

STUDIES ON
SOME ASPECTS OF THE ECOLOGY AND BIOLOGY OF

Channa gachua (HAMILTON) & *Channa stewartii* (PLAYFAIR)

SUKHBEER KAUR

Department of Zoology
School of Life Sciences



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

to

THE NORTH-EASTERN HILL UNIVERSITY
SHILLONG (MEGHALAYA) INDIA

JULY 1981

8/25/5

DS
597.5045
KAU

GENU Library
101366
Kw. Lu
4/12/52
Class. by
Sub. Recd. by
Given by
Prescribed by



Phone ;
Gram : NEHU

North - Eastern Hill University

Lower Lachauriere, Shillong - 793001 (Meghalaya)

DR. S. A. K. NASAR
Lecturer

Department of Zoology,
School of Life - Sciences,
Shillong-793014, India.

I certify that the thesis entitled " STUDIES ON SOME ASPECTS OF THE ECOLOGY AND BIOLOGY OF CHANNA GACHUA (HAMILTON) AND CHANNA STEWARTII (PLAYFAIR)" submitted by Miss SUKHBEER KAUR 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. She 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 15th July, 1981

(S. A. K. NASAR)
DR. S. A. K. NASAR
Department of Zoology
North - Eastern Hill University
SHILLONG - 793014, (INDIA.)

PREFACE

P R E F A C E

The unity of organisms and their environment is the basic principle of modern ecology. Any population, species, or organisms (including fish) live at the expense of their environment; in the absence of this interaction it ceases to exist. The successful existence and development of any fish, like other organisms, depends on its adaptive interaction with its environment and it is based on the interrelationships with their abiotic and the biotic environment. Any alteration in the nature of any fundamental abiotic and or biotic component, inevitably evokes a reconstruction not for the better but normally for the worse of the entire system of relationships between the organisms themselves and their immediate habitat. The characters of the interdependence of organisms to its natural environment, is known to be specific not only for the various species, but also for different individuals of the same species.

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. Freshwater 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.

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 sillimanite, 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.

The study pertains to the specimens of Channids (= Ophicephalids) commonly known as "Murrels" or "Snake-Heads", collected during the period from September 1978 to August 1979 from a pond and a torrential hill-stream situated in Shillong (Meghalaya), India. The results obtained during the present study are presented here under the title "Studies on some aspects of the ecology and biology of Channa gachua (Hamilton) and Channa

stewartii (Playfair)", and the investigations were carried out at the Fish Ecology Laboratory, Department of Zoology at the North-Eastern Hill University, Shilong, under the supervision and guidance of DR. S.A.K. NASAR, Ph.D., F.A.Z., F.Z.S. (Lond.).

.....

ACKNOWLEDGEMENTS

A C K N O W L E D G E M E N T S

I wish to express my heartfelt gratitude, though beyond my capacity to express merely in words, to Dr. S.A.K. NASAR of the Department of Zoology under whose supervision and direction this work has been carried out. I am deeply indebted to him, not only for suggesting the problem, but also for his generous guidance, wise counsel, constant encouragements and advices at the critical moments.

My thanks are due to Professors R. George Michael, Professor R.R. Mishra, Dean, School of Life Sciences and Professor M. K. Khare, Head of the Department of Zoology, not only for providing the necessary laboratory facilities but also for their interest in this work.

The cooperation received from the colleagues particularly Messers Sisir K. Shahoo, Mrinal Dasgupta and Shyama P. Biswas and Mrs. P. Chaurasia are also gratefully acknowledged.

I am highly grateful to my parents for taking so much pains in enabling me to reach this goal and also for their ungrudging sacrifices.

I express my appreciation to Mr. Khambor Tariang not only for his diligence in typing but also for his help in various ways and to Mr. Salil R. Choudhury for illustration of diagrams.

Last, but not the least, I am thankful to Didi, Mrs. R. Nasar, for her affectionate encouragements and to my little nieces, KHUKU and DIMPU for their loving pranks particularly in my tense moments I had during the course of this work.

This work was carried out under the tenure of a Research Fellowship awarded to me by the University Grants Commission, through North-Eastern Hill University, Shillong which is also thankfully acknowledged.

Sukhbeer
15th July 81
(SUKHBEER KAUR)

C O N T E N T S

PREFACE	iii
ACKNOWLEDGEMENTS	vi
LIST OF TABLES	ix
LIST OF FIGURES	xi
<u>CHAPTER</u>	<u>PAGE</u>
I GENERAL INTRODUCTION	1
II ENVIRONMENT OF THE FISH	
INTRODUCTION	14
Review of Literature	18
Study Area	22
MATERIALS AND METHODS	29
Physico-chemical Analysis	29
Plankton Analysis	35
RESULTS	36
Physical Conditions	36
Chemical Conditions	37
Plankton	40
Phytoplankton	40
Zooplankton	46
DISCUSSIONS	47
Physical Conditions	47
Chemical Conditions	50
Plankton	59
Phytoplankton	61
Zooplankton	61
Factors influencing plankton periodicity.....	67

III	BIOLOGY OF THE FISH	
	INTRODUCTION	76
	Review of Literature	84
	Taxonomic Status	90
	Diagnostic Characters	91
	Synonyms and Distribution	93
	Vernacular Names	97
	MATERIALS AND METHODS	98
	Collections Spots	98
	Collections Procedures	98
	Biological Parameters	100
	RESULTS	112
	Morphometric & Meristic Characters... 112	
	Length-Weight Relationships	126
	Condition Factors	131
	Maturity and Spawning	133
	Fecundity	136
	Food and Feeding Habits	140
	DISCUSSIONS	156
	Morphometric & Meristic Characters... 156	
	Length-Weight Relationships	165
	Condition Factors	170
	Maturity and Spawning	173
	Fecundity	178
	Food and Feeding Habits	185
IV	SUMMARY AND CONCLUSIONS	203
	LITERATURE CITED	216
	APPENDIX	245

LIST OF TABLES

<u>TABLE</u>	<u>TITLE</u>	<u>PAGE</u>
1	Meteorological conditions of Shillong (Meghalaya).	24
2	Physico-chemical conditions of the pond water.	38
3	Physico-chemical conditions of the stream water.	39
4	Seasonal periodicity in phytoplankton of the pond water.	42
5	Seasonal periodicity in phytoplankton of the stream water.	43
6	Zooplankton periodicity in the pond.	44
7	Zooplankton periodicity in the stream.	45
8	Morphometric analysis of <u>Channa qachua</u> .	115
9	A comparison of the meristic characters of two population of <u>Channa qachua</u> , one from the pond and the other from the stream.	116
10	Regression equations of variable morphometric characters of <u>Channa qachua</u> .	117
11	Mean biometric indices in various size-groups of <u>Channa qachua</u> from the pond.	120
12	Mean biometric indices in various size-groups of <u>Channa qachua</u> from the stream.	120
13	Morphometric analysis of <u>Channa stewartii</u> .	121
14	Morphometric analysis of <u>Channa punctatus</u> .	122
15	Regression equations of the morphometric characters in <u>Channa stewartii</u> and <u>Channa punctatus</u> .	124
16	Mean biometric indices in different length-groups of <u>Channa stewartii</u> .	125
17	Mean biometric indices in different length-groups of <u>Channa punctatus</u> .	125
18	Length-weight regression equations in <u>Channa qachua</u> during different seasons and life stages.	128
19	Length-weight regression equations of <u>C. qachua</u> , <u>C. stewartii</u> and <u>C. punctatus</u> .	128
20	Monthly fluctuations in the condition factor of <u>Channa qachua</u> .	132

21	Fluctuations in the condition factor in different length groups of <u>Channa qachua</u> .	132
22	Stages in the ovarian development, range of ova diameter and mean Gonado-somatic index (Gn.S.I.) in <u>Channa qachua</u> .	135
23	Fecundity in the stream population of <u>Channa qachua</u> .	139
24	Fecundity in the pond population of <u>Channa qachua</u> .	139
25	Percentage occurrence of different food item in the gut of <u>Channa qachua</u> from the pond and stream population.	142
26	Monthly variations of diet composition (%) in <u>Channa qachua</u> from the pond.	144
27	Seasonal variations in the percentage composition of the diets of <u>Channa qachua</u> from the stream.	145
28	Percentage frequency of occurrence of different food items in different size groups of <u>Channa qachua</u> from the pond.	148
29	Percentage composition of the gut content in different length groups of <u>C. qachua</u> from the stream.	149
30	Seasonal variations in the values of G.S.I., Gn.S.I. and 'K' factors of <u>C. qachua</u> .	153
31	Values of G.S.I., Gn.S.I. and K factor of <u>C. qachua</u> at different length groups.	153
32	Relative length of the gut and its relationship with K, G.S.I. and Gn.S.I.	154
33	Percentage composition of the gut content in <u>C. stewartii</u> and <u>C. punctatus</u> .	154
34	Comparative values of 'b' as reported for log body weight to log body length in various air-breathing fishes of India.	169
35	Comparative values of fecundity in different air-breathing teleosts from India.	182

LIST OF FIGURES

FIG. NO.	TITLE	PAGE NO.
1	Map of Shillong showing study sites.	23
2	Photographs showing the Pond and stream.	26
3	Climatic conditions of Shillong.	27
4	Standard graph for Nitrate	32
5	Standard graph for Phosphate	33
6	Standard graph for Silicate	34
7	Physico-chemical conditions of the water bodies (Temperature, Conductivity and pH)	48
8	Physico-chemical conditions of the water bodies (Free CO ₂ , Alkalinity and Dissolved Oxygen)	53
9	Physico-chemical conditions of the water bodies (Silicate, Nitrate and Phosphate)	57
10	Percentage occurrence of Phyto- and Zooplankton in the Pond water.	62
11	Percentage occurrence of Phyto- and Zooplankton in the Stream water.	63
12	Percentage occurrence of Phytoplankton in the pond water.	64
13	Percentage occurrence of Phytoplankton in the stream water.	65
14	Percentage occurrence of Zooplankton in the pond water.	71
15	Percentage occurrence of Zooplankton in the stream water.	72
16	Percentage occurrence of Diatoms showing the relationship with silicate.	73
17	Length-frequency distribution of <u>Channa qachua</u> during the study period.	130
18	Biometric indices of <u>C. qachua</u> from the stream at different length groups.	161
19	Biometric indices of <u>C. qachua</u> from the pond at different length groups.	162
20	Biometric indices of <u>C. stewartii</u> at different length groups.	163
21	Biometric indices of <u>C. punctatus</u> at different length groups.	164
22	Length-weight relationship of <u>C. qachua</u> from the pond.	167
23	Length-weight relationship of <u>C. qachua</u> from the stream.	168
24	Condition factor of <u>C. qachua</u> (a) In different length groups and (b) In different months.	172

25	Seasonal variation in the Gonado-somatic index of <u>C. qachua</u> .	175
26	Gonado-somatic index of <u>C. qachua</u> at different length groups.	176
27	Maturity of females in <u>C. qachua</u> showing M ₅₀ (a) From Pond and (b) From Stream.	177
28	Logarithmic relationships between Fecundity of <u>C. qachua</u> and A: Body weight (Pond); B: Body weight (Stream); C: Ovary weight (Pond); D: Ovary weight (Stream); E: Total length (Stream); and F: Total length (Pond)	183
29	Logarithmic relationships between Gonad weight and Total length : (A) Stream population and (B) Pond population.	184
30	Relative importance of the major food items in the diet of <u>C. qachua</u> from the : (A) Pond and (b) Stream.	187
31	Monthly changes in the occurrence of the major food items in the diet of <u>C. qachua</u> A: Pond; and B: Stream.	188
32	Frequencies of occurrence of food item in the diet of <u>C. qachua</u> at different length groups.	189
33	Gastro-somatic index of <u>C. qachua</u> . A: At different length groups; B: During different months.	192
34	Seasonal variations in the Gastro-somatic index showing relationship with condition factor.	193
35	Gastro-somatic index showing relationship with the condition factor in different length groups.	194
36	Gut length in relation to Body length of <u>C. qachua</u> - A: Pond; and B: Stream.	196
37	Logarithmic relationship between gut weight and Body length of <u>C. qachua</u> from the pond.	197
38	Logarithmic relationships between Gut weight and Body length of <u>C. qachua</u> from the stream.	198
39	R.L.G. values of <u>C. qachua</u> at different length groups.	200
40	Relative importance of the major food items in the diet of (A) <u>Channa punctatus</u> and (B) <u>C. stewartii</u> .	201

CHAPTER I

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Ecology may be defined broadly as the science of the interrelationship between living organisms and their abiotic and biotic environment and emphasizing interspecific as well as intraspecific relations. This science has undergone profound changes as far as range and scope are concerned, since the publication of certain pioneering studies on synthesis of the ecological facts and ideas of their day (Shelford, 1913; Elton, 1927). However, according to Regier (1974) limnologists and ecologists, at least those interested particularly in fish, can turn to the writing of their scientific leaders of 50 years ago and not find them obviously outdated.

One of the origins of animal ecology was Shelford's (1913) early account which attempted to explain the distribution mainly on the result of different tolerances and responses of

organisms to the physico-chemical conditions of the environment. Much work by so called autoecologists, is derived from this conception and it has produced many valuable discoveries. A major aim of modern ecologists is to obtain better understanding of entire functioning of the organisms living in the natural world. It can therefore, be said that ecology has a central, rather than a peripheral role to play in the development of biology (Weatherley, 1972).

According to Nikolskii (1963) the ecology of fishes is the section of Ichthyology in which the mode of life of fishes is investigated namely: the dynamics of fish populations, intraspecific and interspecific variations, distribution, migrations, diurnal and seasonal rhythms in life processes, character of feeding inter-relationships, reproduction and so on. Naturally, the mode of life of any organisms (including fishes) is inseparably connected with its structure and function of its organs.

It is an established fact that the organisms cannot exist without the environment. Any population, species or organism live at the expense of its environment, 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-physiologo-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.

~~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 state of nourishment; fat content; the state of maturity of its gonads; and so on. All these factors are generally taken into account while studying the interactions of the fish with any particular element of its abiotic and biotic environment.

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 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 the limits of 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 the 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 fishing is having upon that population. In particular, much effort has gone into examining the relationships between recru-

itment of fish into a fishery and size of the parent stock. The first general model of this relationship was developed by Beverton and Holt (1957). Although this model was applied successfully to some 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 temperatures. 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 found to be in many countries, but the problem was of no general concern until the mid-nineteenth century. However, Ber (1854) 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 (Nikolskii, 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 years 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 (Nikolskii, 1969). According to Regier (1974) 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 organism and environment. There was no need 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.

The 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 call 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.

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 expend, at a given conjunction 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 containing 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 fisheries 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 has formed under the evolutionary paradigm that now tends to dominate academic thought. As discussed previously, their approach often appears remote and unrealistic to the fisheries analyst, who typically is 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-discipline. 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, the growth of the scientific approach of aquaculture, which may eventually develop into an applied scientific disciplines.

Since fishes are both poikilothermic and live permanently immersed in water, they are very directly 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 inter-relationships.

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

tem 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. Since air-breathing fishes are in great demand for their nutritive and therapeutic qualities, in recent years, culture of air-breathing fishes is gaining a fillip in the country particularly because of the need to put vast areas of swampy and fallow waters to immediate use for the benefit of mankind without getting involved into costly processes of their reclamation.

As mentioned earlier any programme of fisheries development presupposes an understanding of the salient features of the biology of the species concerned along with their immediate environment and its impact on the biological aspects of the species. While most of the species of air-breathing fishes have extensively been investigated to a variable extent, no systematic studies have so far been conducted on the species belonging to the family Channidae (= Ophicephalidae).

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 Channids, it has been aimed in the present investigation to have a basic information on the general biology of Channids

from the highlands of the North-Eastern Region of the country, in relation to their environment, as it is essential to be available before realistic models of fisheries can be developed.

The highlands of the North-Eastern India is 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 reveal that both the lotic and lentic ecosystems in Shillong, have a good number of representative of Channids commonly known as "Snake-head" or "Murrels". This is one of the most valued group of air-breathing fishes of the Indian sub-continent, hence attracted the attention and prompted to undertake the present study. The family Channidae is represented in this part of the country by Channa gachua (Ham.), C. stewartii (Playfair) and C. punctatus (Bloch), among which the former is the most common species and have adapted themselves in both the lotic and lentic systems.

Keeping in view, the basic necessity to have a knowledge on the structure of lotic and lentic ecosystems from the same geographical region and on the biology of the air-breathing fishes adapted in such systems, a study has been undertaken on some aspects of the biology of the above mentioned species with particular reference to Channa gachua (Ham.).

The study pertains to the specimens of fish collected from a pond and a stream situated in Shillong (India) during the period from September, 1978 to August, 1979 with emphasis on the following :-

- (a) The structure of a pond and a stream with limnological standpoint and impact of the abiotic and biotic factors on the biology of channids; and
- (b) An inter- and intraspecific comparisons within channids on some aspects of the important biological parameters.

CHAPTER II

ENVIRONMENT OF THE FISH

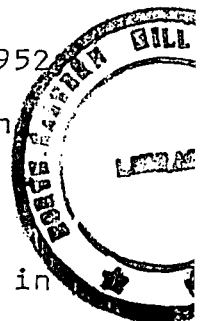
I N T R O D U C T I O N

The traditional way of considering an ecosystem is to regard it as a self contained complex system to which energy is supplied in the form of radiation. This energy passes through a series of trophic levels-primary producers, primary consumers, secondary consumers and so on and it returns basic materials to their original form. Similar trend, however, does not apply to the ecosystem in running water, where everything released into solution by metabolisms tends to go downstream and has little opportunity of being recycled at the spot. The unidirectional flow of streams sets their waters off from lentic habitats. This current is a salient feature of stream and therefore, there is little or no opportunity for retention of ions and compounds in stream 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 especially 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 limnology is 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. It includes the study of running water (lotic habitat) as well as of standing water (lentic habitats). Thus, the study of abiotic environment is of utmost importance as the seasonal and diurnal variations in the physico-chemical properties form the substructure upon which the whole framework of biological productivity rests.

Inland waters are ecologically diverse and only few are intensively studied. Streams outnumber the units of the standing water series and investigations of the running waters particularly from limnological stand point has lagged behind that of lakes and ponds. In only few instances extensive researches have been carried out extensively in relation to pollution as has been reported by Gaufin and Tarzwell, 1956; Garmer and Lovett, 1936; Causton, 1948; Patrick and Ruth, 1950; Mohr, 1952; Klein, 1956; Butcher, 1964; Hannon and Young, 1974 and Hannan and Broz, 1976.

Ecological studies of ponds have proliferated rapidly in the past decade but most of the interest however, has concentrated on artificial fish ponds. Information on ponds, is rather fragmentary and for the most part widely scattered in literature. Studies on the ecology of ponds have been mainly descriptive



with emphasis on seasonal succession of the biological components and seasonal changes in the physico-chemical parameters and the seasonal patterns of change are not necessarily duplicated from year to year.

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 geographical region. However, very few attempts have been made to determine the exact and comparative relationships amongst various components of the ecosystems during different seasons of an yearly cycle.

Moreover, such studies relating to Indian freshwaters are meagre and majority of these investigations have however, mainly dealt with the abiotic factors and few biotic factors only without paying much attention to fishes, which have great significance in the life of mankind, being an important natural source of protein and also providing certain other useful products, as well as in the economics of many nations. Correlation of fish yields with limnological factors in temperate regions has received much attention, of course, with moderate success whereas similar analysis are lacking in the tropics.

(In India too, limnological studies in general have been the object of research during the last few decades but only few have been carried out on freshwater ecosystems from higher altitudes. 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 during the period from September, 1978 to August, 1979 to elucidate certain important abiotic aspects of a stream and a pond ecosystem situated in Shillong (Fig. 1), together with the biotic factors with special reference to the fishes belonging to the family Channidae which is commercially one of the most important air-breathing fishes to this region. The aim of this study is to obtain basic information on the physico-chemical factors of the freshwater ecosystems of the highlands of Shillong, which will not only be useful in knowing the environmental conditions where such fishes thrive and such information is essential for the proper propagation and management of such fishes in aquaculture and also from the academic point of view.)

REVIEW OF LITERATURE

Studies relating to Indian freshwaters extend back to the latter half of 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 (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), on Rotifers (Donner, 1949; George, 1961a; Pasha, 1961; Arora, 1962, 1963a,b, 1965, 1966; Nayar, 1965a, 1968; Nayar and Nair, 1971; Michael, 1966, 1973; Naidu, 1967; Wycliffu and Michael, 1968; Wulfert, 1966; Vasisht and Gupta, 1967; Vasisht and Dawar, 1968; Vasisht and Bhattish, 1969, 1970, 1971a,b; Rajendran, 1971; Dhanapathi, 1973, 1974, 1975, 1976a,b, 1978; Das and Akhter, 1976; Sharma, 1976, 1977, 1978, 1979; Nasar, 1973; Laal 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; Pahwa and Mehrotra, 1966; Krishnamoorthi 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; Swarup 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 organisms as to their 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 (Krishnamoorthi 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 aquatic insects has also been done (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 aquatic macrophytes and their production were conducted (Kaul, 1971; Unni, 1971a,b; Nasar and Munshi, 1971, 1976, 1978). 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) and Jana and Sarkar (1971a,b). There lacks a total information at the decomposer level except a preliminary report by Nasar and Munshi (1980).

Among 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 technique and their theoretical computations respectively (Sreenivasan, 1963, 1964a,b, 1968; Hussainy, 1967; Ganapati and Sreenivasan, 1970; Kaul, 1971; Khan and Siddiqui, 1971a; Sumitra, 1971; Nasar and Munshi, 1975; Michael and Anselem, 1978; Nasar and Sharma, 1980 and Nasar, 1980a). Recently Nasar (1979b) studied the effect of certain organochlor insecticides on primary production.

The foregoing review of literature reveal that a good deal of limnological works have been carried out in India and

the available literature is too vast to be reviewed in details due to its diversity and moreover, as most of the earlier works have not been carried out from limnological view point. It would not be out of place to mention the outstanding efforts made by Nasar (1980b) and Michael (1980) to review the limnological knowledge in India. It is likely that a few other publications of Indian works might have been omitted due to usual difficulties in literature collection.

STUDY AREA

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

The Meghalaya region is a table land which is the eastward extension of the massive block of the Indian Peninsular shield from which it has been separated by the Malda gap as a result of denudational and tectonic forces.

The Shillong hills towering above Shillong contain the highest peneplained 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 Umian 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 mainly 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 $1.7^{\circ}C$. The temperature seldom rises above $26^{\circ}C$ in any part of the year. During deep 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. How-

TABLE 1
METEOROLOGICAL CONDITIONS OF SHILLONG (MEGHALAYA)

MONTHS AND YEAR	TEMPERATURE (°C)		RAINFALL (mm)	HUMIDITY (%)
	MEAN MAX.	MEAN MIN.		
<u>1978</u>				
SEPTEMBER	23.1	16.6	264.4	88.5
OCTOBER	22.4	15.2	50.6	80.0
NOVEMBER	18.5	10.3	20.4	69.5
DECEMBER	17.8	7.4	-	62.0
<u>1979</u>				
JANUARY	16.2	6.6	01.2	65.5
FEBRUARY	17.9	5.1	25.7	59.5
MARCH	22.6	10.4	11.7	47.0
APRIL	25.5	14.8	136.5	61.5
MAY	26.0	16.7	56.1	67.5
JUNE	25.3	14.4	354.5	81.5
JULY	23.3	17.8	572.0	89.0
AUGUST	24.3	17.7	127.0	84.5

ever, 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 renders 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 East Pakistan and is suddenly cut 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 sides 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. The winter months remain almost dry, whereas July is the hottest month with an average temperature of 26°C.

Meteorological condition of the Study Area :- Data on certain meteorological factors for the year 1978-1979 have been tabulated in Table-1 and graphically presented in Fig. 3. The meteorological data have been obtained from the Meteorological station, Upper Shillong situated about 10 kms from the study site.

During the period of study, Shillong experienced heavy rainfall from June to September. June and July were the wettest months (Fig. 3) and experienced 354.5 mm and 572.0 mm of rainfall respectively. The relative humidity always remained more than 47 percent (Table-1). The average minimum temperature varied between 5.1°C in February to 17.8°C in July. The average maximum temperature varied from 16.2°C in January to 26.0°C in May.



Fig. 2A: POND



Fig. 2B: STREAM

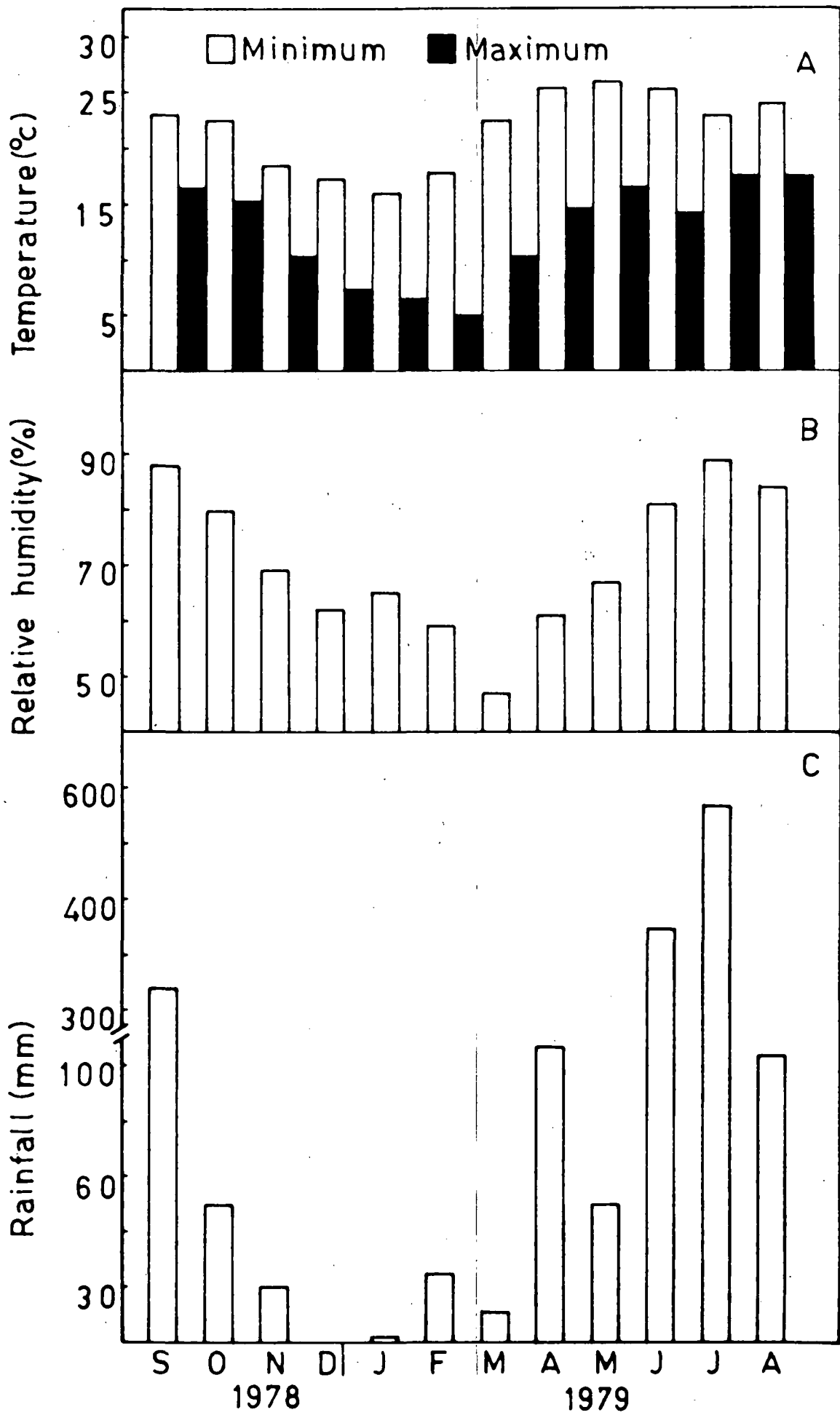


Fig.3: Climatic conditions of Shillong.

Description of the sites :- A pond and a stream (Fig. 1) were selected for the present investigations, situated in Shillong (25°5'N Latitude and 91°9'E Longitude), at an altitude of 4,862 feet above sea level.

Pond :- It is shallow in nature, having a maximum depth of about 1.5 metres, during the monsoon season. The main source of the pond water is subsurface seepage and rainfall. The pond harbours a rich growth of macrophytic vegetation, which covers most of the pond basin (Fig. 2A).

Stream :- This is a hilly torrential stream which is moderately narrow with a varying depth of 0.5 to 1.0 metre and has a gravelly bottom. For a major part of the year, there is the presence of rooted vegetation on the banks of the stream (Fig. 2B).

