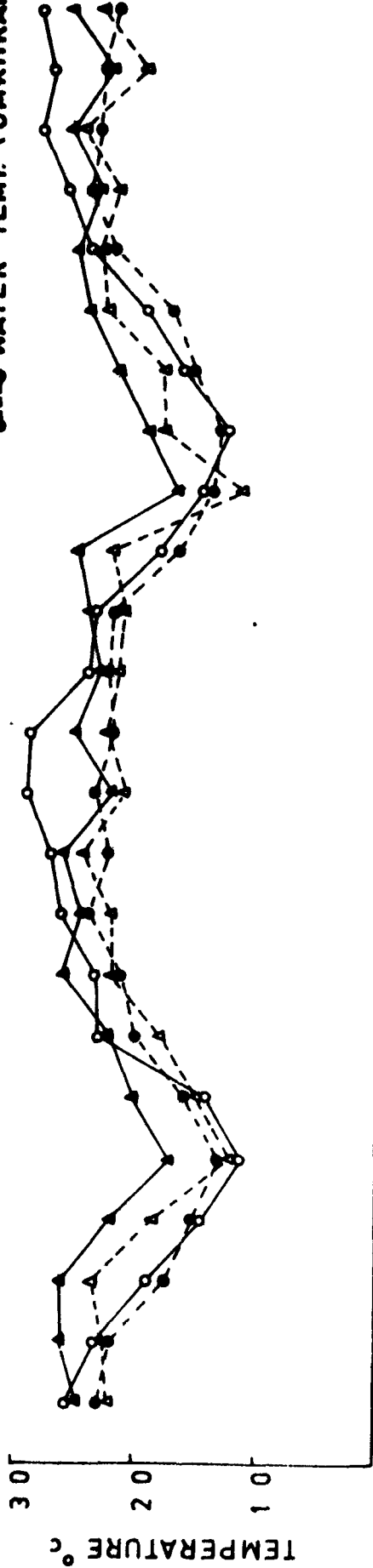
The general climatic conditions of the present study area do show some uniqueness in being different in many respects from that obtained in the plains of India. Thus, the vegetational composition is quite different, dominated by the coniferous tree Pinus kesiya. In-spite of this dominance, it is felt that a major portion of the allochthonous input into the streams is through the litter-fall from the various shrubs like Eupatorium and Polygonum including

other shrubs, ferns and grasses. The streams are almost entirely devoid of submerged macrophytic aquatic vegetation which needs explanation. It is known that generally low pH in these streams resulting in an acidic medium with low buffering capacity, and the allelopathic effect of conifers and other plants together with the lotic system of the nature could be the factors responsible for a virtual absence of macrophytes. It has also been seen that the algal diversity and abundance are fairly low in the streams, which is likely to be due to the lateritic soil and the low substrate diversity, which consists mostly of round pebbles and on certain occasions larger boulders in the sampling sites.

The seasonal rhythmicity of air and water temperature showed a co-linearity throughout the study period in all the stations. The air temperature was seen to be always higher than the water temperature (Figs. 5A & 6A) except in the cold months, particularly January, during the study period. The occurrence of this phenomenon might be due to the fact that water possess a unique property of having more specific heat than the air (Golterman, 1975). Water temperature showed a seasonal fluctuation as those of the air temperature as has been reported by Zafar, 1955; Ganapati, 1960; Munawar, 1970; Nasar and Munshi, 1971; and Nasar and Kaur, 1981. However, the difference in the range of temperature in the three study sites is very less. This uniformity could be due to the fact that the lotic systems continue to receive ground water seepages along their lengths which tend to keep the temperature uniform as has also been observed in such systems by Beck, 1965.

▲ AIR TEMP. (UMIAM)
 △ AIR TEMP. (UMKRAH)
 ○ AIR TEMP. (UMKRAH)
 ● AIR TEMP. (UMKRAH)

A



B

● UMIAM
 ○ UMKRAH

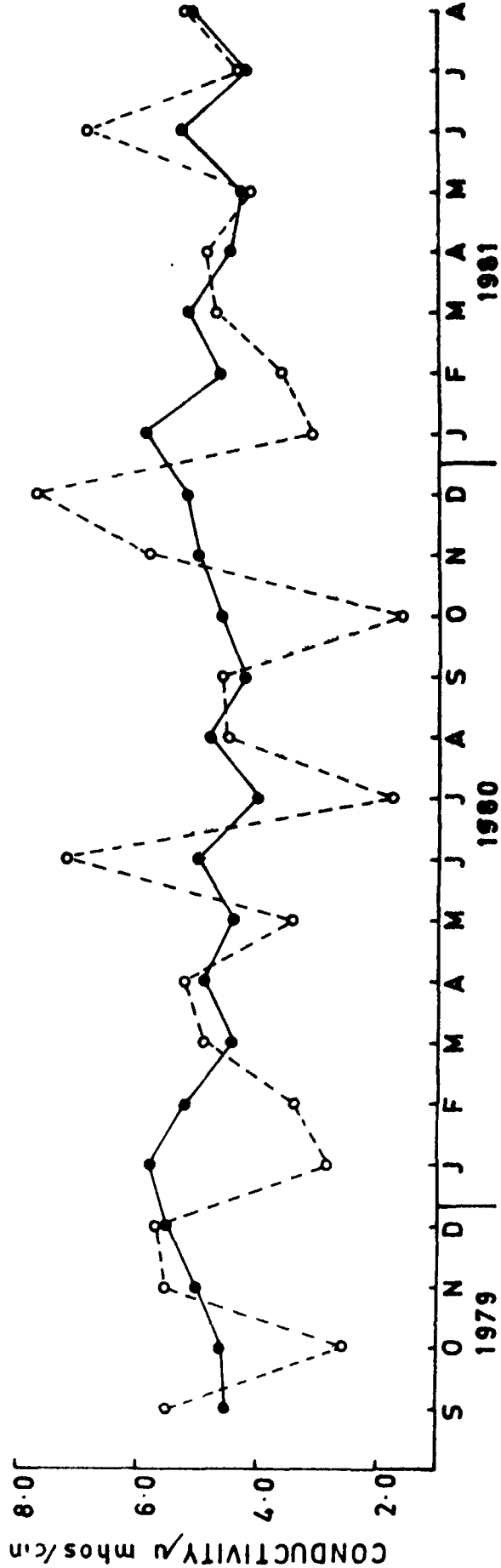


Fig. 5: Physico-chemical conditions of Umiam and Umkrah water bodies

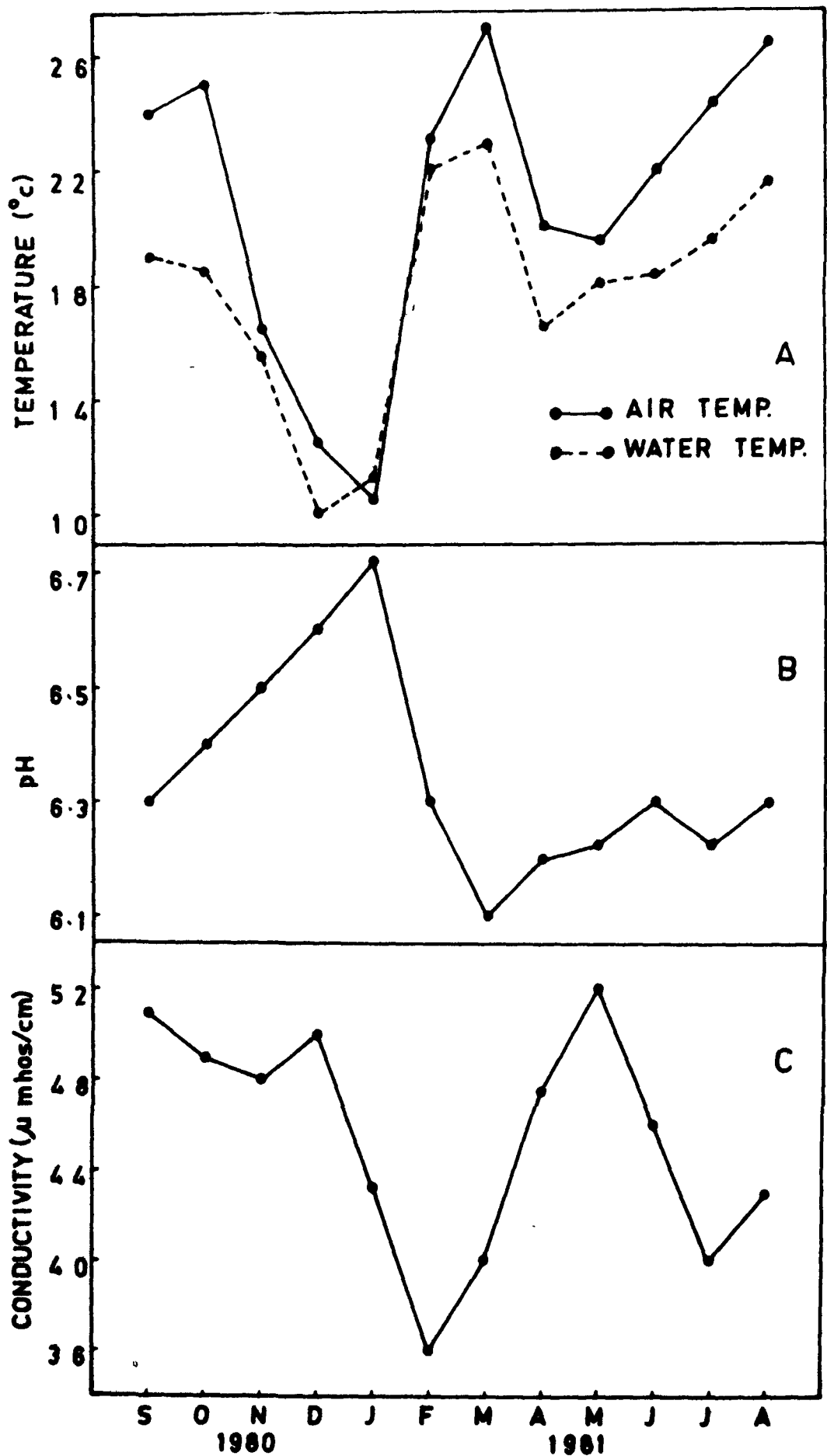


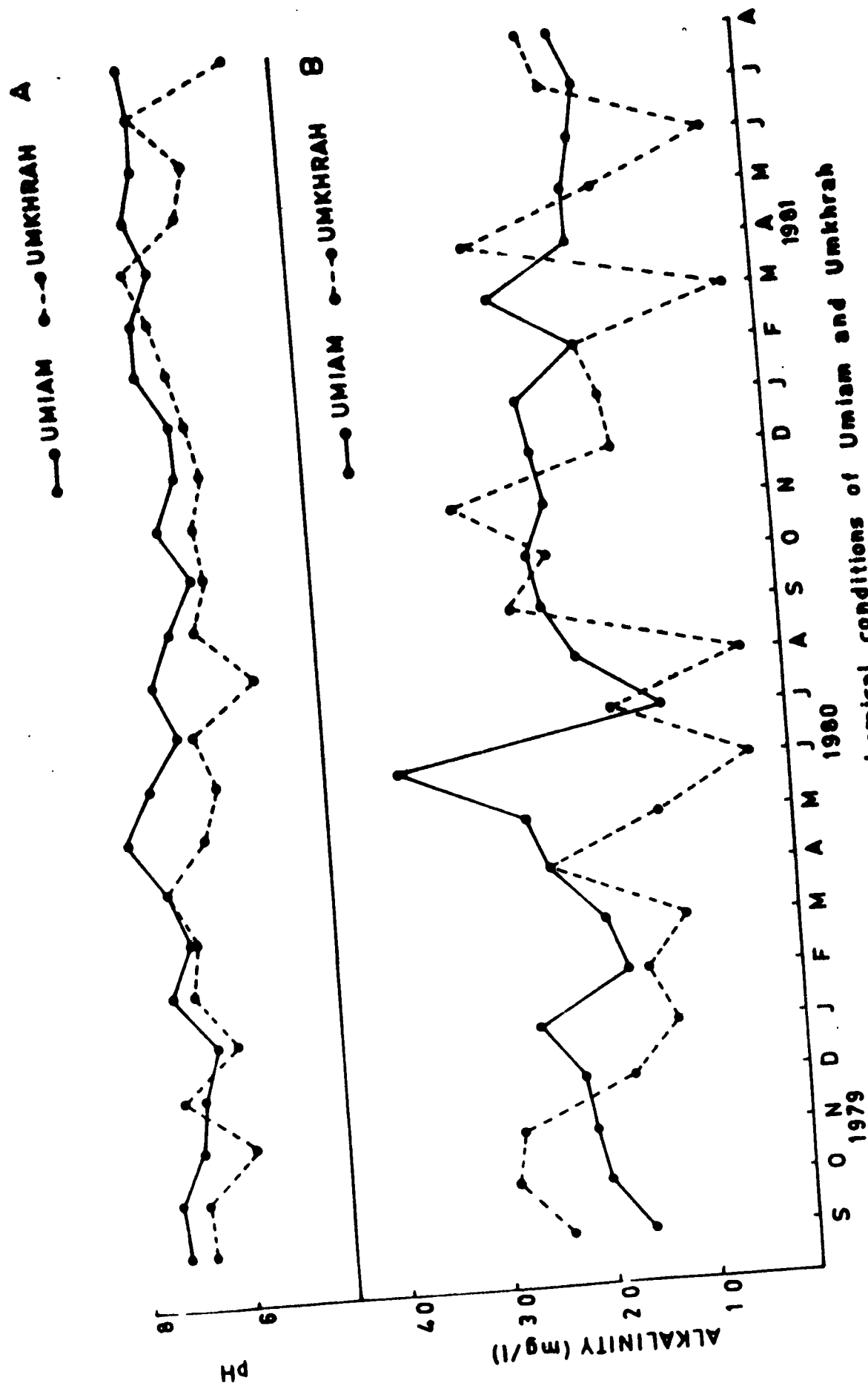
Fig. 6: Physico-chemical conditions of Umshing stream water

It is an established fact that specific conductivity as a factor is usually taken up as an indicator for assessing the trophic status of aquatic ecosystems. As this is related to the salts in the waters it is primarily a measure of resistance to electrical flow. In the present study, conductivity did not show any definite pattern of seasonality, although, a trend of winter maxima and summer minima are evident (Fig. 5B & 6C). The above findings could be attributed to the changes in ionic composition of the precipitation and the diluting effects of rain and flood waters in tropical streams (Bishop, 1973). The winter maxima in conductivity values can be explained by the fact that the water volume discharge, decreases considerably whereas, the inflow of nutrients by way of leaching remain the same or increases. The wider range of fluctuation of conductivity in Umkhrah (Fig. 5B) might be due to the input of heavy allochthonous sewage wastes through the run-off from the catchment areas resulting from human activities.

Though the pH values were found to fluctuate widely (Figs. 6B & 7A), it remained generally in the acidic range. Apart from this, there was a tendency of the pH values to reach a maxima during winter and a minima during summer. However, the pH values of Umkhrah did not follow any definite trend of fluctuation as reported in many tropical streams (Hynes, 1970; Bishop, 1973). The pH values showed a definite inverse relationship with free CO₂ concentration in all the systems studied (Tables-2, 3 & 4). It is believed that pH is generally influenced to a greater degree by the presence of carbon-dioxide in the water and at low pH, most of the

carbon-dioxide exist in free form (Welch, 1952). The changes in pH values and carbon-dioxide concentration reflects a mirror image of each other (Verduin, 1956; Beyers and Odum, 1959, 1960; and Lyman, 1961). It is well known that pH depends upon the amount of carbonates of calcium and magnesium and the carbon-dioxide tension in the water or in other words, there exists a "buffer system". The latter, in its turn is influenced by the photosynthetic activities and the animal life present in the system (Ganapati, 1940). As during photosynthesis the carbonates of calcium and magnesium are precipitated from their respective bicarbonates due to rapid carbon assimilation from the dissolved bicarbonates and hence the water becomes more alkaline (Welch, 1952) and this seems to be true in the present investigation.

Hutchinson (1967) is of the opinion that in almost every instance where the water is neither very acidic nor very alkaline, it may justly be assumed that pH is regulated by the carbon-dioxide bicarbonate system, which seems to be true in the present study too. A similar case has also been reported by Nasar (1975). A close and direct relationship between pH and carbonates has also been reported by Atkins (1926), Pearsall (1930), Howland (1931), Pringsheim (1946), Rao (1955), Zafar (1964) and Nasar (1979a). The acidic nature of water in the present study may be attributed to the inflow and runoff of surface water that flows over the pine-litter and lateritic soil of recent origin both of which are acidic in their properties as reported by Thapa, 1981.



Dissolved oxygen content showed an inverse relationship with temperature. Periods of high temperature coincided with those of low levels of oxygen, following the law of solubility of gases, whereas around August contrastingly high temperature corresponded with high oxygen values, which did not depend upon the physical factor of solubility of gases. Therefore, it appears that the limiting factor for dissolved oxygen around August was not the temperature. During the period, the photosynthetic activities of the periphytic communities might have elevated the oxygen content of the water. This supports the fact that during photosynthesis, carbonic acid gets split up, whereby assimilation of carbon takes place with the simultaneous liberation of oxygen into the surrounding waters (Welch, 1952; Ganapati, 1940; Nasar and Munshi, 1971). According to Welch (1952) water has the capacity to hold more oxygen with the decrease in temperature. Ruttner (1953) has also stated that temperature is one of the factors which effects the quantity of oxygen. In the present study also low temperature indicated higher oxygen level and vice-versa.

The seasonal variations in dissolved oxygen content of running and standing water have been investigated by various workers such as Fritsch (1907), Eddy (1934), Alikunhi (1957), Odum (1957), Chakraborty et al (1959), Swale (1964), Pahuwa and Mehrotra (1966), Venkateswarlu and Jayanti (1968), Nasar and Munshi (1971), Nasar (1975) and Hannan et al (1979). According to them the dissolved oxygen is generally found to be maximum during winter and minimum in summer as has been recorded in the present study.

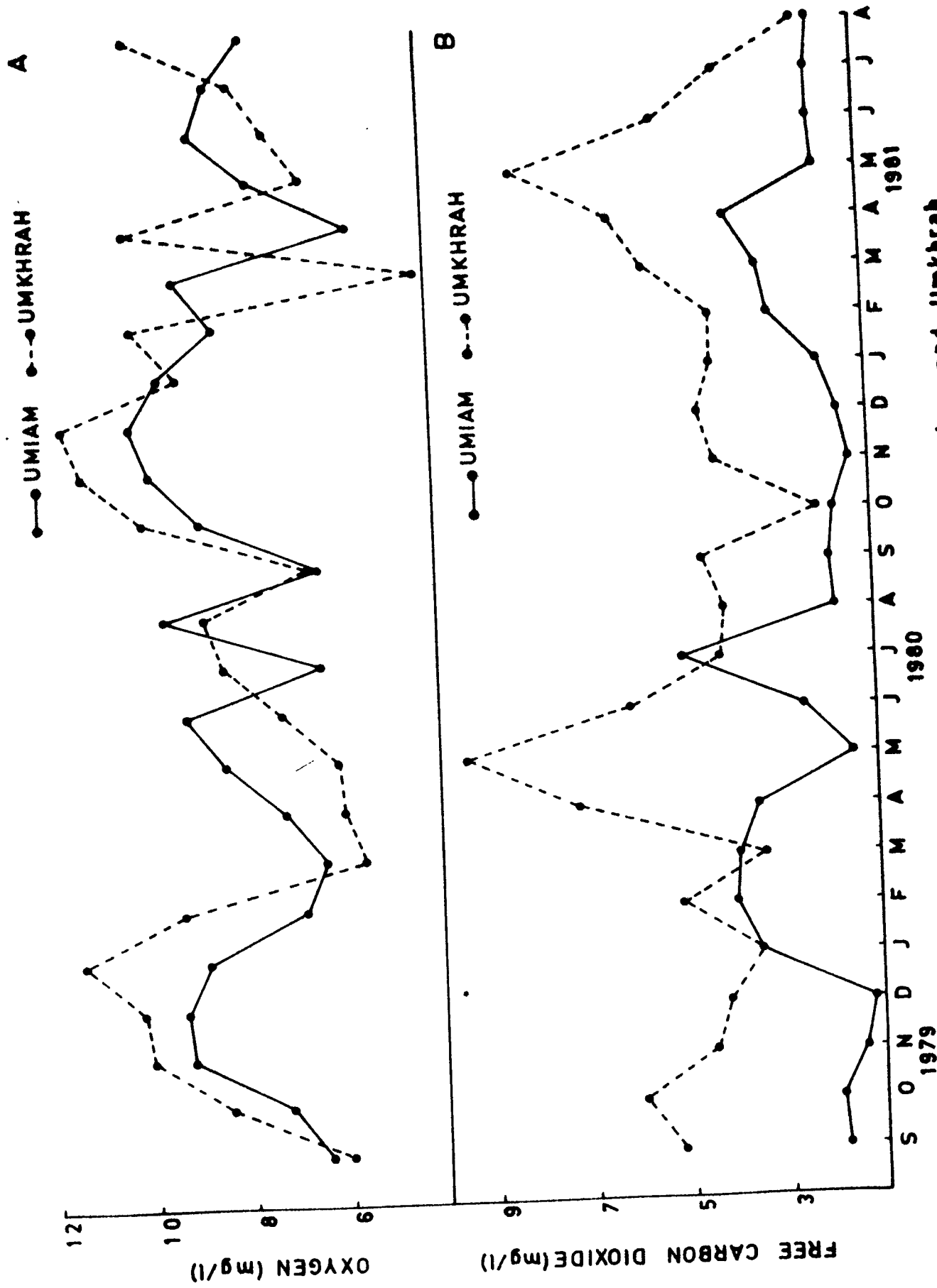


Fig. 8: Physico-chemical conditions of Umiam and Umkhrab water bodies

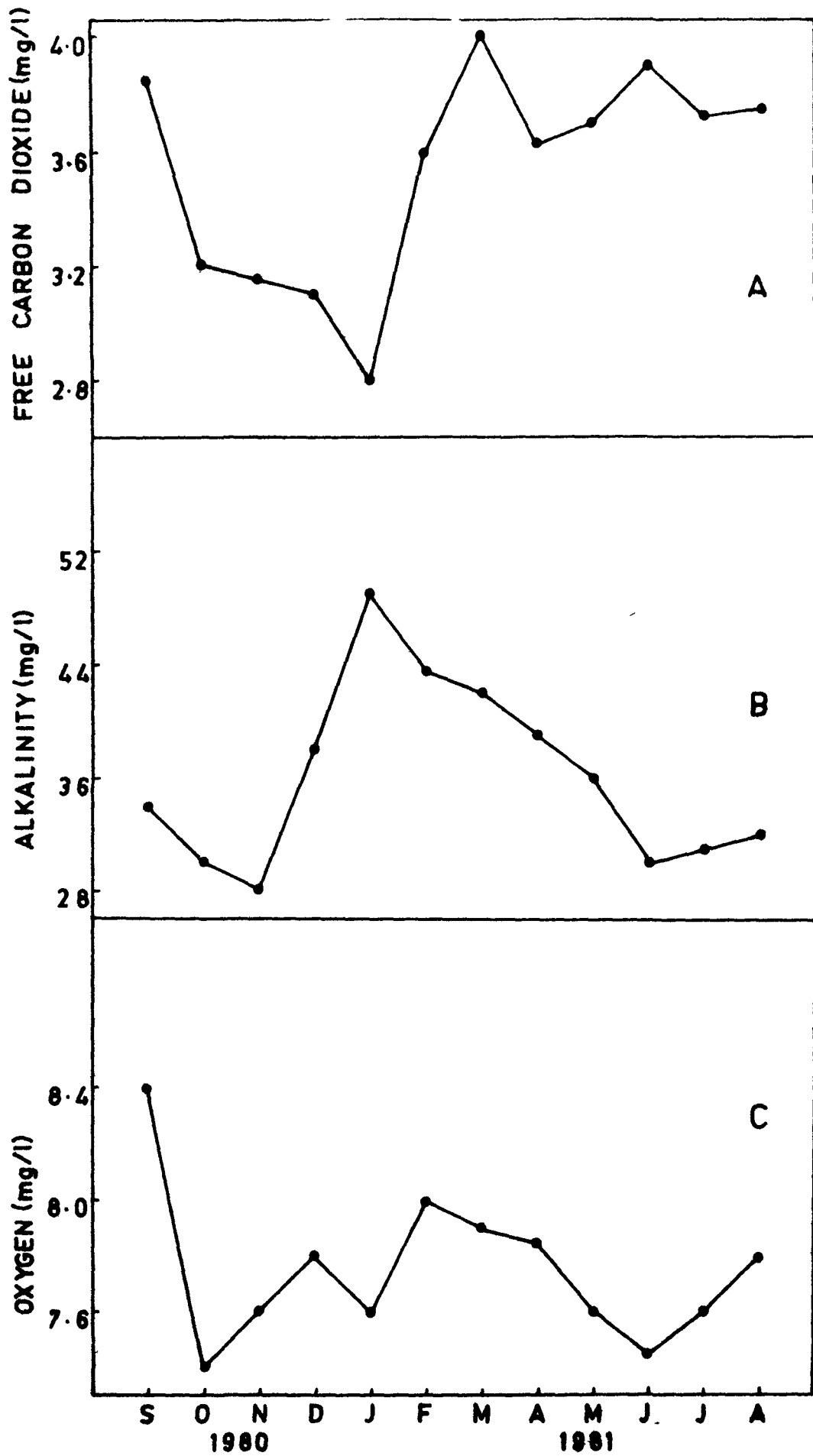


Fig. 9: Physico-chemical conditions of Umshing stream water

The main source of free CO_2 in the systems studied seems to be due to the decomposition of organic matter and respiration of plants and animals, coupled with physical sources of carbon-dioxide supply. Allegeier et al (1932) reported that the carbon-dioxide is the second largest decomposition product. The concentration of carbonates and bicarbonate is generally influenced by carbon-dioxide. Three factors namely, carbon-dioxide, bicarbonates and carbonates are known to be responsible for maintaining the "buffer system" in fresh waters. Free carbon-dioxide (Figs. 8B & 9A) and alkalinity (Figs. 7B & 9B) showed an inverse relationship in which the former shows a higher concentration in summer and the latter a lower concentration in that season and vice-versa in the winter months. Similar observations have also been reported by Atkins (1926), Pearsall (1930), Howland (1931), Pringsheim (1946), Rao (1955), Zafar (1964), Munawar (1970) and Nasar (1977a). The fluctuation in alkalinity values may be due to the photosynthetic activities, as has also been reported by Hussainy (1967) and according to him, this mainly depends on the "buffer systems". The general relationship between pH, carbonate and bicarbonate alkalinity and free CO_2 may be interpreted on the basis of dissociation of these into ionic state. As mentioned earlier, free carbon-dioxide in the water forms carbonic acid which dissociates into H^+ and HCO_3^- ions, and brings a change in the pH of the water as hydrogen ions are set free (Ruttner, 1953). Hydrogen-ion reacts with Calcium to form soluble calcium bicarbonate. If at this stage, free carbon dioxide is not available, calcium bicarbonate gets converted into insoluble calcium carbonate. The amount of carbon-dioxide that

inhibits the conversion of bicarbonates into carbonates has been termed as "Equilibrium-Carbon Dioxide" by Ruttner (1953). Thus, it is evident that the concentration of carbon-dioxide in water controls the pH, bicarbonate and carbonate concentration. The decline in total alkalinity values in the summer monsoon months is attributed to the heavy rainfall which might have diluted the ionic content of the water (Hynes, 1970; Bishop, 1973) as has also been found in the present study.

The concentration of dissolved orthophosphate in all the three systems was found to be quite poor (Figs. 10A & 11C). According to Welch (1952) and Ruttner (1953), the water which is free from any effluent contamination has lower levels of phosphate which support the present finding as the systems studied hardly gets any type of effluents directly. In the present study, the phosphate content (Fig. 11C) of the Umshing stream showed an inverse relationship with the dissolved oxygen level. This situation may be due to the fact that when there is lack of oxygen in water bodies, the iron in water is reduced from ferric to ferrous state releasing phosphate into water, as suggested by Einsele (1936). Therefore, during oxygen deficiency, phosphate gets released in water, specially from the sediments, thus the inverse relationship is evident (Table-4). However, in the Umiam and Umkhrah systems, no such well defined inverse relationship could be observed and at times there occurred a tendency of direct relationship of phosphate with oxygen. This situation may have been primarily due to the human interferences by way of washing clothes thereby adding some quantity of phosphate into the systems by using detergents. It may

be recalled that Umkhrah and Umiam lotic systems are in nearer proximity to the settlement of Shillong township than the Umshing stream. Besides these, phosphate level is known to be also dependent on various factors like temperature, salinity and bacterial activities (Welch, 1952). The increase of phosphate levels in all these systems during the monsoon could be due to run-off from the catchment areas (Kaur, 1981; and Nasar and Kaur, 1981) coupled with the increased addition of allochthonous materials and leachates into the systems.

Nitrate levels (Figs. 10B & 11B) of the streams showed an inverse relationship with their corresponding oxygen contents almost throughout the period of study. No definite relationship could be observed between pH and nitrate in Umiam and Umshing, whereas a direct correlation has been reported by Ganapati (1943) and Zafar (1964). The reduction in nitrate levels in all the system may be attributed to the photosynthetic activities of the algal community or due to oxidation of organic compounds as suggested by Blum (1956). According to Hannan and Young (1974), this decrease can be attributed to decreased run-off associated with rainfall and increased autotrophic assimilation, and this run-off has been shown to be an important contribution of nitrate-nitrogen in rivers.

Zafar (1964) suggested that when the organic matter decomposes in water, complex protein molecules are converted into nitrogenous organic matter and finally into nitrates by bacterial activity. Accordingly, when ammonoid-ammonia and nitrate go hand in hand and show an inverse relationship to the dissolved organic

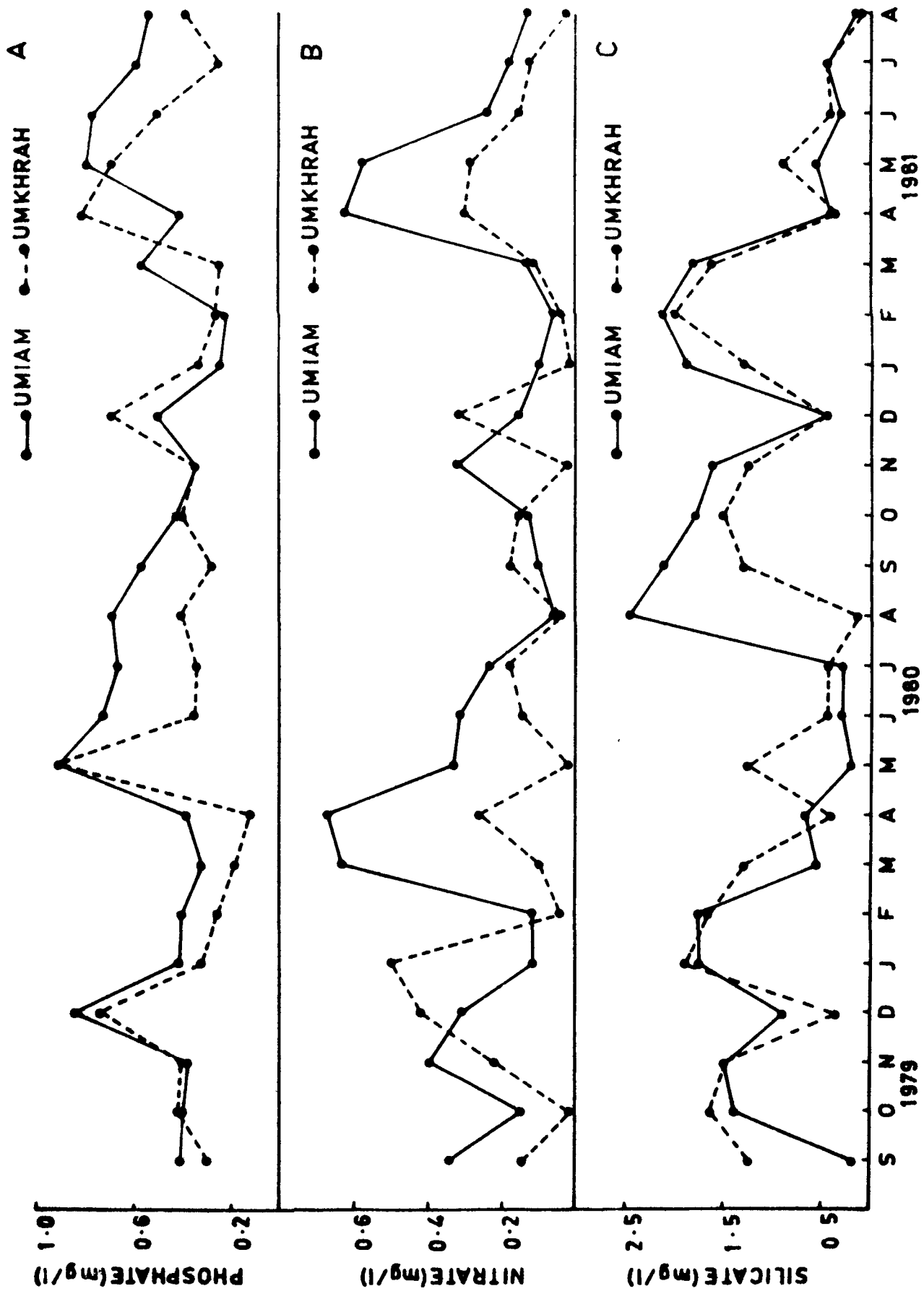


Fig.10: Physico-chemical conditions of Umiam and Umkhrach water bodies

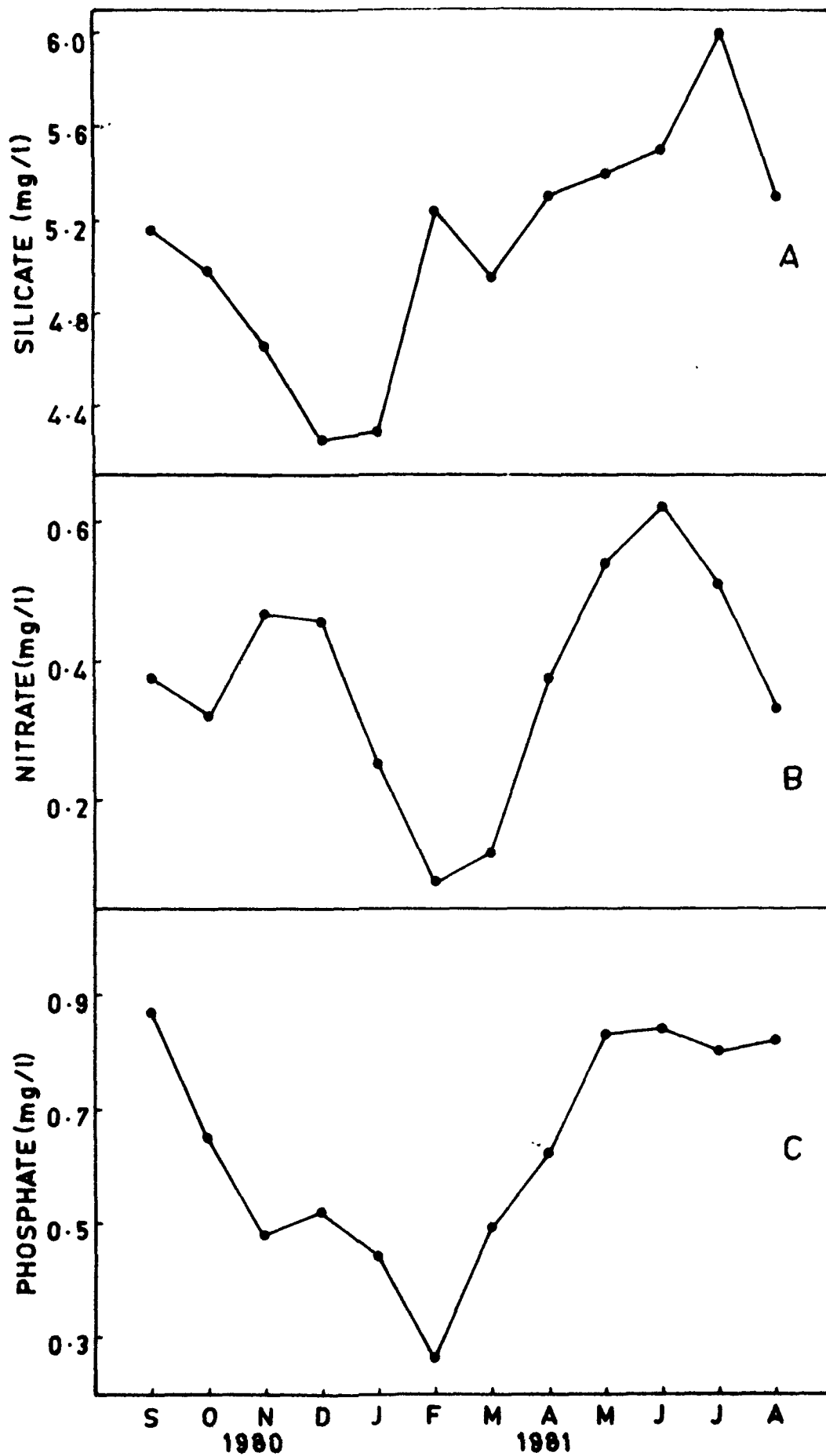


Fig.11: Physico-chemical conditions of Umshing stream water

matter, it may indicate that the main source of nitrogenous organic matter is the dissolved organic matter which is undergoing decomposition whereas on the other hand, if the alluminoid-ammonia fluctuates inversely with the nitrate, it may be assumed that the planktonic organisms are living at the expense of nitrates dissolved in water and they themselves are the main source of nitrogenous organic matter (Munawar, 1970). However, in the present investigation, no definite conclusion could be made regarding the main source of nitrate in these water bodies as alluminoid-ammonia and dissolved organic matter could not be estimated. However, a major source could be, by precipitation as suggested by Vollenweider (1968) and Schindler (1971).

Nitrate showed an inverse relationship with the temperature, which suggests that temperature has a profound effect on nitrate concentration, in view of the fact that the temperature accelerates the activity of denitrifying bacteria in the presence of organic matter (Nasar, 1978) and the process of reduction of nitrates may stop with the nitrite production, which is sometimes accompanied by hydroxylamine or it may proceed to the formation of molecular or perhaps to nitrogen or to ammonia (Hutchinson, 1967), which seem to be the reason of the nitrate depletion during the months of June, July and August in the Umiam and Umkhras systems.

The silicate content (Fig. 10C) of the water was found to vary inversely with free carbon-dioxide in Umiam and Umkhras lotic systems during the present study. Possibly this is due to the fact that as Silicic acid is more weakly dissociated than carbon-dioxide,

it is removed from its strongly hydrolyzed compounds - the silicates, in the presence of carbon-dioxide or bicarbonate and is then held in the water as free silicic acid in dissolved or colloidal form (Ruttner, 1953), thus an inverse relationship has been observed between the two factors. In the Umshing stream, the silicate content (Fig. 11A) seemed to be governed mainly by temperature as the quantity of silicate recorded increased with a rise in temperature. Similar results have also been recorded by Beklemishev (1961) and Tessenow (1966). Atkins (1926) reported that the silica content in freshwaters is influenced not only by temperature, but also by evaporation of water. In all the three systems, an inverse relationship has been observed between alkalinity and silicates. It is further evident from the records, that low levels of silicate in the water correspond with the peaks of diatom abundance during March to May, since diatoms take up silicates and the presence of large numbers of diatoms might have caused the exhaustion of silicate to low levels in these systems.