MATERIALS AND METHODS

Samples for the physico-chemical analysis of water and plankton were collected at fortnightly intervals from the pond and stream (Fig. 2A,B) keeping the collection spots same throughout the period of study. While taking the samples, all the precautions were taken so that the water should be least disturbed.

Samples for the determination of dissolved oxygen content were collected in ground glass stoppered reagent bottles of 125 ml capacity. The samples were fixed immediately at the sites with one ml each of Manganous Sulphate ($MnSO_4$) solution and Alkaline iodide as per the methods described in A.P.H.A. (1965).

Plankton samples were collected by filtering 50 litres of water through a plankton net, made of bolting silk (No. 21

with 77 meshes/sq.cm.) and were preserved in Lugol's Iodine for qualitative and quantitative estimation.

The following abiotic parameters were taken into consideration in the present study: Hydrogen-ion-concentration (pH), Conductivity, Free Carbon-dioxide, Dissolved Oxygen, Alkalinity, Phosphate, Nitrate and Silicate. All the above mentioned parameters were analysed by the following methods.

TEMPERATURE : Both the air and water temperature were measured with the help of an ordinary mercury thermometer graduated upto 110.0°C.

CONDUCTIVITY : A Conductivity Meter Bridge (Make - Elico, Model No. CM-82) has been used for measuring conductivity.

DISSOLVED OXYGEN : The dissolved oxygen content of the water has been determined using the modified Winkler's method (A.P.H.A. 1965).

FREE CARBON-DIOXIDE : Free carbon-dioxide of water has been measured according to A.P.H.A. (1965) by titrating a known volume of sample against a standard alkali (N/44 Sodium Hydroxide) using phenolphthalein as an indicator.

HYDROGEN-ION-CONCENTRATION : The pH was recorded in the field with the help of BDH pH paper (narrow range) and thereafter confirmed in the laboratory with a Toshniwal pH Meter (Make Toshniwal, Model No. CL 43).

ALKALINITY : Carbonate and Bicarbonate alkalinity were estimated by titration with N/50 Sulphuric Acid using Phenolphthalein and Methyl Orange as indicator according to A.P.H.A. (1965). Further differentiations of alkalinities due to hydroxide, normal carbonate and bicarbonate were calculated as per methods described by Welch, 1948.

PHOSPHATE : Phosphate has been determined following the methods described 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 (Fig. 5) from which the amount of phosphate in the solution was calculated.

NITRATE : This has been also estimated according to the method outlined by A.P.H.A. (1965) as follows :-

50 ml of the sample was evaporated to dryness. To the residue, 2 ml of Phenol-disulphonic 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 (Fig. 4).

SILICATE : It has been determined spectrophotometrically by

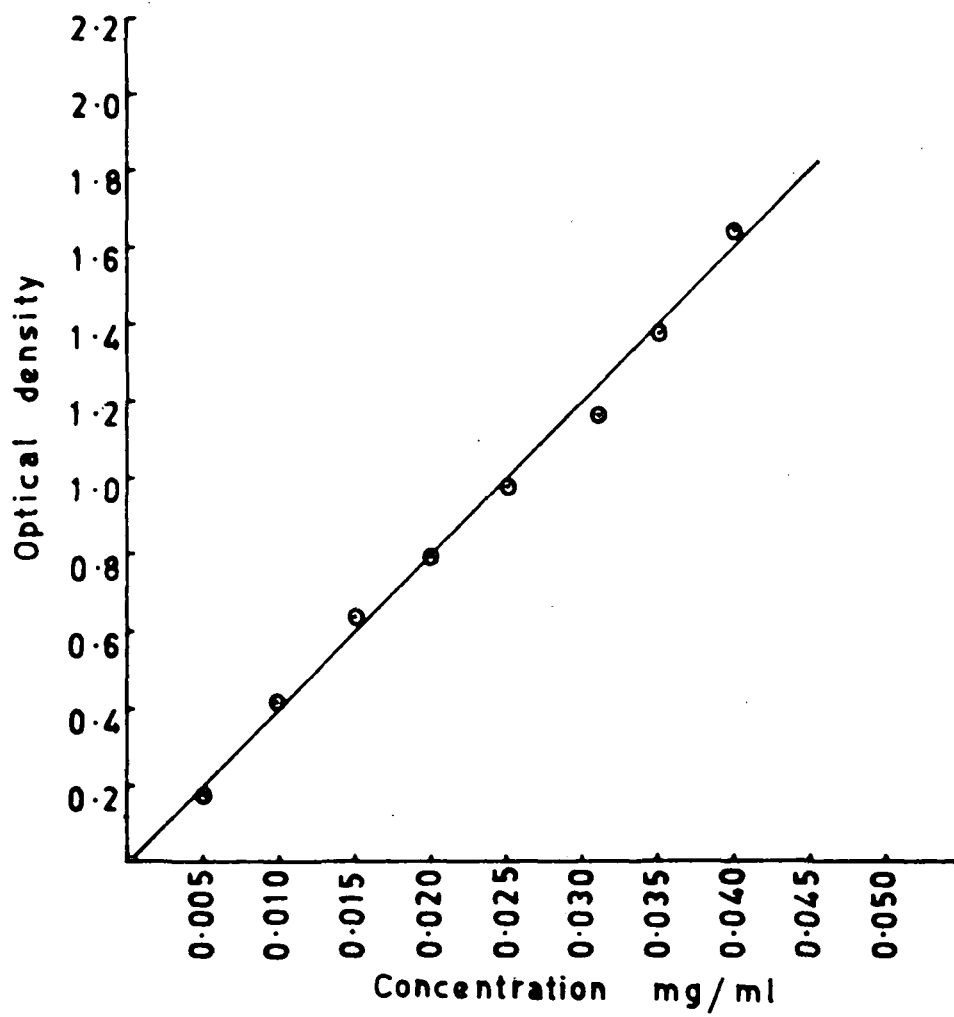


Fig. 4: Standard graph for Nitrate

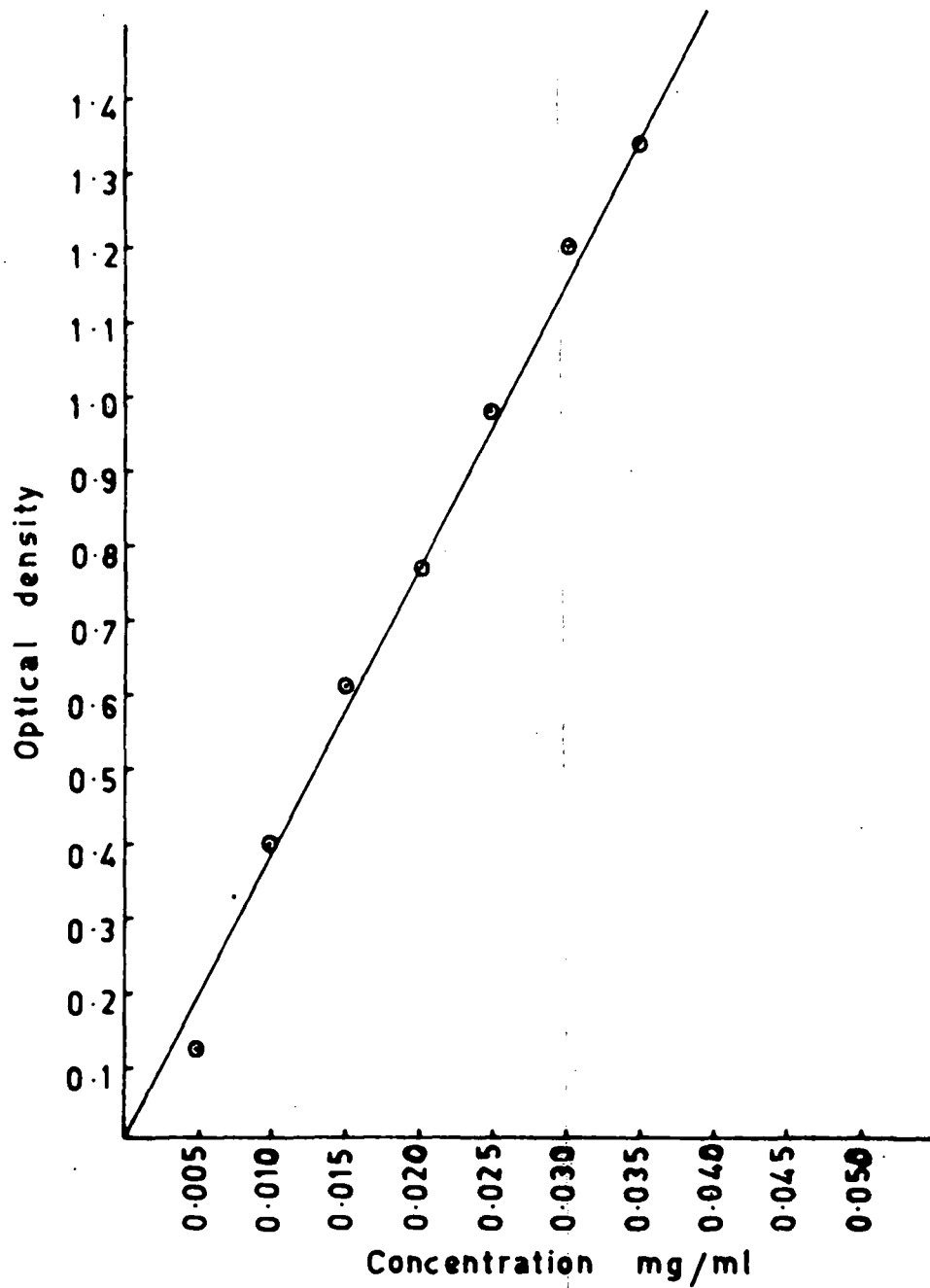


Fig. 5: Standard graph for Phosphate

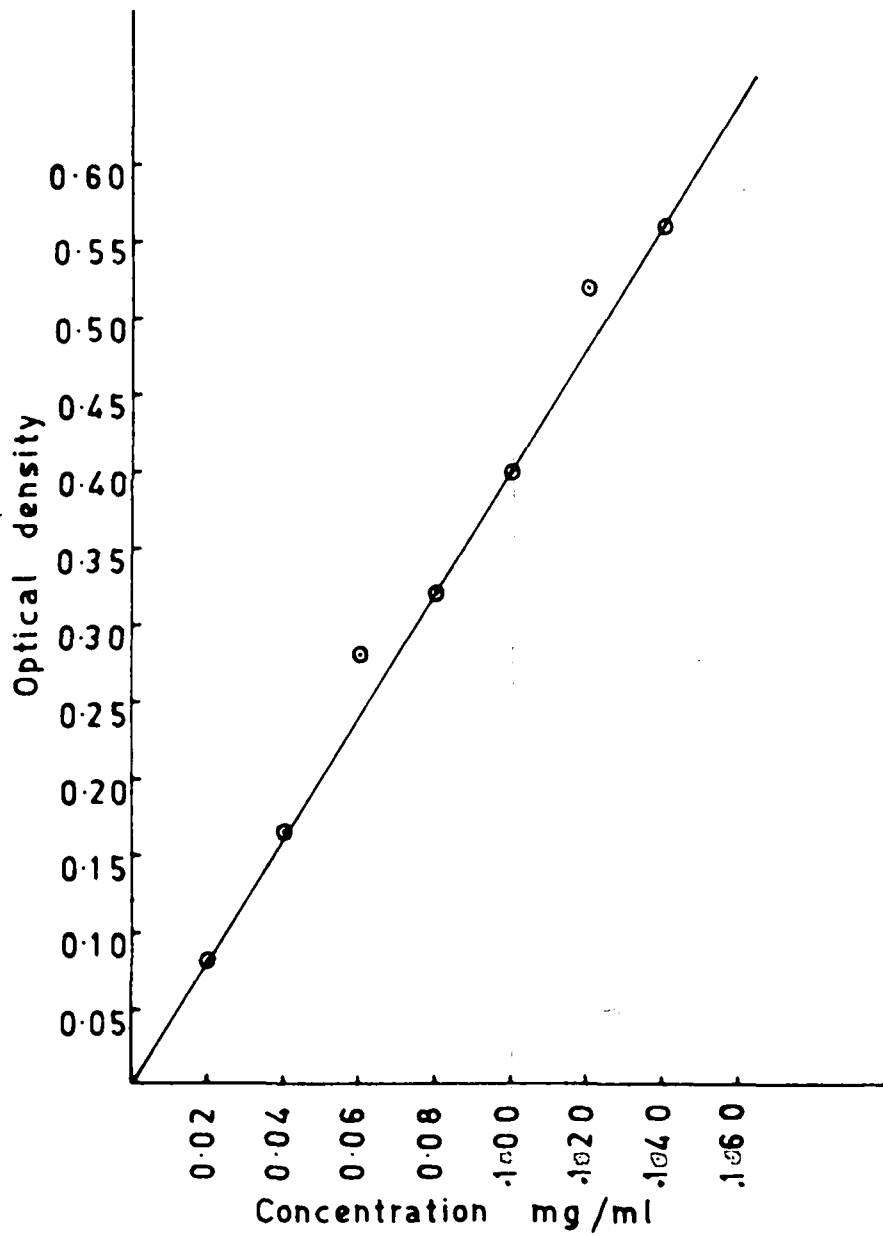


Fig. 6: Standard graph for Silicate

reduction of silico-molybdate (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 (Fig. 6) prepared in the same way using known amounts of silicon.

PLANKTON : Various methods have been employed by limnologists from time to time for qualitative and quantitative analysis of plankton as follows :-

- (a) By counting the individual species (Allen, 1930; Carpenter, 1941).
- (b) Estimation of the percentage of the volume.
- (c) The points method (Hynes, 1950).

However, in the present study the former method i.e. by counting individual species has been preferred and adapted, as it was found to be the most satisfactory and convenient method.

After shaking the vial containing the plankton sample, a sub-sample of 1 ml was drawn with a wide mouthed pipette and poured into a plankton counting cell of 1 (one) ml capacity. The organisms were enumerated and then represented in absolute numbers.

R E S U L T S

The data on the physico-chemical parameters of the pond and the stream have been tabulated in Tables 2 & 3 and were illustrated in Figs. 7, 8 & 9.

PHYSICAL CONDITIONS

WATER TEMPERATURE : The temperature of the pond water varied from 15.0 in January to 27.0°C in June. For the stream water, temperature ranged from 11.0 in January to 23.2°C in May (Fig.7).

CONDUCTIVITY : The conductivity values fluctuated from a minimum of 9.45 μ mhos/cm in August to a maximum of 39.30 μ mhos/cm and from 31.92 in October to 71.4 μ mhos/cm during June in both the pond and stream water respectively (Fig. 7).

HYDROGEN-ION CONCENTRATION : The pH was found to be on the acidic side throughout the period of study and varied from 4.1 (November) to 6.1 (January) in the pond water, whereas in the stream, it ranged from 4.2 to 8.1 being minimum in November and maximum in April (Fig. 7).

CHEMICAL CONDITIONS

DISSOLVED OXYGEN : The dissolved oxygen concentration in the pond water ranged from 5.0 to 12.4 mg/l during February and June respectively, whereas in the stream water it ranged from 6.2 to 9.76 mg/l in May and January respectively (Fig. 8).

FREE CARBON-DIOXIDE : The values of free carbon-dioxide were found to be in the range of 18.0 to 37.6 mg/l in December and January respectively in the pond water and from 2.9 in November to 18.2 mg/l during May in the stream water (Fig. 8).

ALKALINITY : The alkalinity values in the pond water ranged from 6.0 in August to 52.0 mg/l in September. In the case of stream water, it varied from 8.0 mg/l in February to 40.0 mg/l in March (Fig. 8).

PHOSPHATE : The dissolved phosphate concentrations ranged from 0.1 mg/l during December, January, February and July to 0.32 mg/l in April and 0.02 mg/l in March to 0.37 mg/l in June for the pond and stream water respectively (Fig. 9).

NITRATE : Nitrate values ranged from 0.06 mg/l in June and July to 0.51 mg/l during January in the pond water and from 0.2 mg/l in August and May to 2.3 mg/l during April in the stream water (Fig. 9).

SILICATE : Silicate values were found to fluctuate considerably from a minimum of 0.1 mg/l in October to a maximum of 5.05 mg/l

TABLE 2
PHYSICO-CHEMICAL CONDITIONS OF THE POND WATER

MONTHS	WATER TEMP. (°C)	CONDUCTIVITY (µmhos/cm)	pH (unit)	OXYGEN (mg/l)	FREE CARBON DIOXIDE (mg/l)	ALKALINITY (mg/l)	PHOSPHATE (mg/l)	NITRATE (mg/l)	SILICATE (mg/l)
<u>1978</u>									
SEPTEMBER	21.2	27.30	5.1	9.0	27.0	52.0	Traces	Traces	0.68
OCTOBER	20.0	15.12	5.2	11.6	23.0	20.0	0.20	0.14	0.10
NOVEMBER	16.0	24.37	4.1	10.9	21.0	46.0	0.28	0.11	4.32
DECEMBER	16.0	15.12	5.0	10.5	18.0	11.6	0.10	0.28	5.05
<u>1979</u>									
JANUARY	15.0	23.10	6.1	10.4	37.6	12.0	0.10	0.51	2.60
FEBRUARY	18.0	14.07	5.4	5.0	34.0	8.2	0.10	0.45	1.35
MARCH	20.2	28.14	4.9	5.9	24.0	28.8	0.17	0.38	3.62
APRIL	22.5	25.20	5.6	5.0	30.0	14.0	0.32	0.35	3.95
MAY	24.0	39.31	4.8	5.6	31.0	12.0	0.20	0.12	1.50
JUNE	27.0	38.30	5.0	12.4	32.0	7.0	0.15	0.06	1.00
JULY	25.0	16.27	5.3	9.6	28.0	6.8	0.10	0.06	0.95
AUGUST	22.5	9.45	4.7	10.0	24.0	6.0	0.02	0.37	1.40

TABLE 3

PHYSICO-CHEMICAL CONDITIONS OF THE STREAM WATER

MONTHS	WATER TEMP. (°C)	CONDUCTIVITY (μmhos/cm)	pH (unit)	OXYGEN (mg/l)	FREE CARBON DIOXIDE (mg/l)	ALKALINITY (mg/l)	PHOSPHATE (mg/l)	NITRATE (mg/l)	SILICATE (mg/l)
<u>1978</u>									
SEP	21.5	40.82	6.8	7.9	5.5	27.0	0.05	1.7	0.5
OCT	18.5	31.92	6.6	8.0	4.0	36.0	0.075	1.4	0.6
NOV	16.25	52.92	4.2	8.6	2.9	26.0	0.20	1.6	4.0
DEC	14.5	38.22	6.2	9.6	3.2	15.0	0.07	1.5	5.0
<u>1979</u>									
JAN	11.0	66.155	7.5	9.76	4.0	20.6	0.052	0.6	2.1
FEB	18.0	34.65	6.4	9.0	4.0	40.0	0.05	0.51	1.2
MAR	17.0	48.80	7.2	9.64	4.2	40.0	0.02	0.95	0.5
APR	21.0	56.7	8.1	6.8	9.36	9.0	0.10	2.3	5.6
MAY	23.2	32.0	5.2	6.2	18.2	13.5	0.20	0.2	1.0
JUN	23.0	71.4	5.5	7.4	4.0	3.2	0.37	1.32	1.8
JUL	22.0	36.75	6.5	7.2	3.6	16.0	0.02	1.1	1.4
AUG	20.0	40.95	5.7	8.0	3.8	9.0	0.014	0.2	1.1

in December in the case of pond water, whereas it ranged from 0.5 mg/l in September to 5.6 mg/l in April in the stream water (Fig. 9).

PLANKTON

The plankton composition of the pond and stream waters comprised of the Chlorophyceae, Bacillariophyceae and Euglenophyceae among the phytoplankton and Rotifera, Copepoda and Cladocera (recorded only from the stream) among the zooplankton. The varying percentage composition of phyto- and zooplankton have been shown in Tables-4 to 7 and Figs. 10 & 11.

PHYTOPLANKTON

Among phytoplankton, Chlorophyceae formed the most dominant group qualitatively as well as quantitatively, as the members of this group were present all throughout the year in varying percentages both in the pond (Fig. 12) as well as in the stream (Fig. 13). The extent in which their relative percentage composition ranged are from 1.52 in April to 95.28% in August for pond and 30.68 in September to 100% (February) in the stream (Fig. 13). In the pond water, Chlorophyceae comprised of Ulothrix sp., Spirogyra sp., Scenedesmus sp., and Closterium sp. These did not show any definite pattern of seasonal fluctuation.

In the stream, the members of Chlorophyceae showed a rise in their percentage composition from September onwards to reach their maximum during the months of December to April, whereafter the population reduced, but maintaining uniformly a good population (Fig. 13). The most dominant species were Ulothrix sp., Microspora sp., Spirogyra sp., Zygnema sp. and Closterium sp.

Bacillariophyceae was found to be the next in the order

of abundance. Its presence was recorded throughout the year in the pond showing considerable seasonal variations in its abundance, being minimum of 4.72% in August and maximum of 94.74% in February. However, the Bacillariophyceae population decreased quantitatively during the winter, but on the onset of early spring, it showed an increasing trend, reaching peaks in February and May (Fig. 12). The group was mainly dominated by Navicula sp., Synedra sp. and Diatoma sp., however, Asterionella sp. and Nitzschia sp. were also recorded.

In the stream, Bacillariophyceae was represented by Navicula sp., Synedra sp., Fragillaria sp. and Diatoma sp. It was found to be present in varying quantities throughout the period of the study, excepting February, when members of this group were marked by a complete absence. Their percentage composition ranged from 1.13% in January to 69.31% in September. During September to November, the members of Bacillariophyceae were found to be present in good numbers whereafter the percentage occurrence reduced to a minimum of 1.13% in January. From March onwards their population build up to reach a maximum in May.

Euglenophyceae was present in a scattered manner during the annual cycle showing their presence only in certain months and a complete absence in others both in the pond and stream. Their percentage composition ranged from 0.30% in September to 8.33% in November in the pond and ranged from 0.25% in December to 3.7% in November in the stream. This group was mainly represented by Euglena sp. and Phacus sp. Phytoplankton formed 94.6% and 98.66% of the total plankton population in the pond and the stream respectively.

TABLE 4

SEASONAL PERIODICITY IN PHYTOPLANKTON OF THE POND WATER

PHYTOPLANKTON	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
<u>CHLOROPHYCEAE</u>												
Spirogyra	43	743	-	25	-	-	6	-	-	-	-	-
Ulothrix	176	853	-	-	47	-	-	-	-	23	-	117
Mougoetia	-	-	1	1	-	-	-	-	-	-	-	-
Scenedesmus	2	3	1	-	-	-	1	1	108	1	4	2
Zygnema	-	-	-	5	-	-	3	-	-	-	-	-
Coelastrum	4	1	-	-	-	-	-	-	28	-	-	-
Gonatozygon	-	-	3	150	-	-	17	-	-	-	-	-
Closterium	3	12	-	2	-	-	1	-	-	1	-	-
Tribonema	1	-	-	-	-	-	-	-	-	-	-	-
Cosmarium	1	-	-	1	-	-	-	-	-	-	-	-
Decidium	-	12	-	-	-	-	1	-	-	-	-	2
TOTAL	230	1623	5	184	47	-	29	1	136	24	4	121
% age composition	67.64	87.50	41.67	71.04	88.68	-	87.88	1.52	18.86	66.67	12.12	95.28
<u>EUGLENOPHYCEAE</u>												
Phacus	-	-	1	-	-	-	-	-	-	2	-	-
Euglena	1	-	1	-	2	-	-	-	-	-	-	-
TOTAL	1	-	1	-	2	-	-	-	-	2	-	-
% age composition	0.30	-	8.33	-	3.77	-	-	-	-	5.55	-	-
<u>BACILLARIOPHYCEAE</u>												
Navicula	76	133	2	12	1	11	2	7	404	6	9	6
Synedra	18	20	1	5	2	7	1	5	106	2	2	-
Diatoma	6	77	1	-	-	-	-	-	28	-	-	-
Asterionella	8	-	-	1	-	-	-	-	-	1	-	-
Nitzschia	-	-	-	-	-	-	-	-	46	-	-	-
TOTAL	108	230	4	18	3	18	3	12	584	9	11	6
% age composition	31.76	12.40	33.33	6.95	5.66	94.74	9.09	18.18	81.00	25.00	33.33	4.32
<u>OTHERS (UNIDENTIFIED)</u>												
TOTAL	1	2	2	57	1	1	1	53	1	1	18	-
% age composition	0.30	0.10	16.67	22.01	1.89	5.26	3.03	80.30	0.14	2.75	54.55	-
TOTAL PHYTOPLANKTON	340	1855	12	259	53	19	33	66	721	36	33	127

TABLE 5

SEASONAL PERIODICITY IN PHYTOPLANKTON OF THE STREAM WATER

PHYTOPLANKTON	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
CHLOROPHYCEAE												
Mougoetia	-	-	-	60	-	-	135	-	-	-	720	-
Ulothrix	1330	285	-	3610	8740	1615	1710	9576	190	570	3420	1197
Zygnema	-	170	-	1360	408	-	-	-	-	-	2040	-
Microspora	200	200	-	600	-	-	1040	-	-	200	-	-
Spirogyra	200	200	-	500	120	-	-	-	190	200	-	360
Cosmarium	184	-	60	-	-	-	-	-	-	-	-	-
Coelastrum	-	-	-	-	32	45	-	-	-	-	-	-
Scenedesmus	70	-	30	-	-	-	-	-	-	-	-	-
Pediastrum	10	-	80	-	-	-	-	-	-	-	-	-
Gonatozygon	-	400	150	600	-	-	300	-	200	600	-	-
Closterium	1484	20	700	180	36	30	-	34	13	25	-	81
Tribonema	-	-	750	750	-	-	-	-	-	-	-	-
Euastrum	132	10	-	-	-	-	-	-	-	10	-	-
Cylindrocystis	-	-	-	-	-	-	-	-	-	-	-	-
Protococcus	-	-	-	-	-	-	-	-	-	-	-	-
Decidium	198	-	-	-	-	-	-	-	-	-	-	-
TOTAL	3558	1285	1020	7660	9336	1690	3185	9610	593	1605	6180	1638
% age composition	30.68	79.07	36.01	96.11	98.52	100.0	95.73	97.51	47.89	81.18	93.92	87.50
BACILLARIOPHYCEAE												
Navicula	5995	265	1660	170	88	-	52	126	361	226	240	189
Synedra	351	40	47	50	20	-	30	63	142	48	60	27
Fragillaria	-	-	-	70	-	-	45	-	60	-	-	-
Frustulia	-	-	-	-	-	-	-	-	-	10	-	-
Nitzschia	627	-	-	-	-	-	-	-	-	10	-	-
Diatoma	1063	35	-	-	-	-	-	56	72	58	-	18
Asterionella	-	-	-	-	-	-	15	-	-	-	40	-
TOTAL	8036	340	1707	290	108	-	142	245	635	352	340	234
% age composition	69.31	29.92	60.27	3.63	1.13	-	4.26	2.45	51.25	17.80	5.16	12.50
EUGLENOPHYCEAE												
Phacus	-	-	30	20	16	-	-	-	-	20	60	-
Euglena	-	-	75	-	16	-	-	-	10	-	-	-
TOTAL	-	-	105	20	32	-	-	-	10	20	60	-
% age composition	-	-	3.7	0.25	0.33	-	-	-	0.80	1.01	0.9	-
TOTAL PHYTOPLANKTON	11594	1625	2832	7970	9476	1690	3327	9855	1238	1977	6580	1872

TABLE 6
ZOOPLANKTON PERIODICITY IN THE POND

ZOOPLANKTON	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG
<u>ROTIFERS</u>												
Synchaeta	-	10	-	-	-	-	-	-	-	-	-	-
Chromagaster	-	-	-	-	-	-	-	-	82	-	-	-
Lecane	1	-	-	-	-	-	-	-	-	-	-	-
Brachionus	1	1	1	1	20	4	1	-	20	1	2	-
TOTAL	2	11	1	1	20	4	1	-	102	1	2	-
% age composition	25.00	1.16	100.0	50.00	100.0	80.00	50.00	-	29.14	7.69	18.18	-
<u>COPEPODS</u>												
Cyclops	3	16	-	1	-	1	1	1	62	12	9	2
Nauplius	3	918	-	-	-	-	-	-	186	-	-	-
Chydorus	-	2	-	-	-	-	-	-	-	-	-	-
TOTAL	6	936	-	1	-	1	1	1	248	12	9	2
% age composition	75.00	98.84	-	50.00	-	20.00	50.00	100.0	70.86	92.31	81.82	100.0
TOTAL PLANKTON(zoo)	8	947	1	2	20	5	2	1	350	13	11	2
% age composition of Zooplankton	2.29	33.79	7.69	0.76	24.09	20.83	5.71	1.49	32.67	27.08	25.00	1.55
% age composition of Phytoplankton	97.71	66.21	92.31	99.24	75.91	79.17	94.29	98.51	67.33	72.92	75.00	98.45

TABLE 7
ZOOPLANKTON PERIODICITY IN THE STREAM

ZOOPLANKTON	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JUL	AUG
<u>CLADOCERA</u>												
Daphnia	20	-	-	-	-	-	-	-	-	-	-	-
Bosmina	60	-	10	-	-	-	-	-	-	-	-	-
TOTAL	80	-	10	-	-	-	-	-	-	-	-	-
% age composition	17.02	-	11.76	-	-	-	-	-	-	-	-	-
<u>ROTIFERA</u>												
Brachionus	71	-	65	-	24	15	-	-	66	10	-	-
Keratella	231	40	-	15	-	-	-	-	-	-	-	-
Lecane	88	-	10	20	-	-	-	-	-	10	-	-
Platyias	-	-	-	-	-	-	-	-	12	10	-	-
TOTAL	390	40	75	35	24	15	-	-	78	30	-	-
% age composition	82.97	100.0	88.23	100.0	75.00	100.0	-	-	86.06	100.0	-	-
<u>COPEPOD</u>												
Nauplii	-	-	-	-	-	-	-	-	-	-	-	18
Cyclops	-	-	-	-	8	-	-	-	-	-	-	-
TOTAL	-	-	-	-	8	-	-	-	12	-	-	18
% age composition	-	-	-	-	25.00	-	-	-	13.30	-	-	100.0
Total Zooplankton	470	40	85	35	32	15	-	-	90	30	-	18
Total Plankton												
% age composition of Zooplankton	3.89	2.40	2.91	0.43	0.33	0.87	-	-	6.77	1.49	-	0.95
% age composition of Phytoplankton	96.1	97.59	97.08	99.56	99.66	99.12	100.0	100.0	93.22	98.50	100.0	99.04

ZOOPLANKTON

In comparison to phytoplankton, zooplankton were much less both in quality as well as in quantity. In the pond, the percentage occurrence of zooplankton in the total plankton population varied from 0.76% to 33.79%. Rotifers dominated during the winter season and their percentage composition gradually declined to a minimum during summer months, allowing Copepoda to dominate the population during summer (Fig. 14). Brachionus sp. and Cyclops sp. were found to be dominant among the Rotifera and Copepoda respectively. The percentage composition of Rotifera ranged from 1.16% in October to 100% in January. The percentage composition of Copepoda ranged from 20.0% in February to 100% in April and August.

Rotifera was found to be the most dominant group in the stream ranging from 75% in January to 100% in October, February and June. A complete absence has been recorded in the months of March, April, July and August. (Fig. 15). Qualitatively, Rotifera comprised of Brachionus sp., Keratella sp., Lecane sp. and Platylas sp. Next in the order of abundance was Copepoda. Its percentage composition was found to vary from 13.3% in May to 100% in August. This group was recorded by a complete absence in certain months (Fig. 15).

Cladocera was represented by the presence of Bosmina sp. This group was the least abundant among zooplankton and its presence has been recorded in the months of September and November represented by 11.76% to 17.02% of the total zooplankton in the stream population. For the rest of the months a complete absence has been observed. The percentage occurrence of zooplankton in the total plankton population varied from 0.33% to 6.77%.

D I S C U S S I O N

PHYSICAL CONDITIONS

DEPTH : The water depth of both the systems in general depended directly on the rainfall. They lost depth during the summer months due to high rate of evaporation of water. Similar view has also been expressed by Nasar and Munshi (1974).

TEMPERATURE : The water temperature showed a close affinity with the atmospheric temperature. According to Welch (1952) the shallow depth and large expanse of surface as compared with the volume of water, in general tend to follow the temperature of the atmosphere, which seems to be true in the present study also. Similar case has also been observed by many workers from lower latitudes (Zafar, 1955; Ganapati, 1960; Munawar, 1970; Nasar and Munshi, 1974).

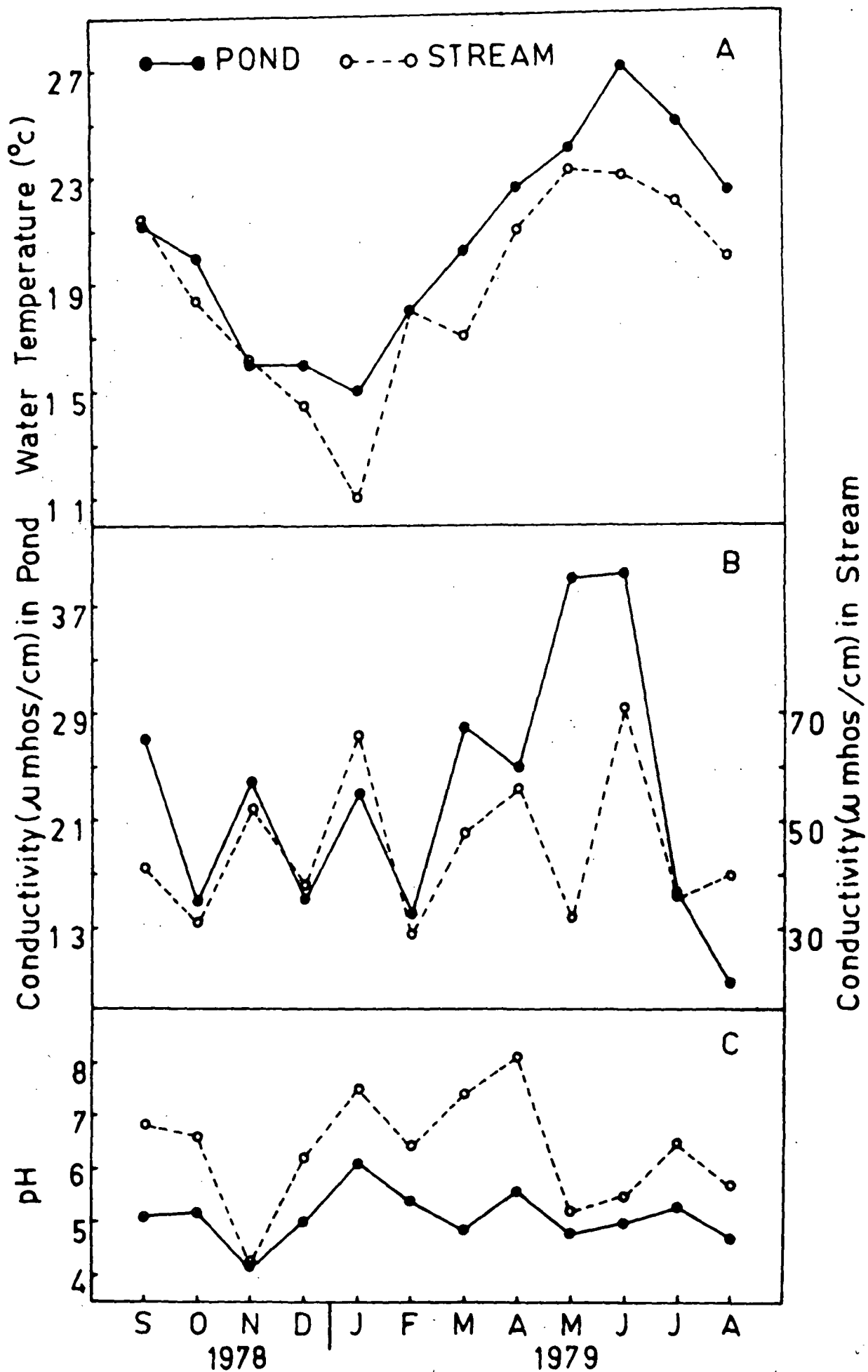


Fig. 7: Physico-chemical conditions of the water bodies.

CONDUCTIVITY : The conductivity values fluctuated widely without showing any definite pattern (Fig. 7). It is a well known fact that the conductivity of the water depends upon the substances dissolved in it. It has been observed the conductivity and alkalinity in the pond water showed a somewhat direct relationship from September onwards to April when the seasonal minima and maxima in alkalinity values and conductivity values occurred approximately at the same time. From May to August, an inverse relationship has been observed (Fig. 7). In the stream water, the two factors (Conductivity and Alkalinity) showed an inverse relationship during September and October, whereafter from November to May, it showed a direct relationship.

It has also been observed that low pH values corresponded with high conductivity values (Tables 2 & 3). Atkins and Harris (1924) suggests that the electrical conductivity may be high when the pH is low and vice versa and attributed that this might be due to the precipitation of the calcium and magnesium carbonate owing to the decrease of carbonic acid in solution and that the reduction in conductivity, may be the result, at least in part, of the removal of electrolytes by algae necessary for their growth.

HYDROGEN-ION-CONCENTRATION : The hydrogen-ion-concentration expressed as pH, was found to be on the acidic side in both the pond and stream. It is believed that pH is generally influenced to a great extent by carbon-dioxide (Welch, 1952) and at low pH most of the carbon-dioxide exists in free form. In the present study, an inverse relationship has been observed between free carbon-dioxide and pH in both the systems (Figs. 2 & 3). As the pH was on the acidic side, large amounts of free carbon-dioxide were recorded.

It is well known that pH depends upon the amounts of carbonates of calcium and magnesium and the carbon-dioxide tension in the water. The latter, in its turn is influenced by the photosynthetic activities of the aquatic vegetation 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. Therefore, high pH values from December to April in the stream and the pond indicate a higher photosynthetic activity than the respiratory process as has also been suggested by Hannan and Young (1974).

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. This 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).

CHEMICAL CONDITIONS

FREE CARBON-DIOXIDE AND ALKALINITY : The main source of free carbon-dioxide in both the systems seems to be due to the decomposition of organic matter and respiration of plants and animals. Allegeier et al., (1932) reported that the carbon-dioxide is the second largest decomposition product. The concentration of carbonate and bicarbonate is generally influenced by carbon-dioxide. Three factors viz. Carbon-dioxide, Bicarbonates and Carbonates

are known to be responsible for maintaining the "Buffer System" of freshwater systems, hence, in the pond and stream waters too. Therefore, the presence of free carbon-dioxide in waters suggest that the water was less alkaline or acidic. Free carbon-dioxide and alkalinity showed an inverse relationship (Fig. 8) which suggests that the former appears to be an important component of the buffer system of the water, as has also been reported by Hutchinson (1967). 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 the alkalinity values may be due to the photosynthetic activity, as has also been reported by Hussey (1967) and according to him, this mainly depends on the "buffer system". The general relationship between pH, carbonate and bicarbonate alkalinity and free carbon-dioxide may be interpreted on the basis of dissociation of these into ionic state. As discussed above, free carbon-dioxide in the water forms carbonic acid which dissociates into H^+ and HCO_3^- ions, which brings change in the pH of the water (Ruttner, 1953) as hydrogen-ions are set free. HCO_3^- reacts with calcium to form soluble calcium bicarbonate. If, at this stage free CO_2 is not available, calcium bicarbonate gets converted into insoluble calcium carbonate. The amount of CO_2 that inhibits the conversion of bicarbonates into carbonates has been named 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.

DISSOLVED OXYGEN : The dissolved oxygen concentrations were found to vary inversely with the free carbon-dioxide all throughout the period of the study (Fig. 8). From September to March

and again in July and August when the dissolved oxygen concentration was found to be high it corresponded with low quantities of free carbon-dioxide in the stream. Similar observations have also been recorded by Whipple and Parker (1902), Birge and Juday (1911), Pearsall (1930), Ganapati (1943), Gonzales and Joshi (1946), Rao (1955) and Saha et al. (1959).

Further, dissolved oxygen content showed an inverse relationship with temperature. Periods of high temperature coincided with these of low levels of oxygen in the pond, as per the law of solubility of gases, whereas in June, the case was contrasting as 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 during June was not the temperature. During the period, the sky was bright and clear providing sufficient sunlight to the macrophytes present in the pond, which might have liberated oxygen by their photosynthetic activity, thus increasing the oxygen content of the water. This supports the fact that during photosynthesis, carbonic acid gets split up, whereby assimilation of carbon takes place and also liberation of oxygen to the surrounding water (Welch, 1952). Hence, the greater the abundance of vegetation the greater the assimilation and consequently greater the liberation of oxygen as also suggested by Ganapati (1940) and 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 factor which affects the quantity of oxygen. In the present study, low temperature was recorded from October to February in the pond and October

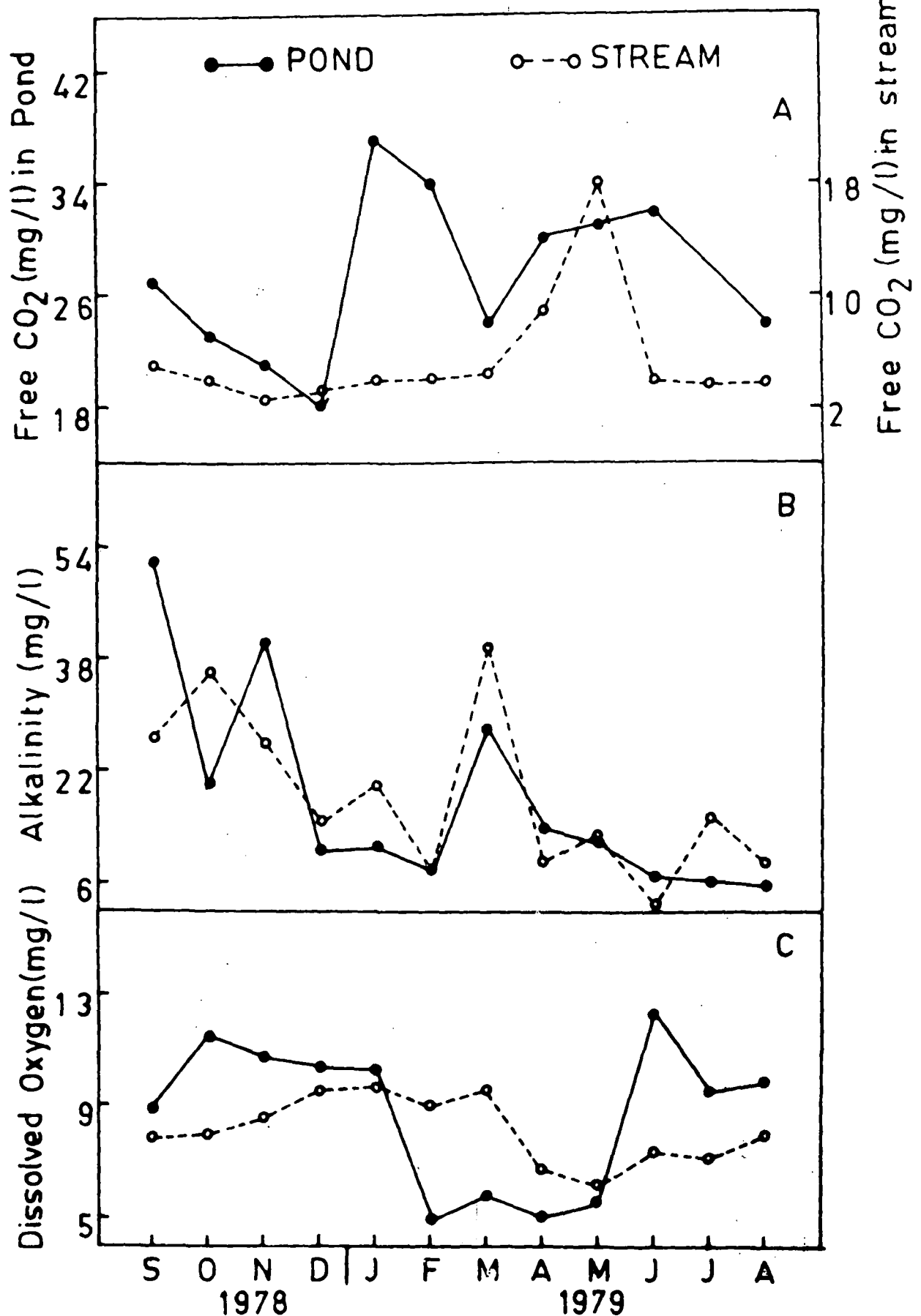


Fig. 8: Physico-chemical conditions of the water bodies

to March in the stream and high levels of dissolved oxygen (Tables 2 & 3) during the period.

The atmosphere was probably another important source of oxygen in the pond and stream. Due to the action of the wind, small ripples might have been formed and thereby different layers of water were exposed to the air and the water got oxygenated. The reduction in dissolved oxygen content might have been due to the respiration which is known as a continuous activity day and night of the plant and animal life. The other factor which seems to be responsible for reduction of dissolved oxygen is decomposition. The oxygen was consumed during decomposition of the bottom materials and suspended organic matter. Hence the dissolved oxygen was low during summer months (Tables 2 & 3) because the decomposition is generally supposed to be quicker in warmer than in cold conditions. Hannan et al. (1979) have reported similar results from Deep-Storage reservoir in Central Texas. Thus, it may be concluded that the oxygen content of freshwaters mainly depends upon several factors such as :-

- i) solubility of oxygen in water depending upon temperatures;
- ii) photosynthetic activities of plant life present;
- iii) respiration of plant and animal life;
- iv) intensity of illumination; and
- v) wind action.

Seasonal variations in the dissolved oxygen content of running and standing waters have been reported by Eddy (1934), Chakraborty et al. (1959), Swale (1964), Pahuwa and Mehrotra (1966) and Venkateswarlu and Jayanti (1968). Fritsch (1907), Alikunhi (1957), Odum (1957), Nasar and Munshi (1971), Nasar (1975) and Hannan et al. (1979). According to them dissolved

oxygen is generally found to be maximum during winter and minimum in summer, as has also been recorded in the present study too.

The nutrient condition in both the systems viz. pond and stream, was found to be poor (Tables 2 & 3). According to Hynes (1970) the nutrient condition varies enormously in running waters from region to region and is a reflection of the local geographical and climatic conditions, which seems to be true in the present study too.

PHOSPHATE : The dissolved phosphate concentration in both the pond and stream was found to be quite poor. Welch (1952) and Ruttner (1953) have reported smaller amounts of phosphorus in those water which are free of contaminating effluents, hence, this may be the reason of lower amounts of phosphate specially in the pond as it was free from any contaminating effluents. In the present study, an inverse relationship has been observed between phosphate and oxygen concentration in both the systems. Such a situation may be due to the fact that when there is lack of oxygen in water bodies, particularly in the sediments, the iron is reduced from the ferric to the ferrous state releasing phosphate into water, as suggested by Einsele (1936). Therefore, during oxygen deficiency, phosphate gets released in water from the sediment, thus the inverse relationship occurs. Moreover, the seasonal fluctuation in the phosphate concentration might be due to the presence of algae in the system, which is known to utilize phosphate during their photosynthetic activities. According to Welch (1952) various factors like temperature, salinity and bacterial activity play an important role upon the rate of phosphorus release. In the stream, an inverse relation-

ship in phosphate concentration during April to June could be due to run-off from the catchment areas during the rainy season (Fig. 9).

NITRATE : Nitrate showed an inverse relationship with dissolved oxygen except in the months of June and July in the stream water when these two factors did not show any definite relationship. An inverse relationship has also been observed between pH and Nitrate, however a direct correlation has been reported by Ganapati (1943) and Zafar (1964). Nitrate depletion in the stream during winter months may be due to photosynthetic activity of the phytoplankton or may be 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 contributor of nitrate nitrogen in rivers.

Zafar (1964) suggested that when the dead organic matter decomposes in water, complex protein molecules are converted into "nitrogenous organic matter" and finally into nitrates by the bacterial activity. Accordingly when alluminoid ammonia and nitrate go hand in hand and show an inverse relationship to the dissolved organic 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 in water and they themselves are the main source of nitrogenous organic matter (Munawar, 1970). However, in the present investigation, it is difficult to draw any

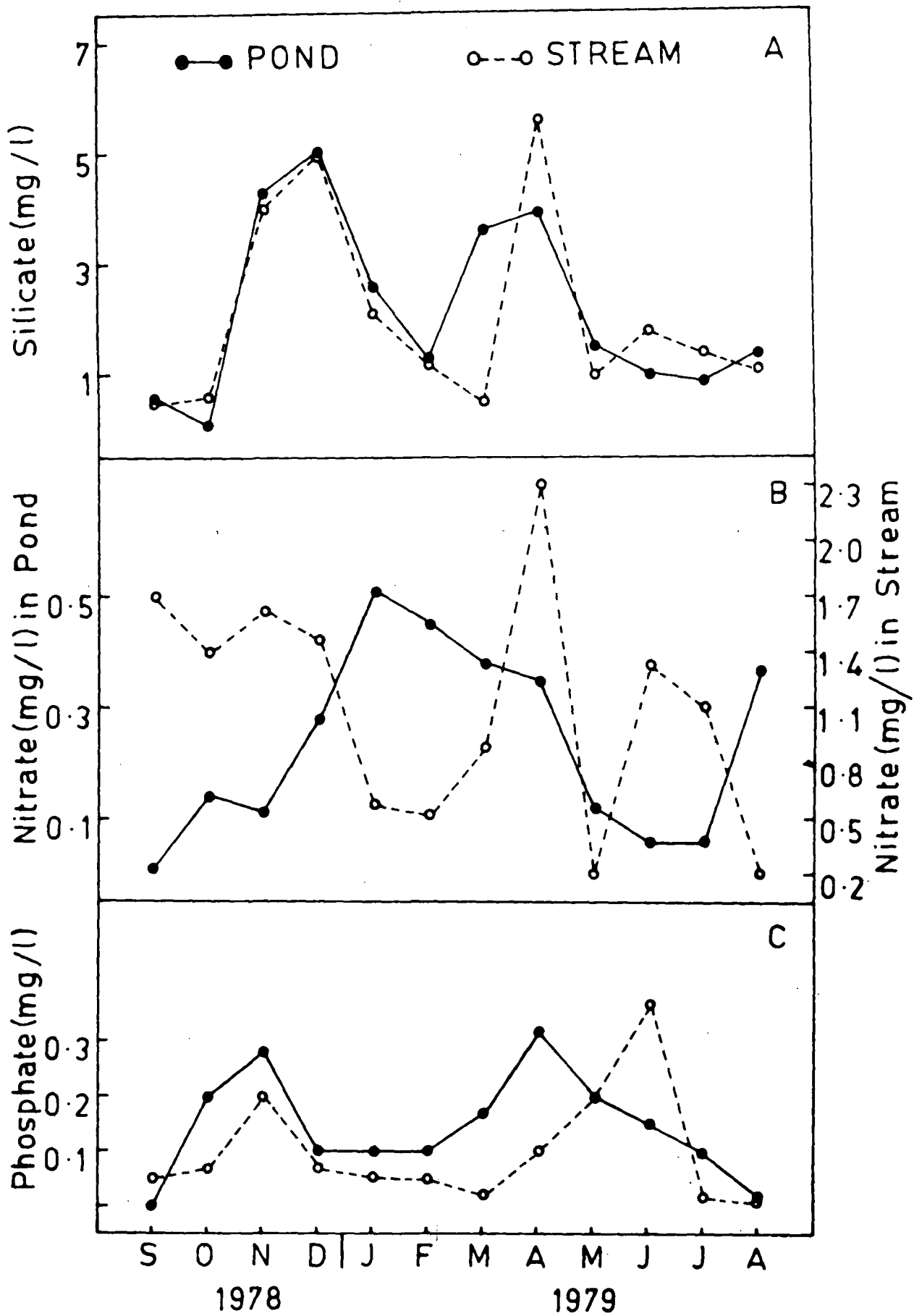


Fig. 9: Physico-chemical conditions of the water bodies

conclusion regarding the main source of nitrates in these water bodies on the basis of above statement as alluminoid-ammonia and dissolved organic matter were not estimated. However, in the light of above, it can be assumed that the main source of nitrates in the pond may be the decomposing organic matter, not the plankton as the former was present in quite large quantities whereas the plankton population was poor both in the pond and stream. According to Vollenweider (1968) and Schindler (1971) the major source of nitrates is by precipitation.

Nitrate showed an inverse relationship to 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 N_2O or to ammonia (Hutchinson, 1967), which seems to be the reason of the nitrate depletion in the pond at higher temperature i.e. during May to July.

SILICATE : The silicate content of the water was found to vary inversely with free CO_2 in the present study in both the systems, possibly owing to the fact that as Silicic acid is more weakly dissociated than CO_2 , 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.

It has also been observed in the pond that the alkalinity increased with the increase in silicate concentration as has

also been recorded by Atkins (1926). He has also reported that the silica content in freshwaters is influenced by temperature and evaporation. In the stream, however, an inverse relationship has been observed between alkalinity and silicates. It is evident from the planktonic studies that peaks of diatom population corresponded with low levels of silicate in the water (Fig. 16), since diatoms take up silicates and the presence of large numbers of diatom might have caused the exhaustion of silicate to low levels, in both the pond and stream.

PLANKTON

It has been observed that quantitatively there is likely to be less plankton in tropical inland waters than in temperate waters (Welch, 1952).

In the present study, 11 species of Chlorophyceae; 5 species of Bacillariophyceae and 2 species of Euglenophyceae in the pond (Table 4) and 15 species of Chlorophyceae; 7 species of Bacillariophyceae and 2 species of Euglenophyceae in the stream (Table 5) have been recorded. Among the zooplankton, Rotifera comprised of 4 species both in the pond (Table 6) and stream; Copepoda was represented by 3 species in the pond and 1 species in the stream. Cladocera was represented by 2 species and its presence was recorded only in the stream (Table 7).

In both the systems, phytoplankton showed a numerical superiority over the zooplankton. It is also apparent from the present study that certain species of plankton disappeared at certain periods only to reappear later and hence at no time during the year, there was a total absence of plankton. The

plankton productivity varied from season to season in both the systems and qualitative variation particularly of zooplankton were quite identical.

The plankton population peaks in the pond as observed in the present study (Tables 4 to 7) were found to resemble that of Kashmir and Kumaon lakes as reported by Das et al. (1969) and Das and Upadhyay (1979) respectively, unlike the water bodies of plains (Das and Srivastava, 1956a,b). This, further reflects that changes in the composition of species and their appearance and disappearance are characteristics of summer and winter unlike the plankton in plains as reported by Nasar (1979a). Thus, it can be said that the plankton peaks of freshwater bodies of high altitudes of India are quite comparable with the spring and autumn plankton peaks of temperate countries.

It can be revealed that in some groups of plankton, the amplitude of rise and fall in quantity may not be large enough to produce more than minimal change in the total plankton population, while in others, the change may be so great that a wave of development of a single group may be sufficient to dominate the whole population. Further, the period of quantitative increase and decrease of the individual may not in many genera coincide with the seasonal minima and maxima of the total plankton. Nasar (1979a) concluded that the rate of development of a pulse may vary greatly, some species may increase slowly and more or less uniformly to the maximum while others may show a burst of development rising from an apparent absence to a numerical dominance of the whole plankton within a very short period, which seems to be true in the present study too.

PHYTOPLANKTON

Phytoplankton in the stream showed two peaks, one in February and the other in July, which correspond with low zooplankton number. Therefore, an inverse relationship between the two has been observed. In the pond too, an inverse relationship between phytoplankton and zooplankton pulses has been recorded. According to Slacdecek (1958), factors which cause fluctuations in phytoplankton abundance are the grazing activity by zooplankton. Hence, the same could be true in the present study too. Srivastava (1950) observed an increase of dissolved oxygen which caused an increase of phytoplankton biomass and this could be the reason of the numerical superiority of phytoplankton over zooplankton. Chacko and Krishnamurthy (1954) has suggested that the temperature is an important factor in controlling both the quantity of species composition of the plankton flora, but it cannot be the only factor involved. In the present study, Chlorophyceae was found to be the most abundant group followed by Bacillariophyceae and Euglenophyceae in both the systems. No similarity could be seen in the seasonal fluctuations in Chlorophyceae and Bacillariophyceae in both the systems. In the pond, no definite pattern of fluctuation could be noticed for Chlorophyceae, whereas in the stream, maximum numbers were found from December to April. Bacillariophyceae population in the pond decreased during winter and peak has been observed in February and May, whereas in the stream maximum number were found in September, November and May.