It has been seen that the calcium and magnesium constitutes one of the major ions in these systems and of these, calcium content was found to be much higher than the former (Tables-2, 3 & 4). Though calcium is known to be an essential nutrient (James, 1973) for the metabolism in higher plants, it is required usually as a micronutrient for algae. Magnesium, on the other hand is very important as it is an essential constituent of chlorophyll molecules (James, 1973). The calcium level revealed a summer maxima and a winter minima (Figs. 12A & 13A). The calcium contents were observed to be inversely related to the pH although this relation-

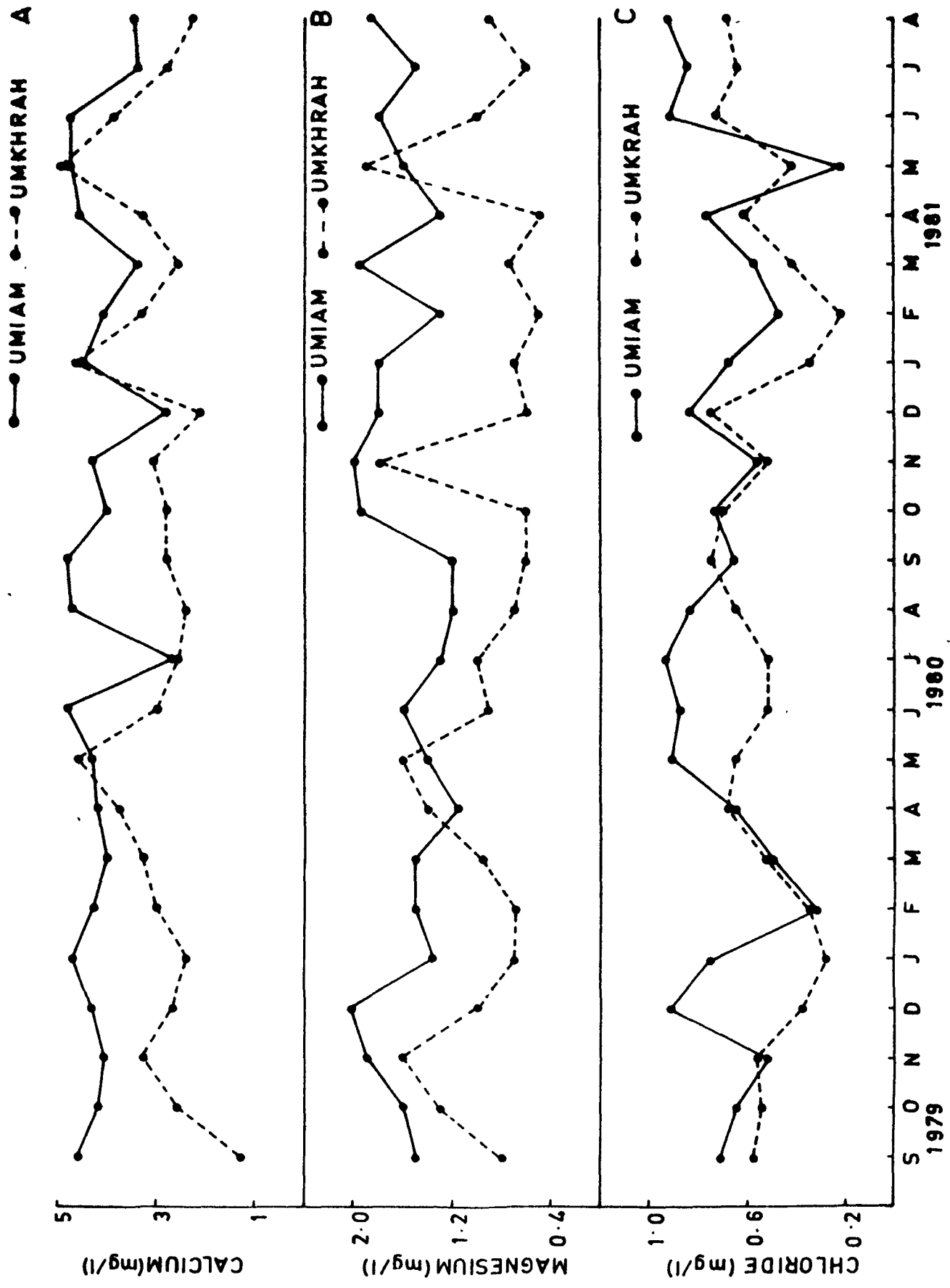


Fig.12: Physico-chemical conditions of Umiyam and Umkhras water bodies

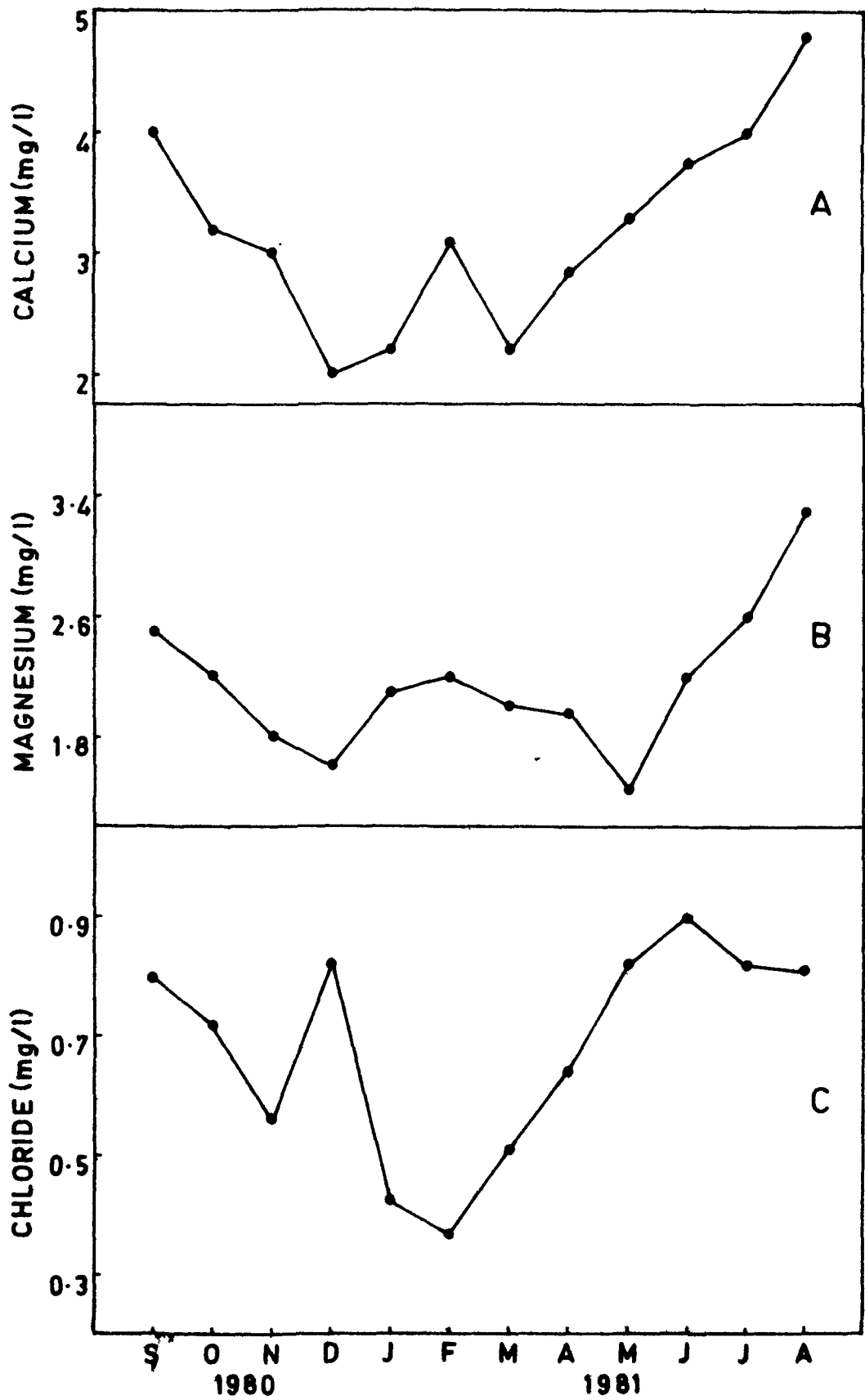


Fig.13: Physico-chemical conditions of Umshing stream water

ship was not clearly demarked in the Umiam and Umkhrach systems. The lower concentration of calcium can be attributed to its being taken up by the sediment (Hongve, 1978). This ion has earlier been shown to possess the greatest adsorbed concentrations in the sediments (Hongve, 1978). This uptake is known to take place as exchange with hydrogen-ion revealing an acidifying effect on the water body. The process depends upon the concentration of calcium ions and hydrogen ions both in the adsorbed and dissolved state with the probability of a reversal with increase in acidity (Hongve, 1978). Hence, the negative relationship of calcium with pH has been observed in the present study. The further implication of calcium is, its involvement in the calcium-bicarbonate system. This is also true in the case with magnesium. Apart from their importance in photosynthesis, the calcium and magnesium ions play a stellar role in antagonising the toxic effects of various ions and in neutralising excess acid produced in the system as also stated by Munawar (1970).

Chloride concentrations were found to be extremely low (Tables-2, 3 & 4) as is expected in the water bodies far away from oceans (Bishop, 1973). The slightly higher values obtained in the Umiam and Umshing systems can be attributed to possible higher chloride salts contents of the parent rocks in the proximity of the systems. The variations (Figs. 12C & 13C) in the levels of chloride concentration from season to season might be due to the changes in discharge volume and precipitation input by way of leachates (Bishop, 1973). In general, the chloride concentrations in all the three systems investigated have been found to be very

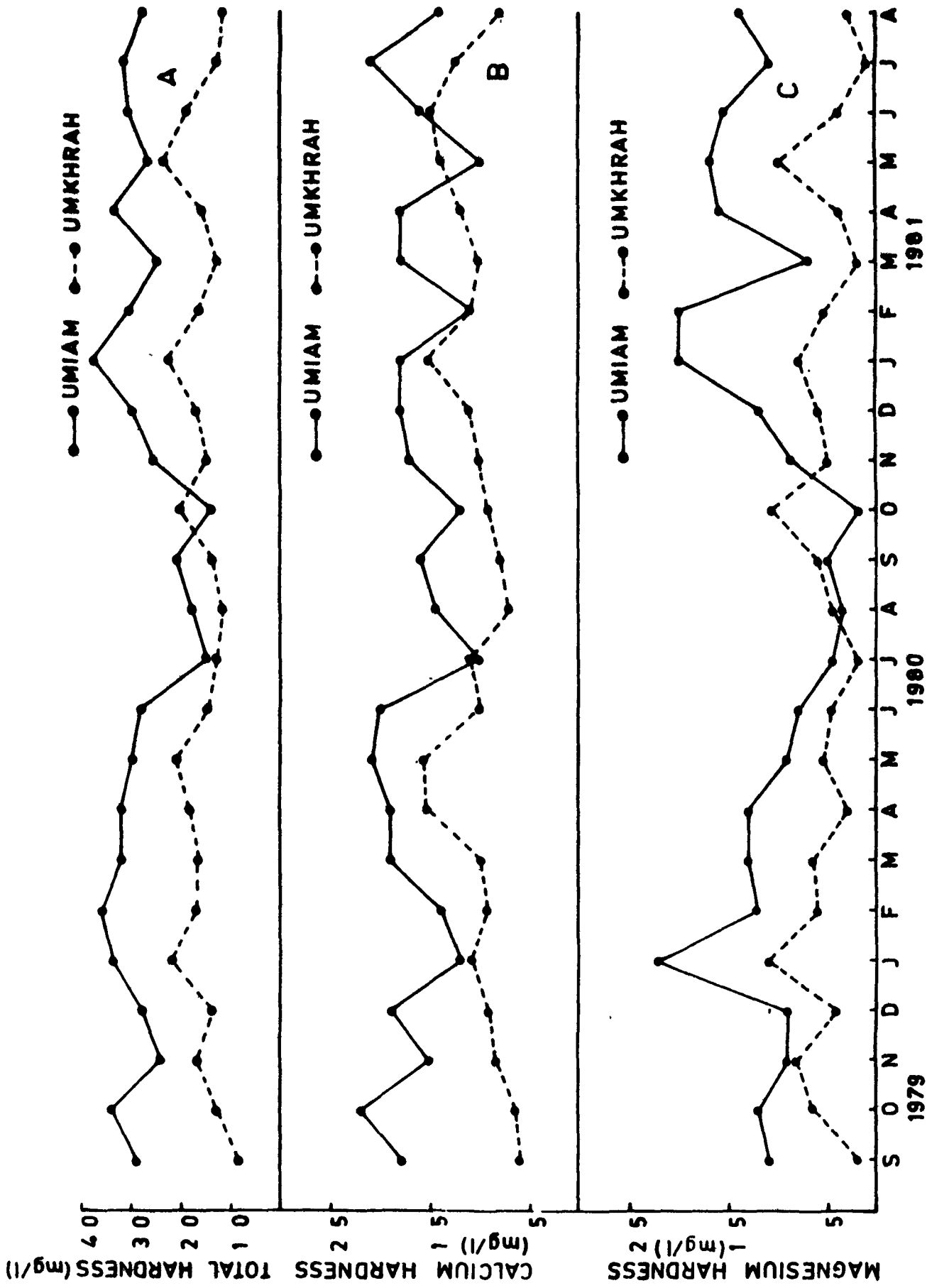


Fig. 14: Physico - chemical conditions of Umiam and Umkhras water bodies

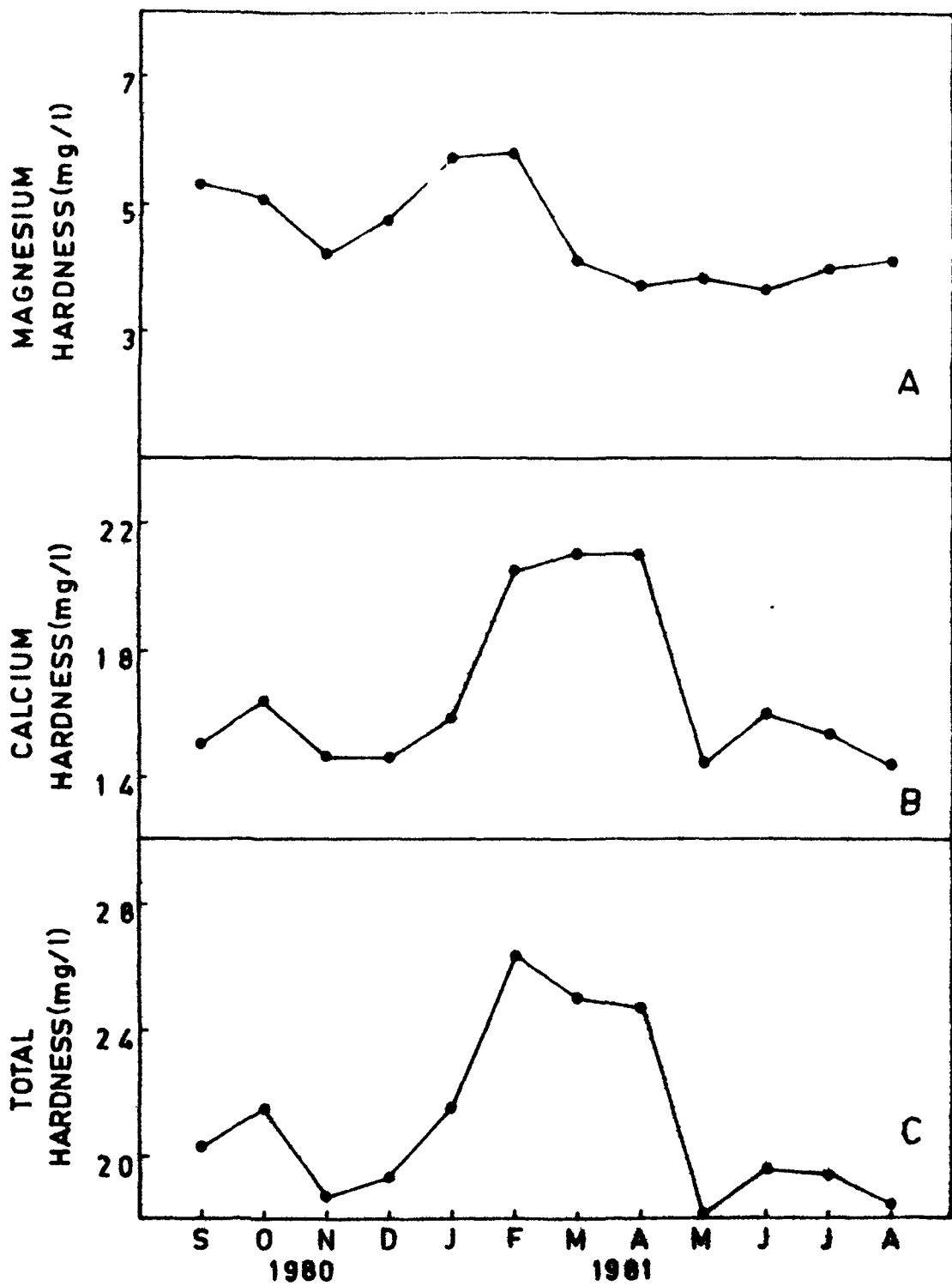


Fig.15: Physico-chemical conditions of Umshing stream water

similar to those in the water bodies of north and south Malaya (Bishop, 1973).

It is known that primarily the ions of calcium and magnesium that account for total hardness. The calcium hardness was found to be comparatively higher than magnesium hardness (Tables-2, 3 & 4) in all the three systems throughout the period of the study. Although limestone abounds in this region, the low levels of calcium and magnesium hardness (= total hardness) suggests that the water of the systems cannot be called truly hard. The source of this minor hardness could be limestone beds that are known to contain calcium and magnesium which might be leaching out into the water (Hynes, 1970). The peak levels of calcium hardness were generally found to be coincided with the peak levels of magnesium hardness (Figs. 14 & 15), which in turn coincided with the peak levels of total hardness in the respective water bodies. The decline in the level of total hardness during the rainy months (May, June, July and August) might be due to the increase in water level and the subsequent dilution of the calcium and magnesium present in the systems. Apart from being inversely related to pH, hardness, in particular calcium hardness, can contribute significantly to alkalinity levels (Reid and Wood, 1976) thus helping the streams to have a greater algal population, resulting better primary production in the system which further supports the view of Horton, 1961 and Willoughby, 1977.

In all the systems where larger boulders were found to be present, the periphyton was found to be moderately rich both in

terms of diversity and density. However, in places with smaller stones and pebbles, periphytic growth was found to be less. This could have been due to the unstable substratum offered by these smaller stones and pebbles compounded with their being more susceptible to the scouring action by currents. Apart from the periphytic forms, planktonic forms were to be harboured mainly where the water current was almost stagnant. The abundance of benthic algae in such waters has also been noted by Hynes (1970). True planktonic forms like Fragillaria, Cosmarium, Closterium and Scenedesmus were also recorded in the system.

When compared with other tropical and sub-tropical streams or rivers as mentioned by Hynes, 1970 and Bishop, 1973, the algal flora seems to be poor in diversity in the present study, although this needs further investigation on these lines. However, the paucity in diversity of periphyton could be due to the effect of substrate instability rather than inadequate light penetration because generally light is not considered as an important factor in such shallow water bodies as is the smothering or grinding effect of siltsand, the scouring action of water at high velocity and flash floods. However, on the other hand, brown mats of diatoms were found to develop on the stream substrates during spring. The presence of diatoms like Nitzschia in the systems, indicate possible nutrient enrichment of the systems as has also been pointed out by Bishop (1973), although the overall dominance of diatoms in the algal community is indicative of oligotrophy which agrees well with the findings of Patrick (1957), Bishop (1973) and Hynes (1970).

Filamentous Chlorophyceae viz., Oedogonium and Spirogyra were more common in Umiam, Umkhrah and Umshing systems compared to their occasional presence in the river Sungal Gombak in Malaysia (Bishop, 1973). The greater abundance of Chlorophyceae in the Umkhrah stream was probably due to its higher nutrient level as has also been recorded by Gupta (1980).

CHAPTER III

Biology Of The Fish

I N T R O D U C T I O N

Knowledge of the occurrence of fish in India dates back to three millenium B.C. (Hora, 1956). According to Nath (1966), fish remains with cut marks, indicative to their use as food, have been obtained from excavation at Mohenjodaro and Harappa of the Indus Valley civilization (2500-1500 B.C.). While Aristotle (384-237 B.C.) is said to be the founder of Ichthyology, King Somesvara, the son of King Vikramaditya VI, who composed the book "Manasol-tara" in 1127 A.D. was the first to record the common sport fishes of India grouping them into marine and freshwater riverine forms (Hora, 1951a). The first modern writer on Indian fishes, according to Day (1878) was Bloch, whose splendid work "Auslandiche Fische" was first published in 1785. Later, Lacepede's work "Historie des Poissons" (1798-1803). Russel (1803) described 200 species from

Vizakhapatnam. Then appeared Hamilton's pioneer work "Fishes of Ganges" (1822) which contains a description of 269 species of fish from the Ganges and its tributaries. Cuvier and Valenciennes "Historie Naturelle des Poissons", published in 1828-1848, provided more impetus to the study of Ichthyology than any other work till then. Other notable works on the taxonomy of fishes are those of McClelland (1839), Bleeker (1853), Blyth (1860) and Gunther (1859-1870).

There is, however, no work of greater importance on Indian fishes than the epoch making contributions of Day's "Fishes of India" (1878) and "Fauna of British India, Burma and Ceylon" (1889). In the present century, valuable contributions on fish systematics have been made by Hora (1944, 1951b, 1955), which are being continued by many zealous workers, notably Shaw and Shebbeare (1937), Misra (1959) and Menon (1951, 1964).

Tropical fish communities are noted for its high diversity. The history and geography of the area dictate the basic stocks of fish which gain access to it (Lowe-McConnell, 1975). The fishes manage to persist in a particular geographical region which depends on the suitability of ecological conditions for all stage of life history. Since fishes are very mobile creatures, they search out different habitats to suit the particular requirements of the eggs, the young fish, juveniles, or adults. Their social requirements too change as many fishes live in shoals when young, but in pairs or solitarily when adult. Thus, the composition of the fish communities, the group of interacting population within a particular habitat may be changing continually (Lowe-McConnell, 1975).

The results of interplay between fish and environment is that in certain places communities are very stable throughout the year and from year to year, while in other places community membership changes radically all the time, often with seasonal regularity. Some fish species are eurytopic, that is to say they can withstand a great range of environmental conditions such as fluctuating temperature or salinity, or they can exhibit wide plasticity in feeding habits, while other species are stenotopic, tolerating only a very narrow range of conditions.

According to Holt (1967), assessment of world production is needed in the next three decades and that inland waters, where control can be exercised of the factors governing production, will have to bear the brunt of this increasing demand. There is, thus an urgent need to understand the factors involved in fish production. This warning is more exemplified by the fact that the world catch of fish which was increasing until recently, has now started declining at an alarming rate, mainly due to the over-exploitation of the fishery resources and the insatiable demand created by the spiralling population growth. Moreover, today almost all the inland water bodies are undergoing eutrophication, in other words, a step prior to pollution.

In India, where the intake of meat and milk is low, fish is of paramount importance as a supplement to the ill-balanced diets. Today, protein deficiency leading to malnutrition is a world-wide phenomenon, and perhaps 30-40% of the world's population is afflicted by protein deficiency. It is estimated that about 8.5 million

tons of fish is required annually to meet the current demand of fish protein in India against an annual production of only about 1.7 million tons (Nasar and Kaur, 1979).

The extensive researches on freshwater fishes in India generally centers around the biology only of those species which are being used to stock dams and lakes rather than on natural fish communities. In this country, the major Indian carps, such as Catla catla, Labeo rohita and Cirrhina mrigala, and the exotic carps viz., Cyprinus carpio, Ctenopharyngodon idella and Hypophthalmichthys molitrix are the main fishes that are cultured (Nasar and Kaur, 1979). However, as already indicated before, the supply and demand ratio, place these fishes beyond the purchasing capacity of the poor people who are the ones that are actually more prone to malnutrition and protein deficiency. It is felt that in a developing country like India more than academic interest should be given to the cultural possibilities and management of smaller fishes that will be within the economic reach of the people belonging to the lower income group. One such fish that is greatly relished as food by the local people of Meghalaya State belongs to the genus Garra which has a wide distribution through parts of China, Indo-China, the Middle-East Countries and the Continent of Africa. The member of the genus which is abundantly found in the highlands of Meghalaya is G. lissorhynchus (McClelland).

According to Menon (1964) the first species of the genus Garra was described by Hamilton (1822) in his classical work on the fishes of river Ganges. Menon (1964) further states that

originally the species was designated as Cyprinus lamta which was subsequently changed to Garra lamta. Rupell (1837) described two species from Abyssinia under two different generic names, Chondrostoma dembeensis and Gobio quadrimaculatus. In the years 1838, 1839 and 1842, McClelland described a number of species from streams in the Eastern Himalayas under two different generic names, Gonorhynchus and Platyicara. Sykes erected another genus, Chondrostoma in 1841. Heckel (1843 and 1844), emphasizing the disc character, described specimens from Syria, Iraq and Iran under a new genus Discognathus and in 1844 he further described D. fusiformes from Bombay and in 1846 recorded the occurrence of this genus in Abyssinia. Jerdon (1846) recorded Gonorhynchus gotyla, G. mcClellandi and G. stenorhynchus from southern India. In 1860, Blyth described a species from Burma under the name Platyicara notata. Bleeker (1863) recognized Hamilton's Garra as a distinct genus and described G. ceylonensis from Ceylon (now Sri Lanka). In 1865, Day described G. malabarica from the Malabar Coast (India) and again in 1867, he described a new species G. jerdoni and also recorded G. gotyla from the rivers of the Nilgiri Hills. From the same region, Day (1867) again described another new species G. alta. Nikolsky (1897, 1899) recorded D. variabilis and D. lamta from Persia and its vicinity. Vaillant (1902) recorded and described a new species from Borneo and designated it D. borneensis. Boulenger (1903) described D. makiensis from the Maki river in Abyssinia and in 1905 he described another new species D. hindi from the Nyiro river in Kenya. Regan (1907) described a new species D. yunnanensis from South China and in

1914 yet another new species D. phryne from Waziristan. Another new species, D. ornatus from the Congo basin was described by Nichols and Griscom (1917). Prasad (1919) described D. kangrae from Punjab while in 1918-1919, Annandale described D. graveli from Burma. Rao (1920) recorded two new species, G. patycephala and G. bicornuta from Mysore. In 1921, Hora from a developmental study of the disc in these fishes, concluded that Disconathus should not be separated as a distinct genus from Garra.

It is clear from the available literature that practically no work has so far been attempted on the biology of this species. However, Hora and Mukherji (1936), Hora (1937), Fraser (1937), Rajan (1965), Agarwal and Tyagi (1969) and Somvanshi and Bapat (1979) have done some work on the feeding habits of the genus Garra. Some reports on some genetical aspects have been reported in recent years by Shahoo and Nasar (1980), Majhi (1980), Khuda-Bukhsa, Gupta and Geewami (1980), Khuda-Bukhsa (1981). Recently, Bhagwati and Ratha (1982) reported on the biochemical body composition of this genus from the North-Eastern part of the country. The notable contributions on aspects of systematics such as morphology, meristic characters, colouration, key to identification, size attainments and habitats of Garra have been made by Day (1878, 1889), Hora (1921, 1937), Menon (1964) and Das, Shahoo and Nasar (1982). Morphological variations in fish as a result of the adaptation to its new environment have been cited by various authors (Schmidt, 1921; Vladykov, 1934; Tanning, 1944; Lindsay, 1954; Fage, 1958; Barlow, 1961). According to Grant and Spain (1977), the concepts of size and shape are fundamental to the analysis of variation in living organisms.

According to Le Cren (1951) knowledge of the length-weight relationship of a fish is essential since various important biological aspects viz., general well being, appearance on first maturity, onset of spawning, fecundity in relation to length and weight of fish etc. can also be assessed with the help of condition factor of this relationship. An important derivations of growth is what fish population analysts have termed "Condition factor" or "Ponderal index" or more popularly known as the "K" factor. Apart from estimating the length-weight relationship of fish which makes it possible to convert length into weight and vice-versa, another approach has been to determine the coefficient of condition (K-factor) with the objective of expressing the condition of the fish in numerical terms i.e. degree of well-being, relative robustness, plumpness or fatness.

For proper fishery management, a thorough knowledge of maturation cycle and depletion of gonads is of utmost importance as it is essential to understand and predict the annual changes that the population undergoes. From these studies, a variety of inference could be drawn, such as the rate of regeneration of stocks and determination of ecological factors which led to synchronization of breeding activity. Similarly, information on such related aspects as fecundity, size at first maturity etc., are also pertinent and all these aspects should be considered for successful aquaculture. The knowledge of the number of eggs produced by fishes is of great value in pisciculture, as it would determine the amount of rearing facilities required and the extent to which various kinds of equipment will be needed. According to Corbin

(1948, 1952), the number of eggs produced by the fish must be known, if survival is to be estimated. The data pertaining to fecundity are also useful in determining the density dependent factor affecting population size (Simpson, 1951) and for separating different fish stocks from the same population (Farran, 1938). For several centuries the attention of laymen, naturalists and fishery scientists have been drawn to the number of eggs in the roes of female fish. Fish fecundity has been studied not only as one aspect of natural history, but also in association with studies of population dynamics, racial characteristics, production and stock recruitment problems (Bagenal, 1978).

The constant demand for adequate nourishment is a selective agent that may greatly influence an organism's existence. This influence can be so persuasive that many ecologists feel it as a primary factor declining an organism's niche (Schoener, 1974). Investigations of the feeding ecology of a species can produce insight into how the organism has evolved ecologically to meet this pressure (Grossman et al., 1980). Most studies of the food and feeding habits of fishes from varying habitat have shown that those of any one species differ in time and space and at different stages of growth (Hardy, 1924; De-Silva, 1973), thereby emphasizing the need to the study in more details, the food habits of a species.

Therefore, in a virtual absence of scientific knowledge on the above biological and ecological aspects of Garra with particular reference to the highlands of the North-Eastern Hill Region,

it has been felt desirable to conduct such studies. These studies will not only fill up the gap of our present day academic knowledge but also help in the proper management and judicious exploitation of the fishes.

The present study pertains to the specimens of Garra lissorhynchus (McClelland), collected from three lotic systems in the vicinity of Shillong, the limnology of which has been presented and discussed in the previous chapter. The results of the biology of the three populations have been compared to gather knowledge on intra-specific variations in morphometric characters, length-weight relationships, food and feeding habits and reproduction. It has also been attempted in the present investigation to establish the relationship of the abiotic and biotic factors of their immediate environment on the biology of the species.

DIAGNOSTIC CHARACTERS OF THE GENUS GARRA Hamilton, 1822

The nomenclature of the genus has had a turbulent history. McClelland (1838) termed this genus as Platycara. Heckel (1843), and Bleeker (1860) favoured to classify the species under Discognathus. Day (1869) preferred to place some of the species under the genus Mayoa. However, Hora (1921) expressed his opinion in favour of Garra and subsequently taxonomists are using this term and hence, in the present study too.

Menon (1964) outlined the diagnostic characters of the genus Garra as :-

"Cyprininae with elongated subcylindrical body. Mouth transverse, semi-circular and inferior; lips continuous covered with anterior and posterior labial folds, jaws covered with horny sharp edge; a suctorial disc behind lower lip consisting of semi-cartilaginous pad bordered anteriorly by a papillated posterior labial fold and posteriorly by a free papillated integument in all species; the edge of the anterior labial fold always fimbriated. Snout more or less rounded or slightly conical, somewhat depressed and projecting beyond the mouth; either smooth or with a proboscis; Barbles four, sometimes two or none. Margins of opercula widely separated except in those species considered most primitive (G. cariabilis and G. rossicus) where they meet in the middle line behind the disc. Gill openings restricted to side. Pharyngeal teeth edentulous in three close approximating rows; the inner 5 or 4, the middle 4 or 3, outer 3 or 2. Lateral line equally distant from back and belly and continued to base of center of caudal. Scales of moderate size. Dorsal fin 9 to 12 rays, originating in advance of pelvic. Anal fin short with 6 to 8 rays; pectoral 12 to 18; caudal with 18 to 20 rays. Gill raker short, few and widely set. Air bladder varies considerably in form and extent".

TAXONOMIC STATUS

(after Menon, 1964)

Phylum	-	Vertebrata
Sub-Phylum	-	Craniata
Series	-	Pisces
Class	-	Osteichthyes
Sub-Class	-	Actinopterygii
Super-order	-	Osteroiophysi
Order	-	Cyprinoidei
Family	-	Cyprinidae
Sub-family	-	Cyprininae
Genus	-	<u>Garra</u> Hamilton, 1822
Species	-	<u>lissorhynchus</u> (McClelland)

KEY TO IDENTIFICATION (after Menon, 1964)

D. 6-7; A. 6; Lateral line scales 32-35.

L. tr. $\frac{3.5 \text{ to } 4.5}{3.0 \text{ to } 3.5}$; Pre-dorsal scales 11 to 14.

SYNONYMSGARRA LISSORHYNCHUS (McClelland)

- 1842 : Platyca liissorhynchus McClelland, Calcutta Jour. Nat. Hist., Calcutta, 2, p. 587, pl. 68, (Type-loc.; "Kasyah Mountains", Assam).
- 1868 : Discognathus macrochir Gunther, Cat. Brit. Mus. Fish. London. 7, p. 70 (Type-loc.; Assam Type in BM).
- 1869 : Mayoa modesta Day, Proc. Zool. Soc. Lond., London, p. 553 (Type-loc.; "Northern India").
- 1871 : Mayoa modesta Day, J. Asiat. Soc. Beng., (Calcutta. 40 (2), p. 108, pl. 9, fig. 2.
- 1889 : Discognathus modestus Day, Faun. Brit. Ind. Fish., London, 1, p. 247.
- 1921 : Garra liissorhynchus Hora, Rec. Indian Mus., Calcutta, 22, p. 662, pl. 26, figs. 2, 2a.
- 1935 : Garra liissorhynchus Hora and Mukherji, Rec. Indian Mus., Calcutta, 37, p. 390.
- 1955 : Garra liissorhynchus Menon, Rec. Indian Mus., Calcutta, 52, p. 22.
- 1964 : Garra liissorhynchus Menon, Mem. Indian Mus., Calcutta, 14, 4, p. 220, figs. d, e.

DISTRIBUTION : India :- Brahmaputra system, Assam, Himalayas, Meghalaya, Nagaland.

M A T E R I A L S A N D M E T H O D S

COLLECTION SPOTS :

The material for this study pertains to the samples of Garra liissorhynchus (Fig. 3) collected at monthly intervals during September, 1979 to August, 1981 from Umiam river and Umkhras stream, and during September, 1980 to August, 1981 from Umshing stream.

COLLECTION PROCEDURES :

Collections of the specimen were made with the help of $\frac{1}{4}$ " wire mesh hand nets. The nets were placed against the water current and the stones immediately in front of the nets were vigorously shaken to dislodge any Garra liissorhynchus that might be present under the stones. The fishes get dislodged from the stones and on being exposed to the water current are swept into the net.

Immediately after collection, the total length and weight of each specimen was recorded to the nearest millimeter and gramme respectively. The specimens were, immediately after necessary measurements, fixed in 5% formalin in the field for further biological studies.

BIOLOGICAL PARAMETERS :

The following biological parameters of the species collected from the three systems (Fig. 1) have been taken into consideration:

(a) Morphometric measurements (b) Meristic characters (c) Length-weight relationship (d) Condition factor (e) Maturity and ova diameter study (f) Fecundity and (g) Food and feeding habits.

The study is based on the examination of 769 specimens of Garra liosorhynchus collected during the period of study. The specimen ranged from 27.0 mm to 120.0 mm in length and from 0.263 gms to 18.50 gms in weight. Altogether 246 specimens were used for fecundity estimation and 523 guts were analyzed for food and feeding studies.

The following methods were adopted for the biological studies as mentioned above.

(a) MORPHOMETRIC MEASUREMENTS :

Slide rules, and measuring boards having graduations in millimeters were used for taking the various morphometric measurements.

Total length : Total length has been measured from the tip of the snout to the tip of the tail to the nearest millimeter.

Fork length : The distance from the tip of the snout to the point of bifurcation of the caudal fin.

Standard length : It has been measured as the distance from the tip of the snout to the caudal base.

Head length : Distance from the tip of the snout to the end of the opercular bone.

Pre-dorsal length : Distance from the tip of the snout to the first dorsal fin ray.

Eye diameter : Distance between the anterior and the posterior margin of the eye in a straight line.

Post-orbital length : Distance from the posterior margin of the orbit to the end of the opercular bone.

Inter-orbital width : From the upper margin of the right orbit to the upper margin of the left orbit as measured from dorsal surface.

Head width : The greatest perpendicular distance from one operculum to the other.

Head depth : Perpendicular distance from the end of the nape to the ventral side of the head.

Body depth : Vertical distance between the dorsal and ventral surface of the body at its greatest depth.

Least height of body : Shortest height of the caudal peduncle between the end of the anal fin and the origin of caudal fin.

Length of caudal peduncle : Distance from the end of the anal fin to the base of the median caudal rays.

Length of pectoral fin : Distance between the anterior and posterior end of the pectoral fin taken along the base of the fin.

Length of dorsal fin : Distance between the anterior and posterior end of the dorsal fin taken along the base of the fin.

Length of pelvic fin : Distance between the anterior and posterior end of the pelvic fin taken along its base.

Length of anal fin : Distance between the anterior and posterior end of the fin taken along its base.

Least diameter of disc : The greatest antero-posterial length of the disc.

Greatest diameter of disc : The greatest straight line distance between the rims of the disc.

Girth : Circumference of the body at its deepest point.

Biometric index : The number of times each character went into the total length of the fish was taken as the Biometric Index (Tabor, 1974). In addition, the number of times some characters went into the head length has also been noted. The characters taken were Standard length (SL), Head length (HL), Fork length (FL), Pre-dorsal length (PDL), Head depth (HD), Head width (HW), Least body height (LHB), Length of caudal peduncle (LCP), Body depth (BD), Length of dorsal fin (DF), Length of pectoral fin (PF), Length of

pelvic fin (VF), Length of anal fin (AF), Eye diameter (ED), Inter-orbital width (IOW), Post-orbital distance (POD), Least diameter of disc (LDD), Greatest diameter of disc (GDD). For each character a mean index for each 10 mm length group has been calculated to see whether it is constant or varying with the increase in the total length.

(b) MERISTIC CHARACTERS :

The following meristic counts were made according to the methods outlined by Lowe McConnell (1971) :-

- (a) Number of rays in the dorsal fin
- (b) Number of rays in the pectoral fin
- (c) Number of rays in the pelvic fin
- (d) Number of rays in the anal fin
- (e) Number of rays in the caudal fin
- (f) Number of barbels
- (g) Lateral line scale count represent the number of paired scales on the lateral line.
- (h) Lateral line transverse scales - scales above lateral line have been counted from the origin of the dorsal fin and counted down and backwards to the lateral line but does not include the lateral line scale at that point. Scales below the lateral line have been counted upward and forward from the origin of the anal fin.

All the above mentioned morphometric and meristic counts numbering to 27 parameters were recorded only from the left side of the specimens. / The specimens from each of the three systems

were grouped into 10 mm length classes for morphometric studies. For the study of the morphometric characteristics, the regression method has been employed using the formula described by Le Cren, 1951.

$$Y = a + bx$$

where: 'Y' is the standard length; 'a' is a constant value to be determined; 'b' is the regression coefficient; and 'X' is the variable character such as total length, head length etc. The value of 'a' and 'b' were determined by the following formula :

$$b = \frac{\sum XY - n \bar{X} \bar{Y}}{\sum X^2 - n \bar{X}^2}; a = \bar{Y} - b\bar{X}$$

where: n = total number of length groups; \bar{X} = mean of X and \bar{Y} = mean of Y.

All linear measurements were made to the nearest 0.1 mm, then converted to a percentage of standard length. Specimens of all three systems were also pooled together to get a combined picture of the various morphometric characteristics.

(c) LENGTH-WEIGHT RELATIONSHIP :

The length-weight relationship in fishes can usually always be adequately represented by the equation (Le Cren, 1951) and the same has been adopted in the present study.

$$W = CL^n$$

where: "W" = weight of the fish; "L" = Total length of the fish; and "C" and "n" are constants. The equation was transformed into logarithmic form as :-

$$\log W = \log C + n \log L$$

The values of "C" and "n" were determined empirically.

The length-weight relationship during this investigation was studied taking into consideration, the intact weight of the fish i.e. including gut and gonads. The observed average weight of Garra lissorhynchus from the three systems were plotted against the average observed length to examine the nature of parabola. On converting the values to logarithms, the exponential relationship has been expressed as the linear equation described above. The regression of log Weight on log Length has been calculated by the method of "least squares" by grouping the sample data into seventeen length groups (5 mm interval) for the specimens collected from Umiam river. The specimens collected from Umkhras stream were grouped into fifteen length groups while those collected from Umshing into thirteen length groups. Specimens of Garra lissorhynchus of all the three systems were also pooled together to form sixteen length groups. The relationship was calculated for the different seasons also to see the seasonal impact. Two seasons viz. summer (April to September) and winter (October to March) have been taken into consideration as the other seasons are not distinctly defined in this part of the country.