ZOOPLANKTON

Among the zooplankton, Copepoda was found to be the most dominant in pond followed by Rotifera, whereas in the stream,

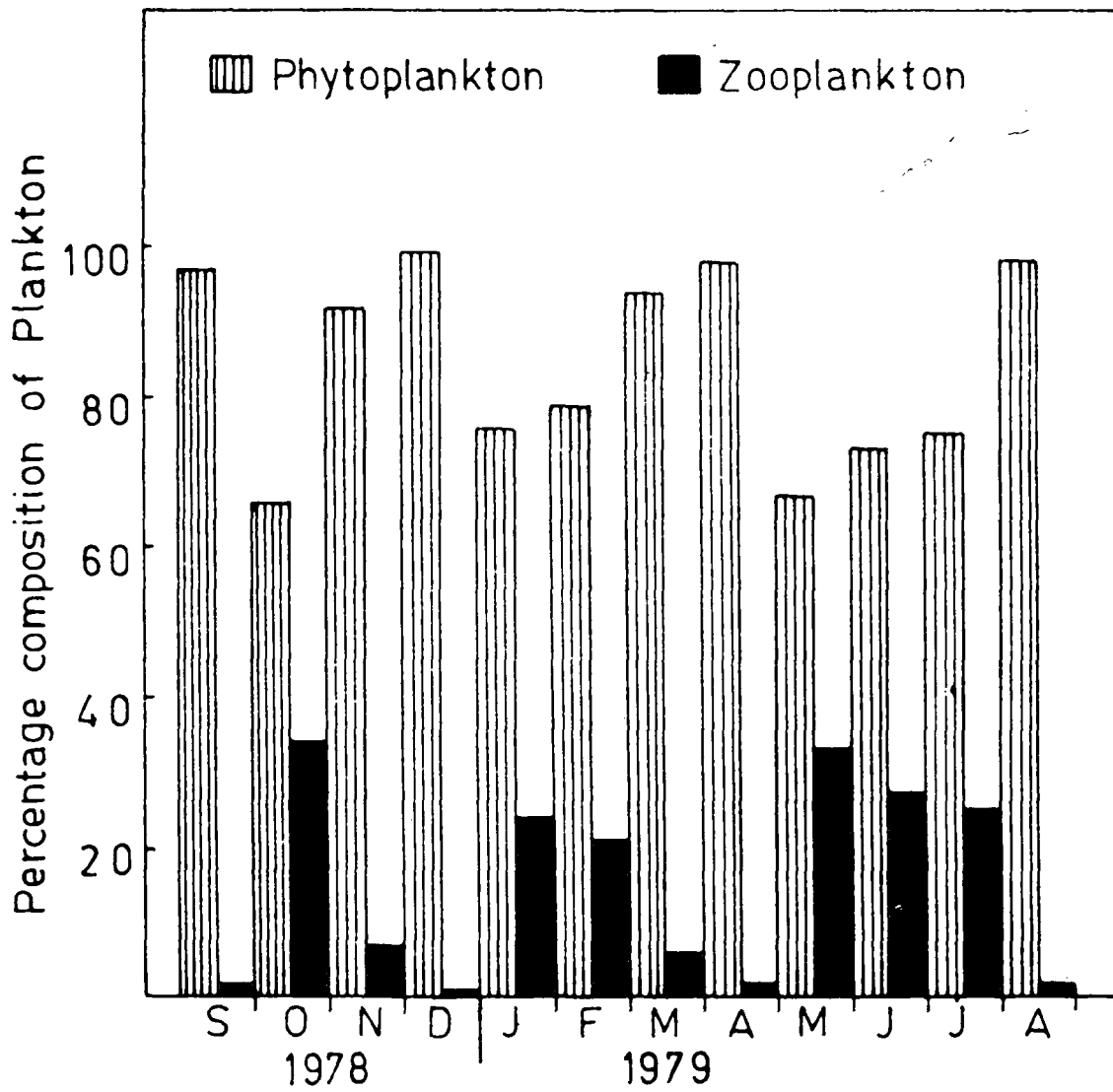


Fig.10: Percentage occurrence of Phyto-and Zooplankton in the pond water

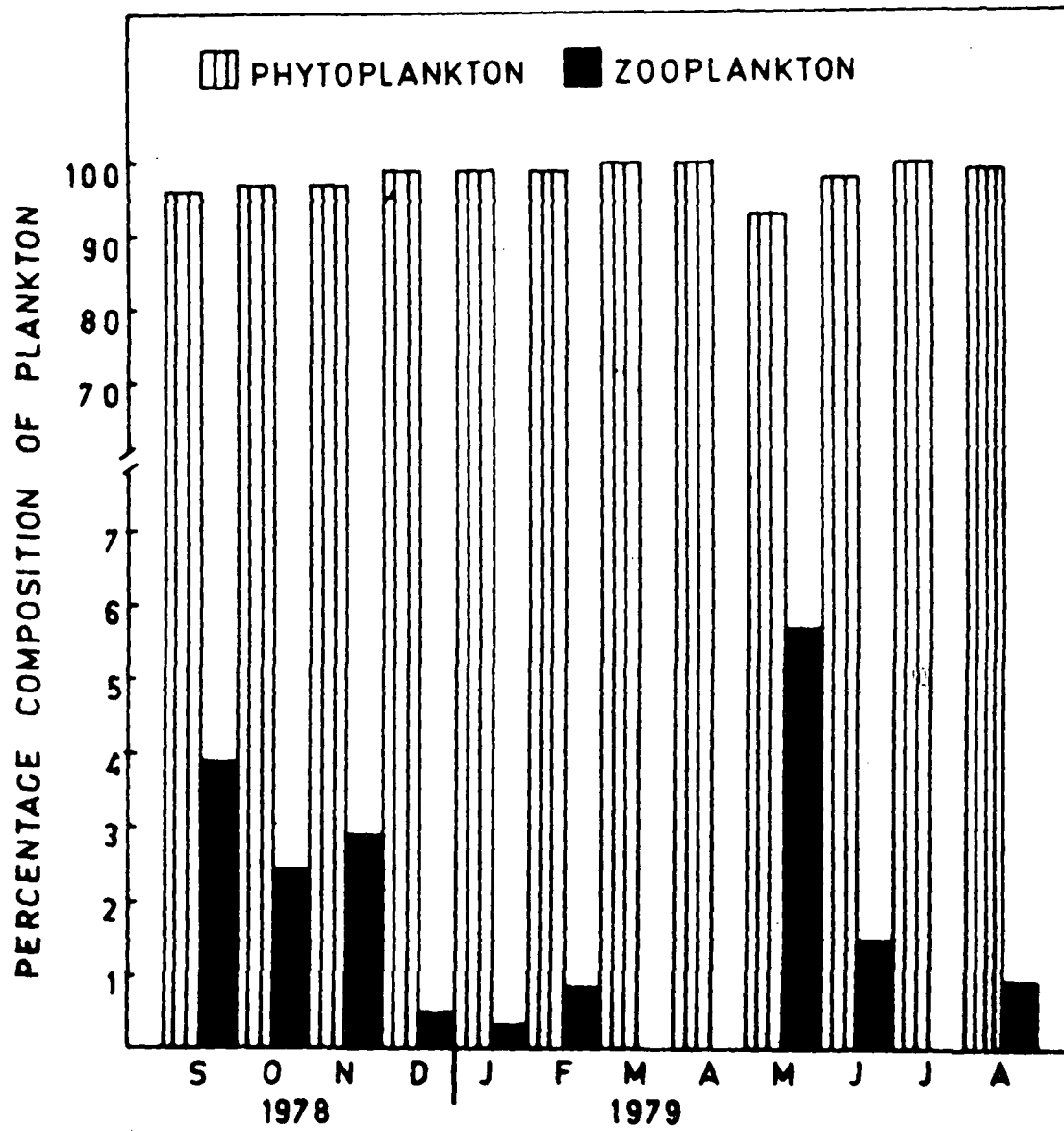


Fig. 11: Percentage occurrence of Phyto- and Zooplankton in the stream water.

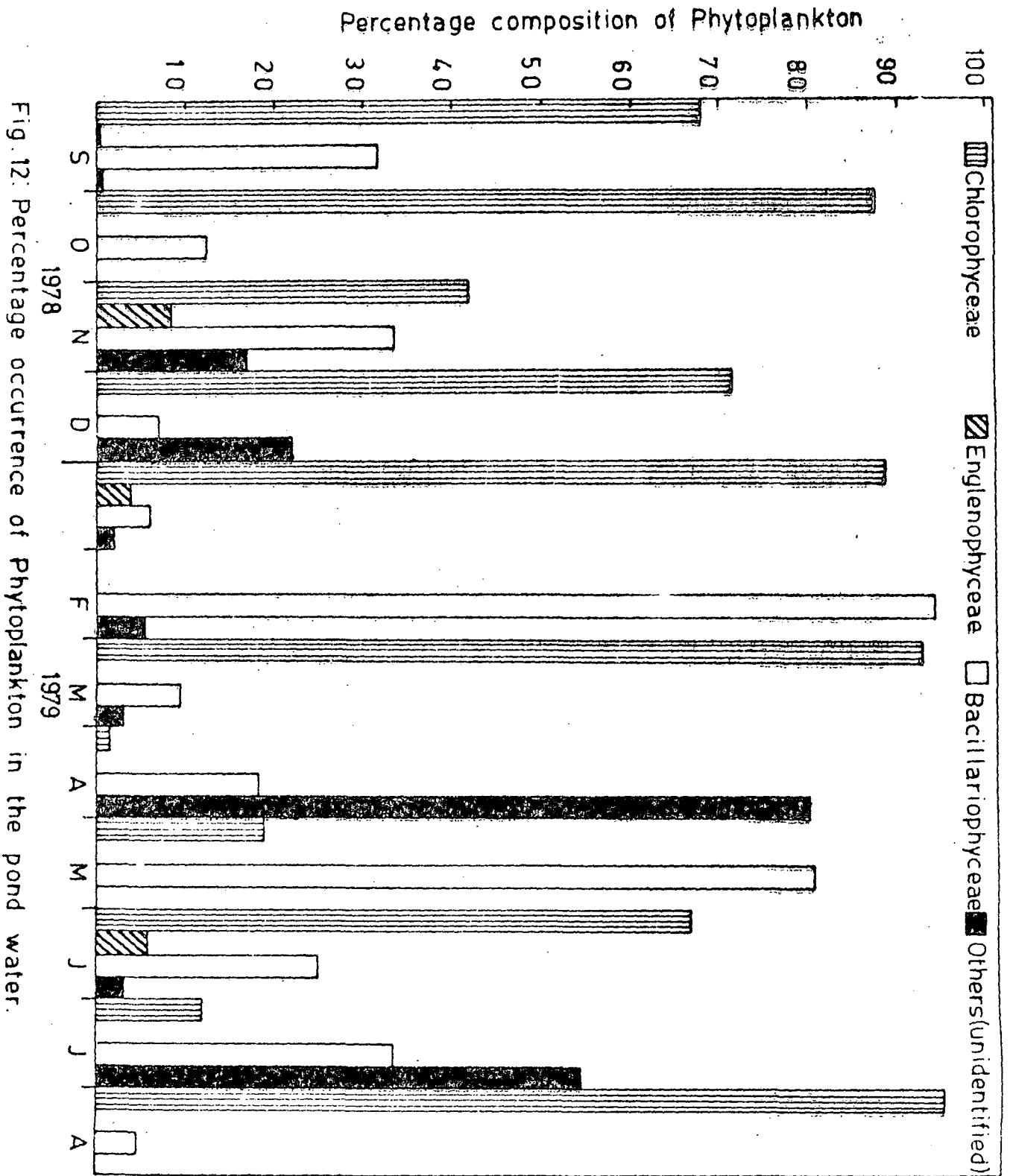


Fig. 12: Percentage occurrence of Phytoplankton in the pond water.

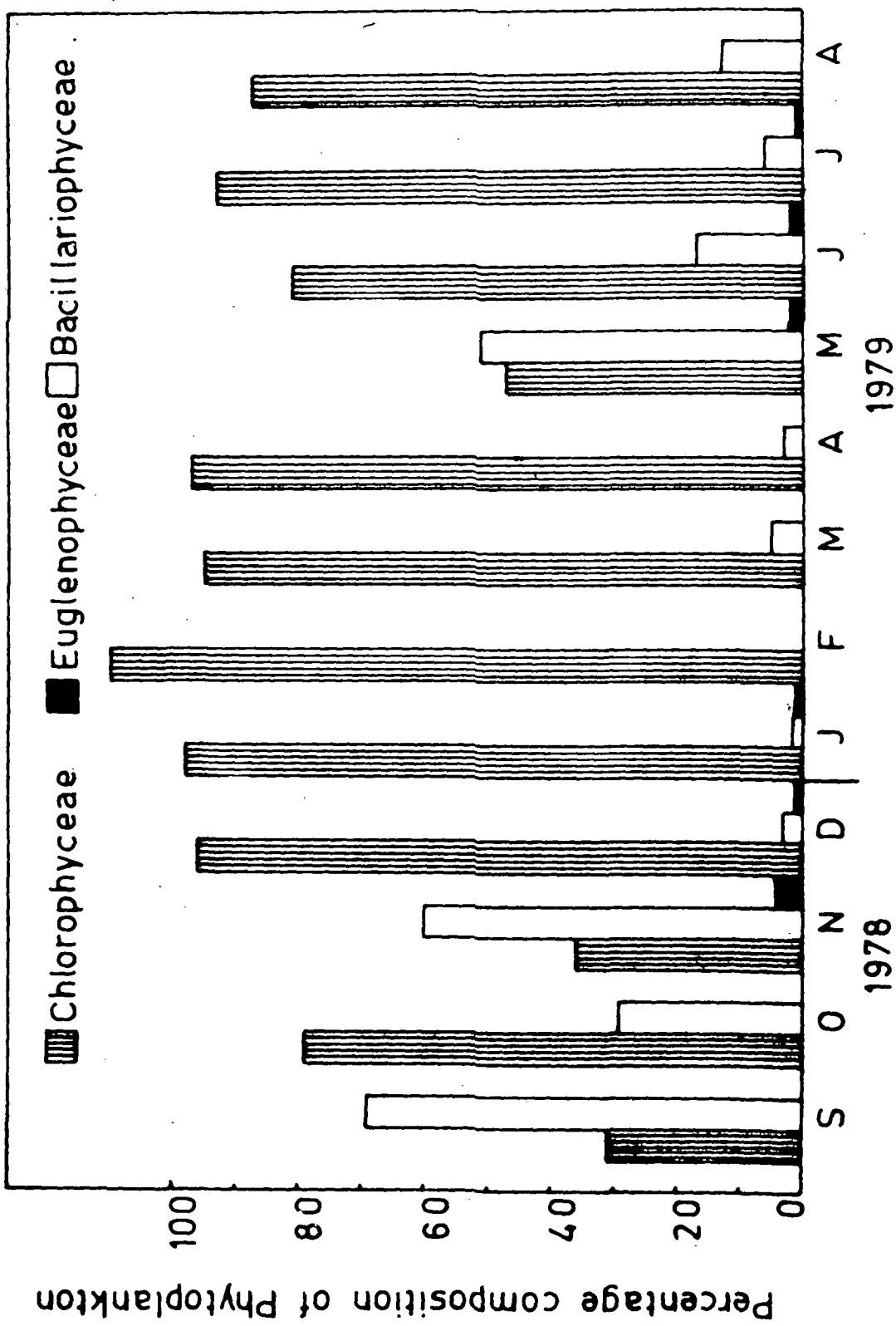


Fig. 13: Percentage occurrence of Phytoplankton in the stream water.

Rotifera was the most abundant group, followed by Copepoda and Cladocera. A similarity between the two systems could be established due to the fact that Rotifera population dominated during the winter and Copepoda during the summer. Thus, the seasonal periodicity in the zooplankton could be observed and the quantitative variations were quite identical in both the systems.

The numerical superiority of Rotifers over the other groups of zooplankton corroborates the view of Nordquist, 1921 (op. cit. Fritsch, 1931), that the abundance of Rotifers compared to other groups is an indication pointing towards the eutrophic nature of the water bodies. Similar view has also been expressed by George (1966a) and Nasar (1975).

Pennak (1957) has pointed out that whenever two species of the same genus are present in any freshwater system, one will always be more abundant than the other. Since quite similar results have been obtained in the present investigation, this is in conformity with the view of Pennak (1957). Similar studies by Carl (1953) gave evidence that genus of Copepoda and Cladocera are seldom represented by more than one species in a body of water. It has been observed by Harvey et al. (1935), Wimpenny (1936), Steemann Nielsen (1937), Mare (1940) and Hart (1942) that large concentrations of phyto- and zooplankton are rarely found at the same time. Two hypothesis have been advanced to explain this. The simplest one is that the zooplankton graze down the phytoplankton population. Harvey (1934), Hardy and Gunther (1935) and Hardy (1936) postulated that the zooplankton avoid areas rich in phytoplankton that they are excluded from the area. Steemann and Nielsen (1937) pointed out that the phytoplankton crop can develop within a few days under favourable

conditions whereas a much longer period is required for the development of zooplankton. Consequently, the peaks of the two population will not fall at the same time. Therefore, in the present investigation too, the phyto- and zooplankton showed an inverse relationship (Figs. 10 & 11).

FACTORS INFLUENCING PLANKTON PERIODICITY

It is a well known fact that the nutrients play a vital role in the growth and abundance of plankton in general. All the factors are mutually entangled and interact to determine the distribution of organisms. Development and maintenance of a population depend upon harmonious ecological balance between environmental conditions and tolerance of the organisms to variations in one or more of these conditions (Reid, 1961).

Temperature is considered to be one of the most important factor in any aquatic ecosystems. Edday (1934), Gambryar (1963) and Nasar (1979a) reported that plankton production is mainly influenced by temperature and these changes were observed even amidst a fairly constant pH and oxygen content, which agrees well with the present results, as the plankton maxima and minima increased or decreased quite distinctly during warmer and colder months. Similar results have also been observed by Moitra and Bhowmick (1968). In the stream, phytoplankton exhibited its abundance during winter (Fig. 13), but in the pond (Fig. 12), no definite variation could be observed. Das and Srivastava (1959), Sreenivasan (1966) and Hutchinson (1967) have reported that temperature is one of the factor responsible for the growth of plankton, but it is not the only factor involved. Alikunhi *et al.* (1955) observed that a variation of water temperature from 29.0°C to 37.2°C but he does not indicate any correlation

between water temperature and plankton variations. Chacko and Krishnamurthy (1954) also could not establish any correlation between the temperature and plankton. The assertion of Worthington (1943) that tropical waters are more productive on account of high temperature and lack of cold waters is untenable about plankton in Indian freshwaters as is evident by the available data.

In the present study, a high phytoplankton population has been observed at low temperature during winter in the stream, whereas for pond, no definite relationship could be observed, thereby suggesting that temperature alone is not a limiting factor for the growth of plankton. Similar case has also been reported by Nasar (1979a). Availability of food may be the other main factor which in turn depends on other physico-chemical factors including temperature.

Knowledge on the limiting effects of pH on plankton is in a very unsatisfactory state (Welch, 1952). However, every species have been described to have its own capacity of tolerance to acidity and alkalinity. According to Welch (1952), many limnologists regarded pH as of secondary importance as no correlation could be established between pH and the occurrence of the organisms in natural waters. However, Das and Srivastava (1956a) and Moitra and Bhattacharya (1965) reported that a high pH is related to heavy phytoplankton bloom and that a low pH indicates a rise in zooplankton. In the present investigation too, such a relationship has been observed with the exception of the anaerobic bacteria, all organisms living in freshwater require an adequate supply of dissolved oxygen. Pearsall (1923) has noted a higher oxygen content after rains in natural waters,

poor in plankton and organic matter. Griffiths (1923) inferred that well oxygenated water is prerequisite for harbouring large number of Chlorococcales. Pennak (1949), Chacko and Krishnamurthy (1954), Singh (1955), Das and Srivastava (1956a), Moitra and Bhattacharya (1965), Moitra and Bhowmic (1968) and Jana (1970, 1973a) observed that increase in dissolved oxygen causes an increase in plankton biomass. Almost similar result has been obtained during the present study. Nasar (1979a) has also reported a direct relationship between dissolved oxygen and zooplankton.

Carbon-dioxide is known to be a necessary constituent in an aquatic environment as free Carbon-dioxide has been universally accepted to be an important abiotic factor for all living organisms. Juday (1922) while studying the fermentation of bottom deposits in Lake Mendota (Wisconsin), observed that carbon-dioxide was the second largest decomposition product constituting 3% to 30% of the total gases evolved. According to Welch (1952) in natural waters, the amount may be very small in the upper circulating waters, but the healthy growth of green plants is a standing evidence of the adequacy of these small quantities.

Large quantities of Carbon-dioxide usually have detrimental effect on plankton, becoming rapidly fatal, if amounts are sufficiently high. Welch (1952) stated that high carbon-dioxide content appears to be more toxic in the presence of low oxygen content. Moitra and Bhowmick (1968) observed that free carbon-dioxide was at its minimum when zooplankton dominated the plankton volume. In the present study, it has been observed that whenever free carbon-dioxide was at its minimum, percentage composition of zooplankton were found to be in higher range, in other words, zooplankton fluctuated almost inversely with free

carbon-dioxide content. Therefore, it can be ascertained that presence of high quantities of free carbon-dioxide have detrimental effect on zooplankton and are toxic, which supports the view of Welch (1952) that free carbon-dioxide is an important abiotic factor for all biotic factors. However, Nasar and Munshi (1974) reported that free carbon-dioxide was not a limiting factor for the growth of zooplankton.

An inverse relationship between Phosphate levels and phytoplankton numbers has been shown by Michael (1969) which seems to be true in the present study too. Taylor and Welch (1970) and Hannan and Young (1970) observed an inverse plant nitrate relationship, which is evident in the present study too.

Silica is an essential nutrient for diatoms, which build their frustules of this glossy material. Diatoms and silicates showed an inverse relationship with each other in the present study (Fig. 15). Since diatoms constitute a very prominent and strategic group in the plankton and require silicon for the manufacture of their shells, the available supply of silicon in the water is regarded as a matter of real consequence (Welch, 1952). Hence, it can be said that large number of diatoms draw heavily upon the silicon producing variation in it. In fact, it is claimed that the production of diatoms is directly determined by the silicon supply (Welch, 1952). Pearsall (1923), Riley (1943), Hasler (1947), and Ruttner (1953) reported that the disappearance of dissolved silica from water is commonly associated with the growth of diatoms and observed that diatom maxima commonly coincided with the lower levels of dissolved silicate. Hence, the present finding is in conformity with them.

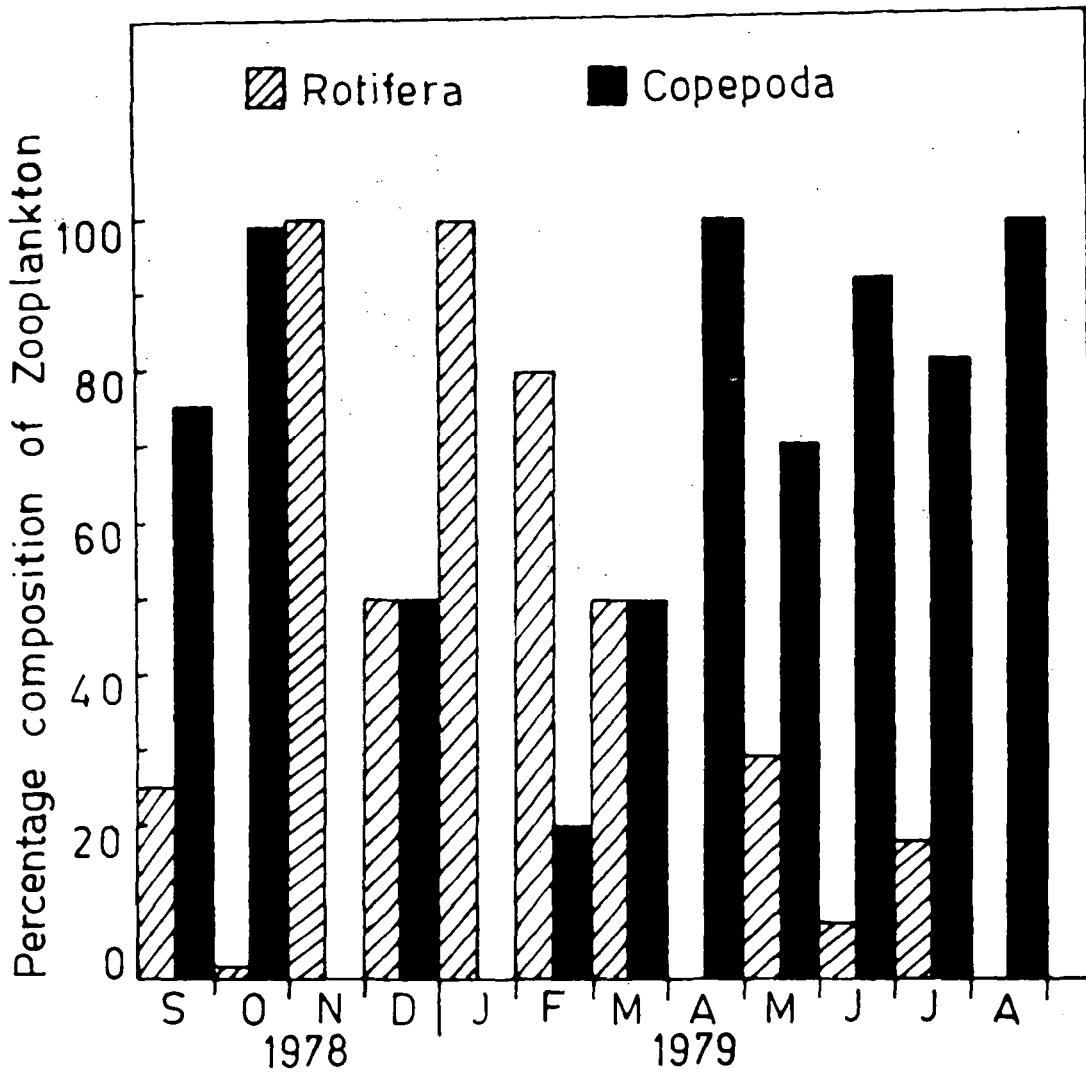


Fig. 14: Percentage occurrence of Zooplankton in the pond water.

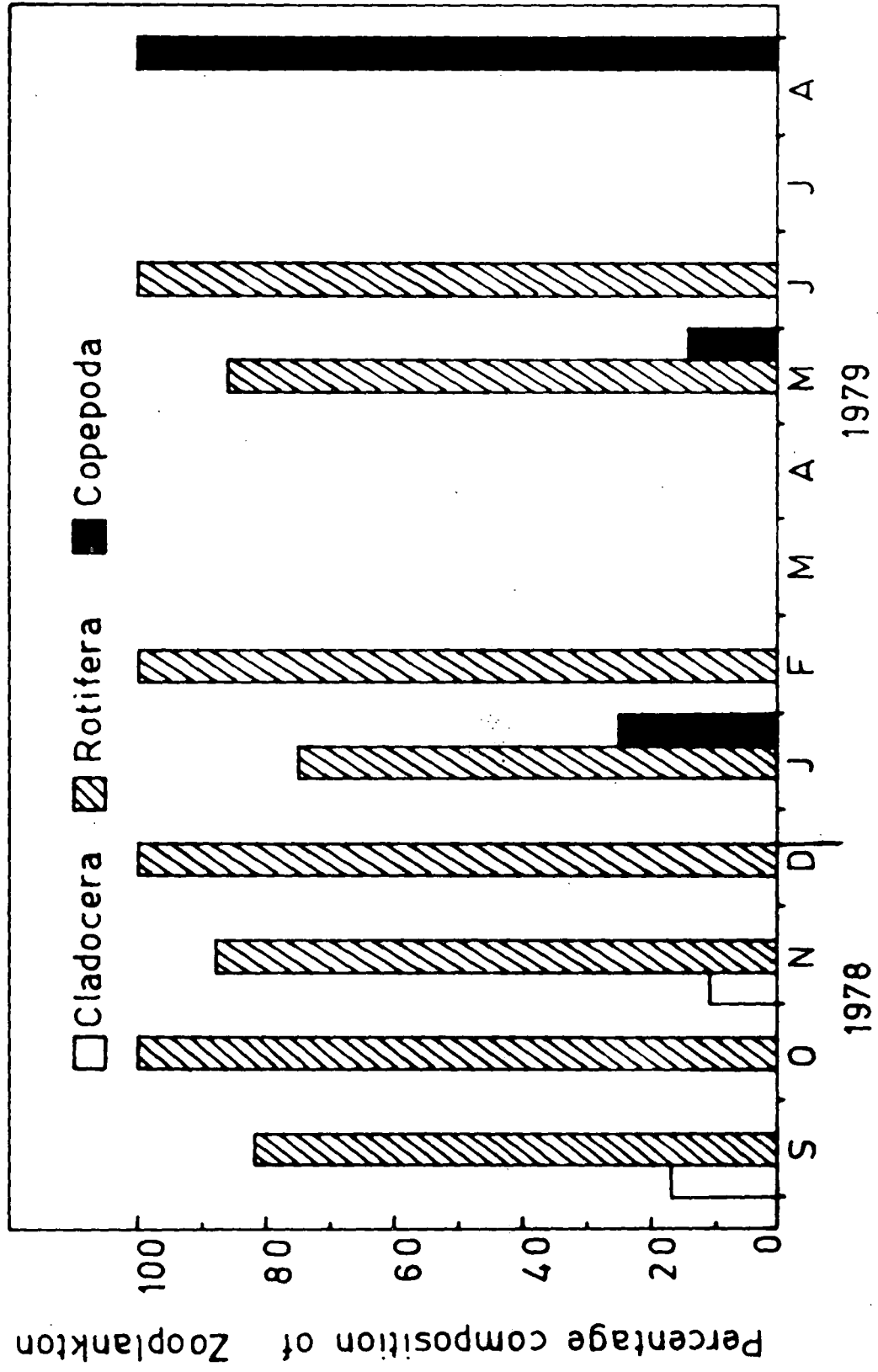


Fig.15: Percentage occurrence of Zooplankton in the stream water.

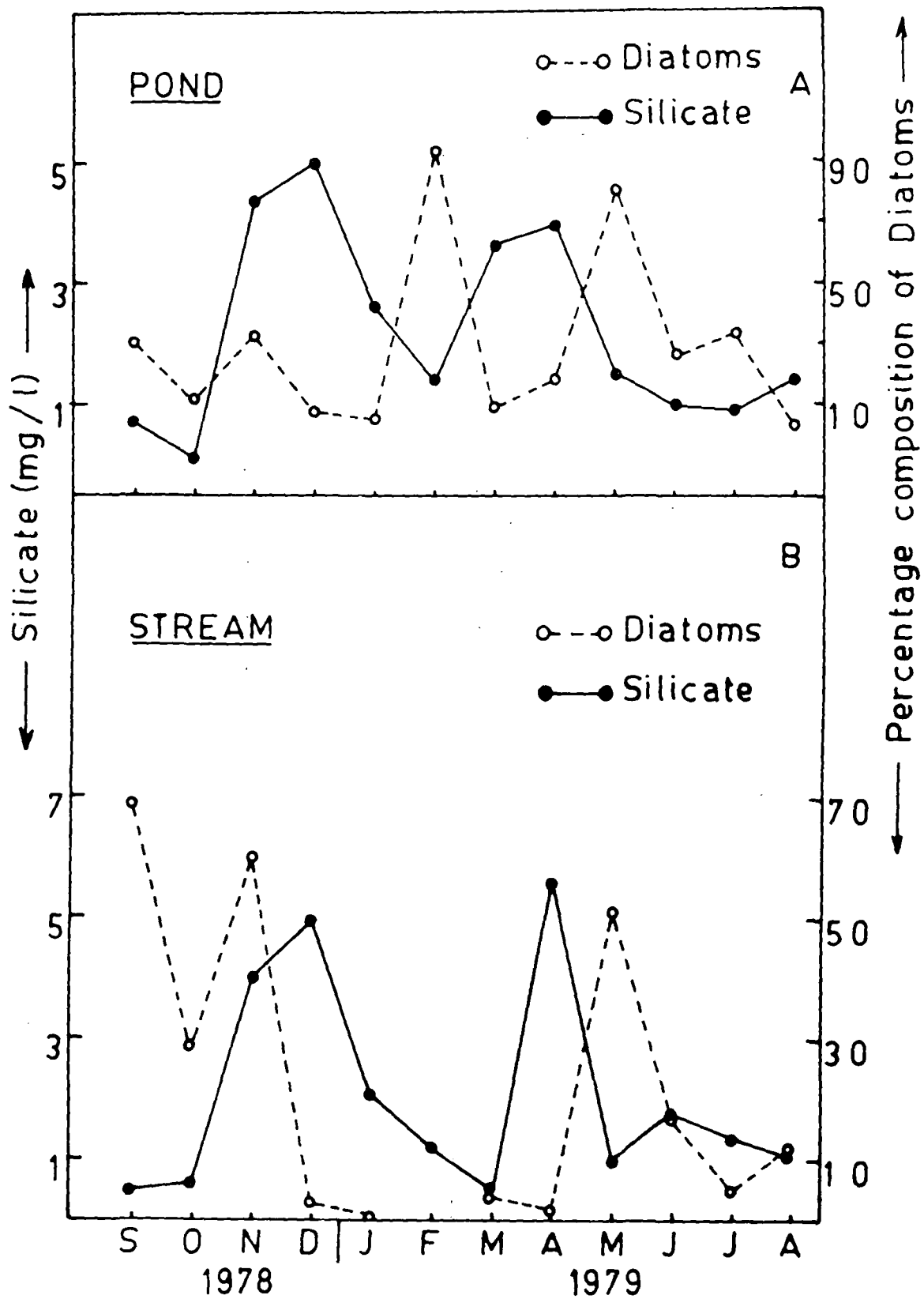


Fig.16: Showing the relationship between Diatoms and Silicate.

Pearsall (1932) is of the view that growth of plankton diatoms is frequently limited by the availability of one or the other major nutrients. According to him, diatoms appear when the water are richest in Nitrate, Phosphate and Silicate and gave importance to phosphate as an important factor controlling diatom periodicity than nitrates, but according to Whipple and Parker (1902) nitrate is the main factor. In the present study, phosphate seems to be an important factor controlling diatom periodicity. Seasonal variations in phytoplankton populations as a result of changing environmental conditions has been well documented (Riley, 1946; Ryther, 1954; Conover, 1956; Hulburt, 1964; Patrick, 1967; Riley, 1967; Carpenter, 1971 and Mulford, 1972). According to Riley (1946) and Samuels et al. (1979), the dynamics of phytoplankton growth and community structure over a seasonal cycle in temperate latitudes is controlled by a highly complex relationship of environmental factor in which one factor after other, gains momentarily greater significance. In the present study too, it has been observed that variation in phytoplankton population are as a result of the change in environmental conditions.

In the present study, no distinct periodicity in the total plankton could be observed, which could be explained as in freshwater bodies, the physico-chemical complexes undergo frequent changes partially due to the changes in the meteorological factors which in turn influences the plankton periodicity accordingly. Therefore, definite and periodic changes as reported from big lakes and oceans may not be observed in similar small ponds.

A general depletion of soluble nutrients was recorded

when the plankton density was high which may be attributed to the biological activity of the plankton and vice versa. It may be concluded that the plankton population is directly or indirectly influenced by the seasonal variations in the complexes of other limnological factors. The annual quantitative abundance of planktonic population depends on the succession of appearance and disappearance of its component species as is clear from the present results which further supports the view of Nasar (1979a).

It is said that (Cole, 1979) streams are rather poor in plankton, except in large streams far from their sources or in relatively quiet side pools where conditions are much like lentic environments. The outlet from lakes and ponds introduces plankton organisms into streams, but they are destined to disappear rather rapidly, reason being the diurnal rate varies for different lake plankters.

According to Hynes (1970), in stream the bulk of the phytoplankton is composed of diatoms and zooplankton is marked by more Rotifers, relative to micro-crustacea, that are typical of lake plankton communities. However, in the present study, the dominance of Rotifera among the zooplankton could be observed, but among phytoplankton, Chlorophyceae was found to be more abundant than Bacillariophyceae.

CHAPTER III

BIOLOGY OF THE FISH

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

The brilliant colours, bizarre shapes and curious habits of tropical fishes are well known, and throughout the tropics freshwater fishes are of immense importance in providing protein food for human beings. The demand for such protein is rising exponentially with the rapidly increasing human population and attempts to raise living standards.

Although the study of ecological processes is of fundamental importance for man's continued existence and well being, such studies from the tropics are still in their infancy and theories about tropical communities are based on few hard data, many of them culled from the behaviours of bird and insect populations. However, fishes have been investigated more than

any other group of vertebrates in the tropics, but unfortunately the results have generally been published in special reports, not readily available to the general ecologists. Tropical ecosystems are now being changed momentously by man, and it is of paramount importance to study the complex web of interrelationships in order to avoid irreparable damage to the environment and to its faunas.

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 stages of life history, since fishes are very mobile creatures, searching out different habitats to suit the particular requirements of the eggs, the young fish, juveniles or adults. Their social requirements change too, many fishes living 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 and probably long periods of time, while in other places community membership is changing radically all the time, often with seasonal regularity. Some fish species are eurytopic, that is to say that they can withstand a great range of environmental conditions such as changing temperatures or salinity, or they can eat diverse type of food 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 over 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.

The extensive researches on freshwater fishes in India generally centres around the biology only of those species which are being used to stock dams and lakes rather on natural fish communities. In India, the major Indian carps, such as Catla catla, Labeo rohita and Cirrhina mrigala and the exotic carps viz., Cyprinus carpio, Ctenopharyngodon idellus and Hypothalmitichthys molitrix are the main culturable fishes (Nasar and Kaur, 1979). Apart from these there exists a wide variety of other teleostean fishes which can breathe air. Such fishes have evolved specialized organs or accessory respiratory organs, in some the swimbladder, in others altogether new organs, in a few the gills and in still others the skin has taken up the respiratory function. These teleosts belong to different families but due to their special adaptations to aerial respiration they are generally grouped together as "Air-Breathing Fishes". Channiformes is one such order in which fishes have a definite pouch or air-chamber which can store the inhaled air for atleast a short period. It has evolved in the pharyngeal region probably as a response to more vigorous and pronounced aerial respiratory exercises. In Channidae, the air-chamber lies above the gills and is enclosed within the skull (DattaMunshi, 1962; Hughes and DattaMunshi, 1973).

These air-breathing fishes are different from the others

by the virtue of their certain physiological adaptations such as development of accessory respiratory organs for aerial respiration, modification of their blood physiology, thyroid hormone specializations, occurrence of diving reflexes and adaptation of certain special behaviouristic patterns. However, much remain still to be understood about the life processes of these fishes with particular reference to their environment. The paucity of information on the general biology of these specialized teleosts has many reasons. One of them, probably is that in favour of culturing major carps, the highly predaceous air-breathing fishes were looked down upon as a hindrance in the endeavour and were methodically eliminated as a recommended practice for ideal pisci-culture. The attention of a few workers, however, drawn towards them was purely of academic nature.

Morphological variations in fish as a result of adaptation to its new environment have been cited by various authors (Schmidt, 1921; Vladykov, 1934; Taning, 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 pisci-culture, 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 and 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 has been drawn to the number of eggs in the roe 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; DeSilva, 1973), thereby emphasizing the need to the study in more details, the food habits of a species. It is also considered important for the propagation of the species to gain more accurate knowledge on its feeding behaviour, since it can be cultivated for exploiting natural food.

Air breathing fishes, as the nomenclature itself suggests, can breathe atmospheric air besides breathing through gills. By virtue of their aerial respiratory habits, they are well adapted to standing waters, deficient in oxygen such as those of swampy water bodies. Air-breathing fishes are in great demand for their nutritive and therapeutic qualities. In recent years, culture of air breathing fishes is gaining a fillip in the country particularly because of the need to put vast areas of swampy and fallow waters to immediate use for the benefit of mankind without getting involved into costly processes of their reclamation.

Among different families of air-breathing fishes, Chanidae (=Ophicephalidae) enjoys quite a wide range of geographical distribution. Fishes of this family can be recognised by the shape of the head which resembles that of a snake, hence,

known as 'Snake-Heads'. They are characterised by the possession of an accessory respiratory organ which enables them to live out of water for hours at a stretch or indefinitely in oxygen poor waters and even in moist mud. The family is represented by a single genus Channa Scopoli 1777. This genus is represented in Shillong (Meghalaya) by three species Channa gachua (Ham.), Channa stewartii (Playfair) and Channa punctatus (Bloch). The genus Channa Scopoli is an important and a very popular fish in the Indian sub-continent, owing to its ability to live out of water enabling live marketing and delicious flesh is highly esteemed as a food fish and is indeed connoisseurs delight in several States of India. It is well known for its nutritive, invigorating and therapeutic qualities and is recommended by physicians as dietary ingredients for the sick and convalescent.

In a virtual absence of scientific knowledge on the biology and environment of the Channids indigenous to the highlands of the North-Eastern Hill region, it has been felt desirable to conduct studies on the biology of these fishes. Such studies is of utmost importance not only to fill up the gap of our present day academic knowledge but also in the utility of the knowledge in increasing the technological efficiencies of the fishery entrepreneurs for evolving judicious pisci-culture management.

The study pertains to the specimens of Channids with particular reference to Channa gachua (Ham.), collected during the period from September 1978 to August 1979 from a pond and a torrential hill stream situated in Shillong (Meghalaya). The results obtained on the biology of Channa gachua from the lotic and lentic systems have been compared to gather knowledge on

intra-specific variations. Further, the results obtained during the present investigations of Channa gachua (Ham.) have been compared with the results obtained for Channa stewartii (Playfair) available only in the stream and Channa punctatus (Bloch) available only in the pond, for inter-specific comparisons in the morphometric characters, length-weight relationships and food and feeding habits. All the biological parameters taken for Channa gachua in the present study, could not be compared inter-specifically owing to the occasional availability of C. stewartii and C. punctatus in the systems. It has also been tried in the present investigations to find out the impacts of the abiotic and biotic factors of their immediate environment on the biology and the adaptive interactions.

REVIEW OF LITERATURE

Knowledge of the occurrence of fish in India dates back to three millennium B.C. (Hora, 1956). According to Nath (1966), fish remains with cut marks, indicative of their use as food, have been obtained from excavation at Mohenjodaro and Harappa of the Indus Valley civilization (2500 - 1500 B.C.). While Aristotle (384-327 B.C.) is said to be the founder of Ichthyology, King Somesvara, the son of King Vikramaditya VI, who composed the book "Manasoltara" in 1127 A.D., was the first record of the common sport fish of India grouping them into marine and fresh-water riverine forms (Hora, 1951a). The first modern writer on Indian fishes, according to Day (1878) was Bloch whose splendid work Auslandische Fische was published in 1785. Later, Lacepede wrote Historie des Poissons (1798-1803). Russel (1803) described 200 species from Vizakhapatnam. There appeared Hamilton's (1822) pioneer work "Fishes of Ganges" which contains a description of 269 species of fish from the Ganges and its tributaries. Cuvier and Valenciennes's "Historie Naturelle des Poissons", published in 1828-1849, 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), Gunther (1859-1870).

There is, however, no work of greater importance on Indian fishes than the epoch making contributions of Day's "Fisheries 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).

Aspects on the systematics (such as morphometry and meristic characters, colouration, key to the identification, size attainments and habits and habitats of Channids with particular reference to Channa qachua, C. stewartii and C. punctatus have been dealt by Hamilton (1822); Sykes (1839, 1841); Gunther (1861); Day (1878, 1889); De (1910); Willey (1910); Raj (1916); Das (1927); Deraniyagala (1929); Myers and Shapolov (1931); Spence and Prater (1933); Shaw and Shebbeare (1937); Anon (1962); DeWitt (1960); Greenwood et al. (1966). A good deal of work on the bionomics, breeding habits, life history and development of these fishes have been reported by Raj (1916); Khan (1924, 1925); Das (1927); Rahimullah (1946); Mookerjee (1945, 1946); Bhattacharya (1946); Mookerjee et al. (1946, 1948, 1950); Alikunhi (1955) and Panameswaran and Murugesan (1976). Qayyum and Qasim (1962) observed the behaviour of an Indian murrel, C. punctatus during brood care.

Taxonomic values of Channa punctatus and C. marulius have been dealt by Tandon and Keur (1979).

With regard to the morphological anatomical, histological studies etc., Dutta and Reddy (1974) described the head scales of Channids. Rana et al. (1978) studied the morphometrics of the olfactory rosette in C. punctatus. Tandon (1964) reported the absence of the right pelvic fin in C. punctatus. The anatomy of the synapses in the central nervous system of C. qachua was described by Mishra (1978). Shanbhag and Nadkarni (1979) studied the histological and histochemical of the testicular cycle of C. qachua, whereas Joshi and Sathyanesan (1979) studied the adrenal histochemistry and histoenzymology of C. punctatus.

In recent years, physiological and biochemical aspects have been dealt by many workers. Garg and Sastry (1976) studied the intestinal transport of fructose and glycine in C. punctatus. Biochemical compartmentation of tissue with reference to brain energy reserves and its metabolic products has been studied by Shaffi (1978), whereas Garg (1978) observed the site and rate of sugar and amino acid transport in intestine and pyloric caeca of some Channids. Srivastava and Gupta (1979) reported the total distribution of free amino acids in the brain of C. punctatus. Saxena and Mani (1979) studied the ovarian recrudescence in C. punctatus during thiourea treatment. Bhattacharya et al. (1979) conducted experiments on the role of synthetic mammalian thyrotropin releasing hormone on thyroid peroxidase activity. Joshi and Sathyanessan (1980) observed cyclical changes in the monoamine oxidase (MAO) activity in the testis of C. punctatus. Muscle fluid compartments and electrolyte distribution in relation to gonadal cycle in C. punctatus have been studied by Sinha and Datta Munshi (1979). Mustafa and Jafri (1977) conducted studies on RNA and protein contents in C. punctatus during growth, whereas in the same fish, Mustafa (1979) studied the RNA and protein synthesis in relation to biological condition. Mahajan and Agarwal (1979) reported regarding Vitamin C deficiency in C. punctatus. Swarup and Srivastava (1975) reported the occurrence of collagen capsules in the testis.

A good deal of research work has been done on the structure of accessory respiratory organs, respiratory physiology and connected aspects in Channids. The most notable contributions from those past workers are of Day (1889); Das (1927); Dubale (1955, 1959); Datta Munshi (1962); Hughes and Datta Munshi

(1973, 1979); Ramaswamy and Reddy (1978) and Hakim et al. (1978). Recently, an excellent review on the gross and fine structure with the functional aspects of the respiratory organs of these fishes has been presented by Datta Munshi (1976, 1980).

Significant contributions have been made on the haematological aspects of Channids. Mahajan and Dheer (1979a) reported the seasonal variations in the blood constituents of C. punctatus. Mahajan and Dheer (1979b) also studied the cell-types in the peripheral blood of the same fish. Chitra and Rao (1979) investigated on some aspects of haematological factors in C. punctatus. Autoradiography and differential haemoglobin staining as aids to the study of fish haematology has been emphasized by Mahajan and Dheer (1979c). A good deal of work on blood physiology with reference to glucose and lactic acid levels have been conducted by Khanna and Singh (1971); Suryavanshi and Chakraborty (1972). Saxena and Sharma (1978) studied the flame photometry and photo-colorimetry of electrolytes of plasma of C. gachua.

Results of investigations on nutritional properties viz., chemical composition of a few species of Channids have been reported by Anon (1962).

In recent years, this group became the target of various significant toxicological studies. The most notable contribution on C. gachua are by Verma et al. (1978); Dalela et al. (1978); Hunumante and Kulkarni (1979) and Mishra and Singh (1979). However, with regard to C. punctatus, contributions have been made by Mahajan et al. (1979); Sharma et al. (1979); Srivastava and Singh (1980) and Goel and Garg (1980). Gill and Khanna (1976); Ray and Medda (1976); Sharma (1978); Sastry and Sharma (1978, 1979, 1980); Verma et al. (1979) and Mathur (1979).

With regard to pathological investigations, Anees (1978) studied the hepatic pathology in C. punctatus exposed to sub-lethal and chronic levels of some organophosphorus insecticides. Bose and Sinha (1979) studied the histopathology of the stomach wall of C. qachua, attributable to the digenetic trematode Genar-chopsis poppo (Ozaki). Mahajan et al. (1978) studied the parasitisation of Isopararchis hypselobaqri in C. punctatus. Kumaraiiah et al. (1978) recorded a bacterium causing eye disease and mortality in C. marulius. Recently, the life history of Allocreadium handiai has been studied in C. punctata by Madhavi (1980).

The necessity and importance of cultivation of such fishes in India have been stressed and emphasized by Jhingran (1976) and Dehadrai and Tripathi (1976). The possibilities of their culture under Indian conditions have been shown by Chacko and Kuriyan (1948) and Mitra (1956). The techniques of cultivation of Channids have been discussed by Jhingran (1976) & Dehadrai and Tripathi (1976).

With regards to the studies on the biology of Channids, the following worthmentioning works are available. The bionomics breeding and growth of C. striatus have been dealt by Willey (1910), Raj (1916), Rahimullah (1946), Bhattacharya (1946), Mookerjee et al. (1948), Alikunhi (1953) and Murugesan (1978), whereas the growth potential and fishery have been dealt by Parameswaran and Murugesan (1976), Srivastava (1977) and Murugesan (1978). A good deal of works on the different aspects of general biology in C. punctatus have been conducted by Mookerjee et al. (1946); Das and Mitra (1958); Dehadrai et al. (1973) and Parameswaran (1975). C. stewartii and C. qachua have received very little attention with regard to their biological studies. However, Ganguly et al. (1963) studied the breeding habits developments length-weight relationship and food and feeding

habits of C. stewartii from Faridpur (East Pakistan). The most poorly studied species among Channids, is C. qachua as the only worthmentioning literature available is by Mookerjee et al. (1950) on the life history of the fish and a casual mention about the general biology of the species collected from West Bengal (India).

The foregoing review of literature reveals, though a fairly good account of the biology in Channids, there are still several points with regards to the general biology of this group, particularly C. qachua and C. stewartii which require elucidation. However, available information on such aspects in other species of Channids is of very general and preliminary nature. Moreover, there is practically no information available on the general biology and ecology of Channids from higher altitudes. Therefore, it has been felt desirable to conduct an investigation on the biology of Channids (viz. C. qachua, C. stewartii and C. punctatus) indigenous to the highlands of Shillong (Meghalaya) in relation to their abiotic and biotic environmental components.

TAXONOMIC STATUS

(after Greenwood et al., 1966)

Phylum	Vertebrata
Sub-Phylum	Craniata
Super Class	Gnathostomata
Series	Pisces
Class	Osteichthys (Teleostomi)
Sub-Class	Actinopterygii
Super Order	Acanthopterygii
Order	Channiformes (=Ophiocephaliformes)
Family	Channidae (=Ophiocephalidae)
Genus	<u>Channa</u> Scopoli 1777
Species	<u>C. gachua</u> (Hamilton) <u>C. stewartii</u> (Playfair) <u>C. punctatus</u> (Bloch)

DIAGNOSTIC CHARACTERS OF THE GENUS CHANNA Scopoli, 1777

Smith (1945) made a plea for retention of the familiar name Ophicephalus Bloch 1793 for this genus, but the rules of nomenclature are adamant in this case and that Channa Scopoli should be used. Moreover, Herre and Myers (1937) expressed their opinion in favour of Channa and subsequently taxonomist are using this name. Hence, the name Channa has been used in the present case,

Day (1878) outlined the diagnostic characters of the genus Channa as follows :-

1. Branchiostegal fins.
2. Pseudobranchiae absent.
3. Gills four. Gill openings wide, the membranes of two sides being connected beneath the isthmus.
4. A cavity exists above and accessory to the true cavity, but although some thin bony lamillae are present, no suprabranchial organ is developed.
5. Body elongated, sub-cylindrical anteriorly.
6. Head depressed, having superiorly somewhat plate like scales.
7. Eyes lateral.
8. Teeth in the jaws, vomer and palate some of which may be conical.
9. A single long, spineless dorsal fin, and a similarly constructed through shorter anal.
10. Ventrals thoracic (Ophiocephalus) or absent (Channa) when present consisting of six rays, the outer of which is unbranched and sometimes articulated at its extremity.

11. Scales of large, moderate or small size.
12. Lateral line abruptly curved or almost interrupted.
13. Air vessel present.
14. Pyloric appendages, when present, few.

The family is represented by a single genus Channa Scopoli 1777. Earlier, the oriental species were described under two genera - (i) Chanua to include two pelvic fin less genera; Orientalis from Ceylon and asiatica from China and (ii) Ophiocephalus Bloch 1793, to include all other species with pelvic fins. Earlier forms with ventral fins were designated as Channa gachua (Ham. Buch 1822) and forms without ventral fins as Channa orientalis (Bl. Schn. 1801). However, DeWitt (1960) has shown the Channa gachua is a synonym of C. orientalis, considering the absence of ventral fins as an anomalous character. This is the only species in which the rosette of head scales is situated behind the orbits so that it touches the frontal head scales in front and the basal head scales behind. The cephalic sensory pores are in the form of single pores.

KEY TO THE IDENTIFICATION

Channa gachua :

- D. 32-37; P. 15; V. 6; A. 21-23;
 C. 12; lateral line scales. 40-45;
 L. tr. 3-4/6-7; Pre-dorsal scales. 12.

Channa stewartii :

- D. 35-40; P. 17; V. 6; A. 23-28;
 C. 14; Lateral line scales. 45-50;
 L. tr. $4\frac{1}{2}$ - $5\frac{1}{2}$ /9-7.

Channa punctatus :

- D. 29-32; P. 17; V. 6; A. 21-23;
 C. 12; Lateral line scales. 37-40;
 L. tr. 4-5/9; Pre-dorsal scales. 12.

SYNONYMS

CHANNA GACHUA

Channa orientalis Bloch, Syst. Ichth., p. 496, pl. 90, fig. 2, 1801, type-locality; India,

Gunther, Cat. Fish. Brit. Mus., 3, p. 483, 1881.

Day, Fish. India, p. 368, pl. 78, fig. 2, 1876.

Day, Faun. Brit. Ind. Fish., 2, p. 365, fig. 119, 1889.

De Witt, Stanford Ichth. Bull., 7(4), p. 81, 1960.

Ophiocephalus gachua Hamilton, Fish. Ganges, p. 68, 367, pl. 21, fig. 21, 1822; type-locality, Bengal.

Bleaker, Verh. Bat. Gem., 25, p. 42, 1853.

Gunther, Cat. Fish. Brit. Mus., 3, p. 471, 1881.

Day, Fish. India, p. 367, 1876.

Day, Faun. Brit. Ind. Fish., 2, p. 364, 1889.

Shaw and Shebbeare, J. Asiat. Soc. Bengal, 3, p. 121, 1937; type-locality : North Bengal.

Menon, J. Bombay nat. Hist. Soc., 48(3), p. 540, 1949, type-locality : Kumaon.

Menon, Rec. Indian Mus., 47, p. 229, type-locality : Hosiarpur.

Ophiocephalus aurantiacus Hamilton, Fish. Ganges, p. 69, 368, pl. 23, fig. 22, 1822; type-locality : Goalpara, Assam.

Ophiocephalus limbatus Cuvier (in C & V), Hist. Nat. Poiss., 7, p. 201, 1831.

Ophiocephalus cormota Cuvier (in C & V), Hist. Nat. Poiss., 7, p. 414 (From Rusel, pl. 11, p. 49), 1831; type-locality : Vizagapatam.

Ophiocephalus fusca Cuvier (in C & V), Hist. Nat. Poiss., 7, p. 414, 1831.

Ophiocephalus marginatus Cuvier (in C & V), Hist. Nat. Poiss., 7, p. 411, 1831, type-locality : Pondicherry.

Ophiocephalus montanus McClelland, Calcutta, J. Nat. Hist., 2, p. 583, 1842; type-locality : Baisoot, Jullalabad, Himalaya and Sadoo.

Bleeker, Verh. Bat. Gen., 25, p. 42, 1853.

Philypnoidies surakartensis Bleeker, Verh. Bat. Gen., 22, p. 119, 1849.

Ophiocephalus kalaartii Gunther, Cat. Fish., Brit. Mus., 3, p. 472, 1861; type-locality : Ceylon.

Ophiocephalus qachua melaccensis Peters, Monatsber. Akad. Wiss. Berlin, p. 262, 1868.

Ophiocephalus harcourt butteri Annandale, Rec. Indian Mus., 14, p. 54, pl. 2, fig. 7, pl. 4, figs. 16, 17, 1918.

Hora, Rec. Indian. Mus., 22, p. 208, 1921; type-locality: Manipur.

Channa burmanica Chaudhuri, Rec. Indian Mus., 16, p. 284, pl. 22, fig. 4, 1919; type-locality : N. Burma, R. Irrawady.

Channa qachua Menon, Rec. Indian Mus., 52, p. 22, 1954; type-locality : Manipur.

Channa qachua Menon, A. check-list of works of the Himalayan and Indo-Gangetic Plains, Spl. Publ. 1, Inland Fish. Soc., India. 1974.