The relationship has also been studied separately for adults and juveniles to find out the differences during their life stages. For this study, specimens ranging from 27.0 mm to 56.68 mm have been regarded to be juveniles and all the specimens above 56.68 mm in length have been regarded as adults.

(d) CONDITION FACTOR :

Individual variations from general length-weight relationship have been studied under the general name "Condition"

(Le Cren, 1951). Such changes in condition have usually been analysed by means of 'condition factor' or 'Ponderal Index', which various workers have calculated by using different formulae. However, in the present study, the same has been determined by using the following formula (Hile, 1936).

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

where K = condition factor, L=Total length and W = weight of the fish. The number 10^5 has been used to bring the Ponderal Index (K) to near unity as suggested by Carlander (1970). Fluctuation in condition factor were examined for each 5 mm size group of the fishes as well as for different months to derive the seasonal fluctuations for Garra lissorhynchus from the three systems.

(e) MATURITY, SPAWNING AND OVA DIAMETER STUDY :

MATURITY : After recording all the necessary morphometric and meristic details, the specimens were dissected and their gonads were carefully taken out from the visceral cavities. The maturity stages of the fishes were determined following the key as outlined by Nikolsky (1963) based on the appearance and size of the gonads:

- I. Immature: Young individuals which have not yet engaged in reproduction; gonads of very small size.
- II. Resting stage: Sexual products have not yet begun to develop; gonads of very small size; eggs not distinguishable to the naked eye.
- III. Maturation: Eggs distinguishable to the naked eye, a very rapid increase in weight of the gonad is in progress, testes change from transparent to pale rose colour.

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- IV. Maturity: Sexual products ripe, gonads have achieved their maximum weight but the sexual products are still not extruded when light pressure is applied to the belly.
 - V. Reproduction: Sexual products are extruded in response to very light pressure on the belly, weight of the gonads decrease rapidly from start of spawning to its completion.
 - VI. Spent: The sexual products have been discharged, genital aperture inflamed, gonads have the appearance of deflated cases, the ovaries usually containing a few left over eggs and the testis some residual sperm.

SPAWNING : The spawning activity has been studied according to the classification described by Hickling and Rutenberg (1936), Walford (1932) and Qasim and Qayyum (1961). Accordingly the spawning activity in fishes can be of the following four types :

- I. Spawning takes place only once a year during a short period of definite duration. In fishes belonging to this category, the mature ovary contains mature ova distinctly separated from the immature stock.
- II. Spawning takes place once a season but with longer duration. In species showing this type of spawning, the range in size of mature ova, irrespective of the number of modes representing them, has been found to be nearly half of the total range in size of the entire intraovarian eggs.
- III. Spawning twice a year. In the ovaries of these fishes, in addition to the batch in ripe condition, another batch of eggs which has undergone the process of maturation.

IV. Spawning extending over a long period, but intermittently.

In this category, the different batches of eggs in the ovary are not sharply differentiated from one another thereby indicating that the passing of one batch of eggs into the next stage is a continuous process.

GONADO-SOMATIC INDEX : Prior to the fixing of the gonads in formalin they were weighed and recorded to the nearest 0.1 gramme in a chemical balance. To study the condition of the gonads, Nikolsky (1963) advocated the use of "Coefficient of Maturity", also known as "Maturity Index" or "Gonado Somatic Index" (Gn.S.I.), which expresses the weight of the gonad as a percentage of total weight and has been calculated according to the following formula (Hodgkiss and Man, 1978):

$$\text{Gonado-Somatic Index (Gn.S.I.)} = \frac{\text{Gonad weight} \times 100}{\text{Total Body Weight (gms)}}$$

Gonado-somatic indices were determined separately for various length groups and also season wise for Garra lissorhynchus from the three different populations.

OVA-DIAMETER STUDY : Measurements of ova diameter were taken from formalin fixed material. Preliminary examination of the ovaries revealed that there was no marked differences in the mean ova diameter of eggs from the anterior, middle and posterior part of the paired ovary of the species. Consequently, random sub-samples were taken and subjected to ova diameter measurement with the help of an ocular micrometer. The diameter of the ova, along whatever axes they lay, were measured to ensure random nature of the readings and unbiased values as suggested by Clark (1934).

(f) FECUNDITY :

ABSOLUTE FECUNDITY : Only ovaries from mature (ripe) specimens just on the verge of breeding were used for fecundity studies. Both the ovaries from 246 preserved gravid females of Garra lissorhynchus of known length and weight were removed. Sub-sampling by weight method (McGregor, 1922) has been employed and fecundity has been calculated from the counts of mature ova in two random sub-samples of the ovary of known weight by using the following formula :

$$F = \frac{W (N_1 + N_2)}{(W_1 + W_2)}$$

where: F = Fecundity; W = Total weight of the ovary; W_1 and W_2 and N_1 and N_2 are the weights and ova counts respectively for each sub-sample.

RELATIVE FECUNDITY : Apart from absolute fecundity, relative fecundity has also been calculated by the following formula (Hardisty, 1964):

$$\text{Relative Fecundity} = \frac{\text{Egg Number}}{\text{Body Weight}}$$

The trends of relationship between (a) fecundity and total length; (b) fecundity and body weight; (c) fecundity and ovary weight; (d) total length and ovary weight; and (e) body weight and ovary weight were examined and a log transformation has been worked out in the form given below (Bagenal, 1978):

$$\text{Log } Y = \log a + b \log x$$

(g) FOOD AND FEEDING HABITS :

For the study of food and feeding habits, a total of 523 guts were analysed from the specimens ranging in length from 27.0 mm to 120.0 mm and in weight from 0.266 gms to 18.499 gms.

The extracted guts were individually measured to the nearest millimeter and weighed to the nearest gramme in the field itself prior to fixing the same in 5% formalin for subsequent analysis. Contents of each preserved gut were teased out and then the emptied gut was weighed. This weight was subtracted from the full gut weight to find out the weight of the gut content. The gut contents were examined microscopically and the various food items present in the guts were counted and identified upto generic level.

Various methodologies have been used by different workers to enumerate the gut contents of fishes. In the present study, however, the following methods described by Ricker (1971) have been adopted.

NUMERICAL METHOD : The number of individuals of each food type in each gut has been counted. These were summed to enumerate the total for each kind of food item in the whole sample, and then a grand total of all the items was made. The quotient of these gave the percentage representation of each type of food item in the gut.

FREQUENCY OF OCCURRENCE : Gut contents were examined and the individual food items were counted and identified. The percentage of

occurrence of a particular food has been calculated with reference to the sum of occurrence of all the items. The gut contents were also analysed for elucidating seasonal variation in the diet component. The data was also analysed for various size groups in order to see if there is any basic change in the diets of the species with the increase in length of the fish.

GASTRO-SOMATIC INDEX : The feeding intensity has been calculated by the following formula (Bhatnagar and Karamchandani, 1970) :-

$$\text{G.S.I.} = \frac{\text{Gut content weight}}{\text{Body weight}} \times 100$$

The feeding intensity or G.S.I. was correlated with the condition factor.

RELATIVE LENGTH OF GUT : The ratio between the gut length and the total length (R.L.G.) has been estimated by employing the following formula (Al-Hussainy, 1949) :-

$$\text{R.L.G.} = \frac{\text{Gut length}}{\text{Body length}}$$

The total lengths and gut lengths were measured to find out the relationship between the two variables. Relationship was also established between weight of the gut and body length. In both the cases, regression equations were determined to describe the relation between them.

R E S U L T S

MORPHOMETRY AND MERISTIC COUNTS

The measurements of morphometric characters in percentage of standard length have been presented in Tables-6 & 7 and summarized below.

FORK LENGTH :

The mean values for fork length were found to be 6.26 in the specimens from the Umiat river, 6.20 in the Umkhrak stream and 5.17 in the Umshing stream population. Their respective average percentage of standard length values were recorded to be 108.12, 110.71 and 113.86. When all the three populations were pooled together the mean value was found to be 6.41 and the average percentage was 109.01.

PRE-DORSAL LENGTH :

The mean values of the parameter were found to be 2.93, 2.82 and 2.55 in the Umiam, Umkhrah and Umshing populations respectively. The average percentages of standard length were found to be 50.61, 50.30 and 56.24 respectively. When the populations were pooled together, the mean value was calculated to be 2.96 and the average percentage of the standard length was 50.34.

HEAD LENGTH :

Mean values of head length for Umiam, Umkhrah and Umshing populations, were calculated to be 1.34, 1.24 and 1.03 respectively and their respective average percentage of standard length were found to be 23.12, 22.14 and 22.76 (Table-7). The mean value of all the three populations pooled together was 1.13, while the average percentage of standard length was 22.30.

HEAD DEPTH :

Mean values for head depth for the three populations of Umiam, Umkhrah and Umshing were recorded to be 0.80, 0.78 and 0.598 respectively and their respective average percentage of standard length were 13.84, 13.85 and 13.18. The mean value of pooled data of all the three populations was 0.80 and the average percentage of standard length was 13.61 (Table-7).

HEAD WIDTH :

The respective mean values for head width of the Umiam, Umkhrah and Umshing populations were recorded to be 1.03, 0.997 and 0.835. The average percentage of standard length values in the same sequence, were found to be 17.70, 17.80 and 18.39. The

three populations, when pooled together showed a mean value of 1.04 and an average percentage of standard length of 17.70.

EYE DIAMETER :

Mean value of eye diameter for Umiam river population was 0.23, for Umkhrah stream population it was 0.18, and 0.18 again for Umshing stream population. Their respective average percentage of standard length were calculated to be 3.98, 3.12 and 3.97. When pooled together, the mean value was found to be 0.21 and the average percentage of standard length was 3.57.

POST-ORBITAL DISTANCE :

The mean values of this morphometric character were found to be 0.55 for Umiam, 0.503 for Umkhrah and 0.45 for Umshing populations. Their respective average percentage of standard length values were 9.45, 8.99 and 9.80. The three populations when pooled together showed a mean value of 0.55 and an average percentage of standard length to be 9.34.

INTER-ORBITAL WIDTH :

The mean values for this character were 0.69, 0.72 and 0.55 and their respective average percentage of standard length were found to be 11.92, 12.90 and 12.12 for the specimens from Umiam, Umkhrah and Umshing systems in the same sequence. The pooled data irrespective of population resulted in a mean value of 0.74 and an average percentage of standard length of 12.50.

GREATEST DIAMETER OF DISC :

The mean values for the greatest diameter of disc were calculated to be 0.45, 0.447 and 0.37 respectively for the

specimens from Umiam, Umkhrah and Umshing systems. Their respective average of percentage values were found to be 7.76, 7.99 and 8.22. The pooled mean value was 0.47, while the average percentage of standard length was 7.99.

LEAST DIAMETER OF DISC :

The mean value of the least diameter of the disc was recorded to be 0.31 for the populations from Umiam river, 0.295 for Umkhrah stream and 0.243 for Umshing stream. Their respective average percentage of standard length values were found to be 5.30, 5.26 and 5.35. When pooled together, the mean value of this character was found to be 0.31 and the average percentage of the standard length was recorded to be 5.27.

BODY DEPTH :

The mean values for Umiam, Umkhrah and Umshing system populations for body depth were 1.23, 1.124 and 0.93 respectively and their average percentage of standard length were 21.23, 20.07 and 20.48 in that sequence. The pooled mean value of the three populations was 1.22 and the average percentage of standard length was found to be 20.7 .

LEAST HEIGHT OF BODY :

The mean values of this character in the specimens from Umiam river, Umkhrah and Umshing streams were recorded to be 0.72, 0.74 and 0.57 respectively, and their corresponding average percentage of standard length were 12.44, 13.21 and 12.60. The mean pooled value for the three populations was 0.75 and the average percentage of standard length was 12.67.



LENGTH OF CAUDAL PEDUNCLE :

The mean values of this morphometric character were deduced to be 2.44, 2.14 and 1.92 for G. lissorhynchus populations from Umiam, Umkhrah and Umshing systems respectively. Their corresponding average percentage of standard length were recorded to be 42.06, 38.13 and 42.34. The mean value, when the three populations were pooled together, recorded to be 2.35, and the average percentage of standard length was found to be 40.02.

LENGTH OF DORSAL FIN :

The mean values of this parameter were deduced to be 0.61 in the specimens from Umiam river, 0.56 for Umkhrah and 0.47 for Umshing stream. Their respective average percentage of standard length were found to be 10.59, 10.03 and 10.37. The mean value of the pooled populations was found to be 0.60 and the average percentage of standard length was recorded to be 10.22.

LENGTH OF PECTORAL FIN :

The mean values of the length of pectoral fin in the specimens from Umiam, Umkhrah and Umshing systems were calculated to be 0.37, 0.35 and 0.29 respectively. Their corresponding average percentage of standard length values were 6.37, 6.29 and 6.37. The mean value and the average percentage of standard length values of the populations when pooled together were recorded to be 0.35 and 5.95 respectively.

LENGTH OF PELVIC FIN :

The mean values in this case were recorded to be 0.29, 0.24 and 0.21 respectively for the Umiam, Umkhrah and Umshing

TABLE-6

MORPHOMETRIC ANALYSIS OF GARRA LISSORHYNCHUS (POOLED DATA)

PARAMETERS	MEAN	AVERAGE % STAN- DARD LENGTH	RANGE	AVERAGE % HEAD LENGTH
Weight (gms)	7.23	-	0.286 - 18.499	-
Total length	7.00	-	2.7 - 12.00	-
Standard length	5.88	-	2.23 - 10.20	-
Fork length	6.41	109.01	2.42 - 10.50	-
Predorsal length	2.96	50.34	1.15 - 4.63	-
Head length	1.31	22.30	0.55 - 2.30	-
Head depth	0.80	13.61	0.24 - 1.39	61.07
Head width	1.04	17.70	0.42 - 1.60	79.39
Eye diameter	0.21	3.57	0.10 - 0.36	16.03
Post orbital distance	0.55	9.34	0.26 - 0.90	41.05
Inter orbital width	0.74	12.50	0.33 - 1.30	56.49
Greatest diameter of disc	0.47	7.99	0.16 - 0.78	35.88
Least diameter of disc	0.31	5.27	0.09 - 0.52	23.66
Body depth	1.22	20.70	0.39 - 2.00	-
Least height of body	0.75	12.67	0.27 - 1.18	-
Length of caudal peduncle	2.35	40.02	0.84 - 3.61	-
Length of dorsal fin	0.60	10.22	0.18 - 1.15	-
Length of pectoral fin	0.35	5.95	0.12 - 0.60	-
Length of pelvic fin	0.27	4.59	0.08 - 0.41	-
Length of anal fin	0.32	5.39	0.10 - 0.55	-
Girth	4.08	69.37	1.56 - 6.22	-

TABLE-7

MORPHOMETRIC ANALYSIS OF G. LISSORHYNCHUS FROM DIFFERENT LOTIC SYSTEMS

	UMIAM RIVER			UMKHRAH STREAM			UMSHING STREAM					
	MEAN	AVERAGE % OF SL	RANGE	AVERAGE % OF HL	MEAN	AVERAGE % OF SL	RANGE	AVERAGE % OF HL	MEAN	AVERAGE % OF SL	RANGE	AVERAGE % OF HL
Weight (gms)	7.24	-	0.269-18.50	-	6.09	-	0.263-18.453	-	3.09	-	0.266-8.228	-
TL	7.04	-	2.7 -12.00	-	6.45	-	2.7 -10.25	-	5.45	-	2.7 -8.475	-
SL	5.79	-	2.125-10.20	-	5.60	-	2.4 - 8.75	-	4.54	-	2.16 -7.15	-
FL	6.26	108.12	2.43 -10.50	-	6.20	110.71	2.6 -9.90	-	5.17	113.86	2.42 -8.13	-
PDL	2.93	50.61	1.185- 4.63	-	2.82	50.30	1.14 - 4.54	-	2.55	56.24	1.134-4.40	-
HL	1.34	23.12	0.565- 2.30	-	1.24	22.14	0.56 - 1.915	-	1.03	22.76	0.54 -1.502	-
HD	0.80	13.84	0.36 - 1.39	59.70	0.78	13.85	0.245-1.245	62.90	0.598	13.18	0.29 -0.90	58.06
HW	1.03	17.70	0.413- 1.58	76.87	0.99	17.80	0.42 - 1.62	80.40	0.835	18.39	0.42 -1.295	81.07
ED	0.23	3.98	0.103- 0.36	17.16	0.18	3.12	0.10 - 0.23	14.52	0.18	3.97	0.10 -2.23	17.48
POD	0.55	9.45	0.253- 0.90	41.05	0.50	8.99	0.26 - 0.79	40.57	0.45	9.80	0.254-0.703	43.69
IOW	0.69	11.92	0.243- 1.30	51.49	0.72	12.90	0.22 - 1.18	58.07	0.55	12.12	0.24 -0.833	53.40
GDD	0.45	7.76	0.15 - 0.74	33.58	0.45	7.99	0.15 - 0.845	36.05	0.37	8.22	0.148-0.63	35.92
LDD	0.31	5.30	0.09 - 0.48	23.13	0.29	5.26	0.08 - 0.57	23.79	0.243	5.35	0.084-0.40	23.59
BD	1.23	21.23	0.40 - 2.00	-	1.12	20.07	0.37 - 1.795	-	0.93	20.48	0.39 -1.395	-
LHB	0.72	12.44	0.26 - 1.12	-	0.74	13.21	0.25 - 1.245	-	0.57	12.60	0.256-0.935	-
LCP	2.44	42.06	0.69 - 3.86	-	2.14	38.13	0.92 - 3.28	-	1.92	42.34	0.93 -2.94	-
DF	0.61	10.59	0.23 - 1.15	-	0.56	10.03	0.22 - 1.05	-	0.47	10.37	0.224-0.81	-
PF	0.37	6.37	0.12 - 0.59	-	0.35	6.29	0.12 - 0.625	-	0.29	6.37	0.120-0.498	-
VF	0.29	4.94	0.08 - 0.43	-	0.24	4.36	0.09 - 0.398	-	0.21	4.59	0.084-0.298	-
AF	0.32	5.54	0.10 - 0.55	-	0.28	4.94	0.10 - 0.50	-	0.24	5.17	0.10 -0.40	-
Girth	4.03	69.52	1.55 - 6.20	-	3.94	70.42	1.60 - 6.35	-	3.07	67.68	1.54 -4.90	-

TABLE-8

MERISTIC CHARACTERS IN THREE POPULATIONS OF G. LISSORHYNCHUS

PARAMETERS	UMIAM RIVER		UMKHRAH STREAM		UMSHING STREAM	
	AVERAGE	RANGE	AVERAGE	RANGE	AVERAGE	RANGE
Dorsal fin rays	7	Constant	7	Constant	7	Constant
Pectoral fin rays	12.96	12-14	13.43	12-14	12.82	11-15
Pelvic fin rays	8	Constant	8	Constant	8	Constant
Anal fin rays	5.22	5-6	6	Constant	5.53	5-6
Caudal fin rays	18.94	18-20	18.97	18-21	18.58	18-20
Barbles (pairs)	2	Constant	2	Constant	2	Constant
Lateral line scales	34.10	33-35	34.22	32-36	34.17	33-35
Scales above lateral line	3.85	3-4	3.92	3.5-4.5	3.87	3-4
Scales below lateral line	4.87	4-5	4.81	4-5	4.83	4-5

TABLE-9

REGRESSION EQUATIONS OF VARIABLE MORPHOMETRIC CHARACTERS OF G. LISSORHYNCHUS FROM UMIAM RIVER

PARAMETERS ANALYSED	REGRESSIONS	"r"
1) Total length (Y) VS Standard length (X)	$Y = 0.3708685829 + 1.150648496 X$	0.9964
2) Standard length VS Fork length	$Y = -0.5723205899 + 1.018597903 X$	0.9965
3) Standard length VS Predorsal length	$Y = -0.7342686476 + 2.229233457 X$	0.9924
4) Standard length VS Head length	$Y = -0.4153631768 + 4.642408051 X$	0.9954
5) Standard length VS Eye diameter	$Y = -1.214329869 + 30.45745871 X$	0.9832
6) Standard length VS Post orbital	$Y = -0.9492665238 + 12.33144467 X$	0.9971
7) Standard length VS Inter orbital	$Y = 0.05223464093 + 8.18264914 X$	0.9063
8) Standard length VS Body depth	$Y = 0.3880987296 + 4.402279308 X$	0.9838
9) Standard length VS Head depth	$Y = -0.2820706224 + 7.588855691 X$	0.9893
10) Standard length VS Head width	$Y = -0.4754054947 + 6.122675412 X$	0.9716
11) Standard length VS Least height of body	$Y = -0.09089387161 + 8.179713710 X$	0.9766
12) Standard length VS Length of caudal peduncle	$Y = 0.3253675789 + 2.247692986 X$	0.9561
13) Standard length VS Greatest diameter of disc	$Y = 0.2343795699 + 12.392225040 X$	0.9491
14) Standard length VS Least diameter of disc	$Y = 0.1596536742 + 18.36757760 X$	0.9243
15) Standard length VS Length of dorsal fin	$Y = 0.3976756027 + 8.753362070 X$	0.9845
16) Standard length VS Length of pectoral fin	$Y = 0.1715398634 + 15.24921446 X$	0.9407
17) Standard length VS Length of pelvic fin	$Y = -0.299659681 + 21.32223664 X$	0.8841
18) Standard length VS Length of anal fin	$Y = 0.8882570691 + 15.29670694 X$	0.9767
19) Standard length VS Girth	$Y = -0.3331760075 + 1.523397765 X$	0.9842

TABLE-10

REGRESSION EQUATIONS OF VARIABLE MORPHOMETRIC CHARACTERS OF G. LISSORHYNCHUS FROM UMKHRAH STREAM

PARAMETERS ANALYSED	REGRESSIONS	"r"
1) Total length (Y) VS Standard length (X)	$Y = -0.1715118511 + 1.82430260 X$	0.9954
2) Standard length VS Fork length	$Y = 0.2749044926 + 0.8596283742 X$	0.9939
3) Standard length VS Predorsal length	$Y = 0.3232801086 + 1.874624567 X$	0.9960
4) Standard length VS Head length	$Y = 0.01563879146 + 4.520148326 X$	0.9902
5) Standard length VS Eye diameter	$Y = -0.6394052981 + 36.2540461 X$	0.9538
6) Standard length VS Post orbital	$Y = -0.4792464978 + 12.08901070 X$	0.9907
7) Standard length VS Inter orbital	$Y = -0.2517491823 + 7.207817106 X$	0.9706
8) Standard length VS Body depth	$Y = 0.416571782 + 4.525276546 X$	0.9982
9) Standard length VS Head depth	$Y = 0.6060036938 + 6.441799106 X$	0.9882
10) Standard length VS Head width	$Y = 0.2547750279 + 5.362697633 X$	0.9964
11) Standard length VS Least height of body	$Y = 1.031365435 + 6.190633245 X$	0.9749
12) Standard length VS Length of caudal peduncle	$Y = 0.06500529904 + 2.591733487 X$	0.9907
13) Standard length VS Greatest diameter of disc	$Y = 1.462219599 + 9.276125275 X$	0.9790
14) Standard length VS Least diameter of disc	$Y = 1.736793748 + 13.13919104 X$	0.9974
15) Standard length VS Length of dorsal fin	$Y = 0.6381544044 + 9.140615615 X$	0.9876
16) Standard length VS Length of pectoral fin	$Y = 1.167045587 + 12.60144785 X$	0.9739
17) Standard length VS Length of pelvic fin	$Y = 1.14257588 + 18.17503035 X$	0.9767
18) Standard length VS Length of anal fin	$Y = 1.562714982 + 14.49624109 X$	0.9649
19) Standard length VS Girth	$Y = 0.5833554622 + 1.26957326 X$	0.9823

TABLE-11

REGRESSION EQUATIONS OF VARIOUS MORPHOMETRIC CHARACTERS OF G. LISSORHYNCHUS FROM UMISHING STREAM

PARAMETERS ANALYSED	REGRESSIONS	"r"
1) Total length (Y) VS Standard length (X)	Y= 0.1494730525 + 1.164009062 X	0.9978
2) Standard length VS Fork length	Y= 0.0015872248 + 0.8825792402 X	0.9985
3) Standard length VS Predorsal length	Y= 0.2957798165 + 1.711467889 X	0.9944
4) Standard length VS Head length	Y=-0.5788452463 + 4.938365436 X	0.9881
5) Standard length VS Eye diameter	Y=-0.8911182108 +29.99041533 X	0.9338
6) Standard length VS Post orbital	Y=-0.455674512 +11.28857009 X	0.9829
7) Standard length VS Inter orbital	Y=-0.3376094085 + 8.932967587 X	0.9899
8) Standard length VS Body depth	Y= 0.31844451003 + 4.550059031 X	0.9749
9) Standard length VS Head depth	Y=-0.1515383125 + 7.873389518 X	0.9955
10) Standard length VS Head width	Y=-0.05851400329+ 5.486326194 X	0.9951
11) Standard length VS Least height of body	Y= 0.341369863 + 7.383561643 X	0.9961
12) Standard length VS Length of caudal peduncle	Y= 0.08672958289+ 2.319442681 X	0.9922
13) Standard length VS Greatest diameter of disc	Y= 0.5803944315 +10.6873996 X	0.9955
14) Standard length VS Least diameter of disc	Y= 0.8501485332 +15.23468251 X	0.9838
15) Standard length VS Length of dorsal fin	Y= 0.5495442498 + 8.563666743 X	0.9927
16) Standard length VS Length of pectoral fin	Y= 0.7446408317 +13.12192816 X	0.9937
17) Standard length VS Length of pelvic fin	Y= 0.2544004207 +20.73737727 X	0.9745
18) Standard length VS Length of anal fin	Y= 0.6903498478 +16.5751847 X	0.9894
19) Standard length VS Girth	Y= 0.06118539029+ 1.462835301 X	0.9876

TABLE-12

REGRESSION EQUATIONS OF VARIABLE MORPHOMETRIC CHARACTERS OF G. LISSORHYNCHUS (POOLED DATA)

PARAMETERS ANALYSED	REGRESSIONS	
1) Total length (Y) VS Standard length (X)	$Y = -0.165320834 + 1.164314984 X$	0.9990
2) Standard length VS Fork length	$Y = -0.3325049896 + 0.968721527 X$	0.9966
3) Standard length VS Predorsal length	$Y = -0.3970671983 + 2.119617296 X$	0.9872
4) Standard length VS Head length	$Y = -0.3812386175 + 4.773637389 X$	0.9951
5) Standard length VS Eye diameter	$Y = -1.207509391 + 33.10518407 X$	0.9749
6) Standard length VS Post orbital	$Y = -1.261507534 + 13.268660136 X$	0.9871
7) Standard length VS Inter orbital	$Y = -0.2439402319 + 8.327809839 X$	0.9942
8) Standard length VS Body depth	$Y = 0.2350027257 + 4.635987899 X$	0.9912
9) Standard length VS Head depth	$Y = 0.3639103405 + 6.891362074 X$	0.9952
10) Standard length VS Head width	$Y = -0.483324304 + 6.109821617 X$	0.9733
11) Standard length VS Least height of body	$Y = 0.2959341747 + 7.491363523 X$	0.9610
12) Standard length VS Length of caudal peduncle	$Y = -0.2473336839 + 2.602776746 X$	0.9706
13) Standard length VS Greatest diameter of disc	$Y = 0.3009309403 + 11.99154636 X$	0.9489
14) Standard length VS Least diameter of disc	$Y = 0.6782390829 + 16.7701965 X$	0.9161
15) Standard length VS Length of dorsal fin	$Y = 0.776821239 + 8.347197833 X$	0.9944
16) Standard length VS Length of pectoral fin	$Y = 0.3530555833 + 15.09547654 X$	0.9431
17) Standard length VS Length of pelvic fin	$Y = -0.3294688128 + 22.98692152 X$	0.9249
18) Standard length VS Length of anal fin	$Y = 0.784199475 + 16.06561679 X$	0.9885
19) Standard length VS Girth	$Y = -0.07431883046 + 1.459014177 X$	0.9795

populations. Their respective average percentage of standard length were deduced to be 4.94, 4.36 and 4.59. The mean value of all the three populations when pooled together was recorded to be 0.27 and its average percentage of standard length was 4.59.

LENGTH OF ANAL FIN :

In G. lissorhynchus population from the three systems of Umiam, Umkhrach and Umshing, the mean values of this parameter was calculated to be 0.32, 0.28 and 0.24 respectively. Their corresponding average percentage of standard length were found to be 5.54, 4.94 and 5.17. The mean value of the length of the anal fin of the three population when pooled together was 0.33 and its average percentage of standard length was 5.39.

GIRTH :

The mean values of girth was recorded to be 4.03 in case of the population from Umiam river, 3.94 for the population from Umkhrach stream and 3.07 in the case of Umshing stream population. Their corresponding average percentage of standard length were 69.54, 70.42 and 67.78. The mean of the pooled population was recorded to be 4.08 and the average percentage was 69.37.

MERISTIC COUNTS :

The results of the various meristic counts obtained for Garra lissorhynchus from all the three systems are presented in Table-8. The dorsal fin rays were found to be numbering to 7 in all the three populations.

Pectoral fin rays ranged from 12-14 in individuals from Umiam river and Umkhrach stream, whereas, the range was from 11 to

15 in the Umshing stream specimens. The respective average number of rays were 12.96, 13.43 and 12.82. Pelvic fin rays were recorded to be constant in the individuals from the three systems.

The range for anal fin rays were found to be 5-6 in specimens from Umiam river and Umshing stream, while their respective averages were 5.22 and 5.53. In the Umkhras stream population, the number of rays (6) of the anal fin were found to be constant.

Caudal fin rays were recorded to range from 18-20 in the Umiam and Umshing systems, while the average was calculated to be 18.94 and 18.58 respectively. In the case of the Umkhras stream population it was found to range between 18 and 21, the average being 18.97.

The number of barbules were found to be constant (2 pairs) in all the populations.

The lateral line scales ranged from 33 to 35 in the Umiam and Umshing systems while it was 32-36 in the Umkhras stream individuals. The respective averages were found to be 34.10, 34.17 and 34.22. The average lateral line transverse scales were found to be 3.85/4.87, 3.92/4.81 and 3.87/4.83 in the individuals from the Umiam, Umkhras and Umshing systems respectively.

INTRASPECIFIC DIFFERENCE :

The various regression equations of the parameters studied have been presented in Tables-9, 10 & 11. Regression equations of the same parameters have also been calculated for all the populations pooled together and presented in Table-12 for comparison with each population.

The regressions of total length on standard length in the various populations are :-

$$\begin{aligned} Y &= 0.370869 + 1.150649 X \\ r &= 0.9964 \end{aligned} \quad \left. \vphantom{\begin{aligned} Y &= 0.370869 + 1.150649 X \\ r &= 0.9964 \end{aligned}} \right\} \text{for Umiam population}$$

$$\begin{aligned} Y &= -0.171512 + 1.824303 X \\ r &= 0.9954 \end{aligned} \quad \left. \vphantom{\begin{aligned} Y &= -0.171512 + 1.824303 X \\ r &= 0.9954 \end{aligned}} \right\} \text{for Umkhras population}$$

$$\begin{aligned} Y &= 0.149473 + 1.164009 X \\ r &= 0.9978 \end{aligned} \quad \left. \vphantom{\begin{aligned} Y &= 0.149473 + 1.164009 X \\ r &= 0.9978 \end{aligned}} \right\} \text{for Umshing population}$$

$$\begin{aligned} Y &= 0.165321 + 1.164315 X \\ r &= 0.9990 \end{aligned} \quad \left. \vphantom{\begin{aligned} Y &= 0.165321 + 1.164315 X \\ r &= 0.9990 \end{aligned}} \right\} \text{for Pooled population}$$

Similarly, differences have been observed to a greater or lesser extent in regression equations of standard length VS fork length; predorsal length; head length; eye diameter; post-orbital distance; inter-orbital width; body depth; head depth; head width; least height of body; length of caudal peduncle; greatest diameter of disc; least diameter of disc; length of dorsal fin; length of pectoral fin; length of pelvic fin; length of anal fin; and girth. The regression values obtained for all these parameters have been tabulated in Tables-9, 10, 11 & 12.

BIOMETRIC INDEX :

For each character, a mean biometric index for each length group has been calculated and presented in Tables-13, 14 & 15. Biometric indices for each character of the three populations pooled together were also calculated and presented in Table-16 and in Figs. 17, 18, 19 & 20.

It is clear from the Tables-13, 14 & 15, that the growth of the fork length and standard length in relation to the total length in G. lissorhynchus are isometric. The growth of the body

TABLE-13

MEAN BIOMETRIC INDICES IN VARIOUS SIZE GROUPS OF G. LISSORHYNCHUS
FROM UMIAM RIVER

RATIOS	LENGTH GROUPS (mm)									
	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	120-129
TL/SL	1.27	1.48	1.21	1.21	1.19	1.15	1.21	1.23	1.23	1.18
TL/FL	1.11	1.19	1.05	1.06	1.14	1.07	1.06	1.15	1.21	1.14
PL/PDL	2.28	2.37	2.22	2.29	2.46	2.34	2.35	2.44	2.39	2.59
TL/HL	4.78	5.61	5.00	4.95	5.36	5.33	5.41	5.16	5.50	5.22
TL/HD	6.39	10.28	9.20	8.75	8.64	9.09	9.09	9.12	8.54	8.63
TL/HW	6.55	7.55	6.67	6.36	6.41	6.63	7.14	6.59	6.54	8.00
TL/LCP	3.91	3.33	3.03	2.75	2.75	2.71	2.74	2.55	2.70	3.53
TL/LHB	10.39	11.21	10.00	9.37	9.53	9.56	9.41	9.21	9.22	11.01
TL/BD	6.75	6.49	6.89	6.00	5.68	5.41	5.48	5.38	5.24	6.00
TL/ED	26.34	30.83	28.75	26.70	28.17	30.67	28.57	30.78	35.62	33.33
TL/IOW	11.13	10.88	9.02	9.54	10.29	10.51	10.13	10.26	10.43	9.23
TL/DF	11.74	12.23	10.95	11.61	12.46	12.48	12.12	10.71	11.23	10.44
TL/PF	22.50	23.13	18.40	19.07	19.06	16.35	17.39	18.24	17.51	24.00
TL/VF	33.75	19.47	20.00	24.27	21.60	25.38	23.53	22.91	24.02	34.29
TL/AF	27.00	28.46	27.06	22.25	23.14	23.74	21.05	18.94	19.49	21.82
HL/ED	5.51	5.50	5.75	5.40	5.26	5.75	5.29	5.97	6.48	6.39
HL/IOW	2.33	1.94	1.80	1.93	1.92	1.97	2.17	1.99	1.90	1.77
HL/POD	2.24	2.20	2.49	2.46	2.33	2.38	2.51	2.55	2.44	2.56
HL/PF	4.71	4.13	3.68	3.86	3.56	3.07	3.22	3.54	3.19	4.00
HL/LDD	6.28	4.40	4.38	4.50	3.90	3.83	4.23	3.98	3.92	5.75
HL/GDD	3.77	3.14	3.41	2.84	2.69	2.88	3.15	2.77	2.54	3.54
HW/LDD	4.58	3.27	3.29	3.50	3.26	3.08	3.20	3.12	3.29	3.75
HW/GDD	2.75	2.33	2.56	2.21	2.24	2.31	2.38	2.17	2.14	2.31
IOW/ED	2.37	2.83	3.19	2.80	2.74	2.92	2.47	3.00	3.41	3.61

TABLE-14

MEAN BIOMETRIC INDICES IN VARIOUS SIZE GROUPS OF G. LISSORHYNCHUS
FROM UMKHRAH STREAM

RATIOS	LENGTH GROUPS (mm)								
	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109
TL/SL	1.13	1.17	1.16	1.04	1.18	1.16	1.18	1.17	1.17
TL/FL	1.04	1.03	1.13	1.04	1.03	1.00	1.05	1.05	1.04
TL/PDL	2.37	2.33	2.37	2.23	2.24	2.25	2.31	2.31	2.26
TL/HL	4.82	5.00	5.06	5.18	5.35	5.14	5.57	4.96	5.35
TL/HD	11.02	7.78	8.49	8.41	8.35	8.18	8.65	7.74	8.23
TL/HW	6.43	6.86	6.52	6.24	6.37	6.49	6.39	6.64	6.33
TL/LCP	2.94	3.54	2.81	2.83	2.95	2.87	3.00	3.18	3.13
TL/LHB	10.80	8.33	9.20	8.92	9.31	9.15	9.54	7.52	8.23
TL/BD	6.21	5.93	6.00	5.27	5.75	5.54	5.65	5.60	5.71
TL/ED	25.71	35.00	34.14	38.67	36.11	32.73	37.30	40.43	44.57
TL/IOW	8.44	8.97	8.33	9.21	8.67	7.39	9.14	9.30	8.72
TL/DF	12.27	13.46	11.84	12.89	11.89	11.56	11.33	11.73	11.64
TL/PF	22.50	20.59	20.46	20.71	18.57	15.81	18.04	18.93	16.40
TL/VF	30.00	35.00	32.14	27.62	23.21	24.83	27.21	23.46	26.28
TL/AF	27.00	35.00	26.47	29.00	22.67	21.29	25.15	20.72	20.50
HL/ED	6.51	7.00	6.72	7.47	6.58	6.35	6.73	8.17	8.33
HL/IOW	2.55	1.80	1.65	1.78	1.50	1.42	1.83	1.88	1.63
HL/POD	2.15	2.41	2.41	2.29	2.48	2.45	2.61	2.64	2.42
HL/PF	4.67	4.12	4.05	4.00	3.49	3.11	3.25	3.82	3.06
HL/LDD	7.00	6.36	4.68	4.48	4.16	4.13	4.37	3.86	3.36
HL/GDD	3.11	4.67	3.18	2.95	2.73	2.63	2.63	2.85	2.27
HW/LDD	5.25	4.64	3.68	3.72	3.49	3.32	3.72	2.87	2.84
HW/GDD	2.33	3.40	2.56	2.45	2.29	2.12	2.25	2.12	1.92
IOW/ED	3.10	3.90	4.12	4.20	4.09	4.48	3.66	4.36	5.11

TABLE-15

MEAN BIOMETRIC INDICES IN VARIOUS SIZE GROUPS OF G. LISSORHYNCHUS
FROM UMSHING STREAM

RATIOS	LENGTH GROUPS (mm)						
	20-29	30-39	40-49	50-59	60-69	70-79	80-89
TL/SL	1.25	1.26	1.13	1.20	1.19	1.23	1.19
TL/FL	1.12	1.05	1.04	1.05	1.05	1.06	1.04
TL/PDL	2.38	2.27	2.24	2.28	2.05	2.19	2.12
TL/HL	5.00	4.79	4.92	5.59	5.29	5.20	5.64
TL/HD	9.25	9.41	9.07	8.74	8.88	9.08	9.42
TL/HW	6.49	6.73	6.65	6.31	6.39	6.67	6.55
TL/LCP	2.90	3.26	2.84	2.72	2.78	2.72	2.89
TL/LHB	10.55	10.21	9.87	9.38	9.49	9.53	9.06
TL/BD	6.89	6.16	6.27	5.08	5.87	5.58	6.08
TL/ED	27.00	28.01	28.89	25.39	28.83	31.56	37.67
TL/IOW	11.25	9.35	9.07	9.48	9.96	10.10	10.18
TL/DF	12.05	13.22	11.89	11.62	11.65	11.87	10.46
TL/PF	22.50	20.87	19.83	22.00	17.83	18.85	17.04
TL/VF	32.14	27.51	24.63	24.27	23.75	25.98	28.49
TL/AF	27.00	26.30	25.44	22.41	22.31	23.41	21.19
HL/ED	5.40	5.92	5.87	4.51	5.46	6.07	6.68
HL/IOW	2.25	1.95	1.85	1.62	1.88	1.94	1.81
HL/POD	2.13	2.37	2.48	2.09	2.59	2.50	2.14
HL/PF	4.50	4.35	4.03	3.52	3.37	3.62	3.02
HL/LDD	6.43	4.96	4.53	3.84	4.57	3.94	3.76
HL/GDD	3.65	3.16	3.03	2.58	2.77	2.79	2.39
HW/LDD	4.95	3.53	3.35	3.43	3.78	3.08	3.24
HW/GDD	2.81	2.25	2.24	2.31	2.29	2.18	2.06
IOW/ED	2.40	2.99	3.19	2.68	2.90	3.13	3.70

TABLE-16

MEAN BIOMETRIC INDICES IN VARIOUS SIZE GROUPS OF G. LISSORHYNCHUS
(POOLED DATA)

RATIOS	LENGTH GROUPS (mm)									
	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	120-129
TL/SL	1.21	1.33	1.16	1.20	1.19	1.17	1.19	1.19	1.20	1.18
TL/FL	1.12	1.10	1.09	1.05	1.09	1.06	1.05	1.08	1.13	1.14
TL/PDL	2.35	2.29	2.34	2.40	2.35	2.29	2.13	2.36	2.45	2.59
TL/HL	4.91	5.01	5.03	5.26	5.33	5.26	5.61	5.76	5.45	5.22
TL/HD	11.25	9.49	8.81	8.74	8.60	8.96	9.08	8.19	8.44	8.63
TL/HW	6.43	7.02	6.54	6.30	6.26	6.60	6.58	6.64	6.44	8.00
TL/LCP	3.21	3.31	2.92	2.74	2.80	2.72	2.92	2.93	2.85	3.53
TL/LHB	10.00	10.32	9.75	9.35	9.49	9.43	9.29	8.05	8.80	11.01
TL/BD	6.92	6.27	6.27	5.48	5.76	5.50	5.81	5.52	5.42	6.00
TL/ED	27.00	29.25	30.53	27.10	29.32	31.57	36.35	36.54	38.15	33.33
TL/IOW	8.18	9.75	8.64	9.51	9.77	9.81	10.32	9.59	9.72	9.23
TL/DF	15.00	14.04	11.45	11.78	12.17	12.10	11.00	11.73	10.62	10.44
TL/PF	22.50	21.94	19.91	19.36	18.43	16.88	17.42	18.63	17.17	24.00
TL/VF	33.75	23.40	21.81	24.64	22.24	25.04	26.97	24.36	25.12	34.29
TL/AF	27.00	27.00	25.44	22.58	22.24	23.42	22.60	19.79	19.81	21.82
HL/ED	5.50	5.83	6.07	5.15	5.50	6.00	6.48	6.35	7.00	6.39
HL/IOW	1.67	1.94	1.72	1.81	1.83	1.87	1.84	1.67	1.78	1.77
HL/POD	2.12	2.33	2.29	2.42	2.42	2.42	2.37	2.26	2.42	2.56
HL/PF	4.58	4.38	3.96	3.68	3.46	3.21	3.10	3.24	3.15	4.00
HL/LDD	6.11	5.00	4.55	4.12	4.17	3.94	4.03	3.37	3.64	5.75
HL/GDD	3.44	3.18	3.25	2.71	2.75	2.82	2.57	2.46	2.42	3.54
HW/LDD	4.67	3.57	3.50	3.44	3.55	3.14	3.43	2.92	3.08	3.75
HW/GDD	2.63	2.27	2.50	2.26	2.34	2.24	2.19	2.13	2.05	2.31
IOW/ED	3.30	3.00	3.53	2.85	3.00	3.22	3.52	3.81	3.93	3.61

depth, dorsal fin and inter-orbital width illustrates positive allometry in relation to the growth of the total length. The pre-dorsal length growth, in relation to total length, shows a somewhat positive allometry in the specimens from Umkhras and Umshing streams, whereas in the Umiam river population it shows a negative allometry. The growth of the length of caudal peduncle in relation to the total length, depicts positive allometry in G. lissorhynchus from Umiam river, isometric growth in the Umshing stream population, and a slight negative allometry in Umkhras stream population.