Distribution : India, Ceylon, Nepal, Pakistan, Bangladesh, Burma, Thailand, Indo-China, Yunan, Malaya, Malay Archipelago, Hainan and Taiwan.

CHANNA STEWARTII

Ophiocephalus stewartii Playfair, Proc. Zool. Soc. Lond., p. 14, pl. 3, pl. 77, fig. 3, 1876.

Day, Faun. Brit. Ind. Fish., 2, p. 363, 1889.

Shaw and Shebbeare, J. Asiat. Soc. Beng., 3, p. 123, pl. 4, fig. 3, 1937; type-locality : N. Bengal.

Menon, Rec. Indian. Mus., 47, p. 235, 1949; type-locality : Riverkosi, E. Nepal.

Distribution : Eastern Himalaya.

Channa stewartii Menon, A check list of fishes of the Himalayan and Indo-Gangetic Plains. Spl. Publ. 1., Inland Fish. Soc. India. 1974.

Distribution : Eastern Himalaya.

CHANNA PUNCTATUS

Ophiocephalus punctatus Bloch, Naturges. ausland. Fische, 7, p.139, pl. 358, 1793; type-locality : Coramandel Coast.

Bleeker, Verh. Bat. Gen., 25, p. 42, 1853.

Gunther, Cat. Fish. Brit. Mus., 3, p. 469, 1861.

Day, Fish. India, p. 367, pl. 78, fig. 1, 1876.

Day, Faun. Brit. Ind. Fish., 2, p. 364, 1889.

Shaw and Shebbeare, J. Asiat. Soc. Bengal, 3, p. 123, pl. 4, fig. 1, 1937; type-locality : N.Bengal.

Hora, Rec. Indian. Mus., 39, p.44, 1937; type-locality : Nepal.

Menon, Rec. Indian Mus., 47, p.235, 1949; type-locality : River Kosi, East Nepal.

Regan, Res. Indian Mus., 1, p.158, 1907; type-locality : Nepal.

Ophiocephalus karruway Leceped (Buffon), Hist. Nat. Poiss., 3, p. 552, 1802; type-locality : Tranguenan.

Ophiocephalus lata Hamilton, Fish. Ganges, pp. 63, 367, pl. 34, fig. 18, 1822; type-locality : River Ganges.

Ophiocephalus indicus McClelland, Calcutta, J. Nat. Hist. 2, p. 583, 1802; type-locality : Loodianah and Jallalabad.

Bleeker, Verh. Bat. Gen., 25, p. 42, 1853.

Ophiocephalus affinis Gunther, Cat. Fish. Brit. Mus., 3, p.470, 1861; type-locality : Mauritius.

Channa punctata De Witt, Stanford. Ichth. Bull., 7(4), p. 82, 1960; type-locality : Nepal.

Channa punctatus, Menon, Rec. Indian. Mus., 52, p. 22, 1954; type-locality : Manipur.

Channa punctatus Menon, A check-list of fishes of the Himalayan and Indo-Gangetic Plains, Spl. Publ. 1, Inland Fish. Soc. India. 1974.

Distribution : Ceylon, India, Pakistan, Nepal, Bangladesh and Burma.

VERNACULAR NAMES OF CHANNA (= OPHIOCEPHALUS) GACHUA

Hindi	...	Dheridhok; Chenga
Bengali	...	Cheng
Telegu	...	Yarra-matta; Kora-motta
Tamil	...	Para-Koravaik; Manian-Koravai
Kananda	...	Motta; Mahkorava
Malayalam	...	Karayn; Bral
Oriya	...	Chenga; Chayung
Panjabi	...	Doarrah
Nepali	...	Hili
Assamese	...	Chenga
Khasi	...	Dohthli

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

COLLECTION SPOTS :

The material for the present study pertains to the samples of Channa gachua, C. stewartii and C. punctatus collected at fortnightly intervals from the same pond and stream from where samples for physico-chemical and plankton studies were taken. The collection of the fishes were made on the same day and time and from the same spots (Fig. 2) from where the samples for abiotic and others biotic factors were collected.

COLLECTION PROCEDURES :

Specimens of the above mentioned species for biological studies were captured with the help of hand nets, drag nets and a specially designed fish trap described below.

It was observed that no efficient gear, so far evolved, could work perfectly in the shallow water body for capturing of *Channa* sp., due to the shallowness of the water basin, profuse macrovegetation and the hiding habits of these fishes. To overcome this problem, a new modified, simple and economical fishing trap is devised. Catching principle is based on one way entry of the fish into the trap attracted by bait or by any other means from which the fish can not escape. The trap consists essentially of two parts. The first part or outer portion is a net of wire-meshing or bamboo mat and the second part or the inner portion is also of the same material but smaller in size. The shape of the trap may be somewhat similar to a big envelope, or conical or pitcher like in shape. The inner part should be fitted in the outer part but the length of the inner part should not exceed 25% of the total length of the trap. The inner portion should be conical in shape and both the ends should be opened and the inner end which is narrow, should not be smooth which could be done by taking out few strings from the end.

Inside the trap in the lower portion any type of bait has to be kept to attract the fishes. Fishes will not find any difficulty in getting through the trap due to its wide and smooth opening and once it enters it cannot come out due to the narrow and rough opening of the inner part and gets trapped. The trap can be kept anywhere in the water bodies by tagging it with some object or with the help of a string by which it can easily be taken out when desired. A single person can operate several traps at a time. The size of the trap can be prepared according to need.

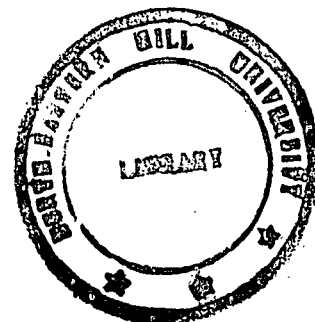
The total length and weight of the fishes to the nearest millimeter and gramme were recorded respectively in the field.

prior to fixing the samples in the formalin for further biological studies.

BIOLOGICAL PARAMETERS :

The following biological parameters were studied in C. qachua (Ham.) collected from both the lotic (stream) and lentic (pond) systems.

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



However, all these parameters could not be studied in C. stewartii which was available only in the stream and C. punctatus only in the pond, due to their occasional availability in the systems.

The study is based on the examination of 510 specimens of Channa qachua in the size range of 16.0 mm to 120.00 mm from both the systems viz., pond and stream.

An interspecific comparison in Morphometric characters, Food and Feeding habits and Length-Weight relationship with all the three species viz., C. qachua, C. stewartii and C. punctatus irrespective of their natural habitat have also been studied. C. stewartii were found only in the stream, whereas C. punctatus were available only in the pond and their size range varied from 36.0 to 95.0 mm and 28.0 to 56.0 mm respectively.

The following methods were adapted for studying the biological parameters taken in the present investigation.

MORPHOMETRIC MEASUREMENTS :

Dividers and measuring board, having graduations in millimeter were used for taking the various measurements.

Total Weight :- Total weights were measured to the nearest 0.1 gm in a double-pan physical balance and for smaller specimens, a chemical balance has been used. The following morphometric measurements have been undertaken according to methods described by Lowe-McConnell (1971).

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

Standard Length :- It is 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.

Snout Length :- From the tip of the snout to the front margin of the orbit.

Eye Diameter :- Distance from the anterior to 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 the dorsal surface.

Length of Upper Jaw :- From the anterior most point of the pre-maxillary to posterior point of the maxillary.

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 the caudal fin.

Length of Caudal Peduncle :- Distance from the end of the anal fin to the base of the median caudal rays.

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

Height of Dorsal fin :- Height of the longest fin ray of the dorsal fin.

Height of Pectoral fin :- Height of the longest fin ray of the pectoral fin.

Height of Ventral fin :- Height of the longest fin ray of the ventral fin.

Height of Anal fin :- Distance between the anterior and posterior of the anal fin taken along the base.

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 (Tobor, 1974). The characters taken were standard length (SL), Head (H), Body Depth (BD), Dorsal fin Length (DF), Eye Diameter (ED) and Inter-Orbital Width (IOW). For each characters, a mean index for each 20 mm length group has been calculated to see whether it is constant or varying with the increase in the total length. Biometric Index was calculated for all the three species viz., C. gachua, C. stewartii and C. punctatus.

MERISTIC CHARACTERS

The following meristic counts were made according to 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 ventral fin.
- (d) Number of rays in the caudal fin.
- (e) Lateral line scales count represent the number of pored scales on the lateral line. The counting of the lateral line scales has been done in two parts in the present study. First the counts were made to the end of the upper lateral line, then by sliding downward and forward (without counting) to the scale in front of the lower line and continuing the count along the lower lateral line.
- (f) Lateral line transverse scales - scales above lateral line have been counted from the origin of the dorsal fin and counted downward and backward to (but not including) the lateral line scale. Scales below the lateral line have been counted upward and forward from the origin of the anal fin.

All the above mentioned morphometric measurements and meristic counts totalizing 26 parameters were made only on the left side of the fish. The specimens of C. qachua from each population viz., lotic and lentic systems were grouped in 20 mm length groups. To study the morphometric characteristics, the regression method has been employed with the formula :-

$$Y = a + bx$$

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

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

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 the standard length. Means, ranges and "b" values were tabulated and compared. The morphometric character of C. stewartii and C. punctatus were also studied. Their mean values and ranges were also tabulated & compared.

LENGTH-WEIGHT RELATIONSHIP

In fishes the length-weight relationship can usually or always be adequately represented by the equation (Le Cren, 1951).

$$W = CL^n$$

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

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

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

The length-weight relationship during the present investigation was studied taking into consideration the intact weight of the fish i.e. including the gut and gonads. The observed average weight of C. gachua from both the 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 fourteen length groups (5 mm interval) for the specimens collected from the pond and sixteen for those from the stream. 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) could only

be taken into consideration as the other seasons are not distinctly marked and merge into each other in this part of the country.

The relationship has also been studied separately for different life stages i.e. juveniles and adults. The length-weight relationship of juveniles is based on the specimens ranging from 18.25 mm to 48.36 mm in total length for pond individuals and 14.0 mm to 54.5 mm in total length for the stream individuals. The individuals ranging from 52.1 mm to 81.5 mm in TL and 58.0 mm to 120.0 mm in TL from the pond and stream respectively were considered as adults.

For interspecific comparisons the length-weight relationship of C. stewartii from the stream and C. punctatus from the pond have also been studied.

As no apparent difference could be noticed between mature and immature individuals, no consideration to these excepting juveniles and adults, has been made during the present study.

CONDITION FACTOR

Individual variations from general length-weight relationships have been studied under the general name "Condition" (Le Cren, 1951). Such changes in condition have usually been analysed by means of a condition factor or Ponderal Index which has been calculated by using different formulae by various workers. However, in the present study, same has been determined by using the following formula (Hile, 1936).

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

where: K = condition factor and W = weight of the fish. The

number 10^5 is a factor to bring the Ponderal Index (K) to near unity (Carlander, 1970). Fluctuations in condition factor were examined for each 5 mm size group of the fishes as well as for different months to elucidate the seasonal fluctuations for C. qachua from both the systems.

MATURITY, SPAWNING AND OVA DIAMETER STUDY

MATURITY :- The study is based on the examination of 510 specimens of C. qachua. After recording all necessary details, specimens were dissected and gonads were carefully taken out from the body cavity. Their maturity stages were determined following the key as outlined by Nikolsky (1963) based on the appearance and size of 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 a pale rose colour.
- IV. Maturity : Sexual products ripe, gonads have achieved their maximum weight but the sexual products are still not extruded when light pressure is applied.
- V. Reproduction : Sexual products are extruded in response to very light pressure on the belly, weight of the gonads decrease rapidly from the start of spawning to its completion.
- VI. Spent Condition : The sexual products have been discharged, genital aperture inflamed, gonads have the appearance of deflated sacs, 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 Rotenberg (1936), Walford (1932) and Qasim and Qayyum (1961). According to their spawning activity in fishes, it can be classified into 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 taking place once a season, but with a 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 intra-ovarian eggs.
- III. Spawning twice a year. In the ovaries of fishes exhibiting this type of spawning, in addition to the batch in ripe condition, another batch of eggs which has undergone more or less the process of maturation, becomes apparent.
- 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 :- The gonads were weighed to the nearest 0.1 gramme prior to fixing the same in formalin for further studies. Weights of the gonads were taken on a chemical balance. In order to study the condition of 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 gonad as a percentage of total weight and has been calculated according to the following formula (Hodgkiss and Mann, 1978).

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

Gonado-somatic indices were determined for various length group and monthwise for the species C. qachua.

OVA-DIAMETER STUDY :- For ova-diameter study, measurements of ova were taken from formalin preserved material. Preliminary examination of the ovaries revealed that within (anterior, middle and posterior part of individual ovary) and among individuals of the paired ovary, there was no significant difference either in relative number or in the mean ova diameter, consequently random sub-samples were taken and subjected to ova-diameter measurement with the help of an ocular micrometer. The diameters of ova along whatever axes they lay parallel to the graduation of the micrometer, were measured to ensure random nature of the readings and unbiased values as suggested by Clark (1934).

ABSOLUTE FECUNDITY :- Ovaries from mature (ripe) specimens collected just before breeding were only used for fecundity studies. Both the ovaries were removed from 89 preserved gravid females of C. qachua of known length and weight. 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, after drying off the excess moisture with the help of a blotting paper, by using the following formula :-

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

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 according to 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) between fecundity and body weight; (c) between fecundity and ovary weight; and (d) between total length and ovary weight were examined and a log to log transformation in the form given below (Bagenal, 1978) has been followed :-

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

FOOD AND FEEDING HABITS'

Food and feeding habits of C. qachua were studied by examining a total of 510 digestive tracts collected from the specimens ranging from 16.0 mm to 120.0 mm from both the systems, viz., Pond and Stream.

The guts were removed from the specimens after measuring and weighing each specimen to the nearest millimeter and gramme respectively and preserved in 5% formalin for subsequent analysis. Contents of the preserved guts were teased apart in order to render their microscopic examination easy. The various food items were identified as far as possible upto generic level.

Several methods for the enumeration of gut contents have been employed by different workers. However, in the present study the following methods were employed as described by Ricker (1971).

NUMERICAL METHOD - The number of individuals of each food types in each gut has been counted. These were summed to enumerate the totals 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 by number of each type of food item.

FREQUENCY OF OCCURRENCE - Stomach contents were examined and the individual food items were sorted out and identified. The number of guts in which each item occurred was recorded and expressed as a percentage of the number of the gut examined. The percentage of occurrence of a particular food item has also been calculated with reference to the sum of occurrence of all the items. The gut contents were analysed for elucidating seasonal variations in the diet components. The data was also analysed for various size groups in order to see, if there is any basic change in dietary habits of the species at various stages of its growth.

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 total length (R.L.G.) has also been estimated by dividing the gut length by total body length (Al-Hussainy, 1949).

The total length and gut lengths were measured to find out the relationship between the two variables and also between

weight of the gut to total length. In both the cases regression equations were determined to describe the relation between them.

The gut contents of C. stewartii and C. punctatus were also studied for interspecific comparison.



R E S U L T S

MORPHOMETRY AND MERISTIC COUNTS

The measurements of morphometric characters of C. gachua in percentage of standard length have been presented in Table 8 and summarised below.

Pre-Dorsal Length :

The mean values for predorsal length was found to be 1.58 and 2.09 for pond and stream populations respectively. Average percentage of standard length was recorded to be 38.63 and 36.6 for pond and stream individuals respectively.

Head Length :

Mean values for head length were 1.25 and 1.67 for pond and stream and percentage of standard length was 30.56 and 29.29 for pond and stream population respectively.

Snout Length :

Mean values were found to be 0.30 and 0.41 and percentage of standard length 7.33 and 7.19 for pond and stream population respectively.

Eye Diameter :

Mean values were obtained to be 0.24 and 0.27 and percentage of standard length being 5.86 and 4.73 for the specimens from the pond and stream respectively.

Post-Orbital Length :

This, in percentage of standard length was found to be 24.02 and 18.42 for pond and stream specimens respectively. Mean values were 0.99 (Pond) and 1.05 (Stream).

Inter-Orbital Length :

Mean values were recorded to be 0.62 (pond individuals) and 0.79 (stream individuals). The percentage of standard length was 15.15 and 13.85 for the individuals from pond and stream respectively.

Length of upper Jaw :

This in percentage of standard length was 10.51 and 9.12 for pond and stream specimens respectively. Mean values were 0.43 (pond) and 0.52 (stream).

Head Depth :

Mean values for head depth were 0.64 and 0.88 whereas, in percentage of standard length, these were 15.64 and 15.43 for pond and stream individuals respectively.

Body Depth :

Mean values were found to be 0.77 and 1.1 and percentage of standard length 18.82 and 19.29 for pond and stream individuals.

Least height of body :

Mean values were 0.40 (pond) and 0.61 (stream). The values of percentage of standard length were 9.77 and 10.70 for pond and stream fishes.

Length of caudal peduncle :

Mean values were 0.57 and 0.79 for pond and stream individuals respectively. Value in percentage of standard length did not differ in both cases, being 13.93 for pond individuals and 13.85 for stream individuals.

Length of dorsal fin :

Mean values were found to be 2.22 and 3.13 and in percentage of standard length these were 54.27 and 54.19 respectively for pond and stream individuals.

Height of pectoral fin :

Percentage standard length values were 20.04 and 19.64 and the mean values were 0.82 and 1.12 for pond and stream individuals respectively.

Height of ventral fin :

Mean values were recorded to be 0.33 and 0.48 and in percentage of standard length 8.06 and 8.42 for pond and stream individuals respectively.

Height of anal fin :

Mean values were found to be 0.43 and 0.68 and in percentage of standard length values were 10.51 and 10.52 for pond and stream specimens.

Base of anal fin :

Value for percentage of standard length was higher in stream population i.e. 34.56 than the pond population 33.98. Mean values were 1.39 and 1.97 for pond and stream individuals respectively.

TABLE 8

MORPHOMETRIC ANALYSIS OF CHANNA GACHUA

	POND			STREAM		
	MEAN	AVERAGE % STANDARD LENGTH	RANGE	MEAN	AVERAGE % STANDARD LENGTH	RANGE
Weight (gms)	2.12	-	0.124 - 5.90	6.47	-	0.07 - 22.0
Total length	4.97	-	2.38 - 7.82	6.83	-	1.94 - 12.0
Standard length	4.09	-	1.91 - 6.50	5.70	-	1.60 - 10.1
Predorsal length	1.50	38.63	0.75 - 2.53	2.09	36.60	0.66 - 3.5
Head length	1.25	30.56	0.62 - 2.00	1.67	29.29	0.50 - 2.9
Snout length	0.30	7.33	0.15 - 0.50	0.41	7.19	0.13 - 0.70
Eye diameter	0.24	5.86	0.14 - 0.37	0.27	4.73	0.14 - 0.30
Post orbital length	0.99	24.02	0.33 - 1.25	1.05	18.42	0.33 - 1.9
Inter orbital length	0.62	15.15	0.30 - 1.03	0.79	13.85	0.30 - 1.4
Length of upper jaw	0.43	10.51	0.197 - 0.67	0.52	9.12	0.17 - 0.90
Head depth	0.64	15.64	0.31 - 1.02	0.88	15.43	0.30 - 1.50
Body depth	0.77	18.82	0.37 - 1.25	1.10	19.29	0.34 - 2.0
Least height of body	0.40	9.77	0.186 - 0.67	0.61	10.70	0.17 - 1.10
Length of caudal peduncle	0.57	13.93	0.25 - 0.93	0.79	13.85	0.22 - 1.50
Length of dorsal fin	2.22	54.27	1.04 - 3.50	3.13	54.19	0.83 - 5.4
Height of dorsal fin	0.46	11.24	0.21 - 0.77	0.63	11.05	0.17 - 1.1
Height of peetoral fin	0.82	20.04	0.416 - 1.27	1.12	19.64	0.39 - 1.9
Height of ventral fin	0.33	8.06	0.137 - 0.50	0.48	8.42	0.14 - 0.90
Height of anal fin	0.43	10.51	0.17 - 0.73	0.68	10.52	0.18 - 1.1
Base of anal fin	1.39	33.98	0.67 - 2.20	1.97	34.56	0.56 - 3.6
Girth	2.68	65.52	1.25 - 4.40	3.64	63.85	1.08 - 6.6

TABLE 09

A COMPARISON OF THE MERISTIC CHARACTERS OF TWO POPULATION OF CHANNA GACHUA, ONE FROM THE POND AND OTHER FROM THE STREAM.

PARAMETERS	P O N D		S T R E A M	
	Average	Range	Average	Range
Dorsal fin rays	32.1	31 - 34	31.5	31 - 34
Pectoral fin rays	13.3	11 - 14	13.2	13 - 14
Anal fin rays	17.6	17 - 19	19.0	16 - 22
Caudal fin rays	13.0	Constant	13.0	Constant
Lateral line scales	38.5	37 - 40	38.5	36 - 40
Lateral line transverse scales.	$3\frac{1}{2}/5\frac{1}{2}$	Constant	$3\frac{1}{2}/5\frac{1}{2}$	Constant

TABLE 10

REGRESSION EQUATIONS OF VARIABLE MORPHOMETRIC CHARACTERS OF CHANNA GACHUA

Parameters analysed	POND	STREAM
1) Total length (Y) vs Standard length (X)	$Y = 1.279927 + 1.1849743 X$	$Y = 0.44145 + 1.1894575 X$
2) Standard length vs Predorsal length	$Y = 0.084891 + 0.3858304 X$	$Y = 1.330713 + 0.3441885 X$
3) Standard length vs Head length	$Y = 0.365555 + 0.2983371 X$	$Y = 0.327331 + 0.2872802 X$
4) Standard length vs Snout length	$Y = -0.107599 + 0.0769114 X$	$Y = -0.1770993 + 0.076694 X$
5) Standard length vs Eye diameter	$Y = 0.4097057 + 0.0492436 X$	$Y = 0.809952 + 0.0340061 X$
6) Standard length vs Post orbital	$Y = -0.5538671 + 0.1998499 X$	$Y = -0.205194 + 0.1902751 X$
7) Standard length vs Inter orbital	$Y = -0.2998803 + 0.1588242 X$	$Y = 0.4157717 + 0.1320636 X$
8) Standard length vs Body depth	$Y = -0.0580949 + 0.1895686 X$	$Y = -0.315615 + 0.199222 X$
9) Standard length vs Head depth	$Y = 0.156574 + 0.1537795 X$	$Y = 0.5786039 + 0.1457446 X$
10) Standard length vs Length of dorsal fin	$Y = 0.283597 + 0.5367478 X$	$Y = 0.490274 + 0.5415085 X$
11) Standard length vs Length of the caudal peduncle	$Y = -0.2715765 + 0.146526 X$	$Y = -1.0624291 + 0.158558 X$
12) Standard length vs Height of pectoral fin	$Y = 0.6291685 + 0.1865811 X$	$Y = 0.837872 + 0.181632 X$
13) Standard length vs Height of dorsal fin	$Y = -0.378906 + 0.1234919 X$	$Y = -0.2978087 + 0.116935 X$
14) Standard length vs Base of anal fin	$Y = 0.296929 + 0.333612 X$	$Y = -0.442436 + 0.3533585 X$
15) Standard length vs Girth	$Y = -0.983352 + 0.6788846 X$	$Y = -1.981601 + 0.6736477 X$

Girth :

Girth values were recorded to be 65.52 in the pond individuals and 63.85 in individual from the stream when represented as a percentage of standard length.

MERISTIC COUNTS :

The results of the various meristic counts obtained for C. gachua from both the systems are presented in Table 9. The dorsal fin rays were found to range from 31-34 in the individuals from both the ecosystems. Average fin rays were recorded to be 32.1 and 31.5 for individuals from pond and stream.

The pectoral fin rays ranged from 11-14 and average fin ray count was 13.3 for the specimens from the pond. In the case of individuals from stream, the fin rays ranged from 13-14 and the average count was 13.2.

Anal fin rays ranged from 17 to 19 and 16-22 for the individuals from pond and stream respectively. Average counts were 17.6 (for pond specimens) and 19.0 (for stream individuals).

The caudal fin rays were 13 in both the cases and constant in number. The lateral line scales ranged from 37-40 and 36-40 in both the populations. Average counts were 38.5 in both the cases. The lateral line transverse scales were found to be constant. The count being $3\frac{1}{2}/5\frac{1}{2}$ for individuals both from pond and stream.

INTRASPECIFIC DIFFERENCE :

The various regression equations of the studied parameters have been presented in Table 10. The regression of total length on standard length show a difference in the equations as follows :-

$$Y = 1.2799 + 1.1849 X \text{ (Pond population)}$$

$$Y = 0.4414 + 1.1894 X \text{ (Stream population)}$$

Similarly, differences have been observed in regression equations of standard length Vs predorsal length; head length; snout length; eye diameter; post-orbital length; inter-orbital length; body depth; head depth; length of dorsal fin; length of caudal peduncle; height of pectoral fin; base of anal fin and girth. Only standard length Vs height of dorsal fin gave a somewhat similar result in both the populations. The equations are :

$$Y = - 0.3789 + 0.1234 X \text{ (Pond population)}$$

$$Y = - 0.2978 + 0.1169 X \text{ (Stream population)}$$

The value of the height of dorsal fin expressed in percentage of standard length were also found to be similar in the individuals from both the pond and stream (Table 10). The observed values of all the morphometric measurements when plotted as scatter diagram aggregate in straight line.

INTERSPECIFIC DIFFERENCE :

The measurements of morphometric characters in percentage of standard length for Channa stewartii and C. punctatus have been summarized in Tables 13 & 14.

The regression equations of the studied parameters have been found out and presented in Table 15. The regression equations of the various factors on the standard length were found to be different in all the species studied.

The values of pre-dorsal length; head length; eye diameter, post-orbital length, inter-orbital length, length of upper jaw, head depth, body depth, length of caudal peduncle and girth

TABLE 11
MEAN BIOMETRIC INDICES IN VARIOUS SIZE GROUPS
OF CHANNA GACHUA FROM THE POND

Length groups	10-29mm	30-49mm	50-69mm	70-89mm
Ratios				
TL/SL	1.24	1.22	1.21	1.20
TL/H	3.83	3.93	4.10	3.91
TL/BD	6.43	6.45	6.80	6.25
TL/DF	2.28	2.24	2.21	2.23
TL/IOW	7.93	8.42	8.45	7.59
TL/ED	17.0	19.6	22.32	21.13
H/ED	1.44	1.55	1.61	1.66
IOW/ED	2.14	2.33	2.63	2.78
H/PF	1.49	1.52	1.46	1.57

TABLE 12
MEAN BIOMETRIC INDICES IN VARIOUS SIZE GROUPS OF CHANNA GACHUA
FROM THE STREAM

Length groups	10-29mm	30-49mm	50-69mm	70-89mm	90-109mm	110-129mm
Ratios						
TL/SL	1.21	1.18	1.20	1.19	1.20	1.18
TL/H	3.88	4.12	4.14	4.02	4.06	4.13
TL/BD	5.7	6.75	6.36	6.28	6.1	6.0
TL/DF	2.33	2.13	2.16	2.10	2.17	2.22
TL/IOW	6.46	8.90	8.76	8.89	8.71	8.57
TL/ED	13.3	22.4	24.2	24.75	26.91	28.57
H/ED	1.07	1.56	1.70	1.82	1.96	1.98
IOW/ED	2.06	2.51	2.76	2.78	3.08	3.33
H/PF	1.28	1.5	1.43	1.50	1.53	1.52

TABLE 13
MORPHOMETRIC ANALYSIS OF CHANNA STEWARTII

Parameters	Mean	Average % of Standard Length	Range % of Standard Length
Predorsal	17.58	33.38	10.5 - 26.0
Head	14.53	27.59	8.0 - 21.0
Snout	3.80	7.21	2.0 - 5.8
Eye	2.84	5.39	2.0 - 3.6
Post orbital	8.98	17.05	5.2 - 13.0
Inter orbital	7.191	13.65	4.5 - 10.0
Length of Upper Jaw	4.71	8.944	2.5 - 7.0
Head depth	7.63	14.48	4.5 - 11.0
Body depth	9.63	18.28	5.2 - 13.5
Least height of body	5.46	10.36	3.0 - 8.5
Length of caudal peduncle	6.36	12.07	4.6 - 9.0
Length of D.F.	32.15	61.05	18.0- 46.0
Height of D.F.	6.475	12.29	4.0 - 10.0
Height of Pectoral	11.25	21.36	6.0 - 16.0
Height of Ventral	4.71	8.94	2.0 - 7.0
Height of Anal	5.87	11.14	3.0 - 8.8
Base of Anal	22.0	41.77	12.0 - 32.0
Girth	31.75	60.292	19.0 - 44.0

TABLE 14

MORPHOMETRIC ANALYSIS OF CHANNA PUNCTATUS

Parameters	Mean	Average % of Standard length	Range % of Standard length
Predorsal	14.61	38.64	8.2 - 10.0
Head	11.96	31.63	8.0 - 16.0
Snout	2.855	7.55	1.8 - 4.0
Eye	2.30	6.08	1.6 - 3.0
Post orbital	6.95	18.38	4.1 - 10.0
Interorbital	5.43	14.36	3.1 - 8.0
Length of upper jaw	3.88	10.26	2.8 - 5.0
Head depth	6.20	16.39	4.0 - 8.5
Body depth	7.20	19.04	4.8 - 10.5
Least height of body	3.78	9.99	2.0 - 5.1
Length of caudal peduncle	5.08	13.43	2.8 - 7.0
Length of dorsal fin	20.93	55.35	12.0 - 28.0
Height of dorsal fin	4.41	11.66	1.6 - 7.0
Height of pectoral fin	8.26	21.84	5.0 - 12.0
Height of ventral fin	3.05	8.06	1.0 - 4.8
Height of anal fin	3.81	10.08	1.0 - 6.0
Base of anal fin	13.34	35.28	7.0 - 18.0
Girth	24.81	65.61	14.0 - 34.0

when expressed in percentage of standard length were found to be higher in C. punctatus in comparison to C. stewartii (Tables-13 & 14). Only few characters viz. least height of body, length of dorsal fin, height of dorsal fin, height and base of anal expressed in percentage of standard length were found to be higher in C. stewartii.