The growth of eye-diameter and head length in relation to the total length show a negative allometry (Figs. 17, 18 & 19).

The ratios between Total length and Head length (TL/HL), Total length and Head width (TL/HW), Total length and Least height of body (TL/LHB), Total length and pectoral fin (TL/PF), Total length and Pelvic fin (TL/VF), Total length and Anal fin (TL/AF), Head length and Eye-diameter (HL/ED), Head length and Inter-orbital width (HL/IOW), Head length and Post-orbital distance (HL/POD), Head length and Pectoral fin (HL/PF), Head length and Least diameter of disc (HL/LDD), Head length and Greatest diameter of disc (HL/GDD), Head width and Least diameter of disc (HW/LDD), Head width and Greatest diameter of disc (HW/GDD) and between Inter-orbital width and Eye-diameter were also examined and presented in Tables-13, 14, 15 & 16.

LENGTH-WEIGHT RELATIONSHIP

The entire data of length-weight relationship for Garra

lissorhynchus irrespective of populations were converted into regression equations which were calculated to be :-

$$\begin{array}{l} \text{Log } W = -6.090929 + 3.312083 \log TL \\ r = 0.9973019 \end{array} \left. \vphantom{\begin{array}{l} \text{Log } W = -6.090929 + 3.312083 \log TL \\ r = 0.9973019 \end{array}} \right\} \text{Pooled}$$

$$\begin{array}{l} \text{Log } W = -6.689438 + 2.825486 \log TL \\ r = 0.9764155 \end{array} \left. \vphantom{\begin{array}{l} \text{Log } W = -6.689438 + 2.825486 \log TL \\ r = 0.9764155 \end{array}} \right\} \text{Males}$$

$$\begin{array}{l} \text{Log } W = -5.888831 + 3.078111 \log TL \\ r = 0.9977205 \end{array} \left. \vphantom{\begin{array}{l} \text{Log } W = -5.888831 + 3.078111 \log TL \\ r = 0.9977205 \end{array}} \right\} \text{Females}$$

$$\begin{array}{l} \text{Log } W = -6.068277 + 3.130240 \log TL \\ r = 0.9914782 \end{array} \left. \vphantom{\begin{array}{l} \text{Log } W = -6.068277 + 3.130240 \log TL \\ r = 0.9914782 \end{array}} \right\} \text{Juveniles}$$

$$\begin{array}{l} \text{Log } W = -6.687311 + 3.243042 \log TL \\ r = 0.9809007 \end{array} \left. \vphantom{\begin{array}{l} \text{Log } W = -6.687311 + 3.243042 \log TL \\ r = 0.9809007 \end{array}} \right\} \text{Adults}$$

A high correlation between length and weight is indicated by the correlation coefficient. The derived parabolic equations are :-

$$\begin{array}{l} W = 0.000000796 L^{3.3121} \text{ (Pooled)} \\ W = 0.0000002044 L^{2.8255} \text{ (Males)} \\ W = 0.000001307 L^{3.0781} \text{ (Females)} \\ W = 0.0000008545 L^{3.1302} \text{ (Juveniles)} \\ W = 0.0000002054 L^{3.2430} \text{ (Adults)} \end{array}$$

The 'b' values of 3.3121 (pooled populations), 2.8255 (Males), 3.0781 (Females), 3.1302 (Juveniles) and 3.2430 (Adults) indicate that the species closely follow the cubic law.

On plotting the observed average weight of the species from the three populations pooled together as well as separately, against their respective observed length, parabolic curves have been obtained (Figs. 21 to 24). Logarithmic growth prepared with the above data showed straight line relationships (Figs. 21 to 24).

TABLE-17

LENGTH-WEIGHT REGRESSION EQUATIONS OF G. LISSORHYNCHUS FROM DIFFERENT WATER BODIES

WATER BODY	REGRESSIONS	"b"	"r"	PARABOLIC EQUATIONS "W"
Umiam River	Log W = -4.957933 + 3.055714 log TL	3.0557	0.994536	W = 0.00001102 L ^{3.0557}
Umkhrach Stream	Log W = -5.042796 + 3.125132 log TL	3.1251	0.999446	W = 0.000009061 L ^{3.1251}
Umshing Stream	Log W = -4.843737 + 2.997391 log TL	2.9974	0.999128	W = 0.00001433 L ^{2.9974}

TABLE-18

LENGTH-WEIGHT REGRESSION EQUATIONS IN G. LISSORHYNCHUS DURING DIFFERENT LIFE STAGES

STAGE WATER BODY	REGRESSIONS	"b"	"r"	PARABOLIC EQUATIONS "W"
Umiam	Log W = -6.137774 + 3.217828 log TL	3.2178	0.997913	W = 0.0000007281 L ^{3.2178}
JUVENILES Umkhrach	Log W = -6.091747 + 3.100557 log TL	3.1006	0.994177	W = 0.0000008097 L ^{3.1006}
Umshing	Log W = -6.114266 + 3.302964 log TL	3.3029	0.992170	W = 0.0000007686 L ^{3.3030}
Umiam	Log W = -6.102158 + 3.264029 log TL	3.2640	0.996206	W = 0.0000007903 L ^{3.2640}
ADULTS Umkhrach	Log W = -6.147789 + 3.254224 log TL	3.2542	0.985334	W = 0.0000001035 L ^{3.2542}
Umshing	Log W = -6.156632 + 3.351170 log TL	3.3512	0.953246	W = 0.0000006972 L ^{3.3512}

TABLE-19

LENGTH-WEIGHT REGRESSION EQUATIONS IN G. LISSORHYNCHUS DURING DIFFERENT SEASONS

SEASON WATER BODY	REGRESSIONS	"b"	"r"	PARABOLIC EQUATIONS "W"
SUMMER Umiam	Log W = -6.315443 + 3.550975 log TL	3.5509	0.990524	W = 0.0000004838 L ^{3.5510}
(Apr. to Sept.) Umkhrach	Log W = -5.993944 + 3.271247 log TL	3.2713	0.998407	W = 0.000001014 L ^{3.2712}
Umshing	Log W = -5.777574 + 3.881362 log TL	3.8816	0.997569	W = 0.000001669 L ^{3.8814}
Umiam	Log W = -6.028445 + 3.151295 log TL	3.1513	0.989695	W = 0.0000009367 L ^{3.1513}
WINTER Umkhrach	Log W = -6.072822 + 3.116111 log TL	3.1161	0.999178	W = 0.0000008457 L ^{3.1161}
(Oct. to March) Umshing	Log W = -6.031824 + 3.233499 log TL	3.2335	0.987829	W = 0.0000009294 L ^{3.2335}

LENGTH-WEIGHT RELATIONSHIP DURING DIFFERENT SEASONS

The length-weight relationship has been calculated during the different seasons separately to see the seasonal impact on the relationship. Summer and winter are the seasons taken into consideration as other seasons were not clearly demarcated and normally merge into these in this part of the country. The various regression equations have been presented in Table-19. It is evident from the results that the values of regression coefficient tend to be higher during the summer season, in the species from all the three water bodies i.e. Umiam, Umkhrah and Umshing.

LENGTH-WEIGHT RELATIONSHIP IN JUVENILES :

The length-weight relationship in juveniles (Table-18) is based on the specimens ranging from 27.0 mm to 56.68 mm in total length. The regression equations were estimated to be :-

$$\begin{aligned} \text{Log } W &= -6.137774 + 3.217828 \log \text{ TL} \quad \left\{ \begin{array}{l} \text{(Umiam indi-} \\ \text{viduals)} \end{array} \right. \\ r &= 0.9979135 \end{aligned}$$

$$\begin{aligned} \text{Log } W &= -6.091747 + 3.100557 \log \text{ TL} \quad \left\{ \begin{array}{l} \text{(Umkhrah in-} \\ \text{dividuals)} \end{array} \right. \\ r &= 0.9941766 \end{aligned}$$

$$\begin{aligned} \text{Log } W &= -6.114266 + 3.302964 \log \text{ TL} \quad \left\{ \begin{array}{l} \text{(Umshing in-} \\ \text{dividuals)} \end{array} \right. \\ r &= 0.9921701 \end{aligned}$$

The parabolic equations were determined to be :-

$$W = 0.0000007281 L^{3.2178} \quad (\text{Umiam specimens})$$

$$W = 0.0000008097 L^{3.1006} \quad (\text{Umkhrah specimens})$$

$$W = 0.0000007686 L^{3.3030} \quad (\text{Umshing specimens})$$

LENGTH-WEIGHT RELATIONSHIP IN ADULTS :

The length-weight relationships in adults are based on the specimens above 56.68 mm in total length. The regression and parabolic equations derived are :-

Log W = -6.102158 + 3.264029 log TL	}	(Umiam populations)
r = 0.9962062		
W = 0.0000007903 ^{3.2640}		
Log W = -6.147789 + 3.254224 log TL	}	(Umkhrah population)
r = 0.9853336		
W = 0.0000001035 ^{3.2542}		
Log W = -6.156632 + 3.351170 log TL	}	(Umshing population)
r = 0.9532462		
W = 0.0000006972 ^{3.3512}		

A high correlation between total length and body weight is indicated by the correlation coefficient. The "b" values were found to be higher than three (Table-18) which shows that the individuals are heavier in relation to its length.

INTRASPECIFIC LENGTH-WEIGHT RELATIONSHIP :

For intraspecific comparisons of the length-weight relationship, G. lissorhynchus populations from three systems viz., Umiam, Umkhrah and Umshing have been taken into consideration. The regression equations, coefficient correlation and exponential indices have been tabulated in Table-17. The results obtained indicates that the Umkhrah stream specimens (b=3.1251) are heavier than the Umiam river specimens (b=3.0557) and the Umshing stream individuals (b=2.9974).

LENGTH FREQUENCY DISTRIBUTION :

To evaluate and analyse the length frequency distribution, a histogram (Fig. 16) has been prepared by converting the frequencies into percentages and plotting the same against the respective length groups. The frequency polygon indicates the presence of

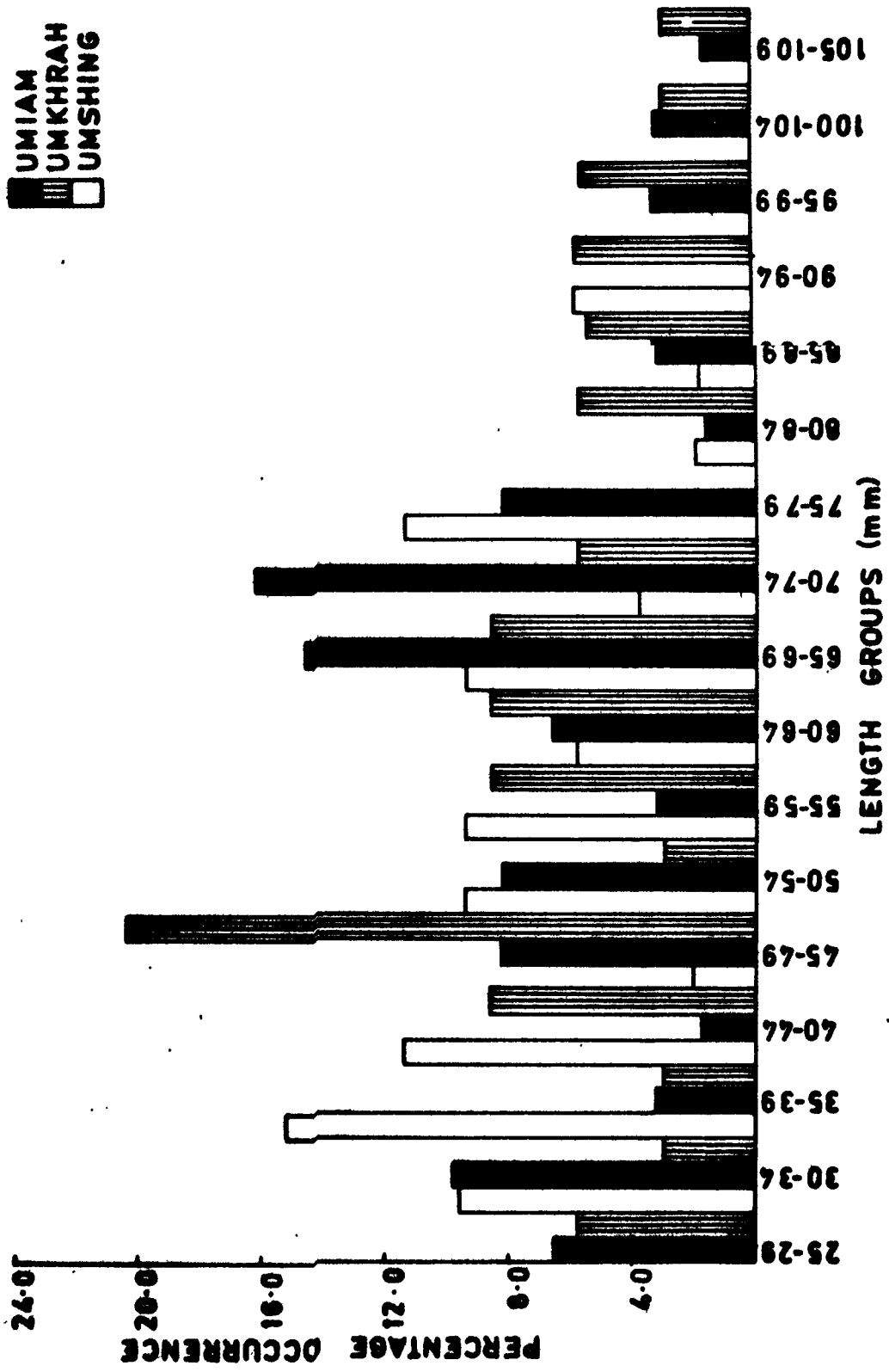


Fig.16: Length frequency distribution of *Garra lissorhynchus*

three distinct modes in various length groups. The first mode for the Umiam river population, is at 30-34 mm length group, the second between 45-54 mm length groups and the third between 65-74 mm length groups. In the Umkhrah population, the first mode is at the 45-49 mm length group, the second between 55-65 mm length group and the third at the 80-84 mm length group, whereas in Umshing population, the first mode is at 30-34 mm length group, the second is at 70-74 mm length group and the third is at 85-89 mm length group.

CONDITION FACTOR

MONTHLY FLUCTUATIONS IN CONDITION FACTOR :

Monthwise averages of ponderal index has been calculated to elucidate the seasonal fluctuations in condition factor. The results have been tabulated in Table-20. The "K" factors registered a sharp decline from October to November in the Umkhrah and Umshing stream populations of G. lissorhynchus, whereas a decline in the "K" factor in the case of Umiam river populations was more prolonged with a gradual decline upto February after which the ponderal index rose again to its peak in May only to drop down again to its minimum in the month of August (Fig. 25B). Similarly, after the initial decline in "K" value of Umkhrah and Umshing populations, this reached to their peaks in August and May respectively. This was again followed by a similar decline in August as was found with the Umkhrah river populations. In the Umiam river and Umkhrah stream populations, the "K" values dropped slightly in the month of April, whereas there was a slight rise in the same month in the case of Umshing river populations.

TABLE-20

SEASONAL FLUCTUATIONS IN THE CONDITION FACTOR OF G. LISSORHYNCHUS

<u>MONTHS</u>	<u>UMIAM</u>	<u>UMKHRAH</u>	<u>UMSHING</u>
September	1.5376	1.3689	1.6258
October	1.8994	1.7456	1.9034
November	1.5265	1.3372	1.2505
December	1.4817	1.6692	1.5018
January	1.4761	1.6702	1.5723
February	1.2995	1.6282	1.4577
March	1.5043	1.6889	1.7320
April	1.3907	1.4976	1.8381
May	1.4975	1.7311	1.4664
June	1.4340	1.6473	1.4916
July	1.3552	1.5844	1.6862
August	0.9699	1.4973	1.3614

TABLE-21

FLUCTUATIONS IN THE CONDITION FACTOR IN DIFFERENT LENGTH GROUPS
OF G. LISSORHYNCHUS

LENGTH GROUPS (mm)	UMIAM	UMKHRAH	UMSHING
25-29	1.3657	1.3380	1.3489
30-34	1.4871	1.4048	1.7145
35-39	1.3456	1.3994	1.5213
40-44	1.4923	1.5352	1.4080
45-49	1.4185	1.5701	1.3173
50-54	1.3838	-	1.3649
55-59	1.5865	1.5513	1.6231
60-64	1.6075	1.6092	1.4684
65-69	1.4521	1.5027	1.4048
70-74	1.5097	1.4492	1.3951
75-79	1.5227	-	1.2080
80-84	1.4707	1.2796	1.3133
85-89	1.7256	1.6415	1.4310
90-94	-	1.4729	-
95-99	1.5329	1.5703	-
100-104	1.5588	1.6020	-
105-109	1.5354	1.7388	-
110-114	-	-	-
115-119	1.0121	-	-
120-124	1.0706	-	-

FLUCTUATIONS OF CONDITION FACTOR IN DIFFERENT LENGTH GROUPS :

In the present investigation, it has been observed that the juveniles from Umiam and Umshing populations have a better condition than their counterpart from Umkhras stream. It is also clear from Table-21 that with the increase in length of the fish, the condition factor exhibited a decline which was more pronounced in the Umiam and Umshing populations. Thereafter, the condition of the species in the three populations reached a peak at 55-59/60-64 length groups. With further increase in the length of the fish, their "K" values gradually declined till they reached 75-84 mm in length, after which there was a sharp rise in their condition factor at a length of 85-89 mm. The Umiam river and Umkhras stream population showed a decline in their condition factor whereas the ponderal index steadily increased till they attained a length of 105-109 mm in the Umkhras stream population. In river Umiam, specimens exhibited a sharp drop at 115-119 mm length group (Table-21).

MATURITY AND SPAWNING

MATURITY STAGES ::

The various maturity stages observed in the present study have been summarized in Table-22.

MATURATION CYCLE :

Ovarian condition progressed from Stage-I (Immature) in February to Stage-IV (Maturity) in June-July, and thereafter they reached to Stage-V (Reproduction) in August-September. Subsequently, the final Stage-VI (Spent) was recorded in October. The ova of Stage-VI from the individuals collected in October were found

to be shrunken, irregular in shape and dark in colour, reflecting the post-spawning season.

OVA-DIAMETER STUDY :

The various stages in the ovarian development of mature Garra lissorhynchus have been presented in Table-22. The ova-diameter study revealed six stages of maturity which is in agreement with those delineated macroscopically following the classification of Nikolsky (1963). The ovaries of the species from all the three systems were found to contain only one batch of maturing ova clearly demarcated from the immature stock. The size of the mature ova in Stage-IV ranged from 1.0395 mm to 1.2375 mm. The spent ovary contained small, shrunken ova in different stages of degeneration having a maximum diameter of 0.8853 mm.

GONADO-SOMATIC INDEX :

Seasonal changes in the coefficient of maturity (Gn.S.I.) of Garra lissorhynchus collected from different population have been shown in Fig. 26.

Individuals from the Umiam river attained a peak in their Gn.S.I. values during June while the Umkhrah stream population attained in July. A gradual increase in Gn.S.I. value was observed in the case of Umshing population reaching its peak in the month of August. However, it was seen that the Gn.S.I. was appreciably high in general during September, whereafter the values started declining. The higher values on an average basis were observed during May to September in all the populations which indicates that the period of gonadal development and spawning takes place

during these months (Table-22). The Gn.S.I. values when plotted against different length groups (Fig. 27) indicates that there is a definite tendency for Gn.S.I. to increase with the increase in total length. In each case, the Gn.S.I. was observed to obey a definite trend in their oscillation (Fig. 27).

SPAWNING SEASON :

As already mentioned, spawning activity in fishes can be classified into four types. Observations based on the data on maturity studies indicate that the fish belong to the type-I of the categories as per classification stated in material and methods.

The data on maturation cycle provides a good indication of the extent of the development of ovaries with respect to the time of the year. Ovary condition progressed from immature (Stage-I) in November to maturity (Stage-IV) in June-July and reproduction (Stage-V) in August-September. The results of Gn.S.I. values and the increase in ova-diameter during the months of August and September supports the observations that spawning occurs during this period.

SIZE AT FIRST MATURITY :

It has been observed (Fig. 28A) that in the Umiam population, all the specimens below 54 mm were immature, whereas in the Umkhras and Umshing populations specimens below the length of 44 mm were found to be immature (Fig. 28B,C). It is clear from Fig. 28 that 50% of the specimens (M_{50}) of Umiam river and Umkhras stream mature at 60-64 mm length group, while the Umshing population, attains 50% maturity (M_{50}) at 55-59 mm length group.

TABLE-22

STAGES IN THE OVARIAN DEVELOPMENT, RANGE OF OVA DIAMETER AND MEAN GONADO-SOMATIC INDEX (Gn.S.I.) IN G. LISSORHYNCHUS

STAGES	DEGREE OF MATURATION	APPEARANCE	MONTHS OF AVAILABILITY	RANGE OF OVA DIAMETER (mm)	MEAN Gn.S.I. OF THE THREE POPULATIONS
I	Immature	Ova transparent	Nov. to Feb.	0.033 - 0.149	1.93
II	Resting	Ova translucent	Mar. to May	0.165 - 0.264	3.92
III	Maturation	Fine granular & milky in colour.	May to Jun	0.792 - 1.0065	10.50
IV	Maturity	Ova large, pale yellow in colour compact.	Jun. to Jul.	1.0395 - 1.2375	16.275
V	Reproduction	Ova large, yellow in colour & loosely attached.	Aug. to Sep.	1.302 - 1.485	13.018
VI	Spent	Shrunken, slightly irregular in shape, darker in colour, sparsely distributed within membranous sac-like covering.	Oct.	0.873 - 0.8853	0.5467

The centpercent maturity has been recorded at 70 mm onwards in length in the Umkhrah stream and Umiam river, whereas the same was found at 65 mm length onwards in the specimens from Umshing stream.

FECUNDITY

The number of eggs ranged from 447 in the specimens measuring 68.5 mm in total length and weighing 4.88 gms to 1808 eggs in those measuring 106.00 mm in total length and 19.29 gms in weight in the individuals from Umiam river. In the individuals from Umkhrah stream, the fecundity varied from 265 eggs in the specimens measuring 63.3 mm in total length and weighing 4.15 gms to 1410 eggs and in the specimen measuring 105.0 mm in length and weighing 20.88 gms. The fecundity in the individuals from Umshing stream ranged from 210 eggs in the specimen having a length of 56.2 mm and weight of 3.92 gms to 1003 eggs in the specimens measuring 86.3 mm in length and weighing 9.67 gm in weight (Tables-23 to 25).

The relationship between fecundity and total length, fecundity and body weight, fecundity and ovary weight, total length and ovary weight and body weight and ovary weight are described below:-

(i) Fecundity VS Total length :- On plotting the log values of fecundity against the log values of total length (Figs. 29B, 30B & 31B), a linear relation has been observed which indicates that the number of eggs in the ovaries increase in proportion to the length of the fish. The regression equations derived are :-

$\text{Log } F = 0.6075 + 2.4541 \log TL$ $r = 0.716828$	for Umiam river populations.
$\text{Log } F = -0.1622 + 3.2210 \log TL$ $r = -0.933674$	for Umkhras stream populations.
$\text{Log } F = -0.1311 + 3.3094 \log TL$ $r = 0.956487$	for Umshing stream populations.

The correlation coefficient was found to be quite high in all the three cases indicating a high degree of positive relationship between the two parameters.

(ii) Fecundity VS Body weight : A linear relationship was obtained when fecundity was plotted logarithmically against body weight (Figs. 29A, 30A, 31A). The regression equations derived are as follows :-

$\text{Log } F = 2.1056 + 0.8551 \log W$ $r = 0.766906$	for Umiam river populations.
$\text{Log } F = 1.8465 + 0.9455 \log W$ $r = 0.882979$	for Umkhras stream populations.
$\text{Log } F = 1.5731 + 1.5034 \log W$ $r = 0.871803$	for Umshing stream populations.

The correlation coefficient values for all the three populations were found to be significantly high thereby displaying high degree of positive relationship.

(iii) Fecundity VS Ovary weight : A linear relationship has been obtained when log fecundity was plotted against log ovary weight (Figs. 29C, 30C, 31C) indicating that the fecundity increases with the ovary weight. The regression equations describing the relationship are as follows :-

$$\begin{aligned} \text{Log } F &= 3.0260 + 0.1985 \log \text{OW} && \text{for Umiam river} \\ r &= 0.948729 && \text{populations.} \\ \text{Log } F &= 2.5828 + 0.1519 \log \text{OW} && \text{for Umkhras stream} \\ r &= 0.732048 && \text{populations.} \\ \text{Log } F &= 2.8926 + 0.1688 \log \text{OW} && \text{for Umshing stream} \\ r &= 0.688732 && \text{populations.} \end{aligned}$$

The high "r" values in all the three populations indicates a significant relationship between the two parameters.

(iv) Total length VS Ovary weight : The mean values of total length and their respective ovary weight were plotted logarithmically against each other to establish the relationship between these parameters (Fig. 32A,B,C). A straight line was obtained in each case which showed an increasing trend in gonad weight with the increase in the total length. The regression equations are :-

$$\begin{aligned} \text{Log TL} &= 0.9488 + 0.0394 \log \text{OW} && \text{for Umiam river} \\ r &= 0.644230 && \text{populations.} \\ \text{Log TL} &= 0.9550 + 0.0555 \log \text{OW} && \text{for Umkhras stream} \\ r &= 0.758175 && \text{populations.} \\ \text{Log TL} &= 0.9078 + 0.0462 \log \text{OW} && \text{for Umshing stream} \\ r &= 0.651989 && \text{populations.} \end{aligned}$$

The "r" values have been found to be significant as before for all the three populations.

(v) Body weight VS Ovary weight : The regression analysis indicated significant relationship between body weight and ovary weight. The equations describing the relationship are :-

$$\begin{aligned} \text{Log W} &= 1.0392 + 0.1295 \log \text{OW} && \text{for Umiam river} \\ r &= 0.689823 && \text{populations.} \end{aligned}$$

TABLE-23

FECUNDITY OF G. LISSORHYNCHUS POPULATION FROM THE UMIAM RIVER

TOTAL LENGTH (mm)	BODY WEIGHT (gm)	OVARY WEIGHT (gm)	FECUNDITY (ABSOLUTE)	RELATIVE FECUNDITY
68.5	4.88	0.531	447	91.82
72.5	5.83	0.785	568	96.46
76.8	6.95	1.191	892	128.38
81.8	8.97	1.953	1143	124.19
86.5	9.61	1.662	1009	101.74
91.0	10.72	0.602	427	39.83
98.0	14.62	2.135	1212	82.88
102.0	16.54	4.219	1577	94.02
106.0	19.29	4.075	1808	93.73

TABLE-24

FECUNDITY OF G. LISSORHYNCHUS POPULATION FROM THE UMKHRAH STREAM

TOTAL LENGTH (mm)	BODY WEIGHT (gm)	OVARY WEIGHT (gm)	ABSOLUTE FECUNDITY	RELATIVE FECUNDITY
63.3	4.15	0.255	265	62.66
68.2	5.79	0.430	263	45.52
71.0	5.94	0.683	445	74.82
80.5	6.89	1.160	853	130.22
87.2	10.53	0.829	503	47.76
92.0	10.66	1.389	843	79.11
96.2	16.89	4.482	1076	64.38
100.0	16.02	1.829	1109	69.23
105.0	20.88	2.325	1410	67.51

TABLE-25

FECUNDITY OF G. LISSORHYNCHUS POPULATION FROM THE UMSHING STREAM

TOTAL LENGTH (mm)	BODY WEIGHT (gm)	OVARY WEIGHT (gm)	FECUNDITY (ABSOLUTE)	RELATIVE FECUNDITY
56.2	3.92	0.248	210	53.47
62.4	5.16	0.582	349	67.72
66.2	4.24	0.798	484	113.83
71.4	4.84	0.744	452	93.34
76.8	5.42	0.821	496	91.42
82.5	6.94	1.102	657	94.73
86.3	9.67	1.664	1003	102.82

Log W = $1.0725 + 0.1615 \log OW$ } for Umkhrah stream
 r = 0.713581 } populations.

Log W = $0.8433 + 0.0948 \log OW$ } for Umshing stream
 r = 0.822569 } populations.

In all the cases, the high "r" values indicate a significant relationship between the parameters.

RELATIVE FECUNDITY :

Data on relative fecundity in the populations from river Umiam, Umkhrah and Umshing streams have been presented in Tables-23, 24, 25. Relative fecundity has been found to be highest in the Umiam river populations (94.78) followed by 88.79 in specimens from the Umshing stream. The relative fecundity has been found to be lowest (71.25) in the Umkhrah stream population.

FOOD AND FEEDING HABITS

COMPOSITION OF GUT CONTENTS AND RELATIVE IMPORTANCE OF FOOD ITEMS :

Different percentage composition of each food items in the individuals from the three systems have been compiled in Table-26. The gut contents have been separated into four broad groups.

(i) Periphytic Bacillariophyceae : This group has been found to constitute the major food item in individuals from all the populations. Bacillariophyceae formed 97.38% of the gut content in the Umiam river individuals, 94.58% in the Umkhrah stream specimens and 97.87% in the individuals from the Umshing stream. The Bacillariophyceae was represented in the guts of the individuals from Umiam river by Meridion, Cymbella, Amphora, Nitzschia, Fragillaria, Tabellaria, Synedra, Navicula, Pinnularia, Bacillaria, Gomphonema,

TABLE-26

PERCENTAGE OCCURRENCE OF DIFFERENT FOOD ITEMS IN THE GUT
OF G. LISSORHYNCHUS FROM DIFFERENT POPULATIONS

	PERCENTAGE OF OCCURRENCE		
	UMIAM	UMKHRAH	UMSHING
<u>PERIPHYTIC</u>			
<u>BACILLARIOPHYCEAE</u>			
Surirella	-	-	0.38
Meridion	25.06	23.64	5.12
Cymbella	4.38	3.15	1.60
Amphora	1.61	1.14	2.07
Nitzschia	1.31	1.16	1.77
Fragillaria	2.32	1.80	5.23
Tabellaria	1.55	3.49	6.36
Synedra	2.77	5.10	2.79
Navicula	37.05	35.59	33.66
Pinnularia	1.81	-	3.72
Bacillaria	0.80	0.65	0.27
Gomphonema	4.75	4.44	27.09
Diatoma	4.68	3.87	2.89
Eunatia	3.26	2.60	0.39
Kirchneriella	-	2.71	1.53
Mastogonia	6.02	5.24	3.00
<u>CHLOROPHYCEAE</u>	0.79	0.79	1.28
<u>MYXOPHYCEAE</u>	0.50	0.73	0.40
<u>DETRITUS</u>	1.79	3.79	0.62

Diatoma, Eunatia and Mastogloia. Of these, Navicula was found to be the most abundant genus followed by Meridion. The Umkhrach stream specimens showed the presence of all the above mentioned genera with a new addition of Kirchneirella, but with the exception of Pinnularia. In this population too, as in the case with the specimens from Umiam river, Navicula followed by Meridion was found to be most abundant in the gut. In the individuals from Umshing stream the most dominant diatom was found to be Navicula closely followed by Gomphonema. The diatoms recorded in the gut of the Umshing stream specimens as mentioned above were similar as in the case with the individuals from the other two systems, but with another addition of Surirella.

(ii) Detritus : This group formed 1.79, 3.79 and 0.62 percent of the diet in the gut from the individuals of river Umiam, Umkhrach and Umshing streams respectively. For specimens from the river Umiam and Umkhrach stream, detritus appeared to be the second important food item whereas in the Umshing stream population, it was the third in order of preference.

(iii) Chlorophyceae : Chlorophyceae formed a comparatively small percentage of occurrence in the diet being 0.79% in the specimens from Umiam river, Umkhrach stream and 1.28% for the specimens from Umshing stream. In order of diet preference, Chlorophyceae was found to be third in the individuals from Umiam and Umkhrach systems, whereas it ranked second in the specimens from Umshing stream. Chlorophyceae was found to be represented in more or less equal quantities and were second in the gut of the individuals from Umiam river and this comprised of Tribonema, Ulothrix, Microspora,

Spirogyra, Oedogonium and Closterium. Similarly, Scenedesmus, Tribonema, Ulothrix, Microspora, Spirogyra, Oedogonium and Coelastrum were found to be the representative members of Chlorophyceae in the gut of individuals from Umkhras stream. In the digestive tract of the specimens from Umshing stream, green algae was represented by Ulothrix, Microspora, Spirogyra and Closterium only.

(iv) Myxophyceae : This group formed the smallest portion of the diet being 0.50%, 0.73% and 0.40% of the total gut content of individuals of Umiam, Umkhras and Umshing systems respectively. Myxophyceae was represented in the diet mainly by Anabaena in the specimens from Umiam river and Umshing stream, whereas this group was represented by Oscillatoria and Anabaena in Umkhras stream population.

SEASONAL FLUCTUATIONS IN THE FOOD COMPOSITION :

The percentage composition of each food item constituting the diet of the species during different months of the year has been enumerated in Tables-27, 28 & 29. It can be seen from these tables that there is slight variation in the pattern of intake of the various dietary groups in the specimens from all the three populations.

Bacillariophyceae, formed the major food item throughout the year. The fluctuations in percentage composition ranged from 94.93 (February) to 99.84 (December) in the specimens from Umiam river, 92.54 (June) to 96.06 (November) in the specimens from Umkhras stream and 96.75 (November) to 98.94 (September) in the

TABLE-27
SEASONAL VARIATIONS IN DIET COMPOSITION (%) OF G. LISSORHYNCHUS FROM UMIAM RIVER

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
<u>PERIPHYTIC</u>												
<u>BACILLARIOPHYCEAE</u>												
Meridion	24.99	30.01	19.52	20.61	25.72	25.58	23.79	23.54	32.03	22.89	26.24	25.83
Cymbella	6.66	0.90	1.79	6.02	5.83	3.85	1.28	0.92	0.82	6.57	5.68	6.51
Amphora	0.87	0.15	3.98	1.84	1.85	1.79	0.42	0.62	-	2.64	2.99	2.21
Nitzschia	1.30	1.37	1.60	0.98	0.83	0.92	1.06	1.40	0.55	1.95	2.13	1.57
Fragillaria	1.85	2.46	1.26	1.03	1.74	1.92	2.15	3.66	0.96	4.89	4.38	1.49
Tabellaria	1.55	0.40	0.34	0.16	1.02	1.87	2.61	4.23	1.50	1.61	1.83	1.43
Synedra	3.31	1.50	2.62	2.13	2.90	2.16	2.95	3.36	1.87	2.84	3.35	3.68
Navicula	38.58	40.68	36.85	50.99	35.33	32.92	45.51	37.90	38.29	31.04	27.93	28.71
Pinnularia	1.88	0.63	1.60	2.12	3.78	3.85	0.61	0.84	1.53	1.52	1.92	1.61
Bacillaria	1.62	0.76	-	0.87	0.63	0.72	0.22	0.59	0.66	1.17	0.96	1.43
Gomphonema	6.03	3.68	7.74	4.05	3.87	1.95	2.92	3.31	5.41	6.15	6.53	5.40
Diatoma	2.80	6.10	6.19	2.43	2.50	5.37	6.48	4.14	4.61	5.94	5.26	4.34
Eunatia	1.05	2.98	6.24	2.60	3.93	4.69	5.04	3.07	1.68	1.46	1.92	4.37
Mastogloia	4.71	5.45	6.24	3.92	6.44	7.84	3.67	7.56	5.19	6.63	7.42	7.22
<u>CHLOROPHYCEAE</u>	0.21	0.29	0.21	0.12	-	0.31	0.65	2.46	1.71	1.01	1.50	1.02
<u>MYXOPHYCEAE</u>	2.49	0.15	-	-	1.34	0.65	0.20	-	0.39	-	-	0.54
<u>DETRITUS</u>	-	2.59	3.81	-	2.43	3.81	-	1.77	2.80	1.70	-	2.57

TABLE-28

SEASONAL VARIATIONS IN DIET COMPOSITION (%) OF G. LISSORHYNCHUS FROM UMKHRAH STREAM

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
<u>PERIPHYTEIC BACILLARIOPHYCEAE</u>												
Meridion	21.42	23.40	20.63	18.47	22.83	21.06	24.74	25.02	28.94	25.78	26.43	24.92
Cymbella	3.44	2.91	2.52	3.48	4.91	4.63	2.37	1.53	1.06	0.94	4.88	5.13
Amphora	1.24	1.24	0.93	0.84	0.82	0.74	0.52	1.78	1.34	0.98	1.37	1.83
Nitzschia	1.13	1.27	0.84	0.86	0.52	0.93	0.57	0.62	1.38	1.74	1.93	2.14
Fragillaria	1.76	1.82	1.43	1.36	1.32	2.13	2.74	1.01	1.21	2.43	2.42	1.95
Tabellaria	5.57	4.01	4.53	5.83	2.96	5.13	4.21	-	1.21	4.41	1.03	3.01
Synedra	6.82	4.92	5.82	6.81	4.01	6.37	5.53	4.31	3.62	5.26	3.48	4.27
Navicula	32.63	38.72	38.43	42.88	39.40	32.89	38.22	35.73	39.51	29.83	31.06	27.81
Bacillaria	1.37	1.13	0.92	0.13	0.12	0.73	1.42	-	-	1.08	0.95	-
Gomphonema	5.24	5.12	6.72	3.40	4.72	3.14	1.25	3.47	4.83	7.16	3.25	4.96
Diatoma	3.64	2.78	3.41	3.02	2.83	4.16	4.28	4.43	3.82	4.06	5.12	4.93
Eunatia	3.42	2.34	2.62	2.55	1.93	2.47	1.93	3.52	1.63	1.72	3.67	3.92
Kirchneriella	3.34	1.72	2.53	2.14	2.83	2.66	2.87	3.72	2.09	1.93	2.95	3.74
Mastogloia	3.63	4.52	4.73	3.84	5.27	6.73	2.84	7.72	5.01	5.22	6.95	6.37
<u>CHLOROPHYCEAE</u>	0.94	0.92	0.62	0.13	0.51	0.43	0.54	0.84	0.57	1.74	1.13	1.08
<u>MYXOPHYCEAE</u>	0.28	0.56	0.72	0.53	0.55	1.24	1.02	1.48	0.75	0.93	0.12	0.57
<u>DETRITUS</u>	3.42	3.01	2.92	3.52	4.37	4.02	5.08	4.97	3.24	4.36	3.12	3.43

TABLE-29

SEASONAL VARIATIONS IN DIET COMPOSITION (%) OF G. LISSORHYNCHUS FROM UMSHING STREAM

	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
<u>PERIPHYTIC BACI-</u>												
<u>LLARIOPHYCEAE</u>												
Surirella	0.26	-	0.13	0.24	-	0.37	0.28	0.73	0.62	0.71	0.87	0.37
Meridion	5.02	3.83	7.82	5.29	3.58	2.93	4.35	5.97	8.21	7.36	7.52	6.71
Cymbella	1.29	1.34	1.02	0.95	1.63	1.72	1.85	1.93	1.08	2.14	2.31	1.93
Amphora	2.32	1.75	1.08	1.19	1.42	2.36	2.87	2.32	2.29	2.31	2.43	2.51
Nitzschia	1.75	1.63	1.48	1.52	1.03	0.98	0.74	0.95	0.43	0.21	1.53	1.79
Fragillaria	3.48	5.72	6.83	7.48	4.28	6.73	4.89	4.83	3.02	2.98	6.71	5.82
Tabellaria	3.21	4.03	5.12	9.83	8.47	9.75	5.01	6.38	7.73	6.28	5.09	5.43
Synedra	2.12	-	3.88	5.98	-	5.02	2.23	2.30	2.01	4.35	2.39	3.23
Navicula	42.13	35.92	38.75	32.94	37.38	29.42	32.94	31.47	36.52	28.31	29.63	28.52
Pinnularia	1.31	1.43	4.32	6.97	6.03	7.14	7.18	3.91	1.03	-	2.41	2.93
Bacillaria	0.24	0.39	0.17	-	0.12	-	0.24	0.63	0.29	0.31	0.48	0.42
Gomphonema	27.92	33.43	18.74	19.44	27.25	24.91	29.43	28.08	27.42	32.98	26.83	28.72
Diatoma	3.14	3.29	2.43	2.03	2.19	1.74	2.96	3.47	2.83	3.87	3.53	3.19
Eunatia	0.46	0.42	0.21	0.17	0.12	0.13	0.54	0.48	0.39	0.49	0.46	0.37
Kirchneriella	1.94	2.06	1.65	1.07	1.21	1.32	1.24	1.26	1.42	1.83	1.64	1.76
Mastogloia	2.35	2.57	3.12	3.41	3.12	3.72	1.33	3.27	2.43	3.31	3.57	3.61
<u>CHLOROPHYCEAE</u>	1.26	1.04	1.32	1.02	1.21	1.32	1.37	1.42	1.36	1.29	1.37	1.35
<u>MYXOPHYCEAE</u>	0.13	0.12	0.36	-	-	0.17	-	0.34	0.43	1.01	1.09	1.14
<u>DETRITUS</u>	0.32	0.85	1.72	1.43	1.12	0.21	0.56	0.16	0.21	0.32	0.24	0.28

specimens from Umshing stream. Detritus ranked as the second most preferred diet in the specimens from Umiam river ranging in percentage composition from 1.70 (June) to 3.81 (December) and for the individuals from Umkhrah lotic system the food item was found to vary from 2.92% (November) to 5.08% (March). For the individuals from Umshing river, Detritus was found to be the third most preferred food item and in percentage values, this constituent ranged from 0.21 (February and May) to 1.72 (November). For Umiam river and Umkhrah stream populations, the amount of Chlorophyceae found in the gut was next to detritus, while it was found to be the second preferred food item for the individuals from Umshing stream. Its percentage composition in the gut ranged from 0.12 (December) to 2.46 (March) in Umiam river populations, from 0.13 (December) to 1.74 (June) in individuals from Umkhrah stream, and from 1.02 (December) to 1.42 (April) in specimens from Umshing stream. Myxophyceae formed the smallest group in the diet of G. lissorhynchus from all the three systems. The percentage composition of this group in the food content varied from 0.15 (October) to 2.49 (September) in Umiam river populations, 0.12 (July) to 1.48 (April) and 0.12 (October) to 1.14 (August) for the specimens from Umkhrah and Umshing streams respectively.

It can be seen (Fig. 33) that Diatoms formed the major dietary constituent followed by comparatively much lesser quantities of Detritus and algal matter. The oscillation in the percentage consumption of the different types of food material were found to be less throughout the period of the study.

FOOD COMPOSITION OF VARIOUS SIZE GROUPS :

The data on the gut contents of various length classes have been presented in Tables-30, 31 & 32, and the percentages of occurrence of various food items are depicted in Fig. 41. Salient features of the observations are described below :-

SIZE GROUP I (25-44 mm) : Periphytic Diatoms constituted the major portion of the gut content in all the individuals from the three water bodies. In Umiam river populations it was found to represent 97.76% of the food ingested and in Umkhrah stream individuals, it was 95.21%, while the percentage composition was 98.03 in the specimens from Umshing stream. Detritus in this size group composed of 1.39% in the gut content of G. lissorhynchus from Umiam river, while in the individuals from Umkhrah and Umshing streams it was 4.21 and 0.72% respectively. Chlorophyceae in the Umiam river specimens was found to be 0.72%, 0.21% in the population from Umkhrah stream and 0.83% in the Umshing stream population. Myxophyceae was found to represent 0.11% of the gut content in the specimens from Umiam river and 0.36 and 0.17% in the individuals from Umkhrah and Umshing streams respectively.

SIZE GROUPS II (45-64 mm) : In the Umiam river individuals, diatoms were found to be composed by 96.71% of the gut content. Next in the order of abundance, was Detritus (1.97%), followed by Chlorophyceae (0.79%) and lastly Myxophyceae (0.34%). The order of abundance has been found to be the same in this size group in the specimens from Umkhrah stream. Bacillariophyceae (92.90%) preceded detritus (4.53%) after which Chlorophyceae (1.45%) ranked,

and then Myxophyceae (0.98%). In this size class the order of abundance was found to be altered slightly. Diatoms (97.92%) were followed by Chlorophyceae (1.34%), which was further followed by Detritus (0.65%) and Myxophyceae (0.24%).

SIZE GROUPS III (65-84 mm) : In this length group too, the specimens from Umiam river exhibited a similar order of abundance with regards to Bacillariophyceae (96.56%) which, in order of preference was followed by Detritus (1.85%), green algae (0.84%) and Myxophyceae (0.44%). In the individuals from Umkhras stream, Bacillariophyceae (95.69%) was found to be the highest in abundance. Then appeared the Detritus (3.01%) and Myxophyceae (0.61%) which was followed by Chlorophyceae (0.32%). Diatoms (98.12%) was followed by Chlorophyceae (0.93%) in the Umshing stream population in this size group. Chlorophyceae in this case preceded Detritus (0.48%) and Myxophyceae (0.46%).

SIZE GROUPS IV (85-104 mm) : The specimens of this length class from Umiam river were found to have 96.09% of diatoms in their guts. Detritus (1.86%) came next in the order of abundance followed by Chlorophyceae (1.16%) and then Myxophyceae (0.83%). In the Umkhras stream, the gut content of the specimens in this size group of Bacillariophyceae was composed of 94.59%; 4.17% detritus; 0.72% Myxophyceae and 0.42% Chlorophyceae in order of abundance. In the Umshing stream population, Bacillariophyceae (96.41%) was followed by Chlorophyceae (1.87%), then came Myxophyceae (0.68%) and Detritus (0.61%).

TABLE-30

PERCENTAGE COMPOSITION OF THE GUT CONTENT IN DIFFERENT LENGTH
GROUPS OF G. LISSORHYNCHUS FROM UMIAM RIVER

	25-44 mm	45-64 mm	65-84 mm	85-104 mm	105-124 mm
<u>BACILLARIOPHYCEAE</u>					
(Periphyton)					
Meridion	18.42	27.54	24.48	27.93	27.55
Cymbella	4.97	4.26	3.43	2.70	4.96
Amphora	1.69	1.88	1.56	0.25	1.24
Nitzschia	1.07	0.94	2.32	2.69	2.10
Fragillaria	2.81	1.21	2.55	2.37	3.23
Tabellaria	2.15	1.38	1.74	0.98	1.47
Synedra	2.41	1.96	2.92	2.43	2.84
Navicula	35.95	33.62	38.31	37.36	29.93
Pinnularia	0.88	1.63	1.56	2.42	1.74
Bacillaria	0.87	0.98	0.93	0.58	1.26
Gomphonema	4.01	6.07	5.62	4.24	3.88
Diatoma	4.00	4.44	4.16	4.17	4.43
Eunatia	3.41	3.83	2.57	3.04	4.66
Mastogloia	5.12	6.97	4.38	4.93	6.30
<u>CHLOROPHYCEAE</u>					
(Unidentified)	0.72	0.79	0.84	1.16	1.43
<u>MYXOPHYCEAE</u>					
(Unidentified)	0.11	0.34	0.44	0.83	1.21
DETRITUS	1.39	1.97	1.85	1.86	1.54

TABLE-31

PERCENTAGE COMPOSITION OF THE GUT CONTENT IN DIFFERENT LENGTH GROUPS OF G. LISSORHYNCHUS FROM UMKHRAH STREAM

	25-44 mm	45-64 mm	65-84 mm	85-104 mm	105-124 mm
<u>BACILLARIOPHYCEAE</u>					
(Periphyton)					
Meridion	19.78	19.24	29.92	27.85	22.03
Cymbella	3.21	3.54	3.12	2.03	3.81
Amphora	0.68	1.39	0.96	1.32	1.29
Nitzschia	1.24	1.56	1.47	1.03	0.98
Fragillaria	2.94	2.03	1.82	1.16	1.48
Tabellaria	2.87	3.96	3.21	3.48	3.83
Synedra	4.93	5.59	5.36	4.92	5.01
Navicula	38.49	34.92	32.30	36.89	35.17
Eunatia	2.51	2.82	2.92	2.43	2.21
Bacillaria	0.60	0.71	0.62	0.61	0.75
Gomphonema	4.39	5.02	3.24	3.16	6.01
Diatoma	4.62	3.53	3.94	3.48	4.01
Kirchneirella	2.94	2.91	2.27	2.32	3.02
Mastogloia	6.01	5.68	4.54	3.91	5.03
<u>CHLOROPHYCEAE</u>					
(Unidentified)	0.21	1.45	0.32	0.42	1.10
<u>MYXOPHYCEAE</u>					
(Unidentified)	0.36	0.98	0.61	0.72	0.81
DETRITUS	4.21	4.53	3.01	4.17	3.62

TABLE-32

PERCENTAGE COMPOSITION OF THE GUT CONTENT IN DIFFERENT LENGTH GROUPS OF G. LISSORHYNCHUS FROM UMSHING STREAM

	25-44 mm	45.64 mm	65.84 mm	85-104 mm
<u>BACILLARIOPHYCEAE</u>				
(Periphyton)				
Surirella	0.12	0.46	0.42	0.50
Meridion	5.34	4.86	5.36	4.87
Cymbella	1.21	1.73	2.59	2.47
Amphora	2.21	2.01	2.67	1.39
Nitzschia	1.03	1.61	2.83	2.31
Fragillaria	4.72	5.46	5.74	4.96
Tabellaria	6.65	6.74	5.83	6.20
Synedra	2.53	2.41	3.36	2.81
Navicula	35.47	34.21	34.05	30.72
Pinnularia	2.06	3.29	4.33	3.76
Bacillaria	0.23	0.24	0.21	0.38
Gomphonema	28.54	26.35	23.47	28.52
Diatoma	3.42	2.97	2.85	2.29
Eunatia	0.28	0.34	0.42	0.49
Kirchneirella	1.47	1.63	1.51	1.48
Mastogloia	2.75	3.41	2.48	3.26
<u>CHLOROPHYCEAE</u>				
(Unidentified)	0.83	1.34	0.93	1.87
<u>MYXOPHYCEAE</u>				
(Unidentified)	0.17	0.24	0.46	0.68
DETRITUS	0.72	0.65	0.48	0.61

SIZE GROUPS V (105-124 mm) : The composition of the gut contents was found to be more or less similar in this size group, both in the specimens from Umiam and Umkhras streams. In the Umiam river population, of diatoms (95.59%) was followed by detritus (1.54%), Chlorophyceae (1.43%) and Myxophyceae (1.21%). In the Umkhras stream population, Bacillariophyceae in the gut content was found to be 94.63%, detritus being 3.62%, Chlorophyceae being 1.10% and Myxophyceae amounted to be 0.81%. It can be seen from Tables-27 to 30 and Figs. 33 & 41 that the fluctuations in percentage composition of various dietary groups in all the three populations was insignificant except that a slight increase has been observed in the composition of Chlorophyceae and Myxophyceae as the fish increases in length.

FEEDING INTENSITY : The observation on the feeding intensity based on gastro-somatic index are presented in Table-34.

Feeding intensity was found to be high in the individuals from Umiam river from January to April (Fig. 34B). Thereafter, the intensity declined from July to September. The month of October showed a sudden increase in the feeding activity. The feeding intensity was somewhat found to be lower in November and December.

In the specimens from Umkhras stream, the feeding intensity was found to be maximum during October to April after which the intensity declined. A similar pattern in the feeding intensity was observed in the individuals from Umshing stream.

Individuals from all the three systems showed two apparent peaks in their feeding intensity, first being in August and the

TABLE-33

SEASONAL VARIATIONS IN THE G.S.I., Gn.S.I. AND 'K' FACTOR OF
G. LISSORHYNCHUS IN DIFFERENT SYSTEMS

MONTHS	UMIAM RIVER			UMKHRAH STREAM			UMSHING STREAM		
	GSI	GnSI	'K'	GSI	GnSI	'K'	GSI	GnSI	'K'
SEP	2.74	10.83	1.5376	1.58	13.50	1.3689	3.14	9.40	1.6258
OCT	4.95	0.12	1.8994	3.22	1.10	1.7456	4.30	0.42	1.9032
NOV	2.00	3.80	1.5265	6.32	0.13	1.3372	5.92	0.13	1.2505
DEC	2.91	2.10	1.4817	2.75	2.02	1.6692	2.03	3.21	1.5018
JAN	4.46	0.25	1.4761	2.84	2.41	1.6702	3.17	1.93	1.5723
FEB	4.32	0.13	1.2995	2.95	3.04	1.6282	5.16	4.02	1.4577
MAR	4.08	0.13	1.5043	3.42	2.58	1.6889	4.19	0.96	1.7320
APR	4.41	0.96	1.3907	4.63	0.22	1.4976	4.48	1.94	1.8381
MAY	3.45	7.01	1.4975	3.15	8.31	1.7311	1.99	7.50	1.4664
JUN	1.81	20.40	1.4340	2.48	8.86	1.6473	1.15	10.93	1.4916
JUL	1.66	17.80	1.3552	2.75	25.53	1.5844	3.20	14.13	1.6862
AUG	2.46	15.03	0.9699	2.95	14.02	1.4973	2.18	15.34	1.3614

TABLE 234

"K" FACTOR, G.S.I., G.S.I., AND R.L.G. VALUES OF G. LISSORHYNCHUS FROM DIFFERENT SYSTEMS

SIZE GROUPS	UMIAM RIVER			UMKRAH STREAM			UMSHING STREAM		
	"K"	GSI	RLG	"K"	GSI	RLG	"K"	GSI	RLG
25-29	1.3657	7.390	2.775	1.3380	7.20	2.740	1.3489	6.22	2.740
30-34	1.4871	4.898	2.858	1.4048	5.52	2.663	1.7145	4.39	2.600
35-39	1.3456	4.406	3.143	1.3994	5.21	2.889	1.5213	4.18	2.748
40-44	1.4923	2.190	3.711	1.5352	3.43	3.150	1.4080	4.48	3.400
45-49	1.4185	3.950	3.958	1.5701	3.20	3.450	1.3173	5.16	3.659
50-54	1.3838	2.630	3.282	-	-	-	1.3649	3.11	3.785
55-59	1.5865	2.900	3.550	1.5513	2.92	3.875	1.6231	1.98	3.286
60-64	1.6075	2.000	3.910	1.6092	1.94	3.711	1.4684	2.03	4.050
65-69	1.4521	2.340	3.560	1.5027	2.19	3.680	1.4048	1.85	4.149
70-74	1.5097	3.620	4.365	1.4492	2.57	4.160	1.3951	2.17	4.205
75-79	1.5227	2.810	4.095	-	-	-	1.2080	2.46	4.495
80-84	1.4707	3.180	4.680	1.2796	2.54	4.576	1.3133	1.40	5.350
85-89	1.7256	1.230	5.060	1.6415	1.36	4.810	1.4310	1.12	5.850
90-94	-	-	-	1.4729	1.55	5.870	-	-	-
95-99	1.5329	3.110	6.550	1.5703	1.12	6.730	-	-	-
100-104	1.5588	2.800	6.840	1.6020	1.32	7.245	-	-	-
105-109	1.5354	3.510	7.560	1.7388	1.15	8.050	-	-	-
110-114	-	-	-	-	-	-	-	-	-
115-119	1.0121	6.010	8.160	-	-	-	-	-	-
120-124	1.0706	5.010	7.460	-	-	-	-	-	-

second in November in the specimens from Umkhrah and Umshing stream, while for Umiam river specimens, it was during the month of October.

The observation on feeding intensity in different length groups is shown in Fig. 34A. It has been observed that the feeding intensity was the highest in the smaller length classes i.e. from 25-29 mm to 45-49 mm length groups, whereafter the feeding intensity was found to be lower. The intensity slightly increased in the 70-74 to 80-84 mm length groups after which the intensity dropped again. It was found that the intensity of feeding again increased at 115-124 mm length groups in the specimens from the Umiam river.

The correlation between feeding intensity and condition factor (K) has been shown in Fig. 35, and the results have been tabulated in Table-33. The data reveals that there is an inverse relationship between the feeding intensity and condition factor. The relation between condition factor and gastro-somatic index in different length groups of the species has been shown in Fig. 36, which indicates an inverse relationship for the individuals from the three systems.

G.S.I. values also showed an inverse relationship with gonado somatic index (Table-34).

The length of the gut (Y) plotted against the total length (X) is depicted in Figs. 37 & 39, which shows that the length of the gut increases in proportion to the total length of the fish. The regression equations derived are as follows :-

$$Y = -9.171881 + 5.559435 X \text{ (Umiam river individuals)}$$

$$Y = -25.079749 + 8.860637 X \text{ (Umkhrah stream individuals)}$$

$$Y = -13.354361 + 6.373547 X \text{ (Umshing stream individuals)}$$

Their corresponding coefficient of correlation 'r' has been calculated to be 0.9787, 0.944 and 0.9317.

The regression equations describing the relation between the weight of the gut versus total length are found to be as follows :

$$\text{Log } Y = -2.171677 + 1.896893 \log X \text{ (Umiam river specimens)}$$

$$\text{Log } Y = -2.222458 + 1.980078 \log X \text{ (Umkhrah stream specimens)}$$

$$\text{Log } Y = -2.149067 + 1.863145 \log X \text{ (Umshing stream specimens)}$$

Their respective coefficient of correlation "r" was found to be 0.9594, 0.987 and 0.9707. The weight of the gut along with its content (Y) has been plotted against total length (X) and shown in Fig. 38.

The ratio of the gut length to body length has been shown in Fig. 40 and compiled in Table-34. The data reveals that the ratio increases as the fish grows in length. The increase of R.L.G. in the specimen from Umiam river has been found to vary from 2.775 to 8.16, whereas from 2.74 to 8.05 in the specimens from Umkhrah stream and from 2.55 to 5.85 in the individuals from Umshing stream.

D I S C U S S I O N

MORPHOMETRIC AND MERISTIC CHARACTERS

Morphological variations in fish due to adaptation to new environment have been cited by many workers (Schmidt, 1921; Vladykov, 1934; Tanning, 1944; Lindsay, 1954; Fage, 1958; Barlow, 1961; Suzuki and Yamaguchi, 1980; Kaur, 1981; and Dasgupta, 1982). In the present study, morphological variations have been observed among the three populations of Garra lissorhynchus from Umiam river, Umkhrah and Umshing streams. Fork length, Pre-dorsal length, Head width, Post-orbital distance, Diameter of the disc and Length of the caudal peduncle were observed to be higher in the population of Umshing stream when compared with the specimens from other two populations (Table-7). Least height of body, Inter-orbital

width and Girth were found to be highest in Umkhrah population. In the specimens from Umiam river, Head length, Eye diameter, Body depth, Length of dorsal fin, Length of pelvic fin and Length of anal fin were found to be the highest among the individuals of the three populations. Head depth was observed to be somewhat similar in Umiam and Umkhrah populations. Length of pectoral fin was recorded to be nearly the same in the specimens from Umiam and Umshing systems. Differences in regression equations as shown in Tables- 9, 10 & 11, which may be attributed to diverse ecological and environmental conditions such as current, temperature etc. prevalent in the three systems. Similar view has also been expressed by Kaur (1981) and Dasgupta (1982).

According to Gould (1966) ratios between morphological characters will not necessarily be constant for the organisms of the same species due to the variations resulting from differences in sex, race, nutrition and other variable ecological factors. Therefore, in the present study too, variations in morphometric measurement may be attributed to the above mentioned environmental factors.

Various authors have shown that morphometric characters of fish can vary under the influence of environment and in particular, the thermal factor during the period of incubation, and the beginning of larval life (Schmidt, 1921; Vladykov, 1934; Tanning, 1944; Lindsay, 1954; Fage, 1958; and Barlow, 1961). According to Hubbs (1922) and Tanning (1944), variation occurs in number of rays in the unpaired fins in several species which is also related to an adaptation to movement of water of various density.

Variations in the body proportions in the same species according to hydrographic conditions, have also been recorded by various authors (Hubbs, 1922; Barlow, 1961). They associated these variation with the effect of the duration of periods of growth and of the relating differentiations which determines the number of vertebrae. Many authors (Schmidt, 1921; Vladykov, 1934; Tanning, 1944; Lindsay, 1954; Barlow, 1961) have reported that meristic characters exhibit plasticity under the influence of ecological factors, as has also been seen in the present study.

As reported by Menon (1964), the eye-diameter of Garra lissorhynchus in relation to its head length ranges from 3.71 to 6.60 and inter-orbital width ranges between 1.80 and 2.40. However, in the present study, eye-diameter in relation to head length was found to range from 5.15 to 7.00 and the inter-orbital width in head length was recorded to vary between 1.67 and 1.94 (Table-16). The greatest diameter of the disc in head length was found to range from 2.42 to 3.54, whereas Menon (1964) observed this parameter to range from 2.36 to 3.57 in length of head. The pre-orbital distance has been found to range between 2.20 and 2.56, while the range of this parameter has been observed to be 1.71 to 2.08 in head length by Menon (1964). He further recorded the number of lateral line scales to vary between 32 and 35, whereas in the present study the widest range regarding this parameter was found to be between 32 and 36 (Table-8). These variations clearly indicates that there may be some variations in the morphometric as well as meristic characters in fishes belonging to different populations which further can be attributed due to

the abiotic and biotic nature of the system from where the fishes were collected as also discussed earlier.

Biometric study of Garra lissorhynchus (Figs. 17-20) reveal that the eye-diameter becomes smaller in relation to head length with the growth of the fish. A similar case has also been reported by Tobor (1974) in Lates niloticus, Kaur (1981) in Channa gachua, and Dasgupta (1982) in Acrossocheilus hexagonolepis. The growth of the fork length and standard length in relation to total length were found to be almost constant in all the populations during the present study. According to Bayagbona (1963), a constant index in any of the biometric indices indicates that the growth of the biometric character in relation to its length is generally isometric. Minor differences in allometry of the biometric characters such as pre-dorsal length, head length and inter-orbital width (Figs. 17-20) have been observed in all the populations. The growth of dorsal fin and body depth in relation to total length and the growth of the pectoral fin in relation to head length showed a positive allometry, whereas the inter-orbital width in total length and eye diameter in relation to head length has been found to exhibit a negative allometry.

From time to time, various features have been reported as characters of certain local populations of the same species, which Nikolsky (1963) with his tidy outlook on adaptations, considered that these variations were designed to ensure that the greatest variety of habitats were occupied and quoted several instances for various fish species which could occur either as an elongated

"river form" or as a high bodied "lake form". However, in the present study, No such well defined variation among the three populations could be ascertained, but certain variations in morphometric measurements are quite evident (Figs. 17-19). Such intra-specific variations in the morphometric characters of the species may be because the specimens belonged to limnologically different types of ecosystems and which might have affected in such variations.

LENGTH-WEIGHT RELATIONSHIP

From the studies on length-weight relationship, it is clear that there are intraspecific variations in the exponential values (Table-17). The values for "b" approximate to the cube law in all the three populations, but are more than "3" in case of the specimens from Umiam river and Umkhras stream and less than "3" in the Umshing stream specimens. According to Tesch (1967) the value $b=3$ indicates that the fish grows symmetrically or isometrically. Values other than 3 indicate allometric growth: if "b" is greater than 3, the fish becomes "heavier for its length" as it grows larger. Thus, it is clear that the specimens of G. lissorhynchus from all the three systems exhibit allometric growth. However, specimens from Umiam river ($b=3.0557$) and the Umkhras stream ($b=3.1251$) have been found to be "heavier for its length" than the Umshing stream individuals ($b=2.9974$). The change in the exponential value "b" is supposed to be under the influence of numerous factors viz. seasonal fluctuations, physiological conditions of the fish at the time of collection, sex, gonadal development and nutritive conditions of the environment of the fishes (Sinha, 1973). Hence,

it is quite likely that the variations in the exponential value relating the length to the body weight might be due to the reasons stated above as the fishes were collected from three different ecosystems. Apart from varying from population to population, the exponential values for Garra lissorhynchus have been found to vary in different seasons (Summer and Winter) and during the juvenile and adult stages too. However, it is seen that the growth in all cases is allometric (Tables-18 & 19).

Lal and Dwivedi (1965) and Sekharan (1968) have also observed variations in the power function (b) of length in relation to body weight in Rita rita and Sardinella albella and Sardinella gibbosa. Hughes et al (1974) while studying the effect of growth on gills and accessory respiratory organs of Saccobranchus (=Heteropneustes) fossilis have mentioned that the compressed body shape of the fish to be a probable cause of the increase of the power function (b=3.325).

Beverton and Holt (1957) suggested that the departure from 3.0 of "b" value is rather rare. However, Narasimhan (1970) reported that the value of "b" increases in the carnivore fish Trichiurus lepturus which devour big prey. Soni and Kethal (1979) reported that the higher value of "b" (4.36) obtained for Cirrhina mrigala is due to the presence of large quantities of sand and mud in the stomach, resulting in an increase in the total weight. In the present investigation, the "b" values for G. lissorhynchus from the river Umiam and Umkhrach stream have been found to be 3.0557 and 3.1251 respectively. The values greater than 3 obtained

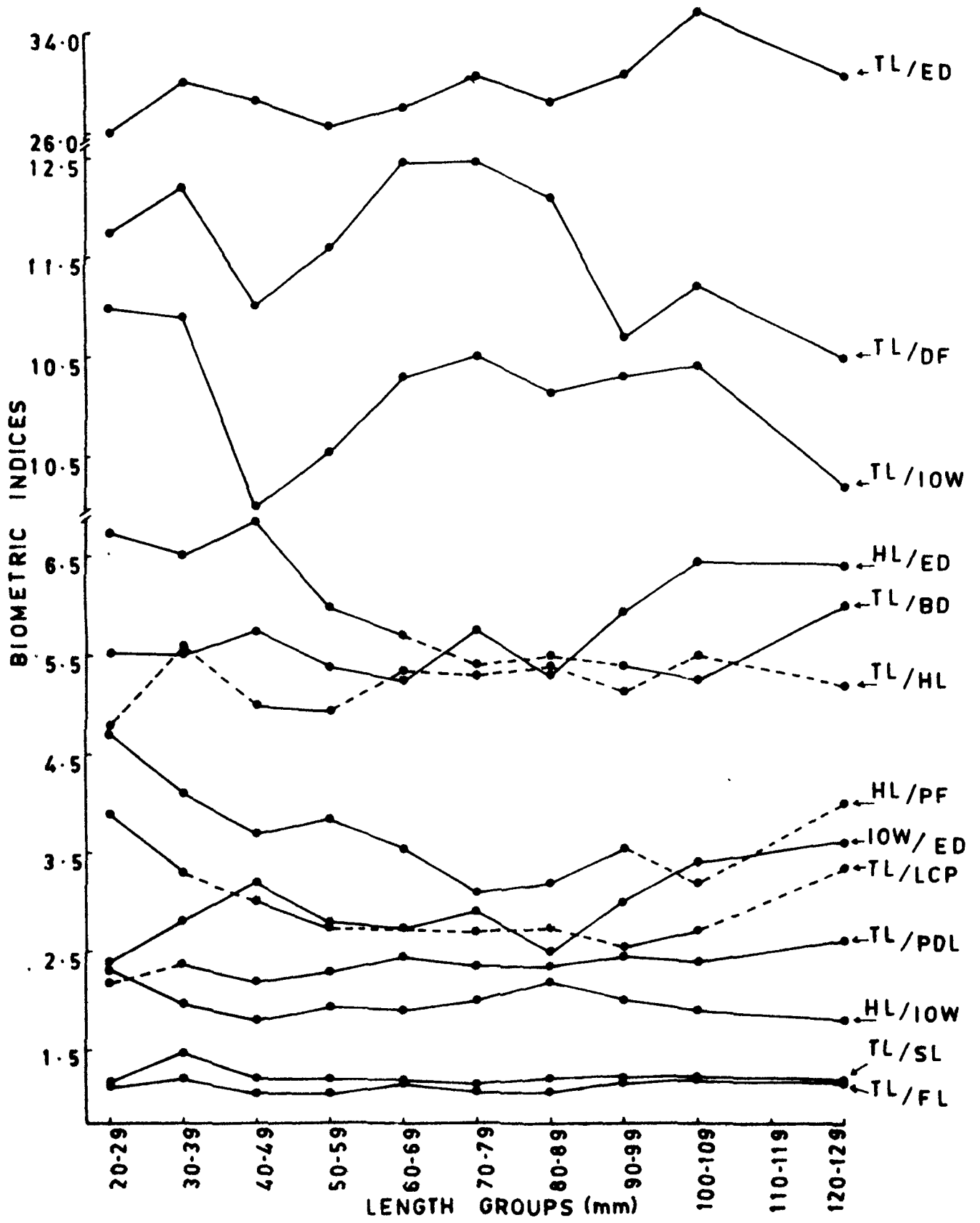


Fig.17: Biometric indices of *G. lissorhynchus* from Umiam river

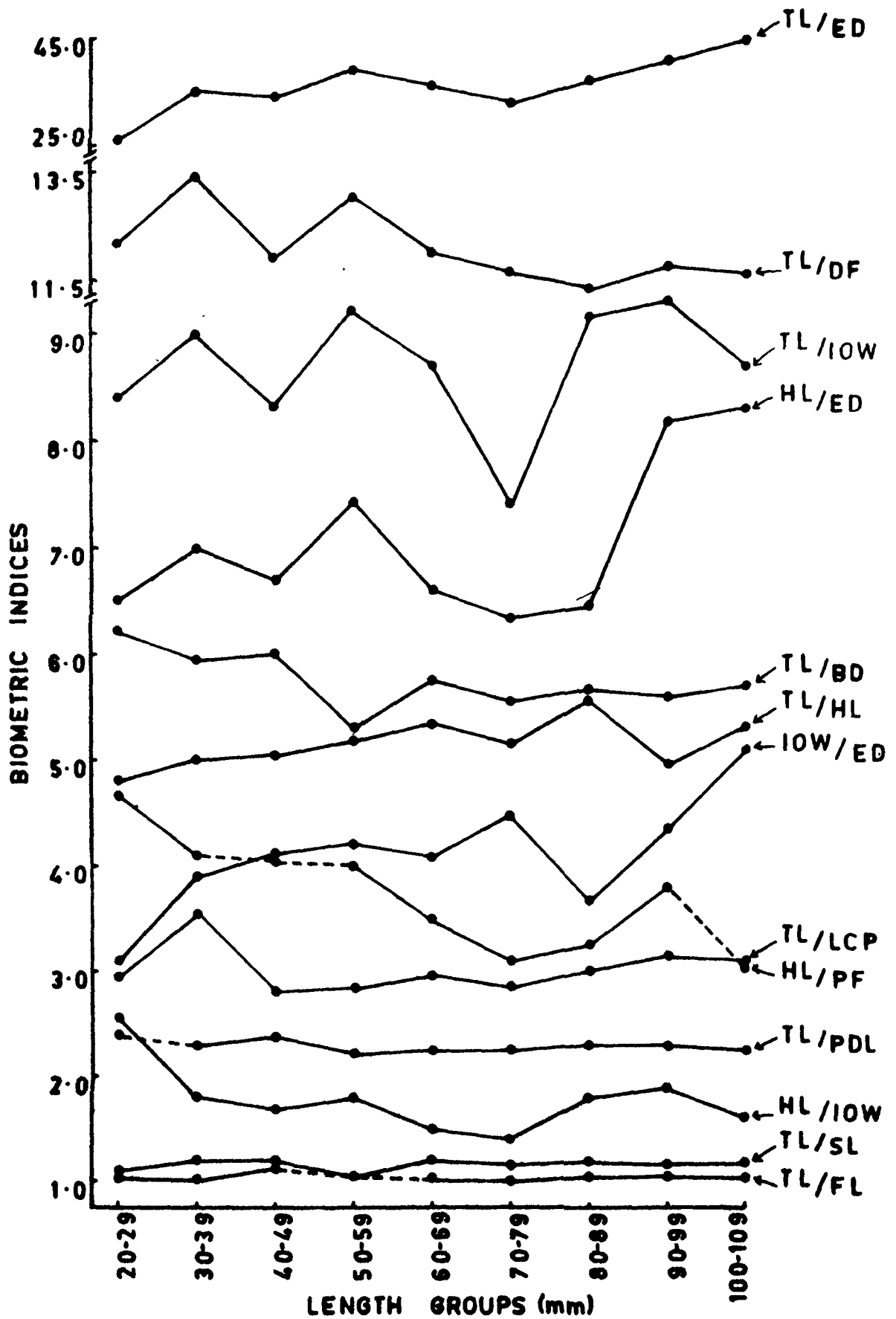


Fig. 18: Biometric indices of *G. lissorhynchus* from Umkhrab stream

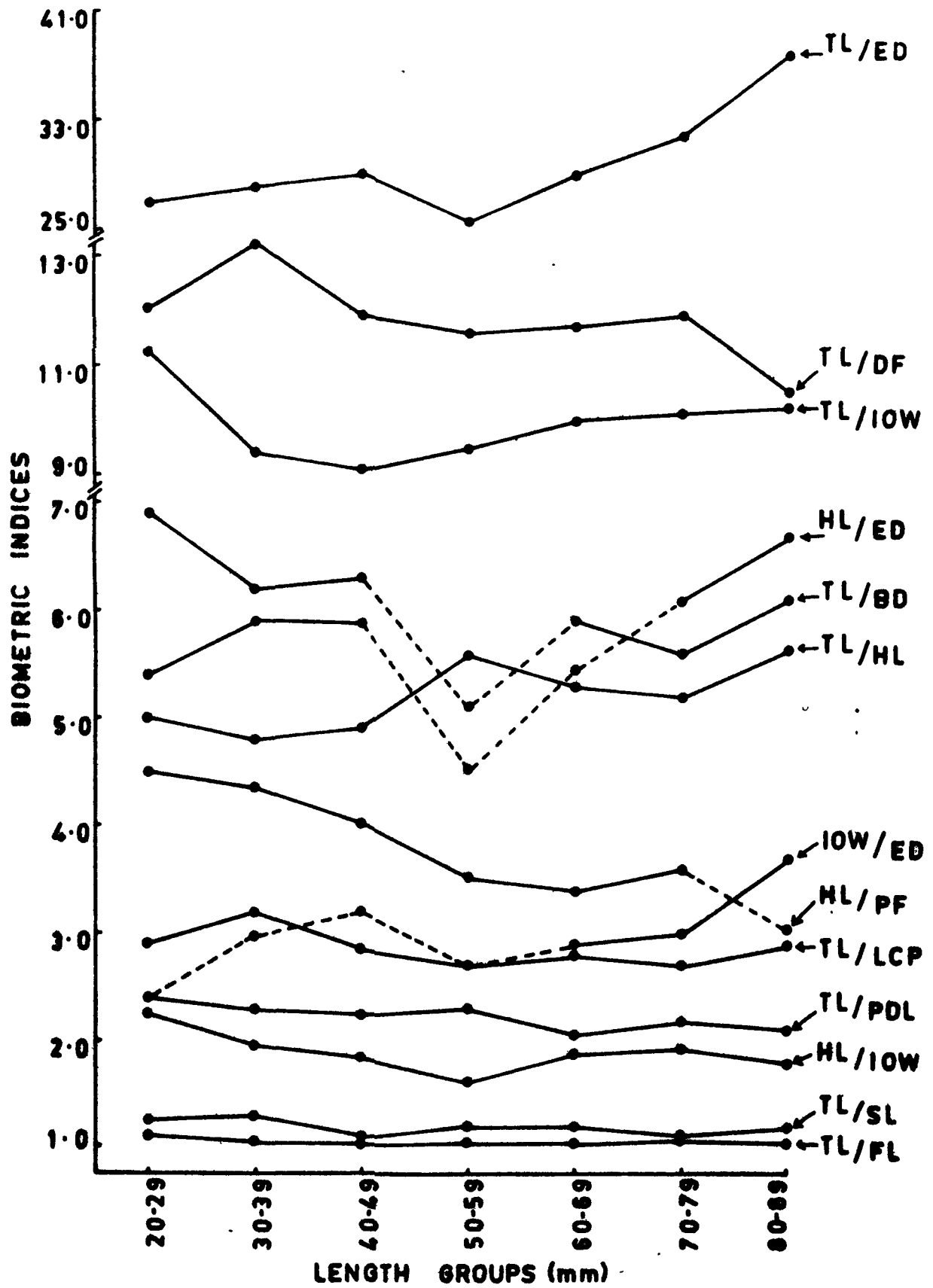


Fig.19: Biometric indices of *G. lissorhynchus* from Umshing stream

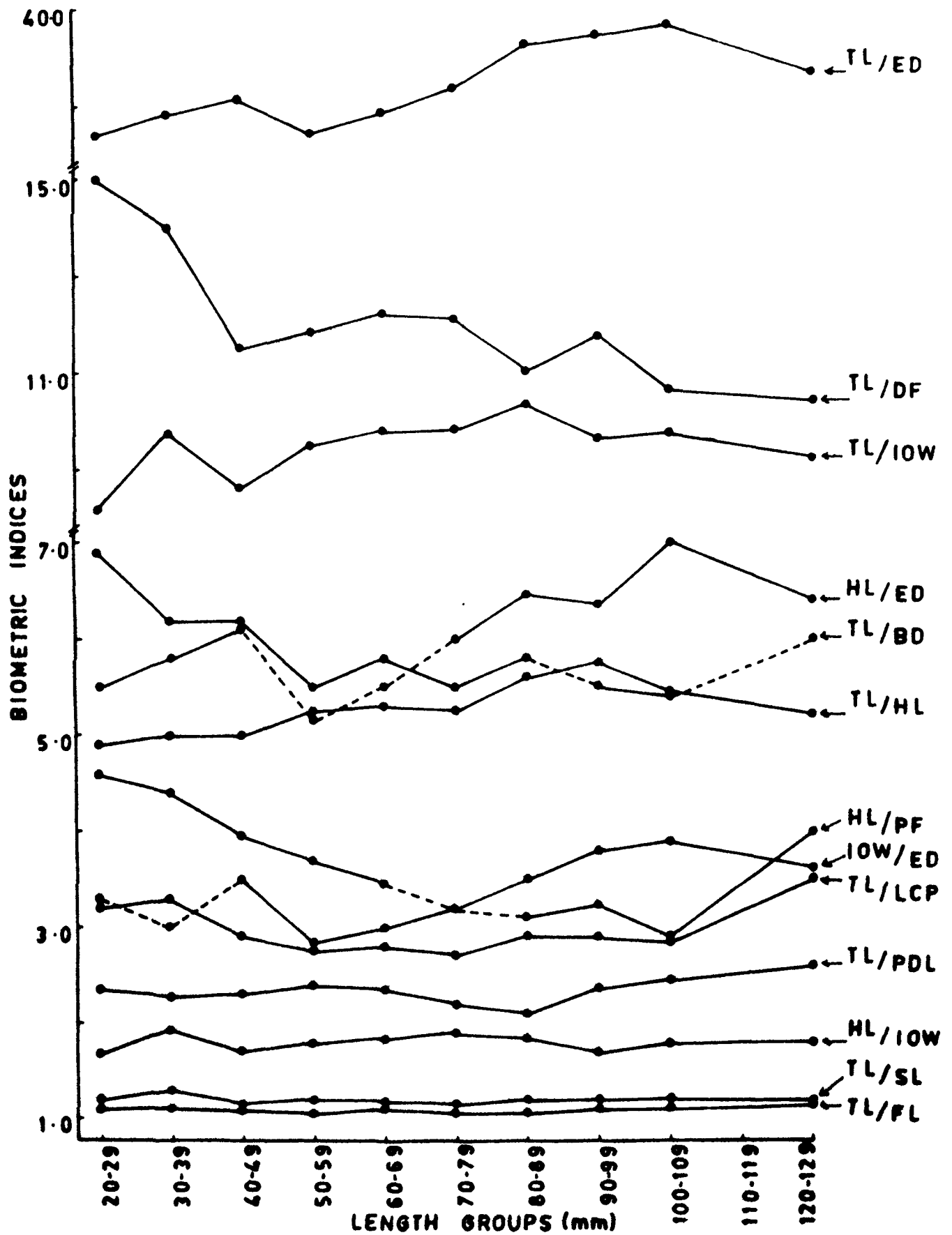


Fig.20: Biometric Indices of *G. lissorhynchus* (Pooled populations)