BIOMETRIC INDEX IN C. SACHUA :

For each character, a mean biometric index for each 20 mm length groups has been calculated. It is quite clear in the present study from the Tables 11 & 12, that the growth of head, dorsal fin and standard length in relation to the total length in C. sachua for the size range studied are isometric. The growth of body depth and inter-orbital width in relation to total length illustrates positive allometry whereas, that of eye-diameter (ED) in relation to total length (TL) shows a negative allometry (Figs. 18 & 19). This has been observed for the individuals both from the pond and stream.

The ratios between head and eye diameter (H/ED); Head and pectoral fin length (H/PF) and between inter-orbital width and eye diameter (IOW/ED) were examined to see whether or not, they vary with increase in size of the fish. The results are tabulated in Tables 11 & 12.

BIOMETRIC INDEX IN C. STEWARTII AND C. PUNCTATUS :

For each character, a mean biometric index for each 10 mm length groups was calculated to see whether it is constant or varying with increase in size of the total length (Tables 16 & 17). In the present study it has been observed that the growth of the head, dorsal fin and standard length in relation to the total

TABLE 15

REGRESSION EQUATIONS OF THE MORPHOMETRIC CHARACTERS IN CHANNA STEWARTII AND CHANNA PUNCTATUS

PARAMETERS ANALYSED	C. PUNCTATUS		C. STEWARTII	
	Y =	X	Y =	X
1) Total length vs Standard length	4.113213 +	1.209729 X	1.000945 +	1.1993744 X
2) Standard length vs Predorsal length	0.190413 +	0.391482 X	1.197636 +	0.3111539 X
3) Standard length vs Head length	2.081228 +	0.2613229X	0.549743 +	0.2655385 X
4) Standard length vs Snout length	0.247053 +	0.0689705X	-0.21	0.0762730X
5) Standard length vs Eye diameter	0.5230621+	0.0469934X	0.8232444+	0.0383292 X
6) Standard length vs Post orbital	-0.1979237+	0.189036 X	0.2024014+	0.1667476 X
7) Standard length vs Interorbital	-0.3232986+	0.1523517X	-1.0611756+	0.1164452 X
8) Standard length vs Body depth	0.8564654+	0.1677629X	0.4965373+	0.1735048 X
9) Standard length vs Head depth	0.5253836+	0.1500725X	0.5928318+	0.1330967 X
10) Standard length vs Length of dorsal fin	0.677181 +	0.5358101X	0.031097 +	0.6099298 X
11) Standard length vs Length of caudal peduncle	-0.2526817+	0.1410296X	1.2213178+	0.0977076 X
12) Standard length vs Height of Pectoral fin	-0.2342447+	0.2247073X	-4.578932 +	0.3005874 X
13) Standard length vs height of dorsal fin	-2.1402478+	0.1734611X	-0.509796 +	0.1326395 X
14) Standard length vs Base of anal fin	-0.472724 +	0.3653613X	0.375319 +	0.4106472 X
15) Standard length vs Girth	-0.382974 +	0.6663266X	3.724996 +	0.5321877 X

TABLE 16
 MEAN BIOMETRIC INDICES IN DIFFERENT LENGTH GROUPS OF CHANNA
STEWARTII

<u>Length groups</u> Ratios	36-45mm	46-55mm	56-65mm	66-75mm	76-85mm	86-95mm
TL/SL	1.24	1.23	1.21	1.22	1.18	1.23
TL/H	4.50	4.36	4.41	4.25	4.41	4.52
TL/BD	6.92	6.40	7.12	6.00	6.58	7.03
TL/DF	2.00	2.08	1.97	2.00	1.88	2.06
TL/IOW	8.00	8.80	8.76	8.80	9.02	9.50
TL/ED	18.00	19.59	25.90	22.00	21.84	26.38
H/ED	4.00	4.48	5.86	5.16	4.94	5.83
IOW/ED	2.25	2.22	2.95	2.50	2.42	2.77
H/PF	1.33	1.29	1.29	1.29	1.25	1.31

TABLE 17
 MEAN BIOMETRIC INDICES IN DIFFERENT LENGTH GROUPS OF CHANNA
PUNCTATUS

<u>Length groups</u> Ratios	28-37 mm	38-47 mm	48-57 mm	58-67 mm
TL/SL	1.33	1.22	1.19	1.21
TL/H	3.50	4.05	4.00	3.87
TL/BD	5.83	7.04	6.70	6.20
TL/DF	2.33	2.33	2.16	2.21
TL/IOW	9.03	8.86	9.13	7.75
TL/ED	17.50	21.50	20.38	20.66
H/ED	5.00	5.30	5.09	5.33
IOW/ED	1.93	2.42	2.23	2.66
H/PF	1.60	1.53	1.44	1.33

length in C. stewartii and C. punctatus are isometric or in other words it exhibits a constant index (Figs. 20 & 21). The growth of the body depth in both C. stewartii and C. punctatus and inter-orbital width in C. punctatus in relation to total length, illustrates positive allometry whereas, eye diameter in relation to total length both for C. stewartii and C. punctatus shows a negative allometry. Inter-orbital width in relation to total length for C. stewartii unlike others also shows negative allometry. The ratios were examined between head and eye diameter, head and pectoral fin and inter-orbital width and eye diameter to see whether they vary with increase in size of the species studied or not ?

LENGTH - WEIGHT RELATIONSHIP

LENGTH-WEIGHT RELATIONSHIP IN C. GACHUA :

The entire length weight data of Channa gachua was pooled into a single equation which was calculated to be :

$$\begin{aligned} \text{Log } Y &= -5.2609 + 3.1821 \log \text{ TL (Limnophilic specimens)} \\ r &= 0.9963 \end{aligned}$$

$$\begin{aligned} \text{Log } Y &= -5.7104 + 3.3942 \log \text{ TL (Rheophilic specimens)} \\ r &= 0.9692 \end{aligned}$$

where: Y = Total weight and X = Total length. A high correlation between length and weight has been indicated by the correlation coefficient. This high value is an index of the reliabilities of the observations. The derived parabolic equation for limnophilic specimens is as follows :-

$$W = 0.000005483 L^{3.1821}$$

and for rheophilic individuals

$$W = 0.000001945 L^{3.3942}$$

Since the "b" values are 3.1821 and 3.3942 in the specimens from the pond and stream respectively, indicates that it follows closely the cubic law for isometric growth.

On plotting the observed average weight of the species (C. gachua) collected from both the systems, against the average observed length, a parabolic curve has been obtained (Figs. 22 & 23). A logarithmic growth prepared with the above data showed a straight line relationship (Figs. 22 & 23).

LENGTH-WEIGHT RELATIONSHIP IN C. GACHUA DURING DIFFERENT SEASONS:

The length-weight relationship was calculated during the different seasons to see the seasonal impact on the relationship. Summer and winter are the seasons taken into consideration as the other seasons are not distinctly marked and merge into these in this part of the country. The various regression equations have been tabulated in Table-18. It is evident from the results that the values of regression coefficient tend to be high during the summer season in the species from both the systems i.e. pond and stream.

LENGTH-WEIGHT RELATIONSHIP IN JUVENILES OF C. GACHUA :

The length-weight relationship in juveniles is based on fishes ranging from 18.25 mm to 48.36 mm (Pond individuals) and 14.0 mm to 54.5 mm (stream individuals) in total length. The regression equation for juveniles were estimated to be :

$$\begin{aligned} \text{Log } W &= -4.8503 + 2.8743 \log \text{ TL (Pond individuals)} \\ r &= 0.9982 \end{aligned}$$

$$\begin{aligned} \text{Log } W &= -5.6768 + 3.3667 \log \text{ TL (Stream individuals)} \\ r &= 0.9028 \end{aligned}$$

The parabolic equation were determined to be :

TABLE 18

LENGTH-WEIGHT REGRESSION EQUATIONS IN CHANNA GACHUA DURING DIFFERENT SEASONS AND LIFE STAGES

Seasons	Ecosys- tem.	Regression	"b"	"r"	Parabolic Equations "W"
Summer (April to September)	Pond	Log W = -4.9827845 + 3.04268 log TL	3.04268	0.994	W=0.00001040 L ^{3.04268}
	Stream	Log W = -4.6805601 + 2.8457028 log TL	2.8457028	0.995	W=0.00002084 L ^{2.8457028}
Winter (Octo- ber to March)	Pond	Log W = -4.2346 + 2.57132 log TL	2.5713	0.898	W=0.00005821 L ^{2.5713}
	Stream	Log W = -3.59486 + 2.26468 log TL	2.2646	0.810	W=0.0002541 L ^{2.2646}
Juveniles	Pond	Log W = -4.8503877 + 2.8743103 log TL	2.8743	0.99824	W=0.00001409 L ^{2.8743103}
	Stream	Log W = -5.6768741 + 3.3667787 log TL	2.3667	0.9028291	W=0.000002104 L ^{3.3667}
Adults	Pond	Log W = -6.12974561 + 3.6456475 log TL	3.6456	0.9945	W=0.0000007413 L ^{3.64564}
	Stream	Log W = -5.5723257 + 3.3247545 log TL	3.3247	0.9978	W=0.000002673 L ^{3.32475}

TABLE 19

LENGTH-WEIGHT REGRESSION EQUATIONS OF C. GACHUA, C. STEWARTII AND C. PUNCTATUS.

Species	Ecosys- tems	Regression	"b"	"r"	Parabolic equations "W"
<u>C. gachua</u>	Pond	Log W = -5.2609531 + 3.1821583 log TL	3.1821	0.9963	W=0.000005483 L ^{3.18215}
<u>C. gachua</u>	Stream	Log W = -5.7104996 + 3.3942382 log TL	3.3942	0.9692985	W=0.000001945 L ^{3.3942}
<u>C. punctatus</u>	Pond	Log W = -4.9308661 + 2.970195 log TL	2.9701	0.9975	W=0.00001172 L ^{2.970195}
<u>C. stewartii</u>	Stream	Log W = -3.9854529 + 2.451779 log TL	2.4517	0.9629	W=0.0001033 L ^{2.451779}

$$W = 0.00001409 L^{2.8743} \text{ for limnophilic specimens and}$$

$$W = 0.000002104 L^{3.3667} \text{ for rheophilic ones.}$$

The exponential index (b) for the specimens collected from pond was less than "three" (2.8743) which reveals that the weight of the species during the juvenile stage is lighter in relation to its length unlike the specimens from the stream.

LENGTH-WEIGHT RELATIONSHIPS IN ADULTS OF C. GACHUA :

The length-weight relationships in adults is based on the specimens ranging from 52.1 mm to 81.5 mm and 58.0 mm to 120.0 mm from the pond and stream respectively. The regression and the parabolic equations are :

$$\text{Log } W = -6.1297 + 3.6456 \log TL \text{ (Pond population)}$$

$$r = 0.9945$$

$$w = 0.0000007413 L^{3.6456}$$

and :

$$\text{Log } W = -5.5723 + 3.3247 \log TL \text{ (Stream population)}$$

$$r = 0.9978$$

$$w = 0.000002673 L^{3.3247}$$

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

LENGTH-WEIGHT RELATIONSHIP IN C. STEWARTII AND C. PUNCTATUS :

For interspecific comparisons in the length-weight relationship in Channids, C. punctatus collected from the pond and C. stewartii from the stream have been taken into consideration.

The regression equations, correlation coefficient and exponential indices have been tabulated in Table 19. The results obtained during the present study indicates that the exponential values (b) in C. punctatus and C. stewartii are less than "3". which indicates that their growth is allometric unlike C. gachua.

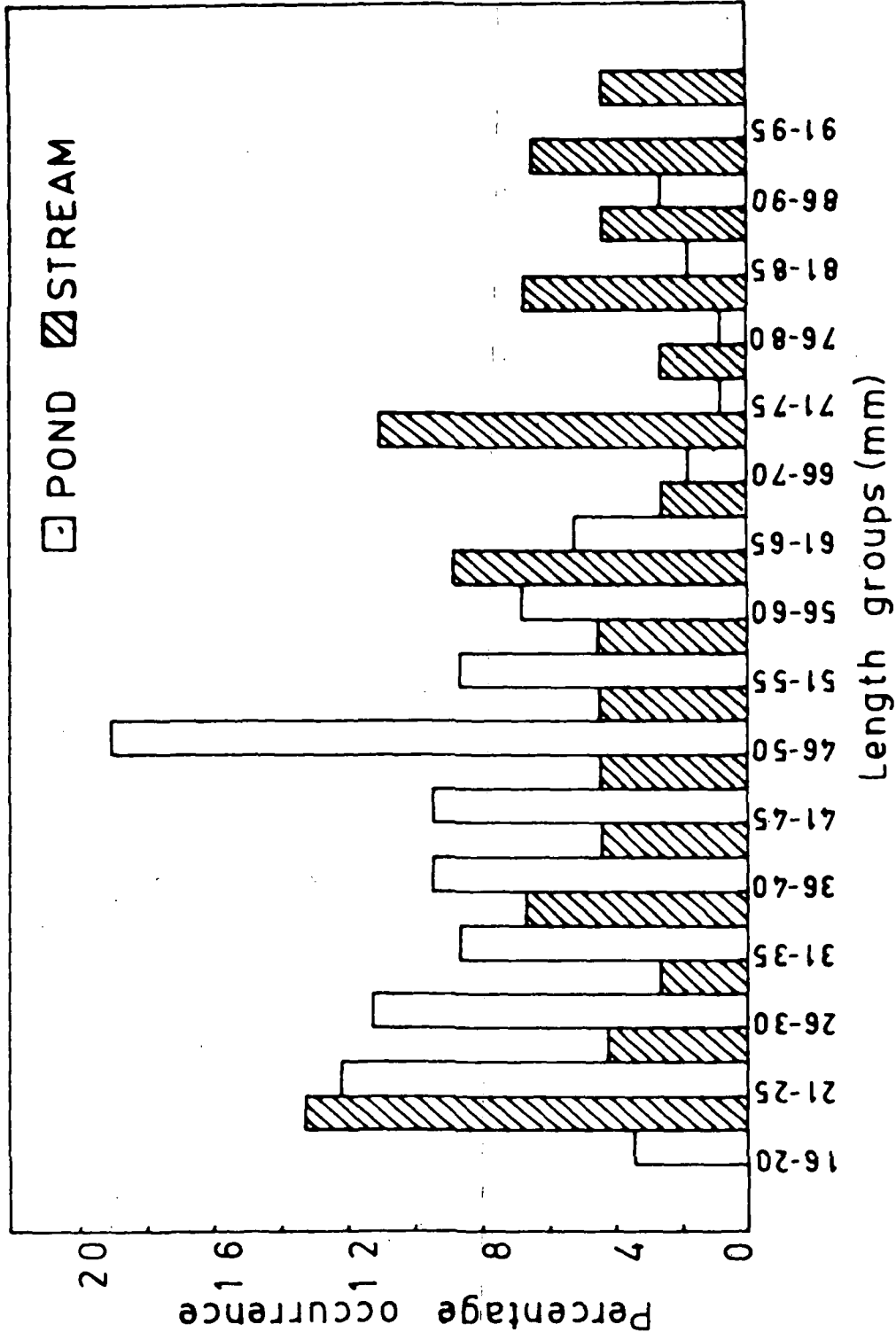


Fig. 17: Length frequency distribution of *C. gachua*.

LENGTH FREQUENCY DISTRIBUTION OF C. GACHUA

To find out the length frequency distribution, a graph (Fig.17) has been prepared by converting the frequencies into percentages and plotting the same against the respective length groups. The frequency polygon for the entire period of study as shown in Fig.17 which indicates the presence of two distinct modes, the first at 21-25 mm length group in both the population and the second at 46-50 mm in the pond population and 91-95 mm length group in the stream population.

CONDITION FACTOR

MONTHLY FLUCTUATIONS OF CONDITION FACTOR IN C. GACHUA :

Monthwise averages of ponderal index of entire one year has been calculated to elucidate the seasonal fluctuations and is tabulated in Table 20. The "K" values showed a steady rise from the month of October to attain a peak during July in the limnophilic specimens (Fig. 24B). In the case of specimens from the stream there was a rise from December onwards attaining a peak in April (Fig. 24A). From August, the values dropped down to a minimum in both the pond and stream (Table 20). It has also been observed that the species (C. gachua) from both the systems attain a small peak during the year i.e. from April to July, whereafter the "K" values drop abruptly.

SEASONAL FLUCTUATIONS OF CONDITION FACTOR IN DIFFERENT LENGTH GROUPS :

In the present study, the condition values at different lengths showed that condition of the smallest size group is much higher (Fig. 24A), which indicates that juveniles have better condition factor.

TABLE 20
MONTHLY FLUCTUATIONS IN THE CONDITION FACTOR OF
CHANNA GACHUA

MONTHS	POND	STREAM
SEPTEMBER	0.977	1.016
OCTOBER	0.710	0.950
NOVEMBER	0.925	0.918
DECEMBER	0.989	0.900
JANUARY	0.980	0.937
FEBRUARY	0.972	0.987
MARCH	0.941	1.000
APRIL	1.015	1.206
MAY	1.009	1.060
JUNE	1.015	1.019
JULY	1.161	1.182
AUGUST	0.862	0.904

TABLE 21
FLUCTUATIONS IN THE CONDITION FACTOR IN DIFFERENT
LENGTH GROUPS OF CHANNA GACHUA

LENGTH-GROUPS mm	POND	STREAM
16.0 - 20.0	1.041	0.771
21.0 - 25.0	0.992	0.893
26.0 - 30.0	0.824	0.819
31.0 - 35.0	0.894	1.019
36.0 - 40.0	0.886	0.941
41.0 - 45.0	0.938	1.014
46.0 - 50.0	0.917	0.876
51.0 - 55.0	0.988	1.010
56.0 - 60.0	0.955	1.060
61.0 - 65.0	1.030	1.029
66.0 - 70.0	1.102	1.002
71.0 - 75.0	1.259	1.051
76.0 - 80.0	1.321	0.993
81.0 - 85.0	1.164	1.212
86.0 - 90.0	-	1.200
91.0 - 95.0	-	1.100
126.0 - 130.0	-	1.273

With the increase in length, the condition of the species falls steadily upto a length of 26-30 mm both in the case of stream and pond population. In the next size group (i.e. 31-35 mm) there is a sudden rise in the condition factor, reaching a peak at 76-80 mm length group in the case of individuals from pond and 81-85 mm length group for stream specimens (Fig. 24A).

The "K" values after reaching its peak in 31-35 mm length groups (Table-21), the growth seems to be somewhat cyclic in nature. Each peak is followed by a decline in the condition factor and gradual recovery.

MATURITY AND SPAWNING IN C. GACHUA

MATURITY STAGES :


The various maturity stages observed are summarized in Table-22, following the classification of Nikolsky (1963).

CYCLE OF MATURATION ::

Ovary condition progressed from immature Stage I from February to maturity (Stage IV) in June and reproduction (Stage V) in July-August. The Stage VI (spent) were recorded in the individuals which appeared during August-September and were found to be present till October-November. This indicates that spawning occurs in July and August. The ovaries in the specimens collected from August onwards were shrunken, small and degenerated with dark coloured ova, reflecting the post-spawning season.

OVA-DIAMETER STUDY :

The various stages in the ovarian development of mature C. gachua are given in Table-22. The ova-diameter study revealed six stages of maturity. These stages were in agreement with

those delineated macroscopically following the classification of Nikolsky (1963). The ovaries of the species from both the population 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 0.64 to 0.74 mm. No ova of intermediate size between small and big  mature ova could be observed. The spent ovary contained degenerating ova in different stages of maturity.

GONADO-SOMATIC INDEX :

The condition of gonads is indicative of the breeding season of fish (Sinha, 1975). Seasonal changes in the coefficient of maturity of female has been presented in Fig. 25. The same could not be calculated in the case of males because of their irregular availability during the whole year.

Gonado-somatic index increased progressively from February onwards (Fig. 25) reaching its maximum (1.54) in July for the specimens from the stream. In the pond population, Gn.S.I. showed appreciably high value during September, whereafter the values showed a decreasing trend in October, November and December (Fig. 25). In August, the Gn.S.I. values dropped down to 0.27 and 0.18 in stream and pond population respectively. High values of Gn.S.I. have been recorded during May to June which indicates that the spawning season ranges from May to July (Table 22).

Plotting the Gn.S.I. values against different length groups (Fig. 26) indicates that there is a definite tendency for the Gn.S.I. to increase with the increase in total length from 41-45 mm (Pond) and 51-55 mm (Stream) onwards till it reaches the maximum in 71-75 mm and 91-95 mm length groups in the

TABLE 22

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

STAGES	DEGREE OF MATURATION	APPEARANCE	MONTHS OF AVAILABILITY	RANGE OF OVA DIAMETER (mm)	MEAN Gn.S.I. OF POND & STREAM
I	Immature	Ova transparent and yolkless	February to March	0.184 to 0.272	0.80
II	Resting	Translucent.	March to April	0.280 to 0.520	1.50
III	Maturation	Translucent and yolkless.	May	0.560 to 0.629	1.45
IV	Maturity.	Ova large and fully yolked	June	0.640 to 0.720	1.61
V	Reproduction	Ova large and free from each other.	July to August	0.744 to 0.772	1.54
VI	Spent	Shrunken, small and degenerated dark coloured ova, together with transparent ovary.	September to October	0.200 to 0.280	1.30

specimens collected from pond and stream respectively and then drops to lower levels.

SPAWNING SEASON :

As mentioned earlier, spawning activity in fishes can be classified into four types. Observations based on the data on maturity studies of C. qachua indicate that the fish belong to the Type-I of the categories stated (as indicated in Materials and Methods).

The cycle of maturation already described earlier 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 from February to maturity (Stage IV) in June and reproduction (Stage V) in July-August, indicating that spawning occurs during June to August.

SIZE AT FIRST MATURITY :

No immature specimens of C. qachua were encountered during the breeding season. It has been observed that all the specimens below 36.0 and 41.0 mm from the pond and the stream respectively, were found to be immature. It is clear from Fig. 27 that 50% of the specimens, mature at length group of 51.0-55.0 mm in both the pond and stream population and practically all were mature at 61.0-65.0 mm and 66.0-70.0 mm size group onwards in the pond and stream population respectively.

FECUNDITY

In C. qachua individual fecundities varied considerably from individual to individual and ranged from 243 eggs in the specimens measuring 77.0 mm in total length and weighing 4.395

gms in total weight to 1523 eggs in those measuring 87.0 mm in total length and 8.624 gms in total weight for individuals from the stream (Table 23). In the individuals from the pond, the fecundity varied from 160 eggs in the specimen measuring 60.0 mm in length and weighing 2.184 gms to 1170 in the specimens measuring 96.0 mm in length and 10.15 gms in weight (Table 24).

The relationship between fecundity and total length, fecundity and total weight, fecundity and ovary weight and total length and ovary weight have been calculated and presented in Fig. 28A to F.

(I) Fecundity versus total length : On plotting the fecundity values against the total length (Fig. 28E & F), a curvilinear relationship has been observed, which indicates that the number of eggs increased with the increase in length. When expressed logarithmically, it gave a straight line relationship which indicates that the number of eggs in the ovaries increase in proportion to the length of the fish. The equations derived are :

$$\text{Log } F = -2.0600 + 2.5490 \log \text{ TL } (r = 0.8657) \text{ for pond population; and}$$

$$\text{Log } F = -5.2465 + 4.1751 \log \text{ TL } (r = 0.7427) \text{ for stream population.}$$

The correlation coefficient were found to be quite high in both the cases thereby indicating a high degree of positive correlation ($P < 0.01$) between the two parameters. The relationship between fecundity and length from both the pond and stream population has been illustrated in Fig. 28E & F.

(II) Fecundity versus Body weight : The relationship between fecundity and body weight was found to be curvilinear for both the populations (Fig. 28A & B). On plotting the log values for

body weight and fecundity, a straight line relationship has been observed and the derived regression equations are :-

$\text{Log } F = 2.1628 + 0.8706 \log W$ ($r = 0.880$) for the Pond population; and

$\text{Log } F = 1.7740 + 1.2320 \log W$ ($r = 0.781$) for the Stream population.

The correlation coefficient values were found to be significantly high ($P < 0.01$), thereby indicating a high correlation.

(III) Fecundity versus Ovary weight : Regression analysis indicated significant relationship between fecundity and ovary weight. The equations describing the relationship are :-

$\text{Log } F = 3.2718 + 0.5084 \log OW$ ($r = 0.9361$) for the Pond population; and

$\text{Log } F = 3.4211 + 0.6924 \log OW$ ($r = 0.8628$) for the Stream population

High 'r' values in both the cases indicate high correlation ($P < 0.01$). Fecundity, plotted against ovary weight revealed a linear trend (Fig. 28C & D).

(IV) Total length versus Ovary weight : The mean values of total length and their respective gonad weight were arranged to establish the relationship between these parameters. Like other parameters, logarithmic representation gave a straight line (Fig. 29A & B) and showed an increasing trend in gonad weight with the increase in the body length. The regression equations are :-

$\text{Log } Y = -6.0186 + 2.7389 \log X$ ($r = 0.9218$) for the Pond population; and

$\text{Log } Y = -8.8250 + 3.9540 \log X$ ($r = 0.7760$) for the Stream population.

High correlation of coefficient in both the cases has been computed which shows a high correlation ($P < 0.01$) between these parameters.

TABLE 23
 FECUNDITY IN THE STREAM POPULATION OF CHANNA GACHUA

TOTAL LENGTH (mm)	BODY WEIGHT (gm)	OVARY WEIGHT (gm)	FECUNDITY	RELATIVE FECUNDITY
67.0	3.10	0.050	318	102.5
70.0	3.45	0.043	251	72.7
77.0	4.39	0.025	243	55.2
78.0	4.94	0.075	547	110.7
82.0	6.54	0.108	333	50.8
84.0	7.12	0.150	862	120.9
87.0	8.62	0.247	1523	176.6
92.0	9.61	0.250	583	60.6
96.0	9.11	0.207	1125	123.4

TABLE 24
 FECUNDITY IN THE POND POPULATION OF CHANNA GACHUA

TOTAL LENGTH (mm)	BODY WEIGHT (gm)	OVARY WEIGHT (gm)	FECUNDITY	RELATIVE FECUNDITY
48.0	1.13	0.010	275	243.3
53.0	1.38	0.013	229	165.7
54.0	1.78	0.017	252	141.0
58.0	1.86	0.015	175	93.9
60.0	2.18	0.012	160	73.2
61.0	2.65	0.040	276	104.1
62.0	2.45	0.028	343	140.0
72.0	4.70	0.150	513	109.1
82.0	6.42	0.200	1040	221.2
96.0	10.15	0.300	1170	115.2

RELATIVE FECUNDITY :

Data on relative fecundity has been presented in Tables 23 & 24. Relative fecundity was found to be higher in the pond population (140.67) whereas, in the stream population, it showed relatively less value (97.044).

FOOD AND FEEDING HABITS

COMPOSITION OF GUT CONTENTS :

Different percentage composition of each food items in individuals both from the pond and stream have been summarized in Table-25. Food elements found in the digestive tracts of all the specimens examined have been arranged in four broad groups, i.e. (I) Detritus (II) Vegetable matter (III) Phytoplankton and (IV) Zooplankton (Fig. 30A & B).