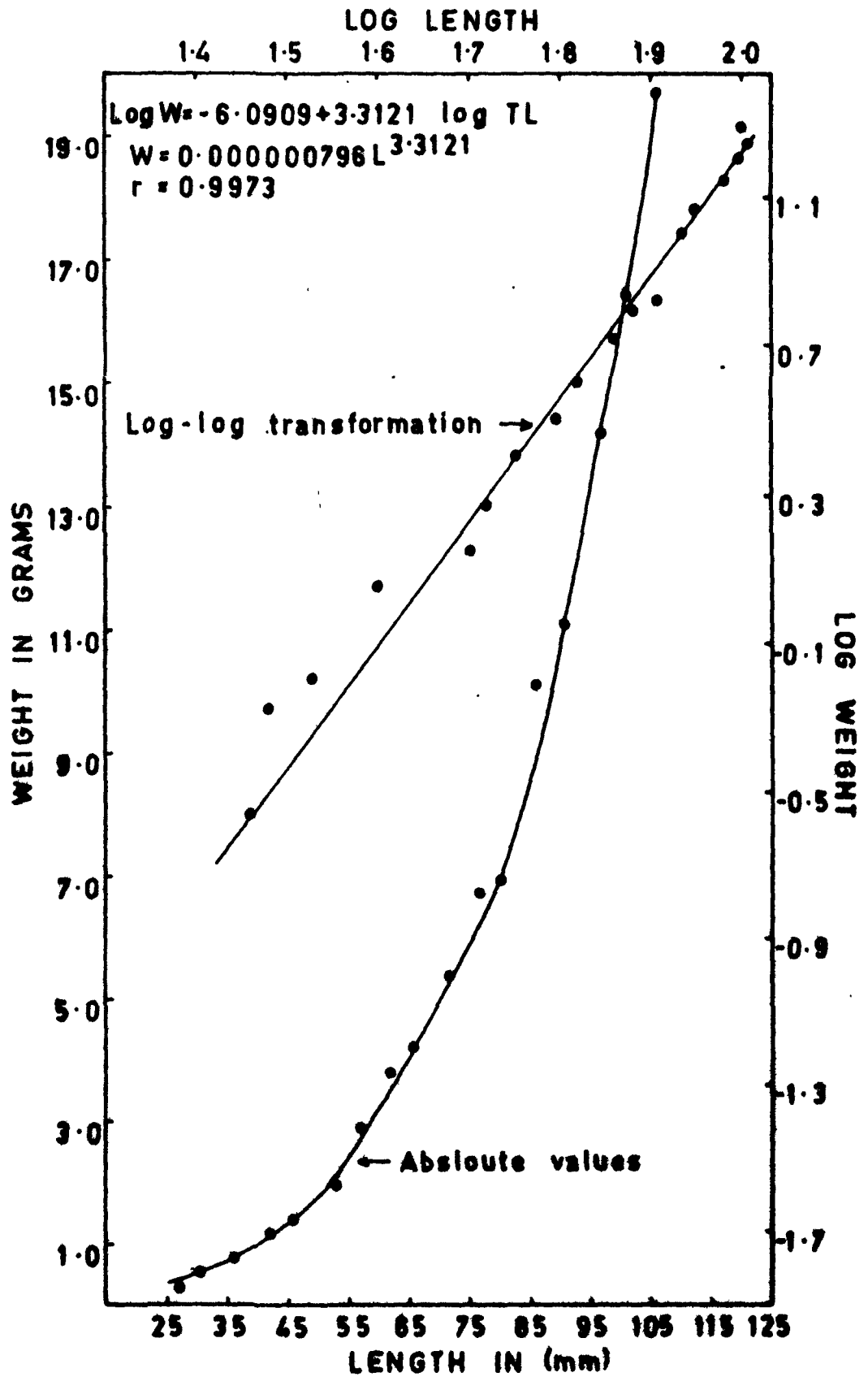


Fig.21: Length-weight relationship of Q. lissorhynchus (pooled data)

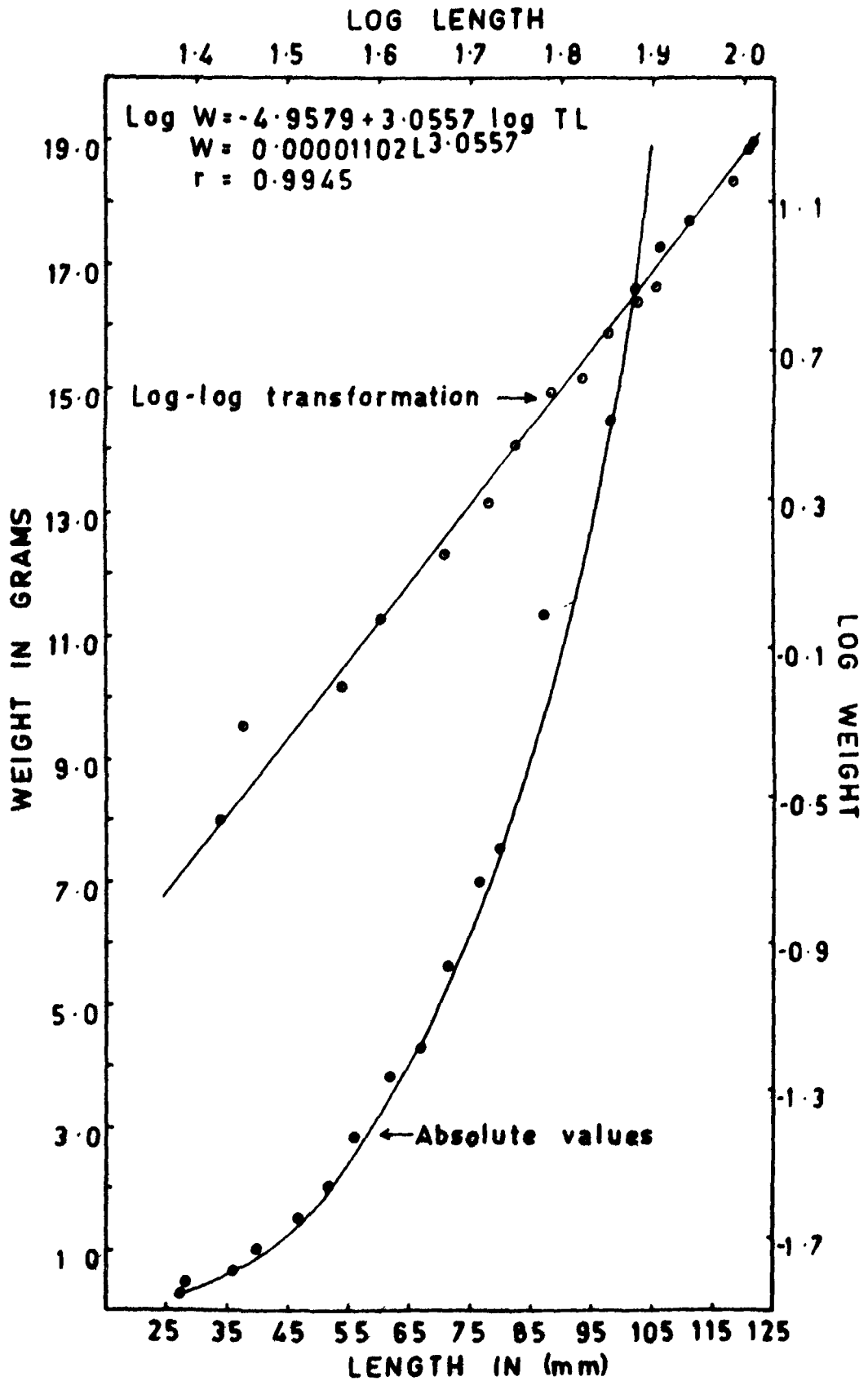


Fig. 22: Length-weight relationship of G. lissorhynchus from Umiam river

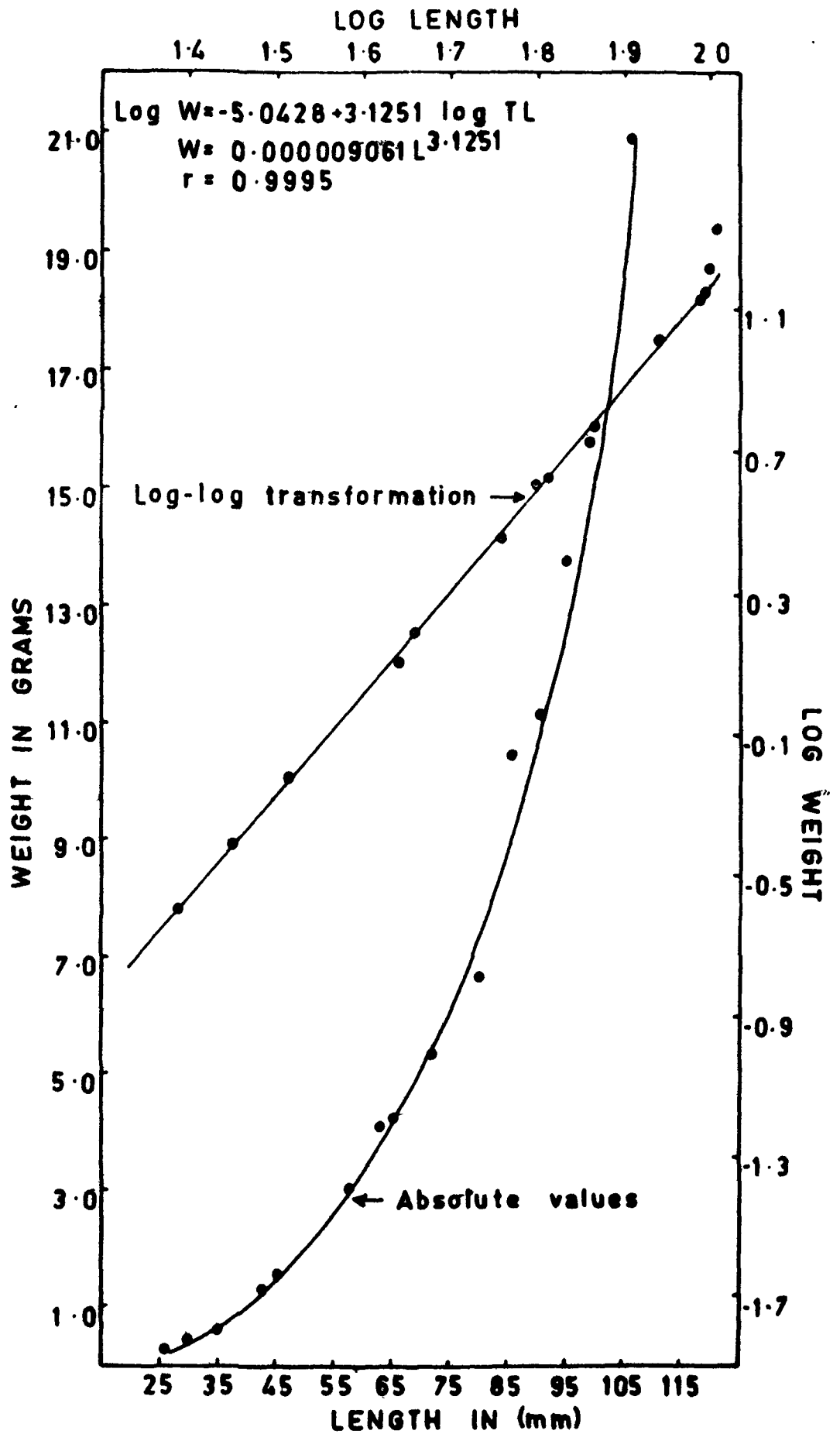


Fig.23: Length-weight relationship of Q. lissorhynchus from Umkrah stream

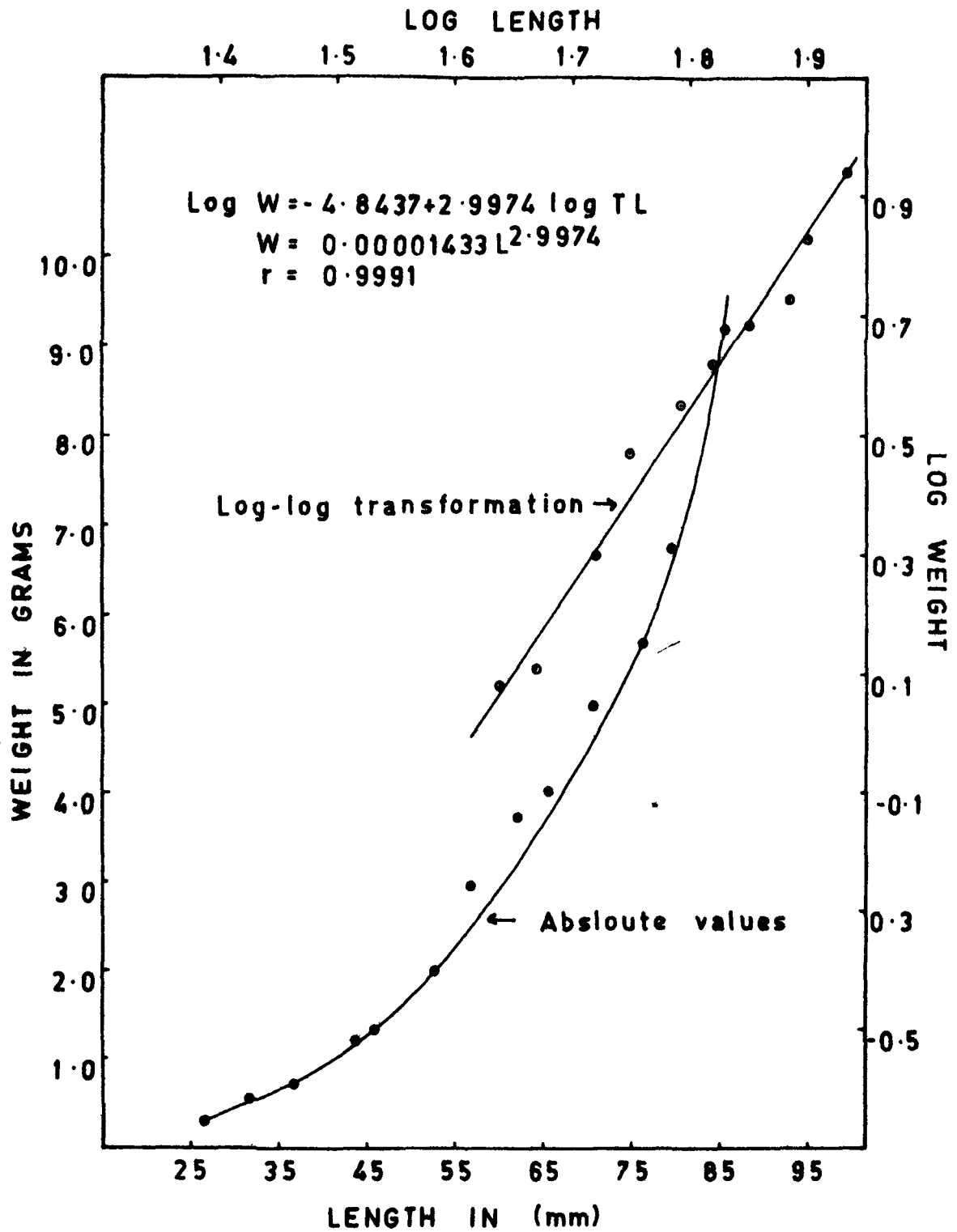


Fig.24: Length-weight relationship of G. lissorhynchus from Umshing stream

in the present study, may be due to the presence of some amount of detritus ingested along with the periphytons into the stomach, which supports the view of Soni and Kathal (1979).

According to Hile (1936) and Martin (1949) the value of exponent "b" usually ranges between 2.5 and 4.0. Allen (1938) suggested that the value for "b" remains constant at 3.0 for an ideal fish. The "b" values obtained for G. lissorhynchus from different ecosystems (Table-17) indicate that the fish closely follows the cube law and hence, according to Hile (1936) and Martin (1949), the species can be considered as "Ideal".

| CONDITION FACTOR

Monthwise averages of "Ponderal Index" or "K" values have been calculated to elucidate the seasonal fluctuations and have been shown in Fig. 25B. Such variation, as evident in Fig. 25B, in the condition factor may be attributed to different factors, such as environmental conditions, food availability and the gonadal maturity, as has also been suggested by many workers (Le Cren, 1951; Jhingran, 1972; Bashirullah, 1975). According to them, study on the changes in the condition values with the increase in length may yield evidence concerning the size at first maturity, while the seasonal fluctuation may reflect the condition of fatness and condition of gonads. In the present study it could be seen that juveniles have high condition factors as has also been observed by many workers like Menon (1950), Pillay (1954), Sarojini (1967), Varghese (1961), Kaur (1981) and Dasgupta (1982) in different species. The 'K' factor in the specimens from Umiam, Umkhrak and

Umshing systems show a tendency to increase with total length till they attain the size of 55 to 64 mm. This could be associated with the attainment of gonadal maturity as has also been reported by Dasgupta (1982). Further, it is evident from the results (Fig. 25A), that increase in body weight due to the weight of maturing gonads is followed by a decrease in the post-spawning period which is also reflected by the values of the condition factor of the species (Table-34). Similar trends have also been observed by Kaur (1981) and Dasgupta (1982) in murrels and game fishes respectively. The decline in "K" values as mentioned above is followed by another increase which may be due to high gastro-somatic indices (Table-34). In the present study, the pattern of fluctuations of 'K' values have been found to follow a similar trend in all the three populations, though the magnitude of fluctuations varied to some extent from one population to another. This supports the view of Jhingran (1972), that 'K' factor may be influenced by the variable environmental conditions. The present study indicates that specimens from Umkhrak stream have a better growth ($b=3.1251$) than those from Umiam river ($b=3.0557$) and Umshing stream ($b=2.9974$).

In G. lissorhynchus high values of ponderal index have been observed in October in all the three population under study which may be due to the high feeding intensity during that period (Table-33). During May to September, "K" values of the species have been observed to decline rapidly which may be due to their reduced feeding activity coupled with the onset of maturation and breeding period as with the increase in the volume of the gonads, the

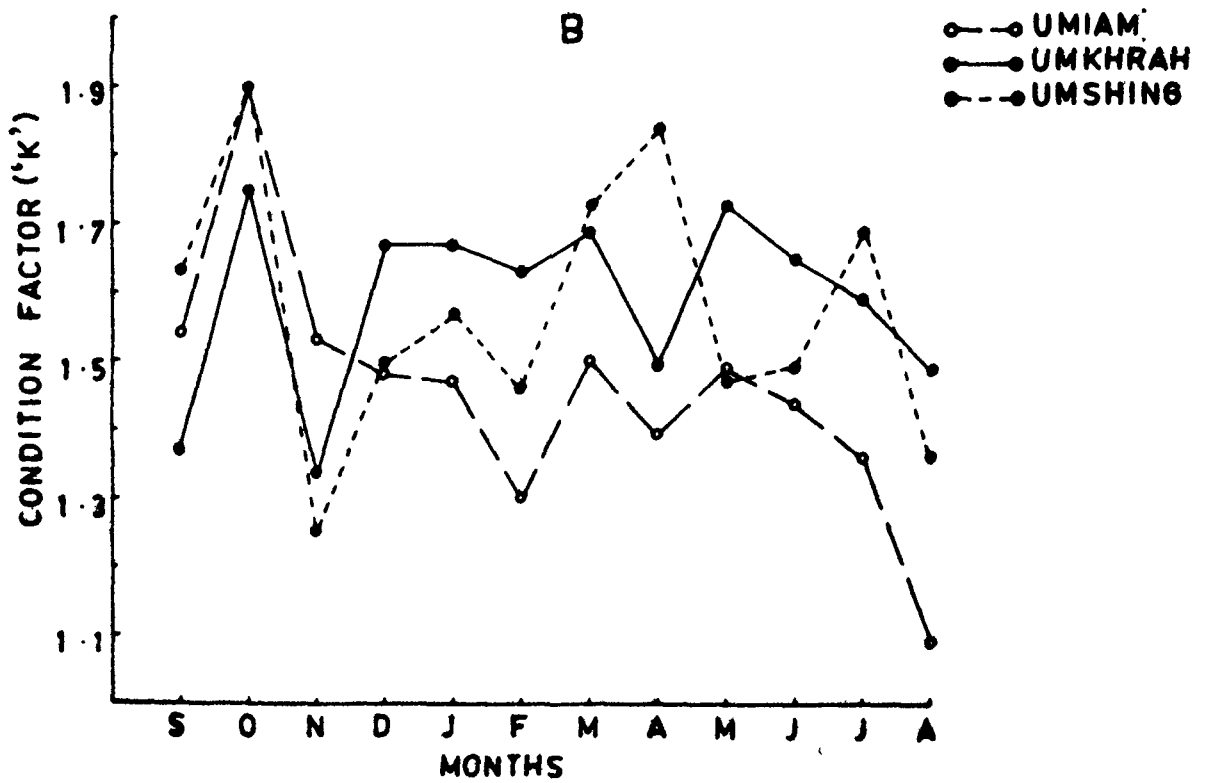
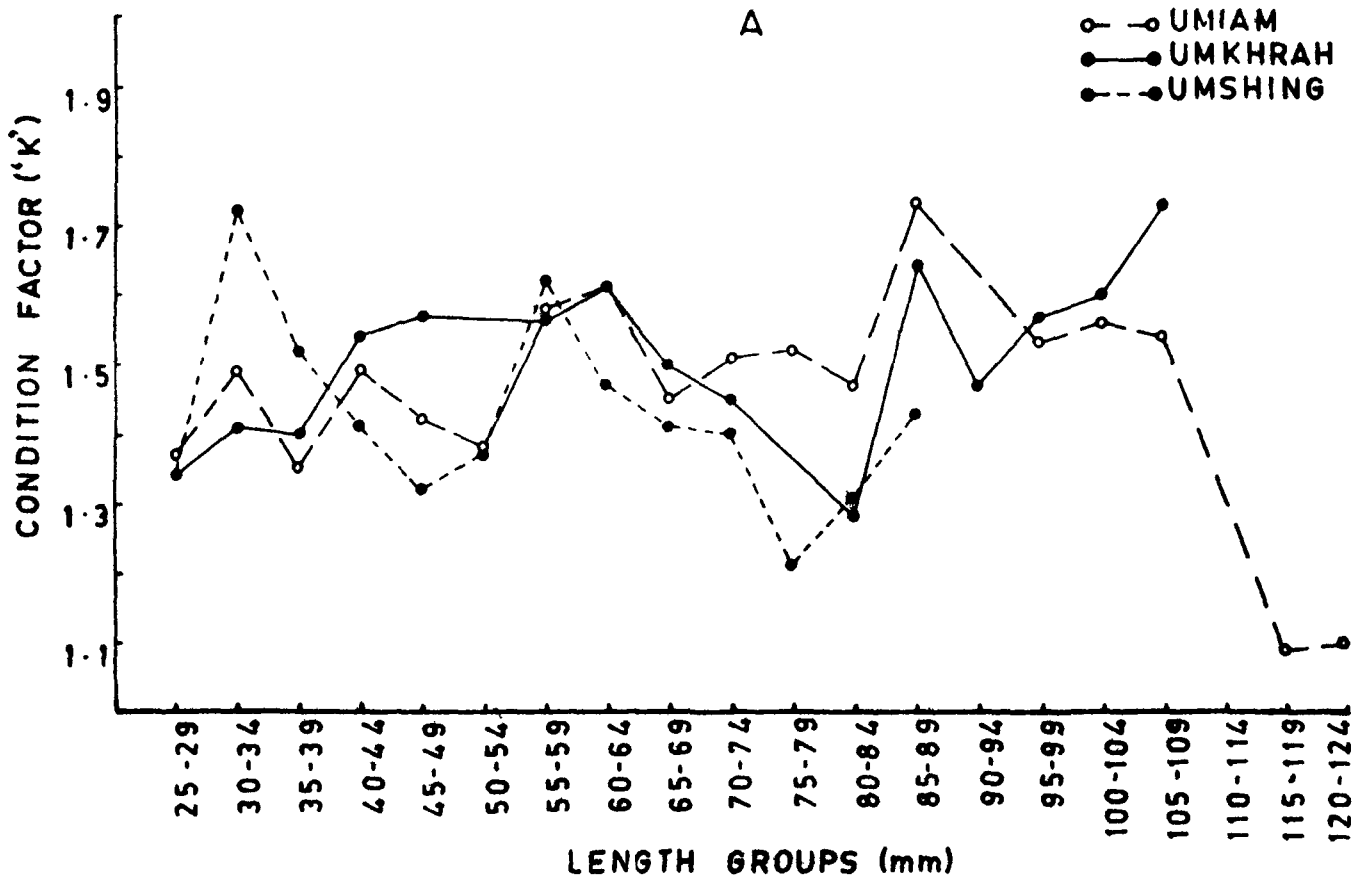


Fig 25: 'K' factor in G lissorhynchus
 (A) In different length groups (B) Seasonal

visceral cavity space diminishes leaving comparatively little room for the intake of food. The Ponderal Index in the remaining months has been found to fluctuate from population to population even during the same season (Fig. 25B).

The present result supports the view of Weatherley (1972) that even among the members of one population, samples on a single date, there may be a considerable variation in 'condition' with the length of the fish. According to him, fish populations display considerable changes in average condition, reflecting normal seasonal fluctuations in their metabolic balance and in their pattern of maturation and subsequent release of reproductive product. Even the state of fullness of the alimentary canal may influence 'K' factor (Weatherley, 1972).

MATURITY AND SPAWNING

Studies on maturity indicates that Garra lissorhynchus matures once in a year and has a definite breeding season (August-September). The occurrence of ripe individuals from June to September and its complete absence thereafter reveal that spawning season is over by October. The availability of the specimens having spent stage during October lends credence to this observation. Moreover, the Ponderal Index or 'K' factor for the same individuals also indicate a similar trend regarding the spawning season. The occurrence of only one batch of maturing ova clearly demarcated from the immature stock indicate that the spawning is strictly periodic, restricted to a definite period and that each individual spawns once during an annual cycle. Walford (1932)

stated that fishes which spawn only once in a season, contain only two types of ova i.e. immature and mature. Similar observations have also been found in the present study which further supports the results obtained by Hickling and Rutenberg (1936), Prabhu (1956), Qasim and Qayyum (1961), Natarajan and Jhingran (1963) and Kaur (1981). It has also been observed that the species (Garra lissorhynchus) from the Umkhrah and Umshing streams mature little earlier lengthwise than the individuals from the Umiam population (Fig. 28). The Umkhrah population was recorded to have the highest growth rate ($b=3.1251$) compared to other two populations. This suggests that good amount of food was available in the system as is also evident from the results on the periphyton population (Chapter I), which in turn might have accelerated its gonadal maturity. Such differences in attainment of maturity have been noted by Nikolsky (1963) and Kaur (1981) who stated that better food availability accelerates the gonadal maturation in fish which seems to be true in the present study.

Gonado Somatic Index (Gn.S.I.) values when plotted against body length (Fig. 27) indicate a tendency of the Gn.S.I. to increase with body length. It is also seen that the seasonal peaks (Fig. 26) in the mean Gn.S.I. coincided with the peaks in the percentage occurrence of mature individuals, hence, Gn.S.I. can be used as an index of gonadal development. The Gn.S.I. values in the present study reveal that a sudden rise of the mean index occurs while the species (G. lissorhynchus) passes from resting to maturity stages. A sudden fall in the Gn.S.I. value has also been observed after 'reproduction' stage which further confirms

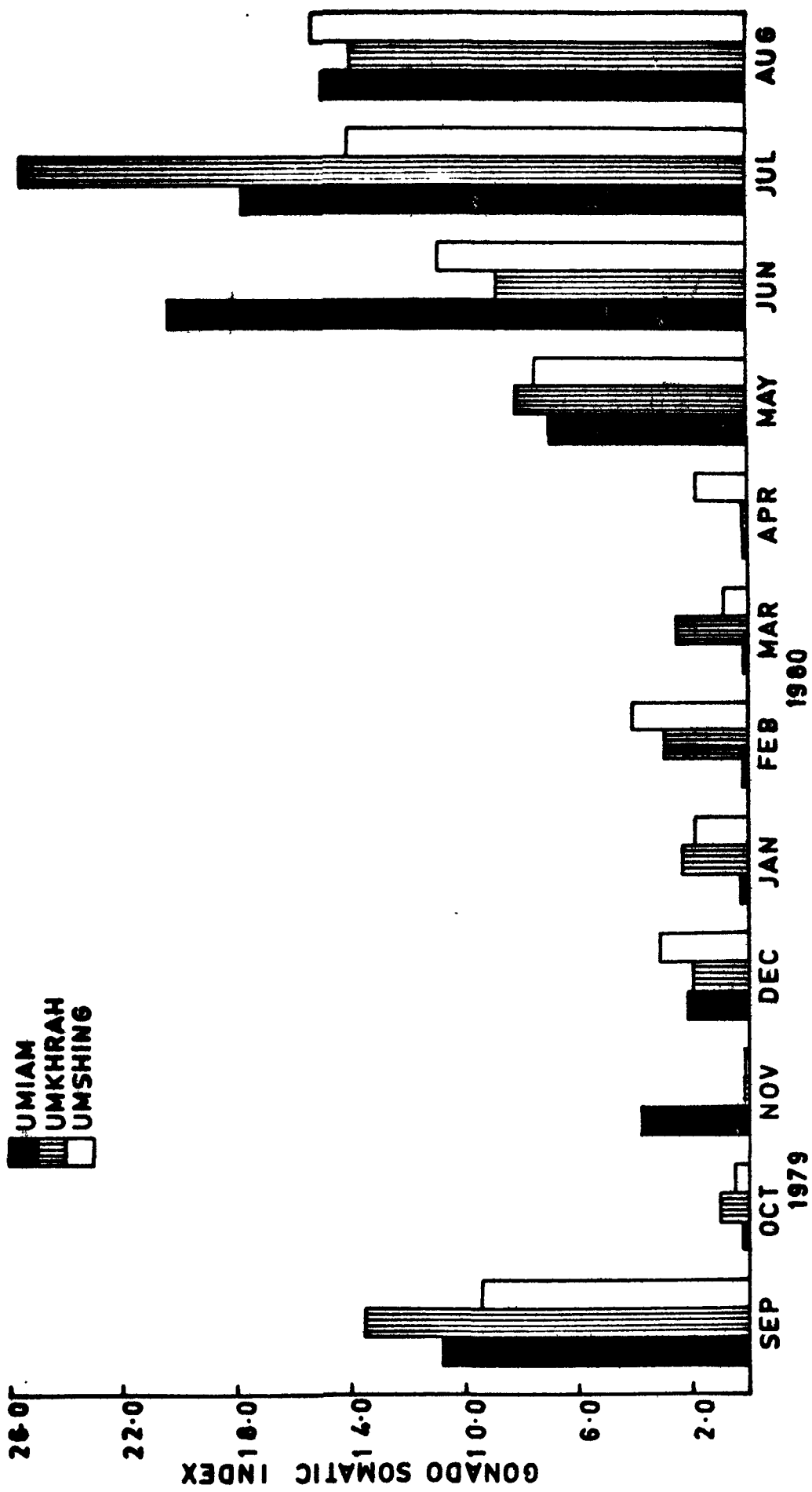


Fig.26:Gn.S.I of G. lissorhynchus

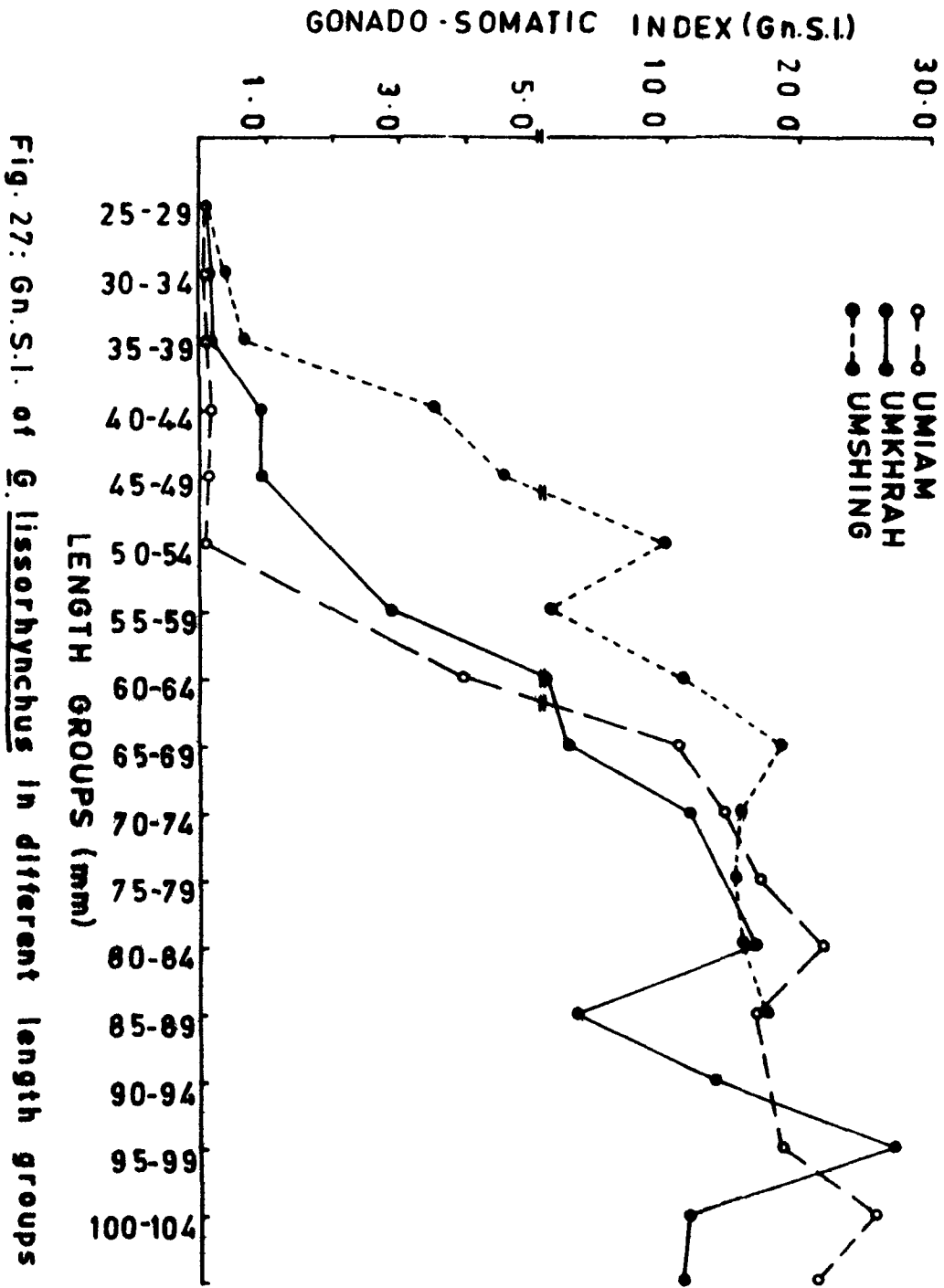


Fig. 27: Gn.S.I. of G. lissorhynchus in different length groups

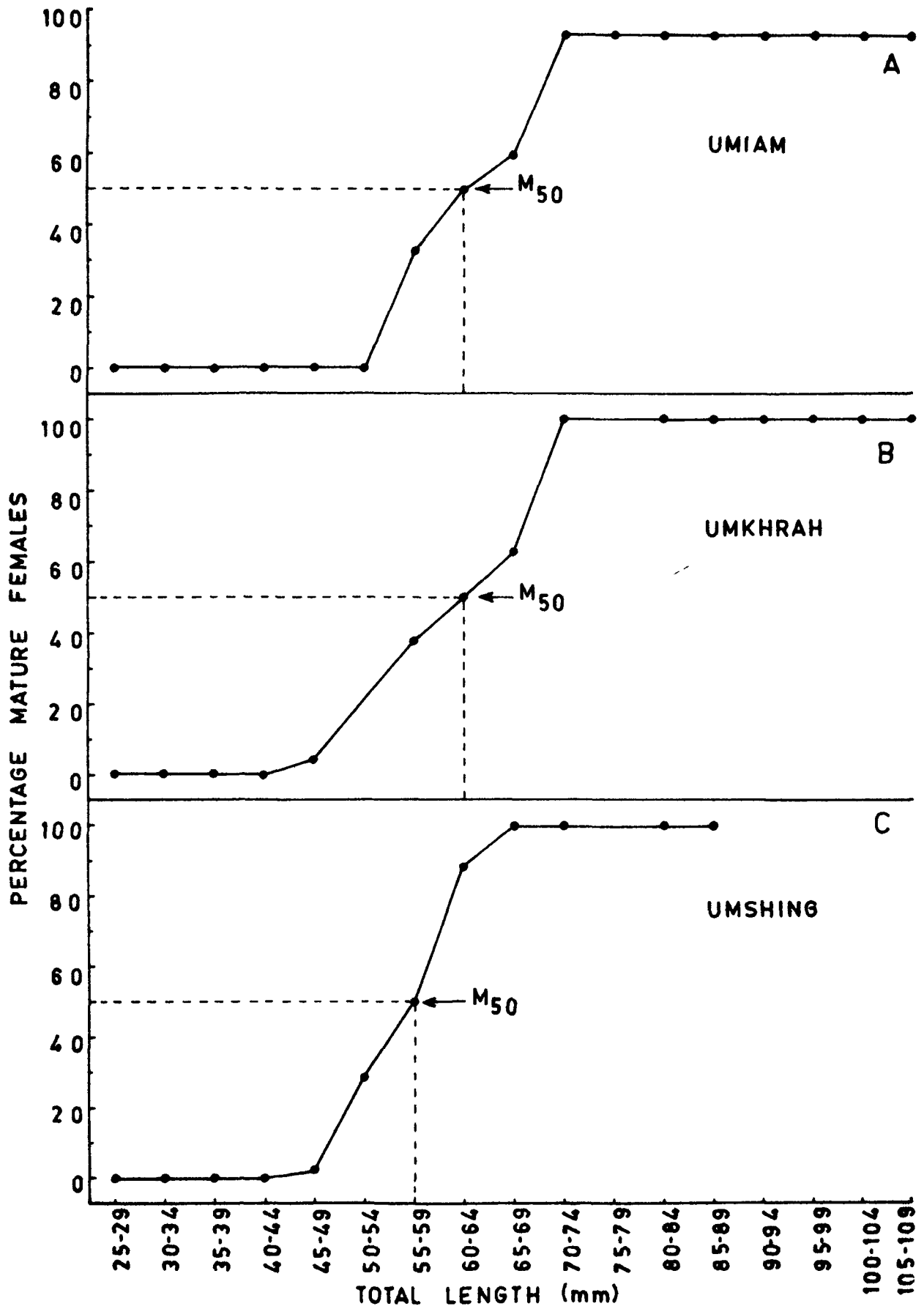


Fig. 28: Maturity (M_{50}) of female *G. lissorhynchus*

the findings of Nikolsky (1963) and Natarajan and Jhingran (1963). Similar results have also been obtained by Kakuda and Nakai (1981), Kaur (1981) and Dasgupta (1982).

FECUNDITY

On plotting fecundity values against body length (Figs. 298, 308 & 318), it has been observed that the egg counts increased with increase in the length. It is also seen that there is an increase in the spread points describing this relationship with increasing size of the species. Similar findings have also been reported by Habib (1979) in Puffer fish, Kaur (1981) in Channa gachua and Dasgupta (1982) in Acrossocheilus hexagonolepis. According to Kesteven (1942), the gonad maintains a relationship with the remainder of the body of the organisms and since the average size of maturing or mature ova are constant in general, the number of eggs, being a number of units of weight, will show an exponential relationship with the length in the same way as does the length of the entire organism. Jhingran (1961), Qasim and Qayyum (1963) and Bagenal (1967) have studied the relationship between fish length and fecundity and reported the exponential value to range around 3.0. Higher values of 4.5 in case of Irish Herring (Farran, 1938) or at a rate proportional to fifth power of body length (Hodder, 1963) have also been reported. However, in the present study the exponential index was found to be 2.4541, 3.2210 and 3.3094 for the specimens from Umiam, Umkhrah and Umshing respectively. The exponent value (2.4541) in Umiam population indicates that the fecundity increases at a lower rate than that of the body weight in relation to its total length, as is

also evident from the exponent value of 3.0557 as obtained in the length-weight relationship during the present study (Table-17). From the exponential values of 3.1251 and 2.9974 obtained in the respective length-weight relationship of the Umkhrah and Umshing populations (Table-17), it appears that the fecundity increases at a rate slightly faster than that of the body weight in relation to total length as indicated by the exponent values of 3.221 (Umkhrah) and 3.3094 (Umshing). The value of exponent obtained in the relationship between ovary weight and total length were found to be 0.0394, 0.0555 and 0.0462 respectively for Umiam, Umkhrah and Umshing populations. The exponential value as obtained with the body weight and ovary weight relationship in all the three systems were found to be 0.1295, 0.1615 and 0.0948 respectively. Thus, it can be said that ovary weight increases at a lower rate than the total length and body weight.

According to Simpson (1951), fecundity is directly proportional to body weight. Bagenal (1967) pointed out that weight is more closely related with the condition of the fish than its length. Yuen (1955), found the relationship between fecundity and weight to be curvilinear as has also been observed in the present study. Logarithmic relationship between fecundity and length, body weight and ovary weight and between gonad weight and length in the species were found to be linear (Figs. 29-32).

Relative fecundity, which is the ratio of egg number to body weight (Hardisty, 1964) is a measure of fecundity that takes into account the weight differences of individuals. In the present

study, relative fecundity was also estimated to make comparisons among the three populations as the basic assumption in using relative fecundity is that the number of eggs per gram does not increase or decrease with the size of the fish (Bagenal, 1973). However, it is seen that the relative fecundity on average basis was found to be lower (71.25) in the Umkhrach stream population (Table-24), whereas the highest average relative fecundity (94.78) was found in the Umiam rivers individuals (Table-23). This may be attributed to the fact that the relative fecundity in the species may change markedly due to change in the "condition" of the species as has been mentioned by LeCren (1951) and Raitt (1968) for Perch and Norway Pent respectively.

According to Bagenal (1963), in most of the fish, the number of eggs does not change significantly as the season progresses but the gonad weight increases due to an increase in water content or organic matter derived from food or organic matter transferred from somatic tissues and only in the later case, if the total weight remains constant, and thus makes the calculation of relative fecundity meaningful.

The maximum fecundity values for G. lissorhynchus in the present study have been found to be 1808, 1410 and 1003 in the individuals from Umiam, Umkhrach and Umshing population respectively (Tables-23-25). This indicates that the species (Garra lissorhynchus) have comparatively higher fecundity than cyprinids of the same size. However, Kryzhanovskiy (1949) stated that a species that protects its eggs and young ones is usually less

fecund that the one that does not. Such cases have also been observed by Fryer and Isles (1972) who discussed the significance of brood and egg size in Cichlids and attributed a close association between egg number and size, as the mouth brooders were found to have fewer and larger eggs than the guarders. Kaur (1981) also pointed out the reason for low fecundity in Channa gachua as the species builds nest and guards its young ones. Hence, these studies suggest that parental care has profound effect on the number of eggs produced, as it would be easier for the fish to take care of their eggs and young ones if they are less in number (Kaur, 1981). However, in the present study, no such evidence could be detected with Garra lissorhynchus which supports the field observations of absence of parental care in this species.

McFadyen et al (1965) found that trout from infertile streams had a lower egg production. He further stated that the difference in age at first spawning and growth rate, together with an actual lower fecundity all led to a lower reproductive rate than in fertile streams. Leggett and Power (1969) correlated fecundity and food supply with land locked salmon. The variations in fecundity as reported by Bagenal (1971), Raitt (1968) and Hodder (1965) were associated with food through population density. Nikolsky (1961 and 1969) mentioned a number of Russian papers associating food supply and fecundity, and the relationship of nutrition and fecundity were reviewed by Woodhead (1960). Thus, fecundity can be associated with the food availability, which is also supported by certain experimental works by Scott, 1962; Hester, 1964; Bagenal, 1969; Wotten, 1973, who related food with

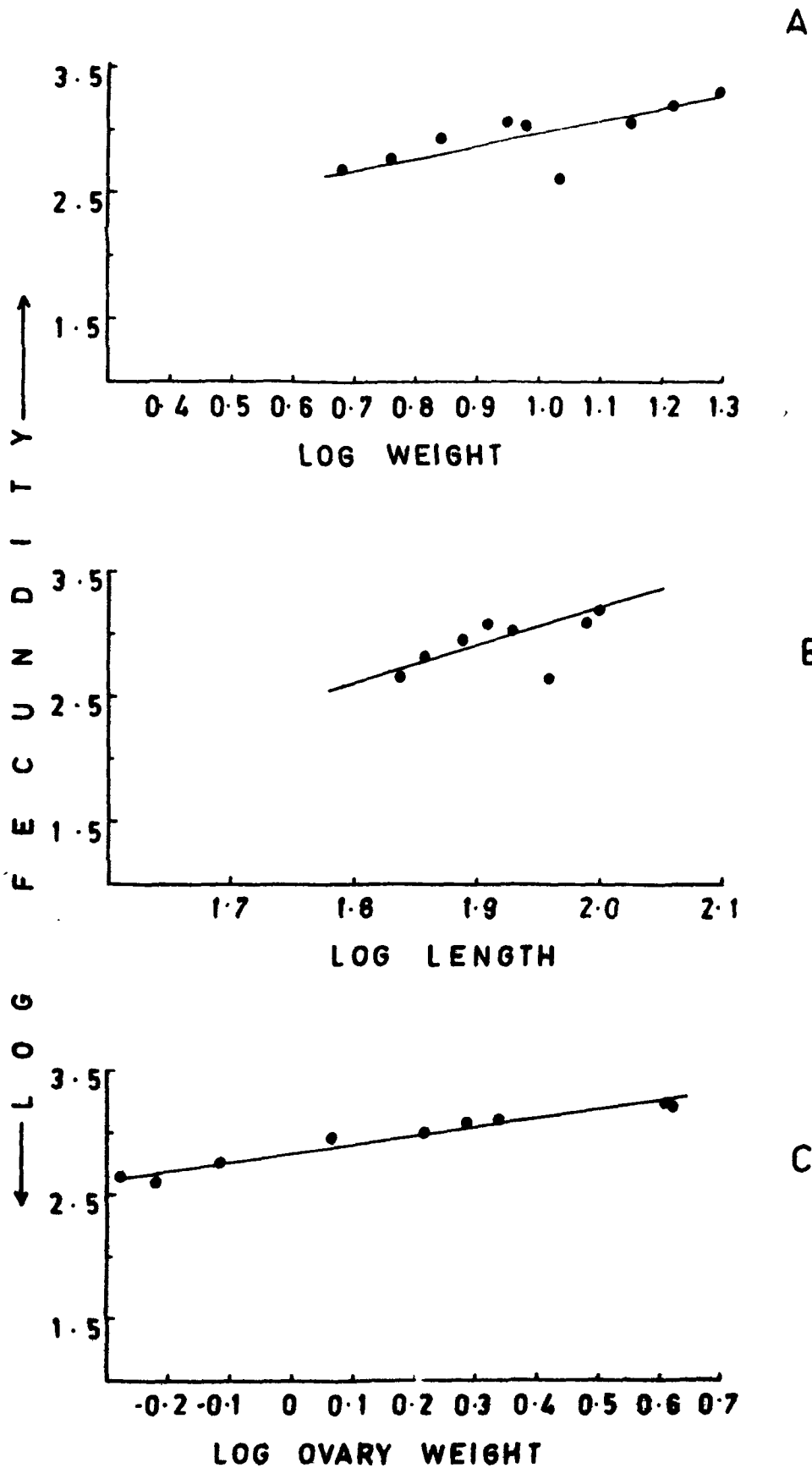


Fig. 29: Log relationship between fecundity with various parameters in G. lissorhynchus from river Umiam

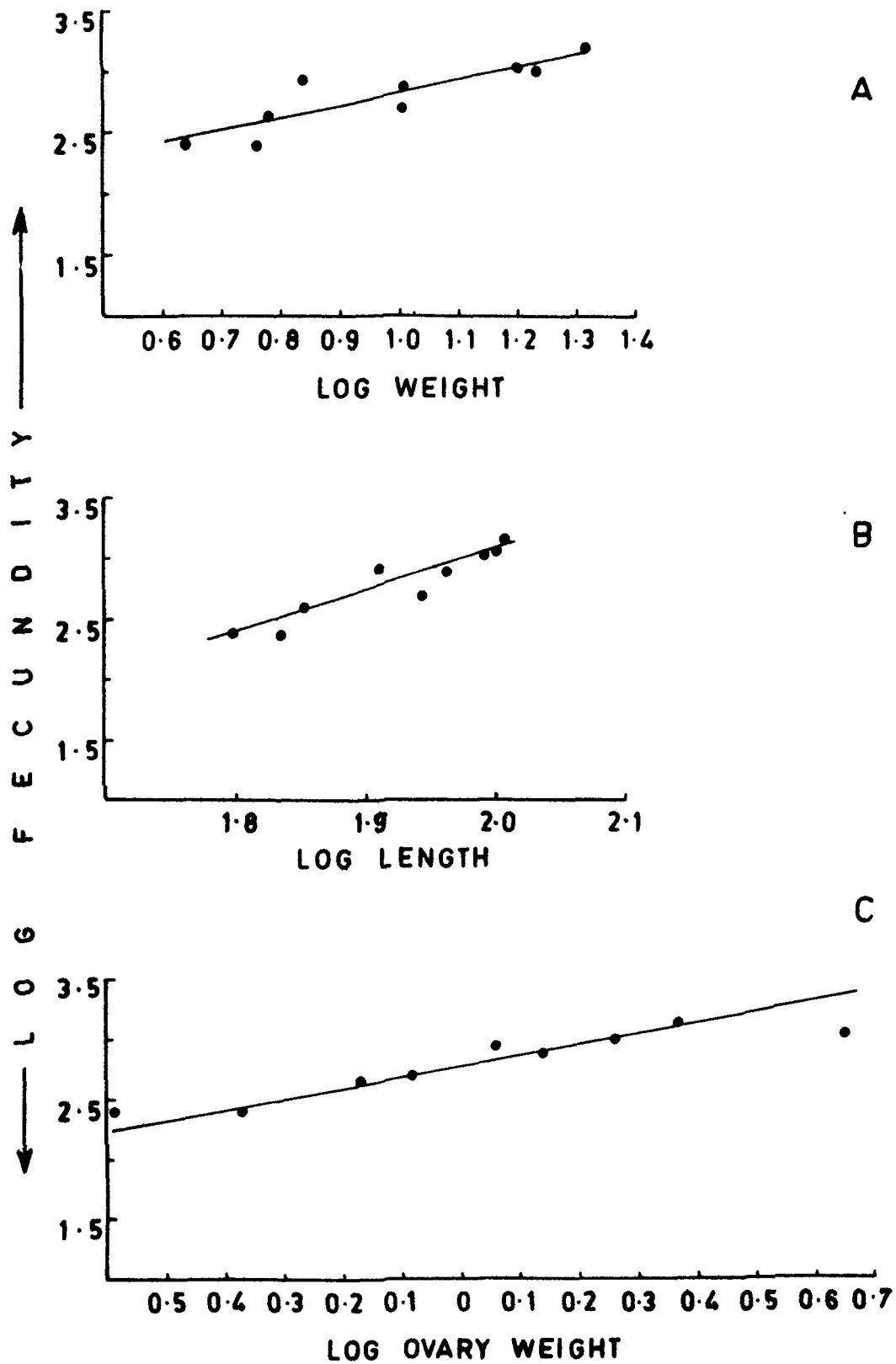


Fig.30: Log relationship between fecundity with various parameters in *G. lissorhynchus* from Umkrah stream

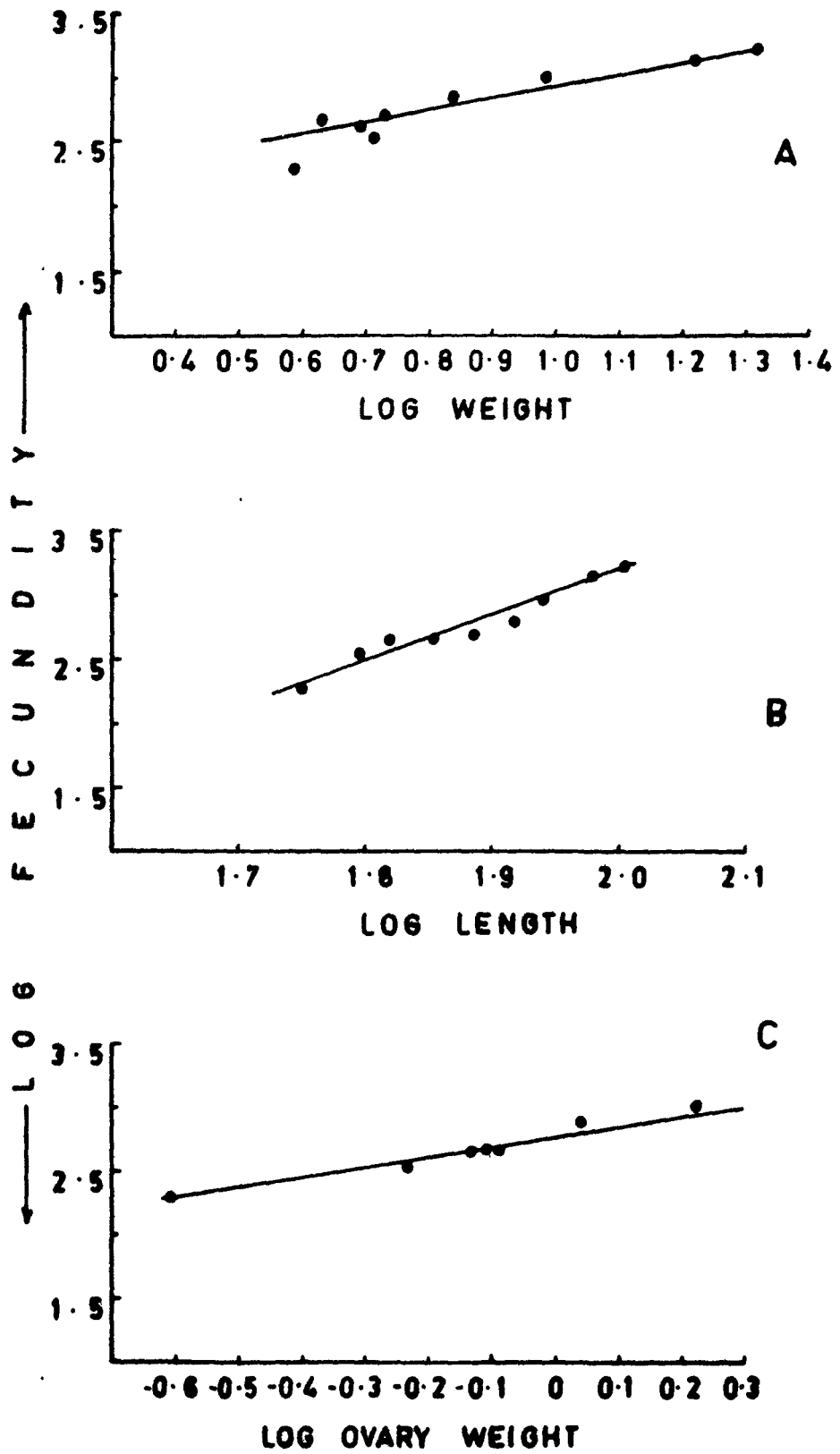


Fig.31: Log relationship between fecundity with various parameters in *G. lissorhynchus* from Umshing stream

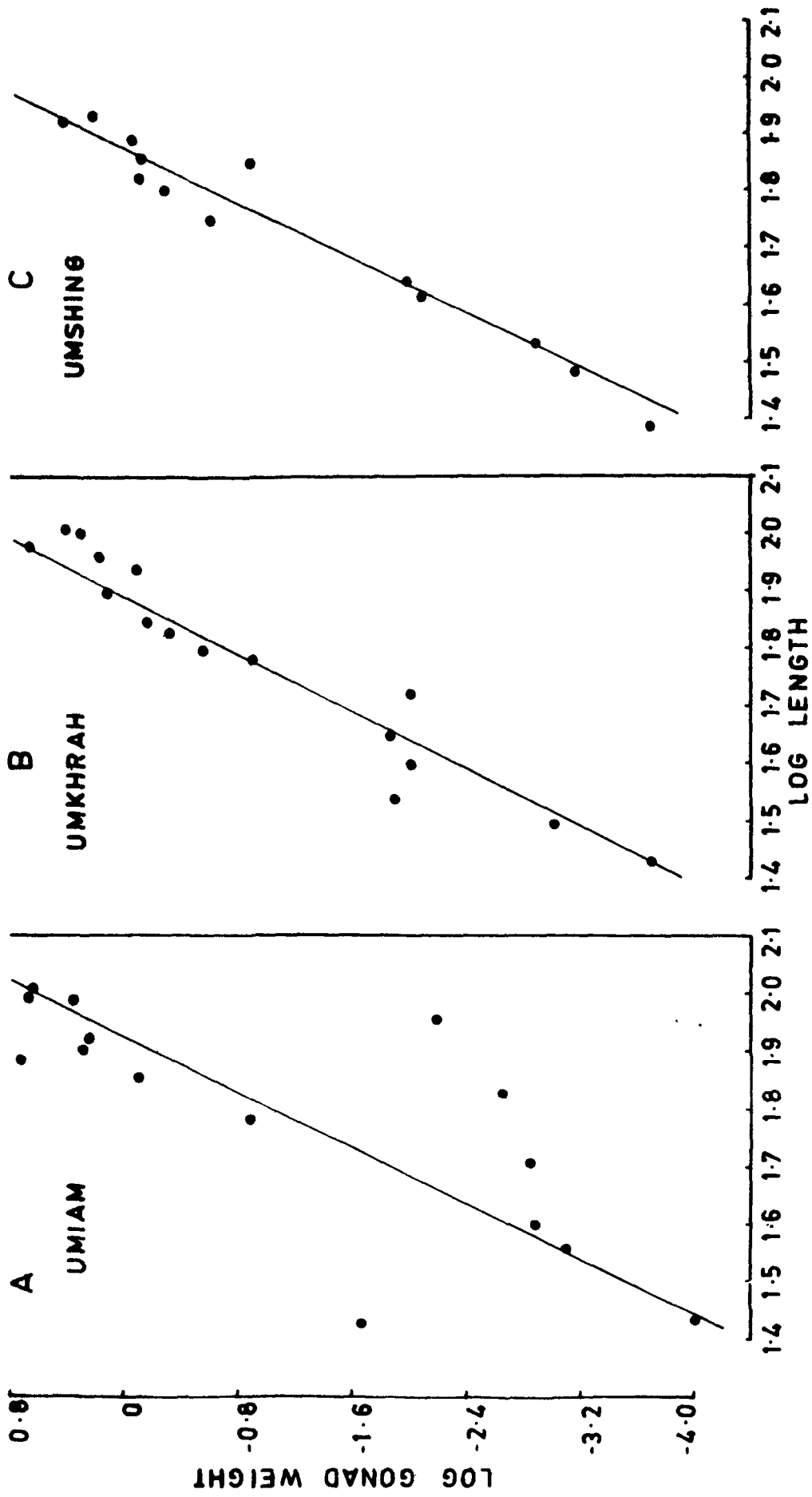


Fig.32: Log relationship between gonad weight and total length in G. lissorhynchus

fecundity confirming the low food intake leading to lower number of eggs. This seems to be true in the present case with the specimen of Umshing stream, where the food were less available in their immediate environment (Chapter I) in comparison to other systems.

FOOD AND FEEDING HABITS

The present study based on the numerical method reveal that the diet composition of Garra lissorhynchus can be divided into the following broad categories :-

- (a) Periphytic Bacillariophyceae
- (b) Detritus
- (c) Chlorophyceae
- (d) Myxophyceae

Nikolsky (1963) recognised three main categories of food on the basis of their preference of diets in fishes.

- (a) Basic food - which is normally eaten by the fish and occupying most of the gut.
- (b) Secondary food - which is frequently found in the gut, but in smaller quantity and
- (c) Incidental food - which is found rarely in the gut contents.

Accordingly, the basic food of Garra lissorhynchus as seen from the present study can be considered as periphytic diatoms comprising of 94-98% of the total gut contents. The secondary food of the species, as indicated by the results were found to be detritus and non-periphytic algae (Tables-30-32). Any type of incidental food, however, could not be detected in the present study. Somvanshi and Bapat (1979) reported the basic food of Garra mullya to be diatoms (26.24-52.29% of the gut contents).

According to them, algae, other than diatoms, comes next forming 14.22 to 36.68% and debris consisting of 10.5-26.72% of the gut contents. Majhi (1980) observed that Chlorophyceae formed the major food item comprising 81.91 to 94.80% in the gut contents of Garra annandalei. He further observed that Bacillariophyceae formed 6.5-16.0% of the gut contents in the same species.

A change in diet with increase in length of fishes has been widely reported by Keast (1966), Larsen (1967), De Silva (1973), Adams (1976) and Kakuda and Matsumota (1978). However, in the present study, no such change in the diet could be observed except in the quantitative differences in the food items (Fig. 41). It has been observed that the gut of young specimens have more periphyton than the adult. The decrease in the percentage composition of periphyton is found to be occupied by the non-periphytic algae in adults (Fig. 41). Such observations were also recorded by Somvanshi and Bapat (1979) in Garra mullya.

The present study further indicates that feeding intensity is higher among the smaller individuals, may be owing to the fact that metabolic activities are generally higher in young ones. Similar results in Herring (Clupea harengus) and Spent (C. sprattus) have been reported by Hardy (1924), Marshall et al (1939), De Silva (1973) and in Murrels (Channa gachua) by Kaur (1981).

Feeding in relation to condition factor indicated an inverse relationship in the Umiam and Umkhras population, whereas degree of the inverse relationship was of lesser extent in the Umshing population (Fig. 35). The relation of feeding intensity to

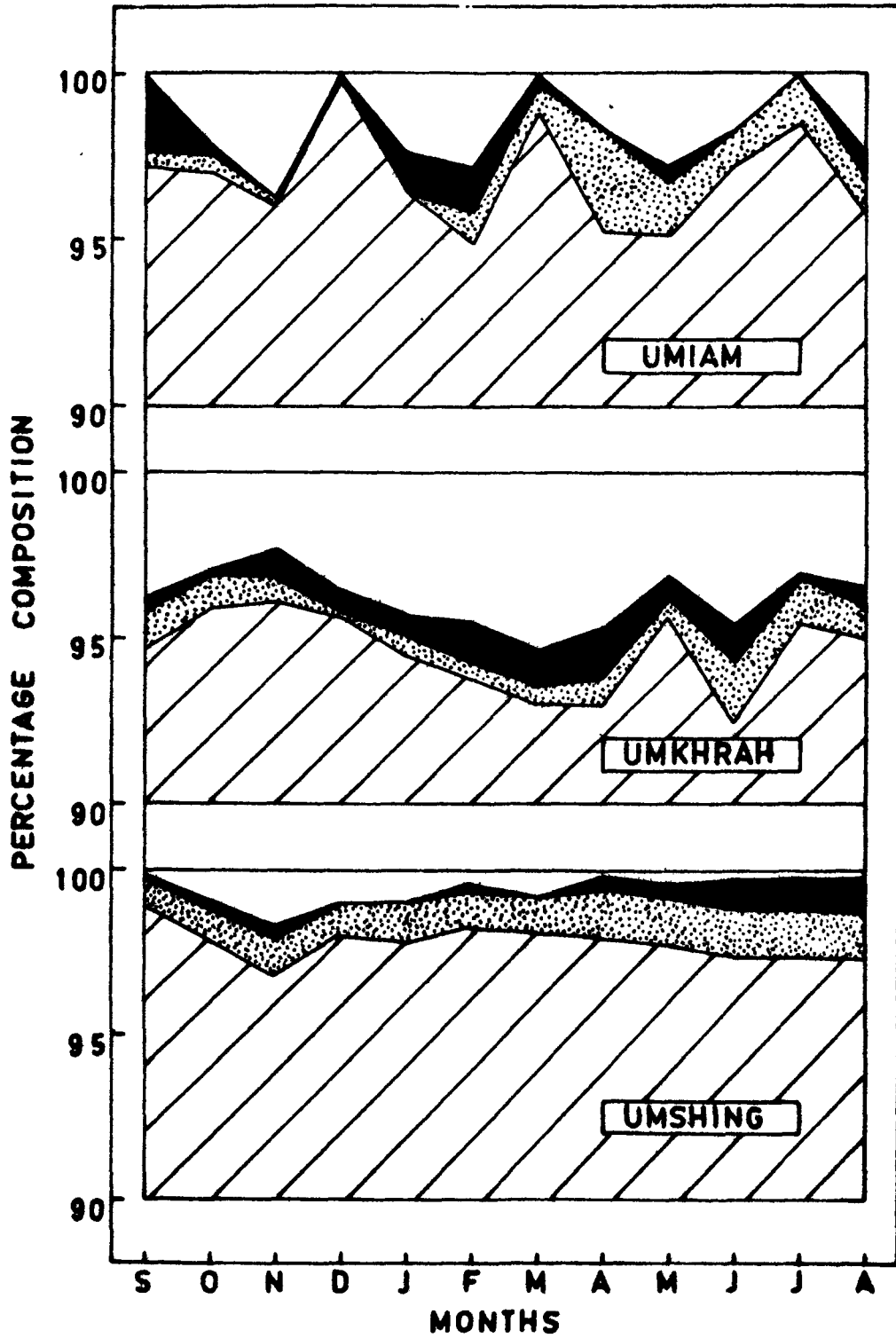
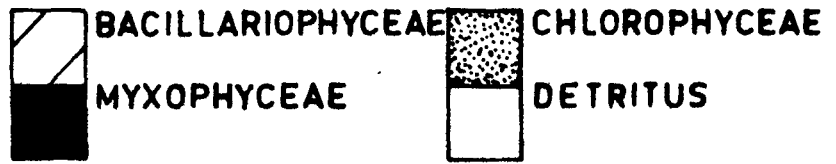


Fig.33: Seasonal variation in the gut contents of Garra lissorhynchus

condition factor in various length groups showed a clear inverse relationship (Fig. 36) in all the three population. An inverse relation is also observed between the feeding intensity (G.S.I.) and the gonado-somatic index (Table-33).

According to Jhingran (1971) the principal factors that are likely to effect the seasonal variations in the ponderal index are generally food and sexual maturity. The G.S.I. values as obtained (Table-33) during the study reflects the assessment of spawning season as has also been indicated by the seasonal fluctuations in the condition factor (Fig. 25B) of the species.

The feeding intensity declined (Fig. 34B) with the progressive maturation of gonads (Table-33) from May to September in all the three systems. Observations on the maturity and breeding of Garra lissorhynchus have shown that this species breeds from August to September (Table-22) indicating that the periods of low feeding intensity coincide with the spawning season. The low feeding activity during peak breeding season may be attributed to the completely developed gonads, permitting limited space in the abdominal cavity for intake of food, which again (feeding intensity) increased after the spawning season.

The coincidence of low feeding with peak breeding season has also been observed by many workers. Various authors (Hardy, 1924; Hickling, 1933; Fage and Veillet, 1938; Menon, 1950; Desai, 1970; Wolfret and Miller, 1978; Kaur, 1981; Dasgupta, 1982; and Biswas, 1982, have reported a decrease in the rate of feeding intensity and amount of food consumed with the maturation of gonads

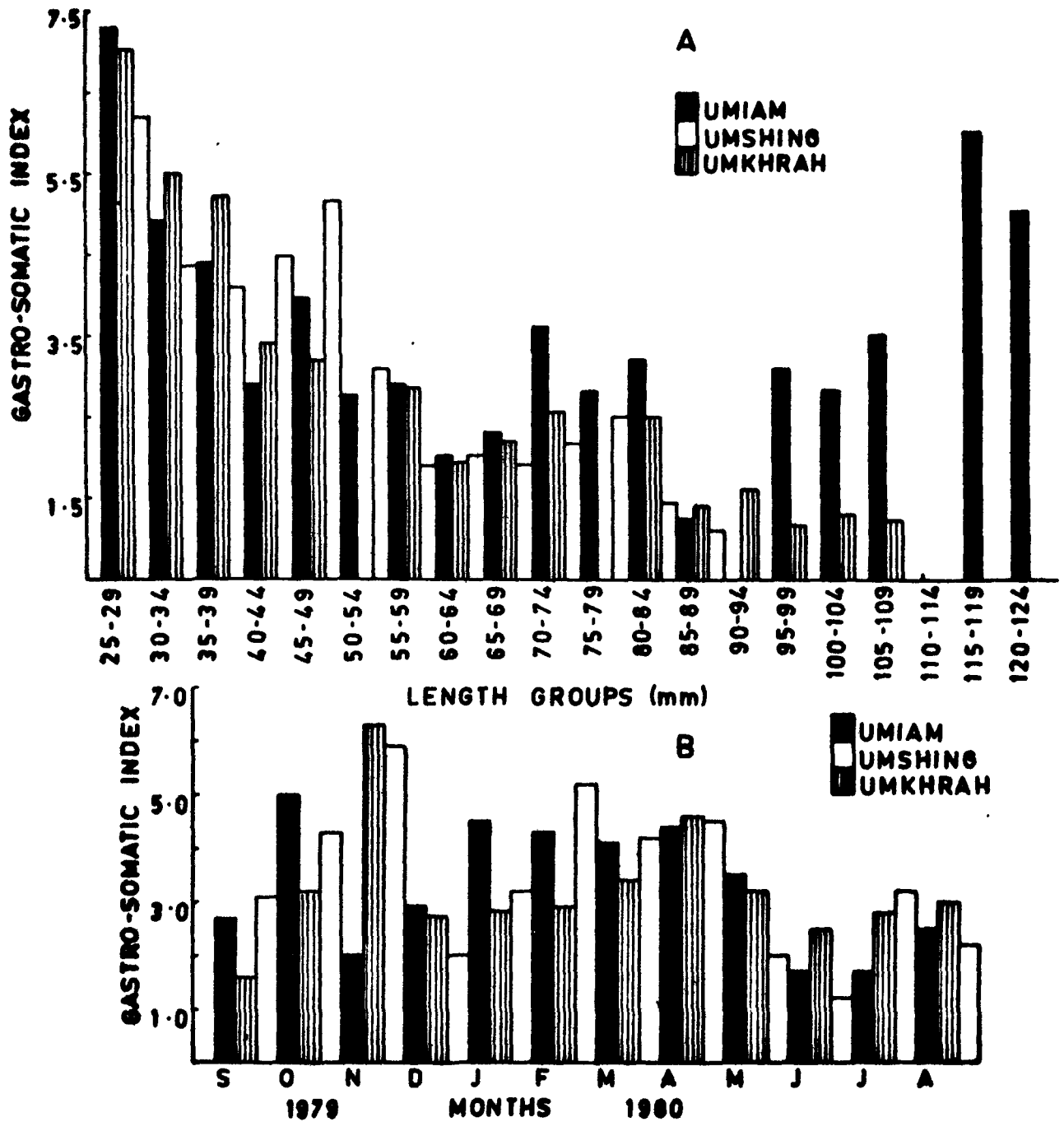


Fig.34: G.S.I. of *O. ligostichus* (A) in different length groups (B) seasonal

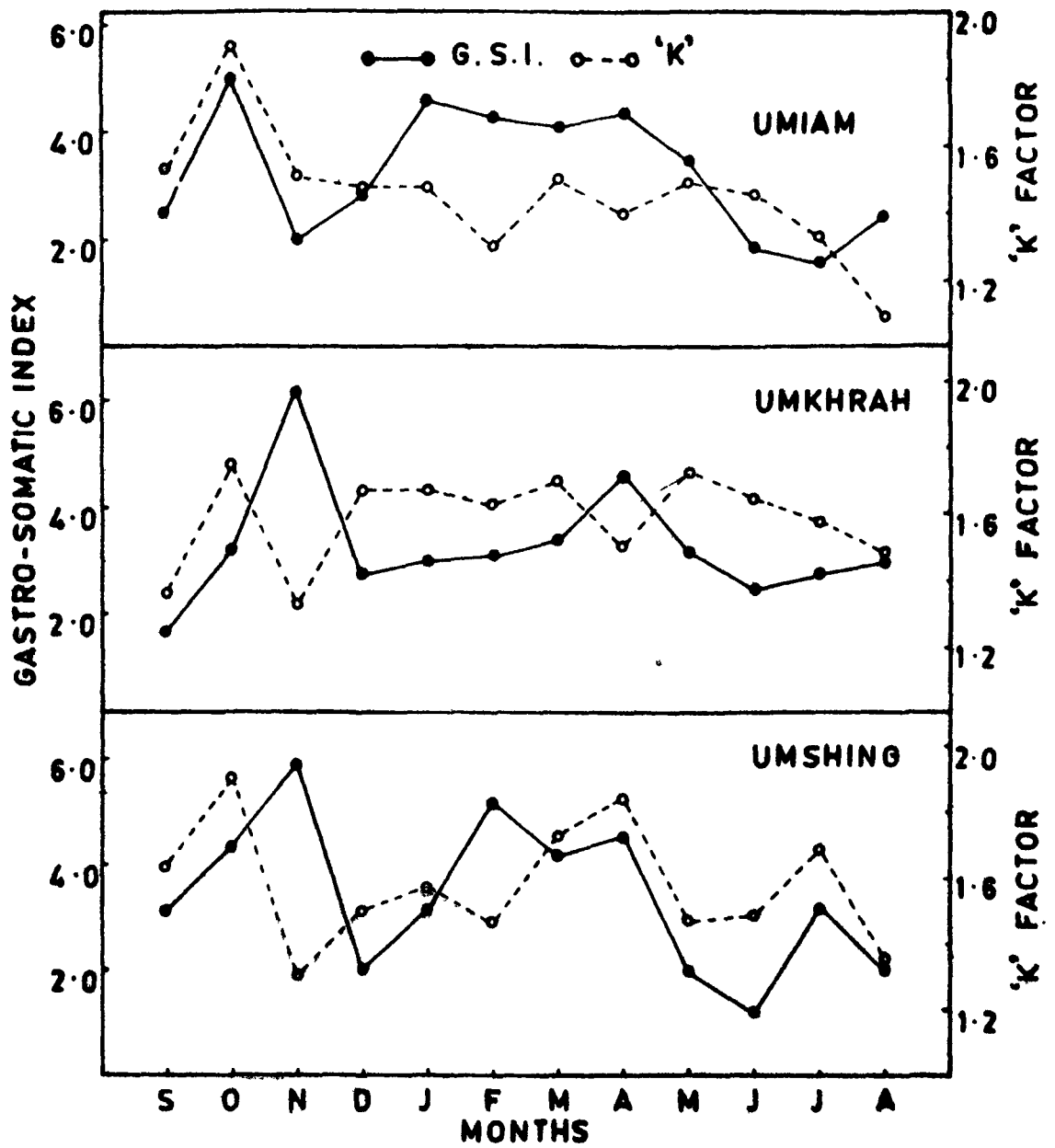


Fig.35: Relationship between G.S.I. and 'K' factor of G. lissorhynchus

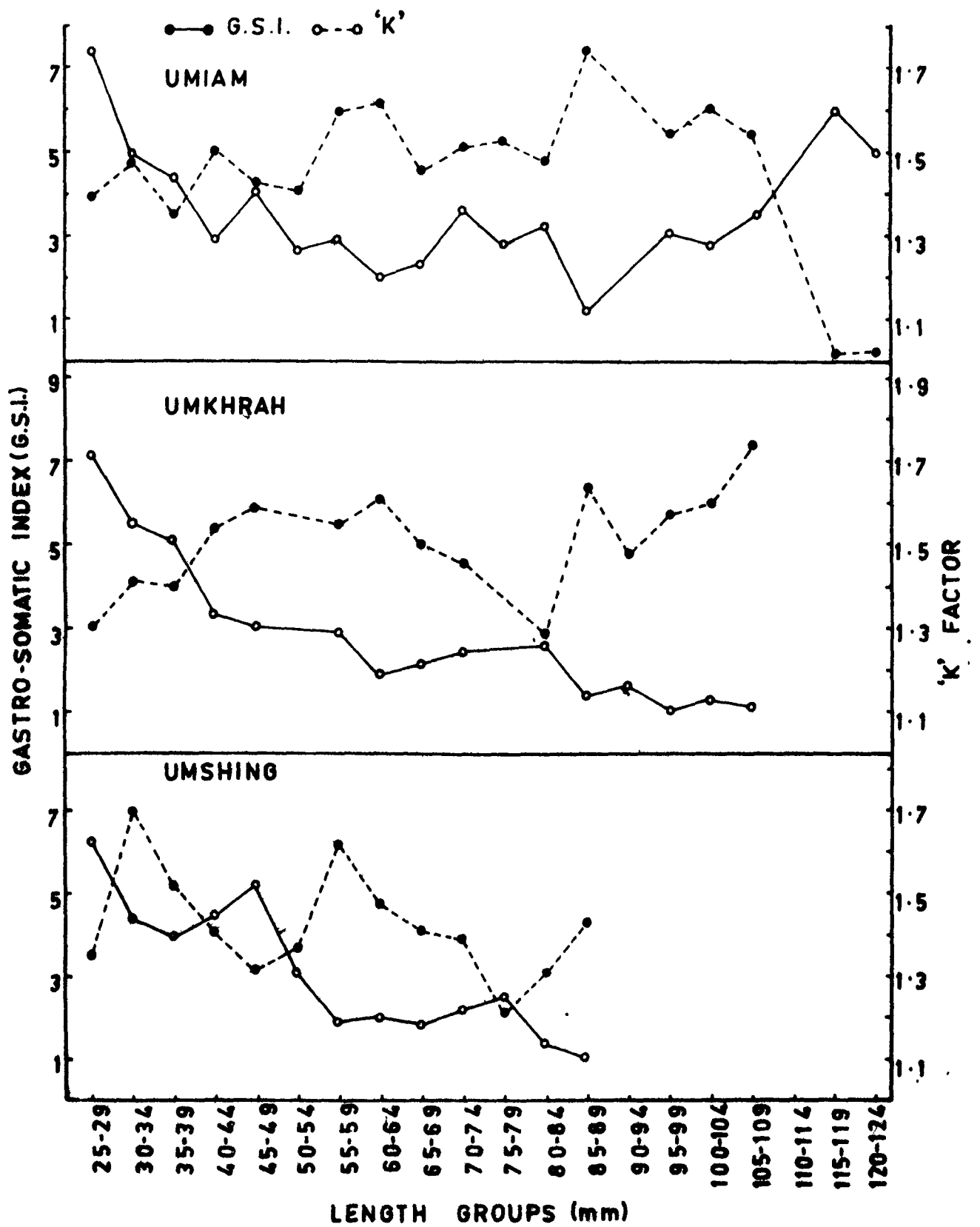


Fig. 36: Relationship between G.S.I. and 'K' factor at different size groups of G. lissorhynchus

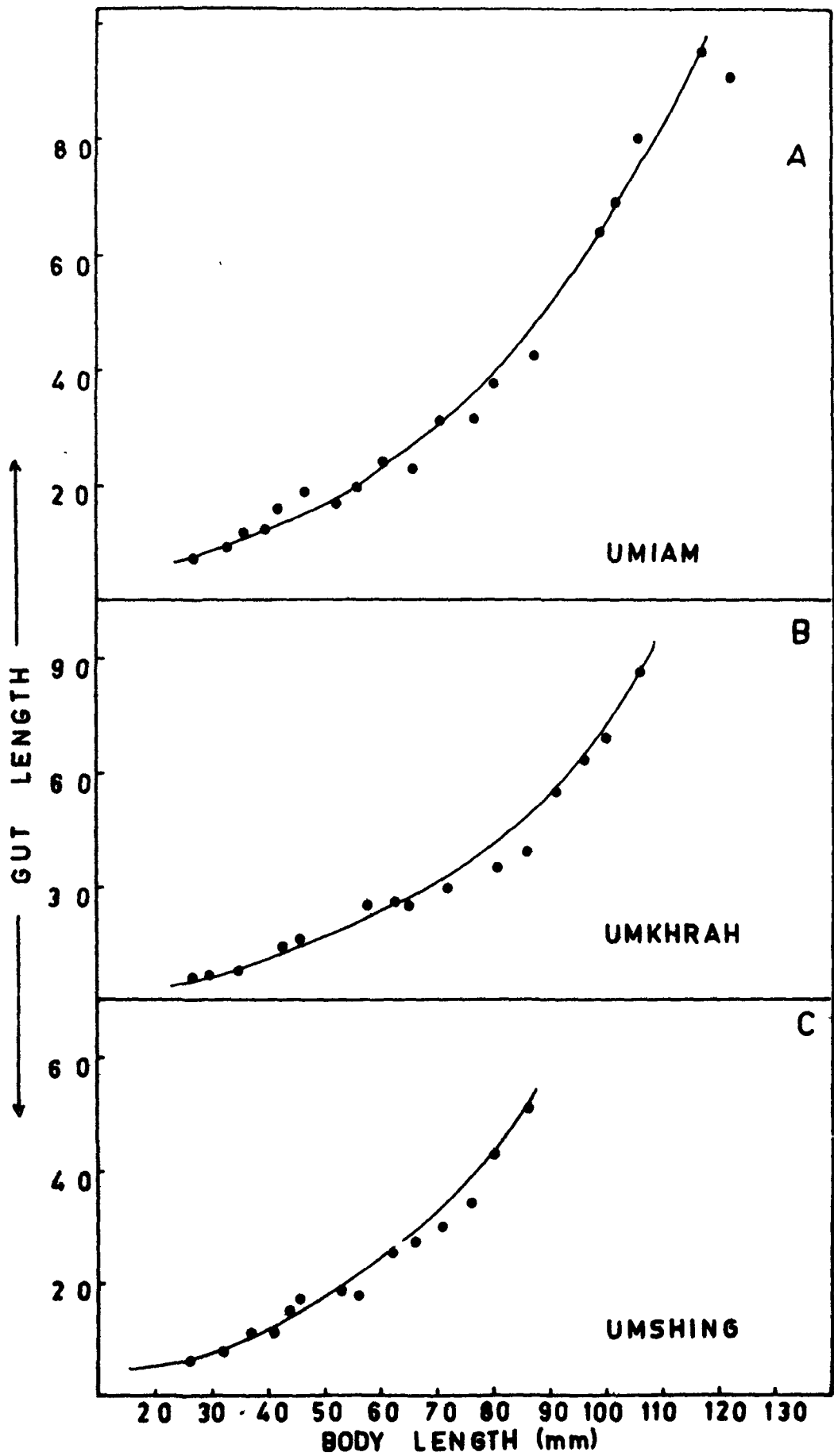


Fig.37: Relationship between gut and total length of *G. lissorhynchus*

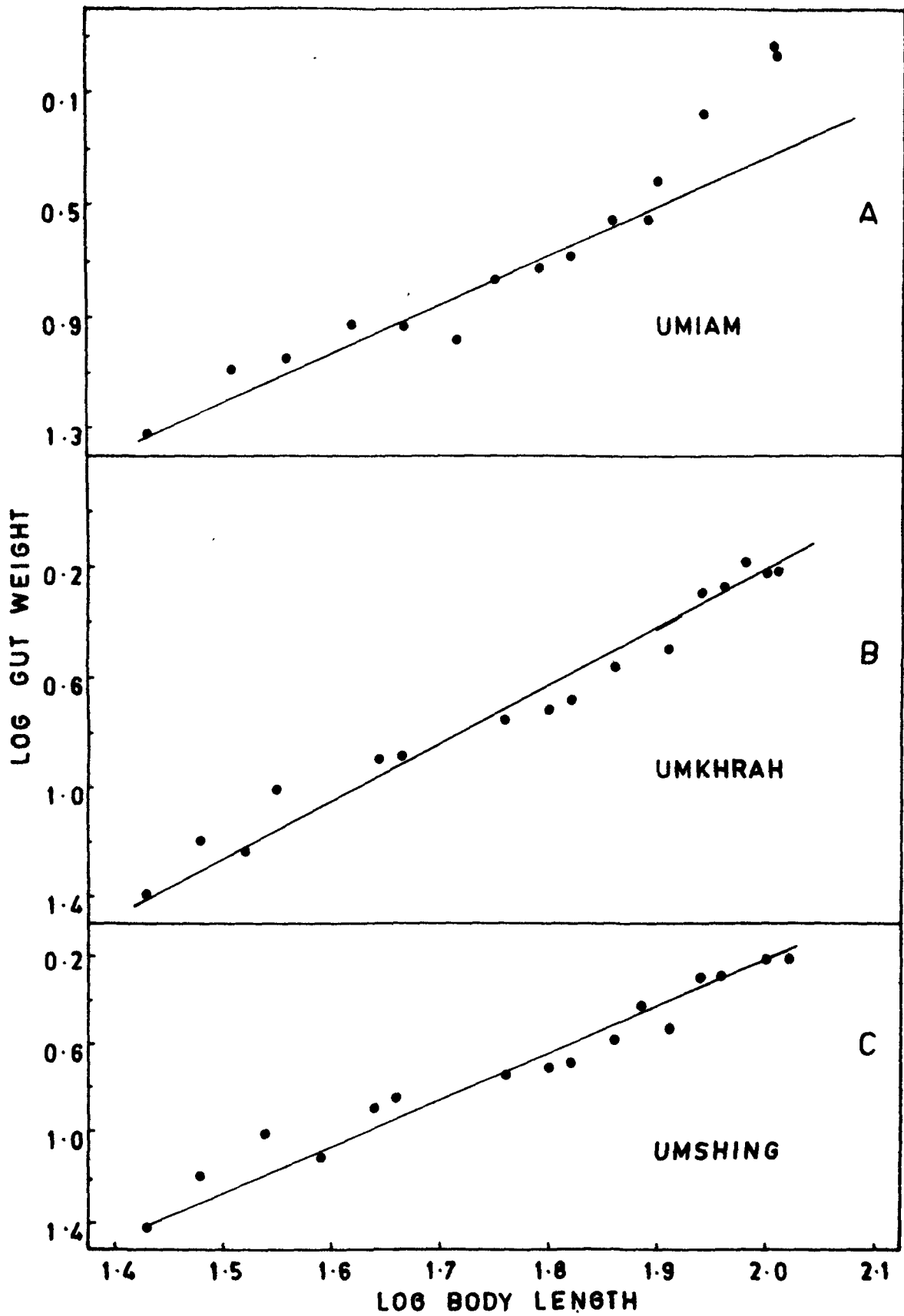


Fig.38: Log relationship between gut weight and total length of *G. lissorhynchus*

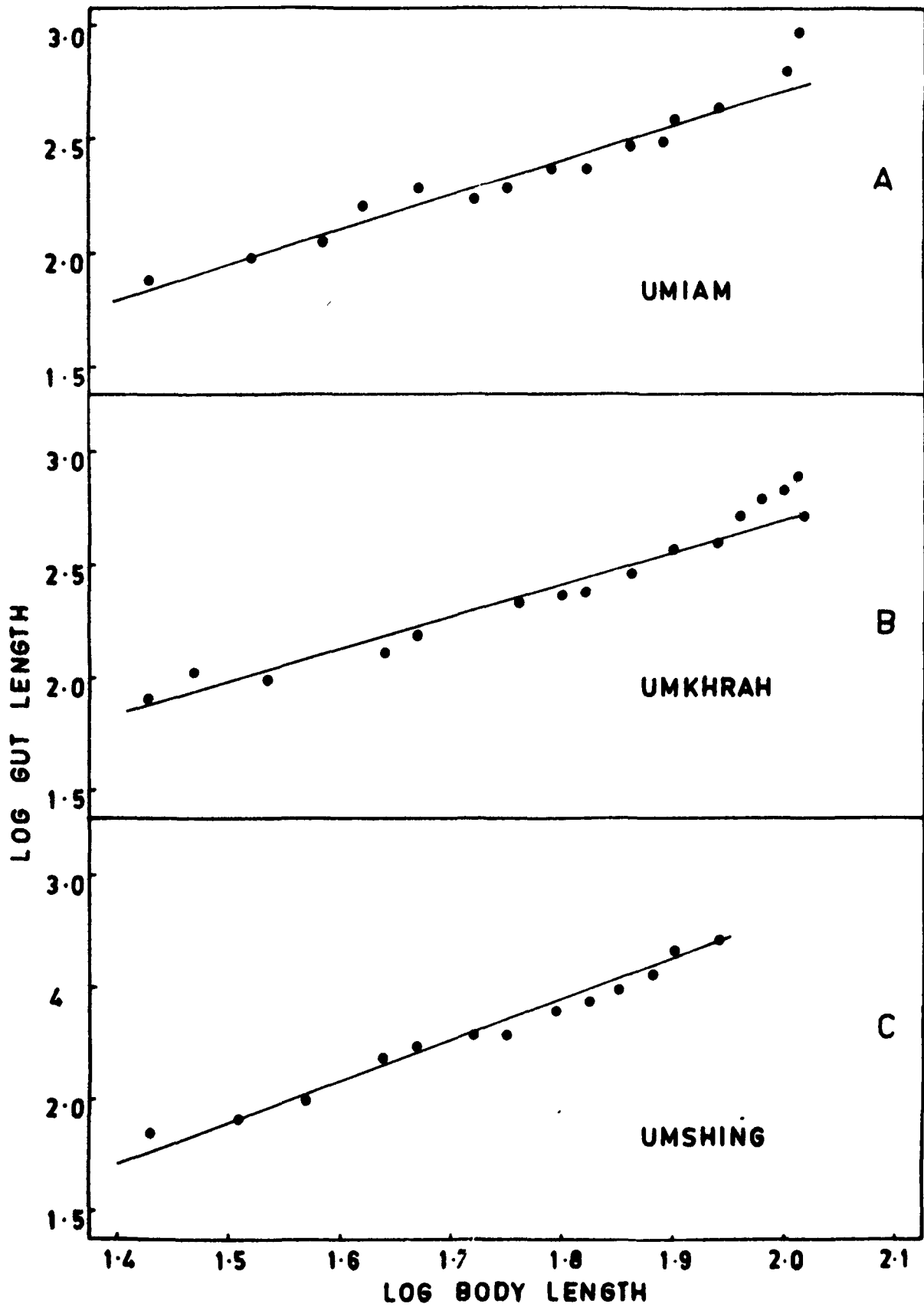


Fig.39: Log relationship between gut length and total length of G. lissorhynchus

in different species. Bhimachar and George (1952) have also referred to reduced feeding in Indian mackerel, Rastrelliger canagurta, with the progressive maturation of the gonads. Karekar and Bal (1958) have also noticed the coincidence of peak breeding with low feeding phase in Polynemus indicus. Jhingran (1961) has observed the feeding intensity of Setipinna phasa to decline in its peak breeding season. Natarajan and Jhingran (1963) have reported a low level of feeding during maturation phase in the case of female Catla catla. Jacobson (1974) observed that spawning brings about a sharp decrease in 'K' factor.

The observation of feeding intensity in different length groups (Fig. 34) in the present study also indicates that feeding intensity is higher in smaller length groups, whereas mature fishes show a decline in the feeding intensity which could be due to the maturation of the gonads as discussed earlier. The diet composition tends to show that the species feeds mainly on periphyton (diatoms) and detritus. According to Moitra (1956), food habits of fish may vary not only due to the availability and abundance of particular food items in the system, but also due to the temperature and other ecological and geographical factors.

It has been observed in the present study that the R.L.G. values of Garra lissorhynchus increases with the increase in length of the species (Fig. 40). It is known that R.L.G. values have a close relationship with the nature of the food the fish prefers (Kaur, 1981). It is also a known fact that vegetable matter requires more time for digestion due to which herbivorous

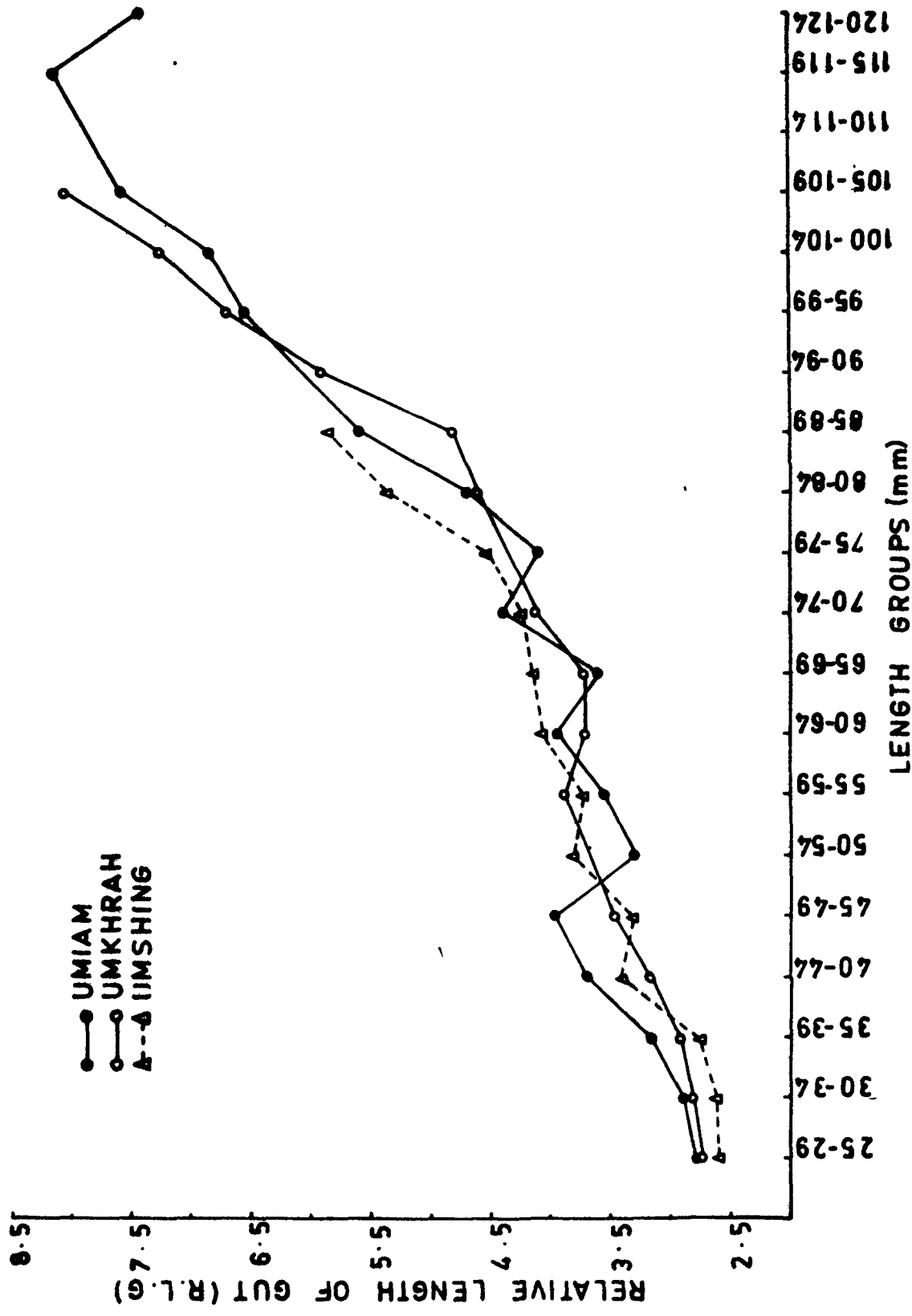


Fig. 40: R.L.G. values of G. lissorhynchus at various length groups

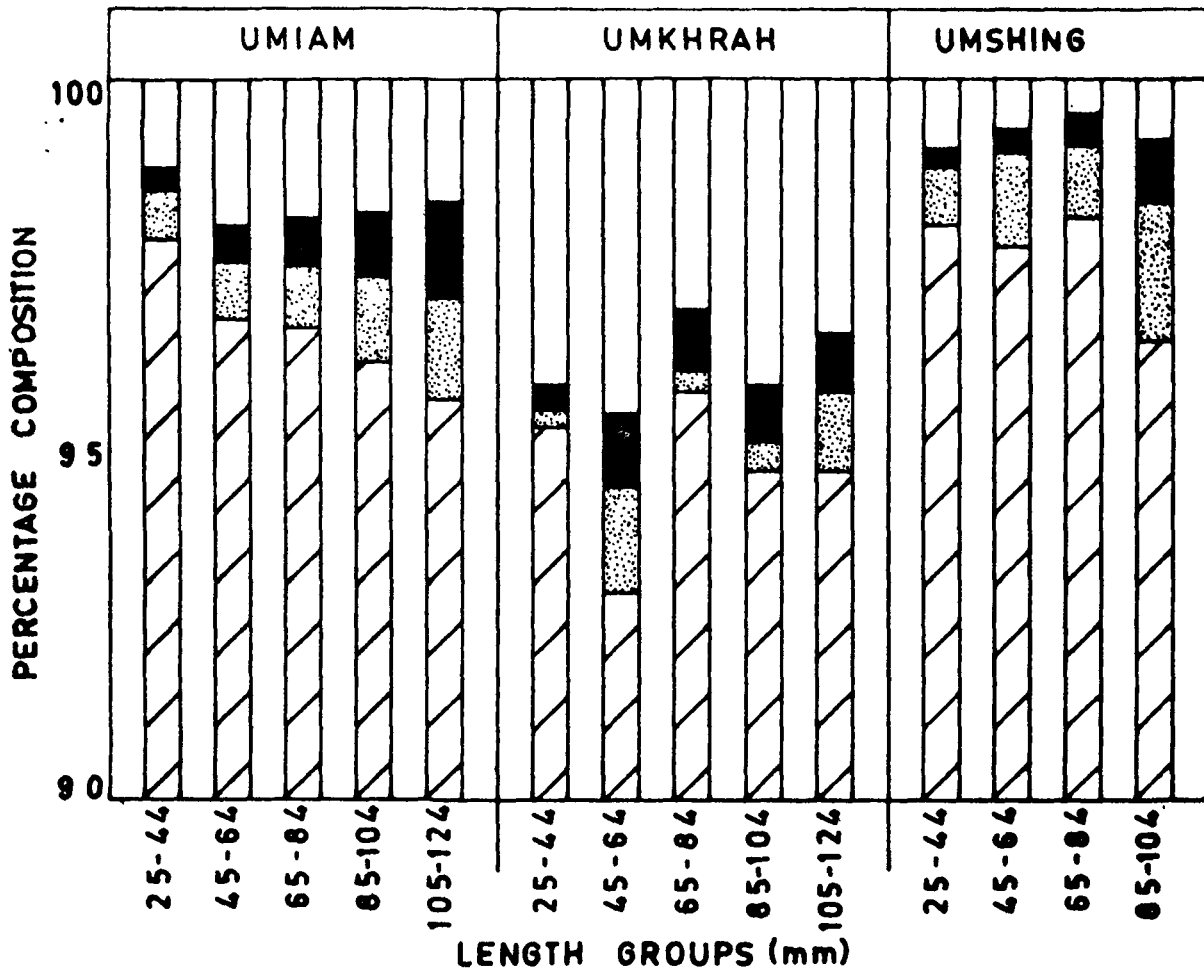
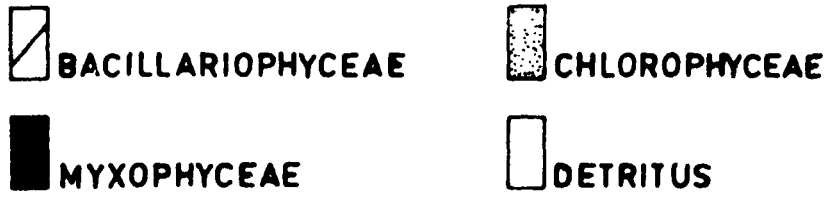


Fig.41: Percentage composition of gut contents in *Q. lissorhynchus* in different length groups

fishes have higher R.L.G. values (Kaur, 1981). The adaptation of the alimentary canal of fish to their food is well known in regard to its relative length of the gut (Sinha, 1972). Kaur (1981) reported the R.L.G. of Channa gachua to range from 0.41 to 0.80. Das and Moitra (1956a) observed the R.L.G. values Bagarius bagarius and Notopterus chitala to be generally low, i.e. less than 1.0 which are known to be carnivorous. Das and Nath (1965) recorded the R.L.G. values of the omnivorous fishes Puntius conchoniis and Barbus hexastichus to be 3.3 and 2.3 respectively. Dasgupta (1982) observed the average R.L.G. in Acrossocheilus hexagonolepis, Tor tor and Tor putitora to be 2.4, 2.1 and 1.3 respectively. In herbivorous fishes such as Labeo rohita and Labeo gonius the respective R.L.G. values were found to be about 12.0 and 9.5 (Das and Moitra, 1956a,b,c; 1958; 1963). However, in the present study, the range of R.L.G. values for Garra lissorhynchus have been found to be 2.55 to 8.16. Thus, accordingly they can be placed in the category of herbivorous fishes and which feeds mainly on periphytic diatoms. The feeding on a substantial quantity of detritus by the species also support this inference which is in accordance to the view of Odum (1968), who reported that detritus feeders possess higher R.L.G. values. The fact that Garra lissorhynchus has a long alimentary canal without a well defined stomach confirms that it is a purely herbivorous fish as mentioned above. Somvanshi and Bapat (1979) made a similar observation in Garra mullya. Hora (1937) and Hora and Mukherji (1936) further states that G. mullya feeds by scraping rocks. Similar observations have been made in the case of Garra lissorhynchus in the present study.

Nikolsky (1969) is of the view that the fish fauna of high altitudes are usually adapted to eating various types of food on account of the high variability of the available food. However, the present findings in the food and feeding habits of Garra lissorhynchus seems to agree more with the view of Das and Moitra (1963) who observed that in herbivorous fishes, fluctuations in the dietary components are not very marked due to the fact that the aquatic plants which usually dominate the diet of these fishes always abound in the environment.

CHAPTER IV

Summary & Conclusion

S U M M A R Y A N D C O N C L U S I O N

Keeping in view, the basic necessity to gain knowledge on the limnological structure of lotic ecosystems from higher altitudes and on the biology of the fish Garra lissorhynchus adapted in such systems, the present investigation has been undertaken. The results obtained during the present investigation have been presented in this thesis entitled "An investigation on some aspects of the ecology and biology of a hill-stream fish—Garra lissorhynchus (McClelland)", the summary and conclusion of which are presented below.

The water temperature in all the systems showed a co-linearity throughout the study period. The winter thermal inversion is attributed to the property of water of having more specific heat than air. Conductivity values did not show any definite pattern

of fluctuations, although a trend of winter maxima and summer minima was observed. This has been attributed to the changes in the ionic composition of the precipitation and the diluting effects of rain water entering into the systems. The winter maxima might be due to the fact that during the period, the volume of water decreases considerably while the addition of nutrients by way of leaching remains the same or increased.

It has also been noticed that though the pH values fluctuated widely they mainly remained in the acidic range in all the systems studied. They were also found to show a definite inverse relationship with the free carbon-dioxide concentrations. Apart from this pH values exhibited a tendency to reach a summer minima and a winter maxima. Higher pH values during winter indicate higher photosynthetic activity than community respiration, which might be due to the cloudless sky during the period and low water levels resulting in higher penetration of sun rays. The reverse conditions seem to be the reason of the summer minima.

The results indicate that the main sources of free carbon-dioxide in the systems, are from decomposition as well as the respiratory processes of the organisms present in the systems. It is also evident that free carbon-dioxide concentration of the water influences the pH, bicarbonate and carbonate alkalinity of the water.

In the present study higher dissolved oxygen level coincided with low temperature maintaining the law of solubility of gases. However, around August, the high temperature corresponded with

high oxygen values. Therefore, temperature alone cannot be taken as the limiting factor for dissolved oxygen in these water bodies. It may, however, be concluded that oxygen content of these water bodies could have mainly depended on the following factors :-

- (a) Law of solubility of gases;
- (b) Photosynthetic activities;
- (c) Respiration;
- (d) Intensity of illumination;
- (e) Agitation in water surface.

Total alkalinity registered an inverse relationship with the free carbon-dioxide content. This situation may be attributed to the "Equilibrium Carbon-Dioxide". The fall in alkalinity values during the summer months could have been due to the dilution of ionic content of the water by rainfall.

The nutrient condition in all the three systems was found to be generally poor. The phosphate content of the Umshing stream, showed an inverse relationship with the dissolved oxygen level. This might be due to the fact that when there is lack of oxygen in water bodies, particularly in the sediments, iron is reduced from ferric to ferrous state, releasing phosphate into water. However, in the river Umiam and Umkhrah streams no such inverse relationship was observed and at times there occurred a tendency of direct relationship of phosphate with oxygen. This has been attributed to the human interferences by way of washing clothes with detergents and thereby adding a sizable quantity of phosphate into the systems. Phosphate level is also known to be dependent on various factors like temperature, salinity and bacterial activi-

ties. The increase in phosphate levels during the monsoons have been attributed to the increased addition of leachates into the systems.

An inverse relationship has been observed between nitrate and oxygen which suggests that oxygen has a profound effect on nitrate concentration in waters. The reduction of nitrate levels and the corresponding increase of oxygen concentration might be due to the photosynthetic activities of the algal community or the oxidation of organic compounds. Nitrate showed an inverse relationship with temperature too. This suggests that temperature also has a profound effect on nitrate concentrations. This could be due to the fact that temperature accelerates the activity of denitrifying bacteria in the presence of organic matter.

The silicate content in the Umiam and Umkhrah lotic systems has been found to vary inversely with the free carbon-dioxide content. This has been attributed to the fact that silicic acid is more weakly dissociated than carbon-dioxide. Silicate is also known to be influenced by temperature as has been found in the Umshing stream, where a direct relationship between the two factors has been observed. It was further noticed that low levels of silicate in the water of the three systems corresponded with the peaks of diatom abundance (March to May). This has been attributed to the presence of large numbers of diatoms which might have resulted into the depletion of silicate to low levels as it is a well known fact that diatoms take up silicate from the surrounding environment for their shell-building.

The calcium content level revealed a summer maxima and a winter minima. The level of concentration of this factor in water depends on the amount of it adsorbed by the sediments. This uptake is known to take place with the exchange of hydrogen ions. This might be the reason of the increase relationship between calcium and pH. Calcium is also involved in the calcium bicarbonate system which is also true for magnesium.

Chloride levels increased in all the three systems during the monsoon months which could be due to the increased amounts of leachates from the catchment areas. The tendency for a brief peak in winter season might be attributed to the low discharge of water resulting in precipitation concentration. However, the general low levels of chloride concentration is to be expected since the systems are far removed from the oceans (Bishop, 1973). The possible low concentration of chloride salts in parent rocks in the proximity of the water bodies could have also resulted in the low levels of this parameter.

The peaks of total hardness coincided with those of calcium and magnesium hardness with a period of decline during the rainy months. This might be due to the increase in water level and subsequent dilution of the calcium and magnesium ions present in the systems.

In the present study, the Umiam river revealed 14 species of Bacillariophyceae, 6 of Chlorophyceae, 2 of Myxophyceae and 1 each of Euglenophyceae and Chrysophyceae. In the Umkhras stream, 15 species of Bacillariophyceae, 9 of Chlorophyceae, 2 of Myxophyceae

and 1 each of Euglenophyceae and Chrysophyceae were found, while the Umshing stream was found to harbour 17 species of Bacillariophyceae, 5 of Chlorophyceae and 1 each of Myxophyceae, Euglenophyceae and Chrysophyceae. True planktonic algae like Fragillaria, Cosmarium, Closterium and Scenedesmus have been recorded from such zones of the systems where water current was almost stagnant. When compared with other tropical and sub-tropical streams or rivers, the algal flora seems to be poor in diversity. This paucity could be due to the effect of substrate instability. In all the three systems it was found that where larger boulders were present, periphytic algal growth was moderately rich, both in terms of diversity and density. This is attributed to the fact that smaller stones and pebbles offered unstable substratum and were more susceptible to the scouring action of water currents.

It has been discussed earlier that the waters of the systems are not truly hard, that is, the values of calcium and magnesium hardness are low. Hardness, particularly calcium hardness, is known to favour algal growth. The low level of hardness might also be responsible for poor diversity in periphytic growth. During March to May, there is a rise in diatom abundance and a fall in silicate levels. This inverse relationship between diatoms and silicates might be due to the fact that diatoms require silicon for the manufacture of their shells. Hence, the available supply of silicon from water can be regarded as a matter of real consequence. The presence of diatoms like Nitzschia in the systems indicate possible nutrient enrichment of the systems, although the overall dominance of diatoms in the algal community is indicative of

oligotrophic nature of the systems. These findings may be due to the reason that the physico-chemical factors in freshwater bodies undergo frequent changes partially due to the changes in meteorological factors. Hence, it can be concluded that the growth and production of periphytic and other algal population is directly or indirectly influenced by the seasonal variations in the complexes of abiotic and biotic factors which is always bringing about changes in the ecosystems. This conforms to the notion of Nasar (1975) that "no one can step into the same ecosystem twice, as the ecosystem is dynamic and the abiotic and biotic factors not only fluctuates seasonally and diurnally, but also each and every moment".

The results indicate that there exists an intraspecific difference in various morphometric characters of Garra lissorhynchus which may be attributed to diverse ecological and environmental conditions prevalent in the three lotic systems.

From the results obtained on length-weight relationship, it is evident that there exists an intraspecific variation in the exponential value. The 'b' values approximate the cube law but are more than three in the case of specimens from Umiam river and Umkhrah stream and less than three in the case of the Umshing stream population, thus showing allometric growth in all the cases. However, due to the close approximation to the cube law, the species can be considered as "ideal".

The condition factor of G. lissorhynchus from all the three populations have been calculated at different length groups as well as different months. The fluctuations in 'K' values observed

have been discussed in relation to gonadal maturity and feeding habits. The results of condition factor indicates that the 'K' value is higher in smaller fishes than the bigger ones. It is revealed from the study that the limiting factors for 'K' value are not only maturity and feeding habits, but also environmental factors which seem to play a significant role.

The fecundity of G. lissorhynchus was observed to range from 427 to 1808 eggs in the specimens of 68.0 to 106.0 mm in length from the Umiar river. In the Umkhras stream fecundity ranged from 263 to 1410 eggs in specimens of 63.0 to 105.0 mm in length, whereas it ranged from 210 to 1003 eggs in specimens of 56.0 to 87 mm in length from the Umshing river. Further, the logarithmic relationships between fecundity of G. lissorhynchus and its length, body weight and ovary weight were found to be linear. The maximum relative fecundity on an average basis was found to be 94.78 in the specimens from Umiar river whereas, the lowest (71.25) was recorded in the Umkhras stream population. Fecundity estimates suggests that G. lissorhynchus have comparatively higher fecundity than Cyprinids of similar size which might be due to the absence of parental care in G. lissorhynchus. It is an established fact that low food intake due to less availability of food items in the system, leads to low fecundity. This seems to be true with the Umshing stream specimens which have been observed to be less fecund than those of the river Umiar and Umkhras stream, where the food available in the system was more.

Studies on maturity indicate that specimens from all the

three systems have a similar spawning period i.e. August to September with just one spawning season during an annual cycle. The occurrence of ripe specimens is restricted only during August to September which also clearly indicates the spawning season of the species. This is also supported by the results obtained on the Gn.S.I. of the species. Gn.S.I. values showed a tendency to increase with length. The seasonal peaks in Gn.S.I. values coincided with the peaks in the percentage occurrence of mature individuals, hence, Gn.S.I. values can be used as an index of gonadal development. Accordingly, it has been observed that 50% individuals (M_{50}) mature at 60-64 mm length group in the Umiam and Umkhras streams, whereas in the Umshing stream the M_{50} has been found to be at the 55-59 mm length group.

Based on numerical and frequency of occurrence methods, the diet composition of G. lissorhynchus has been divided into the following broad categories: (a) Periphytic Bacillariophyceae (b) Detritus (c) Chlorophyceae and (d) Myxophyceae. The observed low feeding intensity during spawning season may be attributed to the completely developed gonad permitting limited space in the abdominal cavity resulting in less intake of food. It is further clear that the feeding intensity in G. lissorhynchus is higher in the smaller length groups than the higher length groups which might be due to the higher metabolic rates in young individuals. It has been further observed that the young specimens prefer more periphyton as food than adult, though the "basic food" of both are periphytic algae.

From the results obtained during the present investigation, the following generalization can be made with regards to the ecology of fishes. It can be said that fish populations are a part of the ecosystem, which are affected by the chemical and physical factors while functioning within the system through biotic interrelationships which supports the view of Weatherley (1972). Fishes, being poikilotherms, are more dependant on the temperature of their habitat and the surrounding water than homoithermal animals. Temperature of the water therefore, is of enormous significance to the life of a fish. According to Nikolsky (1963), in majority of fishes, the body temperature differs from that of the surrounding water by only 0.5-1.0°C and the changes in the metabolic rate are most closely associated with changes in the temperature of the surrounding water. In many cases, changes in the temperature function as a signalling factor, a natural stimulus which determines the start of some process such as spawning, migration and so on. The rate of development of fishes is also related to a significant extent to changes in the temperature. Within the limits of certain amplitude of temperature, there frequently occurs a direct relation between the rate of development and the change in temperature. Growth rate is closely related to temperature and many, probably most, species do not grow at all during winter (Hynes, 1970). Temperature has always been considered as an important ecological factor and for stream fishes particularly, it is an important one which limits both geographical distribution and local occurrences within a single water course. Besides, the adaptation of a fish to a particular temperature (high or low), the amplitude of fluctuation of the temperature at which fishes of the same species can

live are extremely important. This amplitude of temperature varies considerably from one species to another as is evident from the distributional records of Garra. If the total amplitude of the temperature at which a species of a fish can live is very great, it is significantly less for each stage of development. Fishes also react differently to temperature fluctuations, according to their biological conditions. The timing and extent of temperature changes are also important, as they often control breeding. Hence, the optimal temperature to which a fish can adapt can also be considered a species characteristic. The present study further corroborates the view of Weatherley (1972) that fishes of higher altitudes have evolved a metabolic type which enables them to feed successfully at a very low temperature unlike the fishes of lower altitudes. Within limits of the optimal temperature for a given species, a rise in temperature usually leads to an increase in the rate of digestion.

The gaseous metabolism of fishes also changes considerably as the temperature varies. Since the fish is adapted to live at a particular temperature, it is natural that its distribution in the water would be related to that of the temperature. As the temperature changes both seasonally and secularly, the distribution of the fish also changes. One may judge the adaptation of separate species of fishes to particular temperatures visually, from the curves showing the frequency of occurrence of each species in relation to the distribution of temperatures. Thus, the relationship between the distribution of separate species and the temperature is complimentary.

Adaptive changes which occurs in fishes when the temperature varies, are also connected with some morphological reconstruction. Therefore, the adaptive reaction to variations in the temperature, salinity, the density of the water and so on appears as variations in the number of caudal zone vertebrae, and in the number of rays in the unpaired fins. In 1909, Putter (op. cit. Nikolsky, 1963) suggested that the aquatic organisms can live not only by eating particulate food, but also by assimilating salts and organic matter dissolved in the water, which permeated into the body across its walls. Many of the salts dissolved in the water exert a fundamentally indirect effect upon fish by influencing the food organisms or even their food. The organic matter transported downstream by the water current ensures a rich development of the various organisms which form the food of the fishes.

The presence of substances dissolved in the water which are not normal constituents of freshwater, but which enter it as the result of various human activities such as tree felling, industrial effluents, pollution by oil, sewage and so on, has become particularly important to fishes. The effects of other dissolved compounds which enter the water, both organic and inorganic, are rather variable but in general, the majority of them effect primarily the course of respiration.

Like all other animals, fishes cannot live without the access of oxygen to the organisms through its blood, which ensures metabolism and, thereby, the life of the fish. Naturally, therefore, the cessation of access of oxygen to the blood leads to the death

of the fish in a short time. Usually, water masses with fast currents are characterized by super saturation with oxygen. For this reason, rheophilic fishes are also at the same time oxyphilic i.e. they require more O_2 . During the course of investigation it has been noticed that specimen of G. lissorhynchus when transferred to stagnant water did not survive for more than three hours, but there was an increase in the time period of survival when the water was oxygenated.

Apart from oxygen, other gases are also of considerable importance to fishes. It is well known that an excess of carbon-dioxide concentration causes the death of fishes. The mechanism of the action of carbon-dioxide upon fish consists of the reduction of the capacity of the blood to absorb oxygen. The amount of carbon-dioxide in the water is directly proportional to pH, i.e. the more the concentration of dissolved carbon-dioxide, the more acidic the water becomes. As the acidity of the water increases, the rate of metabolism in fishes decline, although there is an increase in the respiratory rate. This results in more energy consumption than gained by the fishes. /

Fishes are adapted to moving through both still and fast flowing water and the body shape, fin structure and certain other features in the form of the fish are connected with this. Garra lissorhynchus has a smooth rounded snout, an arched dorsal surface and flattened ventral surface. The paired fins are at right angles to the body. These characteristics reduce resistance of the water and enable them to traverse even against the faster currents of the streams. The body form of the species not only helps the

fish to reduce the resistance as mentioned above, but also helps in utilizing the medium in getting the necessary lift while spawning upstream. This can be explained by the fact that when water rolls over the arched back (dorsal surface) of the fish, the water molecules are slightly dispersed creating an area of low pressure, whereas the flattened ventral surface of the fish does not create any pressure changes. In other words, with lower pressure on the dorsal surface and higher pressure on the ventral surface, the fish can have the necessary lift while moving forward in fast water currents in the same way as aeroplanes, with wings having an arched upper surface and flat lower surface, obtain their lift by making use of the air current. The body form of G. lissorhynchus is indicative of its bottom dwelling nature. Fishes living on the bottom are usually pigmented in such a manner so as to blend into the background. The mud brown colour of G. lissorhynchus camouflages it well with the river or stream beds.

The food supply has a profound effect on the numbers and masses of fish populations. The amount of food eaten determines the fecundity of the year classes, as well as the growth rate and time of sexual maturity and hence the life span. The length of the feeding season is in turn affected by the onset of unfavourable conditions. The food supply is therefore, governed by the conditions for obtaining and utilizing the food and it is also dependant on the abiotic conditions such as temperature, intensity of illumination, photoperiod, size of feeding area, water velocity and so on. In freshwater conditions the range of food

organisms may vary greatly from area to area, even as regards principal food (Nikolsky, 1969). Although the ichthyo-fauna of high altitudes are usually adapted to eating various types of food, Garra liosorhynchus has established its own niche in the systems it inhabitates by feeding mainly on periphytic algae.

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