(I) Detritus : It is seen that this group formed 61.8 and 57.3 percent of the diet in the gut for pond and stream individuals respectively and these ranked as the most preferred food item (Fig. 30A & B).

(II) Vegetable matter : This group figures next in order of preference, forming a total of 26.3% in the gut of the pond individuals and 25.8% in the stream ones.

(III) Phytoplankton : It was represented by Chlorophyceae and Bacillariophyceae members.

(a) Chlorophyceae : This group of algae was represented by Scenedesmus; Spirogyra; Zygnema; Mouquetia; Phacus; Gymnozyga; Pediastrum; Microspora; Ulothrix; Botryococcus; Hyalotheca; Netrium; Pinnularia; Closterium; Cosmerium; Euastrum; Pleurotaenium; Penium and Desmidium. Of these, Spirogyra was found to be the most abundant, next being Ulothrix in the fishes from the streams, whereas in the pond population,

it was Mouquetia. Chlorophyceae made up to 2.94% and 8.85% for pond and stream individuals respectively.

(b) Bacillariophyceae : The diatom present in the guts were represented by the following genera :- Synedra; Navicula, Diatoma; Nitzschia; Fragillaria; Amphora; Cyclotella; Caloneis and Tabellaria in varying percentages and formed only 3.22% and 6.44% in the individuals from the pond and stream respectively. Navicula was found to be the most abundant in both the cases.

(IV) Zooplankton : In the gut of the species, zooplankton comprised of Cladocera, Copepoda and Rotifera. Their percentage composition in the gut contents were found to be 5.55% (pond individuals) and 1.4% (stream individuals). Copepoda being the most abundant, followed by Rotifera and Cladocera.

Copepoda comprised of Cyclops and their nauplii Rotifera was represented by Brachionus and Chromogaster. Among Cladocera Chydorus, Bosmina, Daphnia, Eurycerus and Alonella were found in the guts.

Apart from these, Crustacean eggs were also present in the gut contents. The rest of the gut contents which comprised of 0.27 in the pond specimens and 0.031% in the stream specimens could not be identified as they were partially digested, hence, kept in a separate group "unidentified materials".

RELATIVE IMPORTANCE OF FOOD ITEMS :

The relative importance of the major food items for the whole year has been shown in Fig. 30. It is evident that the largest component of the diet was detritus which accounted for 61.8 and 57.3% (for pond and stream individuals respectively). Next in order of preference was vegetable matter making up 26.3 and 25.8% for pond and stream individuals respectively. Monthly

TABLE 25

PERCENTAGE OCCURRENCE OF DIFFERENT FOOD ITEM IN THE GUT
OF CHANNA GACHUA FROM THE POND AND STREAM POPULATION.

	% AGE OCCURRENCE	
	POND	STREAM
Detritus	61.86	57.32
Vegetable matter	26.35	25.87
<u>CHLOROPHYCEAE</u>		
Scenedesmus	0.015	-
Spirogyra	1.40	3.62
Mougoetia	0.396	1.26
Zygnema	0.207	0.013
Phacus	0.004	-
Gymnogyga	0.006	-
Pediastrum	0.125	-
Microspora	0.012	0.44
Ulothrix	0.20	2.489
Bolyococcus	0.022	-
Hyalotheca	0.26	0.676
Netrium	0.012	-
Pinullaria	0.053	0.228
<u>BICILLARIOPHYCEAE</u>		
Docidium	0.0045	0.019
Synedra	0.50	0.90
Navicula	1.91	3.878
Diatoma	0.325	0.127
Nitzschia	0.076	-
Fragillaria	0.138	0.636
Amphora	-	0.056
Cyclotella	-	0.074
Caloneis	0.261	0.719
Tabellaria	0.015	0.039
<u>DESMIDIACEAE</u>		
Closterium	0.015	0.059
Cosmarium	0.09	-
Euastrum	0.095	-
Pleurataenium	0.005	-
Penium	0.007	0.021
Desmidium	0.02	0.051
<u>CLADOCERA</u>		
Chydorus	0.0094	-
Bosmina	0.012	-
Daphnia	0.10	-
Eurycerous	0.005	-
Alonella	0.27	0.039
<u>COPEPOD</u>		
Cyclops	1.69	0.733
Nauplii	0.007	0.017
Crustacean egg	3.06	0.641
<u>ROTIFERA</u>		
Brachionus	0.1	-
Chromogaste	0.028	-
U. P. M.	0.27	0.031

variations in the relative importance of the major components of the diet are given in Fig. 31.

SEASONAL FLUCTUATIONS IN THE FOOD COMPOSITION :

The percentage composition of each item of food in the diet of the fish during different months of the year has been enumerated in Tables 26 & 27, from which it can be seen that there are very slight variations. Detritus formed a major part of the food item throughout the year. The fluctuations in the percentage composition ranged from 54.24 (December) to 68.9 (April) and 48.64 (September) to 71.63 (June) in individuals from stream and pond respectively.

Vegetable matter made up from 20% (July) to a maximum of 32.57% (August) in the fish from stream. In the pond individuals, the percentage composition ranged from 18.9 (July) to 32.03% (September), being the second most important component of the diet. Maximum quantities of Chlorophyceae members were found in the months of November (for pond individuals) and December (for stream individuals). Its percentage composition ranged from 0.02% to 17.71% in November. For the individuals, from the stream percentage composition ranged from 1.66% (November) to 13.77% in February.

Highest percentage of diatoms were recorded during September and October and the percentage composition ranged from a minimum of 0.8 (July) to 4.37 (September) in the specimens from the pond. But in the individuals from the stream, the percentage composition were found to be 1.71 (August) to 12.86 (May).

The zooplankton population varied in its percentage composition from 0.78 (February) to 14.62 (July) in the guts of the

individuals from the pond. Cyclops were found to be the most dominant food item among zooplankton, followed by crustacean eggs, Alonella and Brachionus. Among the stream individuals, zooplankton composition ranged from 0.23 in February to 6.49 in September. Cyclops were found to be the most dominant followed by crustacean eggs, Nauplii, Alonella, etc.

It can be seen from Fig. 31 that there were slight variations in the major components of the diet, but on the whole, Detritus and vegetable matter were found to be the most preferred food item, representing 60-80% of the diet, throughout the period of the study.

FOOD COMPOSITION OF VARIOUS SIZE GROUPS :

The data on the gut contents of various size groups have been presented in Tables 28 & 29 and the percentages of occurrence of their groups are depicted in Fig. 32. Salient features of the observations are described below :-

SIZE GROUP I (10-29 mm) :- In the pond individuals, Detritus constituted 60.27% of the gut contents. Next in the order of abundance was vegetable matter (28.53%). Chlorophyceae and Bacillariophyceae were represented by 2.32 and 0.86% respectively. The various members of Chlorophyceae and Bacillariophyceae found in the guts are tabulated in Tables 28 & 29. Zooplankton constituted 7.39%. Stream individuals of the same size groups showed the presence of Detritus making up 65.82% and 30-31% vegetable matter. Chlorophyceae among phytoplankton and zooplankton were found to be absent. Bacillariophyceae made upto 3.79% of the total gut contents being represented by Synedra sps. only.

SIZE GROUP. II (30-49 mm) : In this size group, detritus was represented by 61.33% of the gut contents and vegetable matter by 26.16%. Among phytoplankton, Chlorophyceae consisted of 1.46% and was found to be the richest qualitatively. Bacillariophyceae made up 2.68% and was represented qualitatively by the maximum number of genera. Zooplankton was found to be 8.19% and showed the presence of maximum number of genera, the most dominant being Crustacean eggs among the zooplankton in the individuals from the pond (Table-29).

In the stream fish, percentage of Detritus was found to be 65.51%. Vegetable matter was next in order of preference, making up 29.36% of the total gut contents. Chlorophyceae and Bacillariophyceae were 2.48% and 1.11% respectively. Zooplankton comprised of 1.20% in the total gut contents.

SIZE GROUP. III (50-69 mm) : In the pond individuals, Detritus constituted 60.23% and vegetable matter by 28.53% of the total gut content. Chlorophyceae and Bacillariophyceae represented by 0.38% and 2.93% respectively. Zooplankton made up 7.96% of the total gut contents.

In the individuals from the stream, Detritus was found to represent 54.89% and vegetable matter by 25.5% of the total gut content (Table-29). The members of Chlorophyceae were 10.84% and showed the presence of a large number of genera. Filamentous algae were found to be the most abundant in the guts. Bacillariophyceae comprised of 7.64% and zooplankton 0.99% of the total gut contents.

SIZE GROUP. IV (70-89 mm) : In the specimens of this size groups from pond, Detritus comprised of 64.12%, vegetable matter of

TABLE 28

PERCENTAGE FREQUENCY OF OCCURRENCE OF DIFFERENT FOOD ITEMS IN
DIFFERENT SIZE GROUPS OF CHANNA GACHUA FROM THE POND

	10-29mm	30-49mm	50-69mm	70-89mm
Detritus	60.27	61.33	60.23	64.12
Vegetable matter	28.53	26.16	28.53	31.85
Scenedesmus	-	0.03	-	-
Spirogyra	0.25	-	-	0.446
Zygnema	-	0.26	0.26	0.146
Mougoetia	1.56	0.34	0.047	-
Phæus	0.03	-	-	-
Gymnogyga	0.03	0.003	-	-
Pediastrum	-	0.24	-	-
Ulothrix	0.33	0.183	-	-
Botryococcus	-	0.046	-	-
Netrium	-	-	-	-
Pinnularia	-	0.024	0.045	-
Dœcidium	-	0.009	-	-
Synedra	0.06	0.23	0.28	-
Navicula	0.75	2.038	1.93	1.34
Diatoma	-	0.24	0.33	0.446
Nitzschia	-	0.074	0.045	0.496
Fragillaria	0.05	0.1	0.247	-
Caloneis	-	-	-	-
Closterium	0.06	0.03	-	-
Cosmarium	0.06	0.113	-	-
Eaustrum	-	0.167	0.03	-
Pleurataenium	-	0.011	-	-
Penium	-	0.007	-	-
Chydorus	-	0.082	-	-
Bosmina	0.03	-	-	0.236
Daphnia	0.57	0.02	-	-
Eurycercus	-	0.01	-	-
Alonella	1.87	0.80	0.114	-
Cyclops	2.95	2.97	2.74	0.236
Nauplii	-	0.007	-	-
Crustacean egg	1.87	4.33	5.05	-
Brachianus	0.09	0.121	0.06	-
Chromogaster	-	0.056	-	0.163
U. P. M.	0.59	1.0096	-	-

TABLE 29
 PERCENTAGE COMPOSITION OF THE GUT CONTENT IN DIFFERENT LENGTH
 GROUPS OF CHANNA GACHUA FROM THE STREAM

	10-29 mm	30-49 mm	50-69 mm	70-89 mm	90-109 mm	110-129 mm
Detritus	65.82	65.51	54.89	51.57	47.23	58.30
V. materail	30.37	29.36	25.51	26.81	19.61	28.45
Spirogyra	-	1.81	2.90	9.33	1.97	-
Zygnema	-	-	0.96	0.137	-	-
Mougoetia	-	-	0.52	-	-	-
Microspora	-	-	1.13	-	-	-
Ulothrix	-	0.67	4.90	1.72	-	-
Hyalotheca	-	-	-	-	10.74	-
Pinnularia	-	-	0.15	0.75	-	-
Synedra	-	0.24	1.84	-	2.02	-
Navicula	3.79	1.11	3.55	5.95	10.22	-
Diatoma	-	-	-	0.50	-	-
Fragilaria	-	-	0.44	1.06	6.73	-
Amphora	-	-	-	0.22	-	-
Cyclotella	-	-	-	-	1.19	-
Caloneis	-	-	1.71	0.20	-	-
Tabellaria	-	-	0.10	-	-	-
Closterium	-	-	0.15	-	-	-
Penium	-	-	-	0.08	-	-
Desmidium	-	-	0.13	-	-	-
Alonella	-	-	0.10	-	-	-
Cyclops	-	0.80	0.69	0.55	-	5.69
Nauplii	-	-	0.04	-	-	-
Crustacean eggs	-	0.46	0.16	1.01	0.26	7.31
U. P. M.	-	-	0.046	0.05	-	-

31.85% and Chlorophyceae and Bacillariophyceae of 0.59% and 2.78% respectively. Zooplankton consisted only 0.47% of the gut contents. In the stream fishes, detritus and vegetable matter comprised of 51.57 and 26.81% respectively of the gut contents. Chlorophyceae showed the presence of 12.01% and Bacillariophyceae 7.93%, whereas Zooplankton was represented only by 1.56%.

SIZE GROUP V (90-109 mm) : Individuals of this size group were present only in the stream. In these, the detritus and vegetable matter comprised of 47.23% and 19.01% of the total gut contents. Chlorophyceae members made upto 12.71%. The members of the Bacillariophyceae were found to be present in maximum numbers in this size groups (20.16%), Navicula being the most common (10.22%), Fragillaria (6.73%), Cyclotella (1.19%), Zooplankton were only 0.26% of the entire gut contents.

SIZE GROUP VI (110-129 mm) : Among the individuals of this group, detritus and vegetable matter made upto 58.3 and 28.45% of the gut contents. Chlorophyceae and Bacillariophyceae members were marked by a complete absence. Zooplankton made upto 13%, of which Cyclops being 5.69% and Crustacean egg 7.31%.

FEEDING INTENSITY :

The observations on the feeding intensity, based on gastro-somatic index are presented in Fig. 33. On plotting the values of gastro-somatic index obtained from total weight and dressed weight, it has been observed that apart from magnitude there was no other difference, hence the G.S.I. values were calculated only from the total weight of the individuals from both the pond and stream (Table 30 & 31).

SEASONAL VARIATION IN G.S.I. :

For the pond individuals, high feeding intensity was found in September, October, November, December and July, maximum being in November and July. As indicated by the results (Fig. 33B) rest of the months had a reduced feeding activity. December onwards low G.S.I. values were observed.

In the specimens from stream, high feeding intensity was found in the months of October, November, February and March, whereafter it reduced to a minimum in August (Fig. 33A). Individuals both from the pond and stream showed two apparent peaks of feeding intensity, one around October, November and the other during February (for stream population) and in July (for pond individuals).

FLUCTUATIONS IN G.S.I. IN DIFFERENT LENGTH GROUPS :

The observation of feeding intensity in different length group of fishes is shown in Fig. 33A. It can be seen that for the pond individuals high feeding intensity was observed in the smaller length groups i.e. from 16-20 mm to 36-40 mm length group, whereafter the feeding intensity was found to be reduced with the increase in length.

The stream individuals too, showed comparatively high feeding activity in the lower length groups (21-25 mm till 41-45 mm), whereafter the intensity decreased with the increase in length.

FEEDING IN RELATION TO CONDITION FACTOR :

"K" and " K_1 " values for entire and gutted fish respectively, did not exhibit any marked difference and show more or less the same trend. Therefore, only the "K" value (combined

sexes) has been taken into consideration. The correlation between feeding intensity and condition factor (K) has been shown in Fig. 34 and the data have been tabulated in Table 32.

It is therefore, quite clear that there is an inverse relationship between the feeding intensity and condition factor (Table 32).

The relation between condition factor and gastro-somatic index in different length groups of fishes has been shown in Fig. 35, which indicates a clear inverse relationship both for pond and stream individuals. G.S.I. values were also observed to show an inverse relationship with the gonadosomatic index (Table 31).

GUT LENGTH IN RELATION TO BODY LENGTH :

The length of the gut (Y) plotted against the total length (X) is depicted in Fig. 36, which shows that the length of the gut increases in proportion to the total length of fish. The regression equations are :-

$$Y = 1.9917 + 0.4529 X \text{ (Pond individuals)}$$

$$Y = 2.4241 + 0.5073 X \text{ (Stream individuals)}$$

The coefficient of correlation 'r' is calculated to be 0.9892 and 0.9670 respectively for pond and stream individuals.

WEIGHT OF THE GUT IN RELATION TO BODY LENGTH :

The regression equations describing the relation between the weight of the gut versus total length are :-

$$\text{Log } Y = -6.0186 + 2.7389 \text{ log } X \text{ for pond individuals; and}$$

$$\text{Log } Y = -2.5483 + 0.9537 \text{ log } X \text{ for stream individuals.}$$

The coefficient of correlation 'r' was calculated as 0.9218 and 0.6487 for pond and stream individuals respectively. The weight

TABLE 30

SEASONAL VARIATIONS IN THE VALUES OF G.S.I., Gn.S.I. AND 'K'
FACTOR OF C. GACHUA

MONTHS	P O N D			S T R E A M		
	GASTRO SOMATIC INDEX	GONADO SOMATIC INDEX	CONDITION FACTORS	G.S.I.	Gn.S.I.	'K'
<u>1978</u>						
SEP.	4.20	1.53	0.977	3.05	-	1.016
OCT.	4.10	1.14	0.710	4.60	-	0.950
NOV.	5.81	0.34	0.925	6.55	0.33	0.918
DEC.	4.12	0.75	0.989	0.76	0.18	0.900
<u>1979</u>						
JAN.	3.50	-	0.975	3.70	-	0.950
FEB.	2.69	0.30	0.972	6.24	0.78	0.987
MAR.	0.637	0.80	0.941	4.30	-	1.000
APR.	2.62	1.20	1.015	1.68	0.91	1.206
MAY	2.68	1.45	1.009	2.35	1.02	1.060
JUN.	1.60	1.57	1.015	1.98	1.48	1.019
JUL.	5.59	1.55	1.161	0.98	1.54	1.182
AUG.	2.72	0.28	0.862	0.45	0.25	0.904

TABLE 31

VALUES OF G.S.I., Gn.S.I. AND 'K' FACTORS OF C. GACHUA AT DIFF-
ERENT LENGTH GROUPS

LENGTH GROUPS (mm)	P O N D			S T R E A M		
	G.S.I.	Gn.S.I.	"K"	G.S.I.	Gn.S.I.	"K"
16.0 - 20.0	3.63	-	1.041	19.73	-	0.771
21.0 - 25.0	3.13	0.58	0.992	17.56	1.46	0.993
26.0 - 30.0	5.00	0.69	0.824	13.88	0.69	0.819
31.0 - 35.0	3.55	0.47	0.894	11.84	0.34	1.019
36.0 - 40.0	4.21	-	0.886	9.78	0.19	0.941
41.0 - 45.0	2.23	0.18	0.938	4.32	0.08	1.014
46.0 - 50.0	2.60	0.82	0.917	4.20	0.18	0.876
51.0 - 55.0	2.50	0.94	0.988	3.10	0.07	1.010
56.0 - 60.0	2.84	0.62	0.955	0.83	0.24	1.060
61.0 - 65.0	2.30	0.75	1.030	1.48	0.29	1.029
66.0 - 70.0	1.30	-	1.102	2.22	0.87	1.002
71.0 - 75.0	1.70	3.19	1.259	2.92	0.15	1.051
76.0 - 80.0	1.24	2.87	1.321	1.64	1.22	0.993
81.0 - 85.0	1.51	3.11	1.164	1.22	1.12	1.212
86.0 - 90.0	-	-	-	2.45	3.02	1.200
91.0 - 95.0	-	-	-	3.09	3.05	1.100

TABLE 32

RELATIVE LENGTH OF THE GUT AND ITS RELATIONSHIP WITH K, G.S.I.
AND Gn.S.I.

SIZE GROUP (mm)	P O N D				S T R E A M			
	"K"	GSI	GnSI	RLG	"K"	GSI	GnSI	RLG
16 - 20	1.041	3.63	-	0.49	0.771	19.73	-	0.80
21 - 25	0.992	3.13	0.58	0.57	0.993	17.56	1.46	0.75
26 - 30	0.824	5.00	0.69	0.56	0.819	13.88	0.69	0.65
31 - 35	0.894	3.55	0.47	0.44	1.019	11.84	0.34	0.57
36 - 40	0.886	4.21	-	0.44	0.941	9.78	0.19	0.41
41 - 45	0.938	2.23	0.18	0.48	1.014	4.32	0.08	0.49
46 - 50	0.917	2.60	0.82	0.50	0.876	4.20	0.18	0.45
51 - 55	0.988	2.50	0.94	0.48	1.010	3.10	0.07	0.49
56 - 60	0.955	2.84	0.62	0.51	1.060	0.83	0.24	0.50
61 - 65	1.030	2.30	0.75	0.50	1.029	1.48	0.29	0.51
66 - 70	1.102	1.30	-	0.50	1.002	2.22	0.87	0.52
71 - 75	1.259	1.70	3.19	0.44	1.051	2.92	0.15	0.52
76 - 80	1.321	1.24	2.87	0.48	0.993	1.64	1.22	0.57
81 - 85	1.164	1.51	3.11	0.42	1.212	1.22	1.12	0.59
86 - 90	-	-	-	-	1.200	2.45	3.02	0.58
91 - 95	-	-	-	-	1.100	3.09	3.05	0.51

TABLE 33

PERCENTAGE COMPOSITION OF THE GUT CONTENT IN C. STEWARTII AND
C. PUNCTATUS

	P O N D		S T R E A M	
	<u>C. PUNCTATUS</u> % AGE COMPOSITION	% AGE	<u>C. STEWARTII</u> % AGE COMPOSITION	% AGE
Detritus	54.83		22.53	
Vegetable matter	18.51		9.61	
Ulothrix	4.57		19.20	
Spirogyra	10.27		27.74	
Closterium	-		0.74	
Navicula	3.62		1.32	
Amphora	1.46		-	
Diatomella	2.19		-	
Synedra	1.39		4.41	
Diatoma	-		0.87	
Netrium	-		0.39	
Fragillaria	-		0.25	
Caloneis	-		8.43	
Tabellaria	-		0.50	
Cyclops	-		2.25	
Crustacean egg	2.19		1.69	
Nauplii	0.46		-	
U. P. M.	0.46		-	

of the full gut (Y) plotted against total length has been shown in Figs. 37 & 38.

RELATIVE LENGTH OF THE GUT :

The ratio of the gut length to body length has been shown in Fig. 39, which indicates that the ratio decreases as the fish grows in size from 0.57 to 0.42 for the pond individuals and from 0.80 to 0.415 for stream individuals (Table 32).

FOOD COMPOSITION OF C. STEWARTII AND C. PUNCTATUS :

The various components of diet for C. punctatus and C. stewartii have been presented in Table 33 and shown in Fig. 40.

C. STEWARTII : Chlorophyceae was found to be the most dominant group, being 47.68%, followed by detritus which made upto 22.53% of the diet. Bacillariophyceae was 16.17%. Unidentified plant material constituted 9.61% of the total gut contents. Zooplankton present were Cyclops and Crustacean eggs and their percentage composition was 3.94% (Table 33).

C. PUNCTATUS : Detritus was found to make upto 54.83% of the diet, being the most dominant. Vegetable material constituted 18.51%, Chlorophyceae and Bacillariophyceae comprised of 14.84 and 8.66% respectively. Zooplanktons were represented by crustacean eggs and Nauplii being only 2.65% of the diet (Table 33).

D I S C U S S I O N

MORPHOMETRY AND MERISTIC COUNTS

Morphological variations in fish due to adaptation to new environment have been studied by many workers (Schmidt, 1921; Vladykov, 1934; Taning, 1944; Lindsay, 1954; Fage, 1958; Barlow, 1961; and Suzuki and Yamaguchi, 1980). In the present study, morphological variations have been observed between the two population i.e. from the pond and the stream in C. gachua. Predorsal length, head length, snout length, eye diameter, post-orbital length; inter-orbital length, length of upper jaw and girth were found to be higher in the specimens from the pond (Table 8). Height of anal fin; height of pectoral fin; length of dorsal fin; length of caudal peduncle and head depth are practically

the same in both the populations, but body depth; least height of body; height of ventral fin and base of anal fin are higher in the stream population. Difference in regression equations are evident from Table 8, which may be attributed to diverse ecological and environmental conditions prevalent in both the systems.

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

Various authors have shown that morphometric characters of fish can vary under the influence of environments 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 the numbers 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 variations with the effect of the duration of periods of growth and of the relating differentiations which determines the number of vertebrae and of segments.

As reported by Yazdani and Chanda (1971), Channa stewartii has 4-5 scales between the orbit and angle of preopercle and

12-13 scales before the dorsal fin and further stated that it comes very close to C. orientalis (Bl.) Schu. and could be distinguished from the latter by 39-40 rays in the dorsal (VS 32-33) 26-27 rays in the anal (VS 21-23) and ventral $\frac{1}{3}$ of the pectoral (VS $\frac{2}{5}$) 1,4. However, in the present study for C. gachua, rays in the dorsal fin were observed to be 31-34; 11-14 and 13-14 or rays in the pectoral, for pond and stream individuals; 17-19 and 16-22 ray in the ventral for pond and stream individuals. Lateral line transverse scales were found to be constant, being $3\frac{1}{2}/5\frac{1}{2}$ for individuals both from the pond and the stream.

Yazdani and Chanda (1971) while working out in a collection of C. stewartii and C. orientalis from Khasi Hills, they observed that all the specimens of C. stewartii have considerably lesser number of rays in the dorsal (35-37). There was also a greater range of variation in the number of anal rays (23-28) and ventral was mostly $\frac{1}{2}$ (rarely $\frac{1}{3}$) of the pectoral. Colour pattern and other characters were so distinctive that there is no difficulty in distinguishing it from C. orientalis. According to them, these variations being unrecorded so far, entail a re-definition of C. stewartii and the key character of the species shall therefore, be as 35-40 rays in the dorsal, 23-28 rays in the anal and ventral from $\frac{1}{2}$ to $\frac{1}{3}$ of the pectoral.

In the present study too, C. stewartii showed distinct colour pattern which leaves no difficulty in distinguishing it from C. orientalis.

While examining the material of C. stewartii, they also came across two abnormal specimens, one (A) having its dorsal fin divided owing to a gap caused by the absence of rays after

6th ray to nearly opposite the origin of the anal and the other (B) having a similar gap after the 12th dorsal ray to nearly opposite the 8th anal ray. In specimen (A), the total number of rays were 33, whereas in specimen (B) it was only 31. The specimen (B) also lacked the pelvic fin and the pelvic girdle of the left side. The examination of the alizarin preparation of these specimens shows that the pterygiophores are also absent in the region and the gap. Though occasional absence of both pelvic fins is on the record in the genus Channa, there was no earlier record of such abnormalities as has also been observed by Yazdani and Chanda (1971). However, during the present investigation one specimen of C. qachua without pelvic fin, has been recorded from the pond.

The various meristic counts made during the present study did not show any marked difference in the individuals of C. qachua from lotic and lentic populations (Table 9).

Many authors (Schmidt, 1921; Vladykov, 1934; Tanning, 1944; Lindsay, 1954; Barlow, 1961) have reported that meristic characters exhibit plasticity under the influence of environmental factors, especially temperature, during the incubation period and early larval life. Dutt and Reddy (1978) gave certain meristic counts for C. qachua population from Andhra Pradesh as as dorsal fin rays 33-37; Anal fin rays less than 24; Lateral line after proceeding straight some distance bends down sharply and continues two scale rows below. In the present study too, the dorsal fin rays ranged from 31-34, being less than C. qachua population from Andhra Pradesh. Anal fin rays ranged from 17-19 and 16-22 for pond and stream individuals in the present study whereas, Dutt and Reddy (1978) reported anal fin rays to be

less than 24. Lateral line too, after proceeding straight some distance bends down, in the specimens both from the pond and stream, were found to be similar to the results obtained by Dutt and Reddy (1978).

Biometric study for C. qachua in the present case (Table 16), revealed that Eye diameter becomes smaller in relation to head length and interorbital width as the species grows (Figs. 18 & 19). The pectoral fins exhibit negative allometry and the body of the fish becomes relatively deeper. A similar case has been reported by Tobor (1974) for Lates niloticus. According to Bayagbona (1963) a constant index indicates that the growth of the character in relation to its reference length is isometric.

With regard to C. stewartii (Table 16) and C. punctatus (Table 17) also, the Eye diameter becomes progressively smaller in relation to the head length and inter-orbital width as the fish grows (Figs. 20 & 21). But the pectoral fins unlike C. qachua (from both the systems) do not exhibit negative allometry in relation to head length.

However, various features have from time to time been reported as characters of certain local populations of the same species which Nikolsky (1963) with his tidy out look on adaptation considered that these variations were designed to ensure that the greatest variety of habitats were occupied and quoted several instances for fish species which could occur either as an elongated river form or as a high bodied lake form. In the present case, such well defined variation between the two population could not be ascertained, but certain variations in morphometric measurements are quite evident.

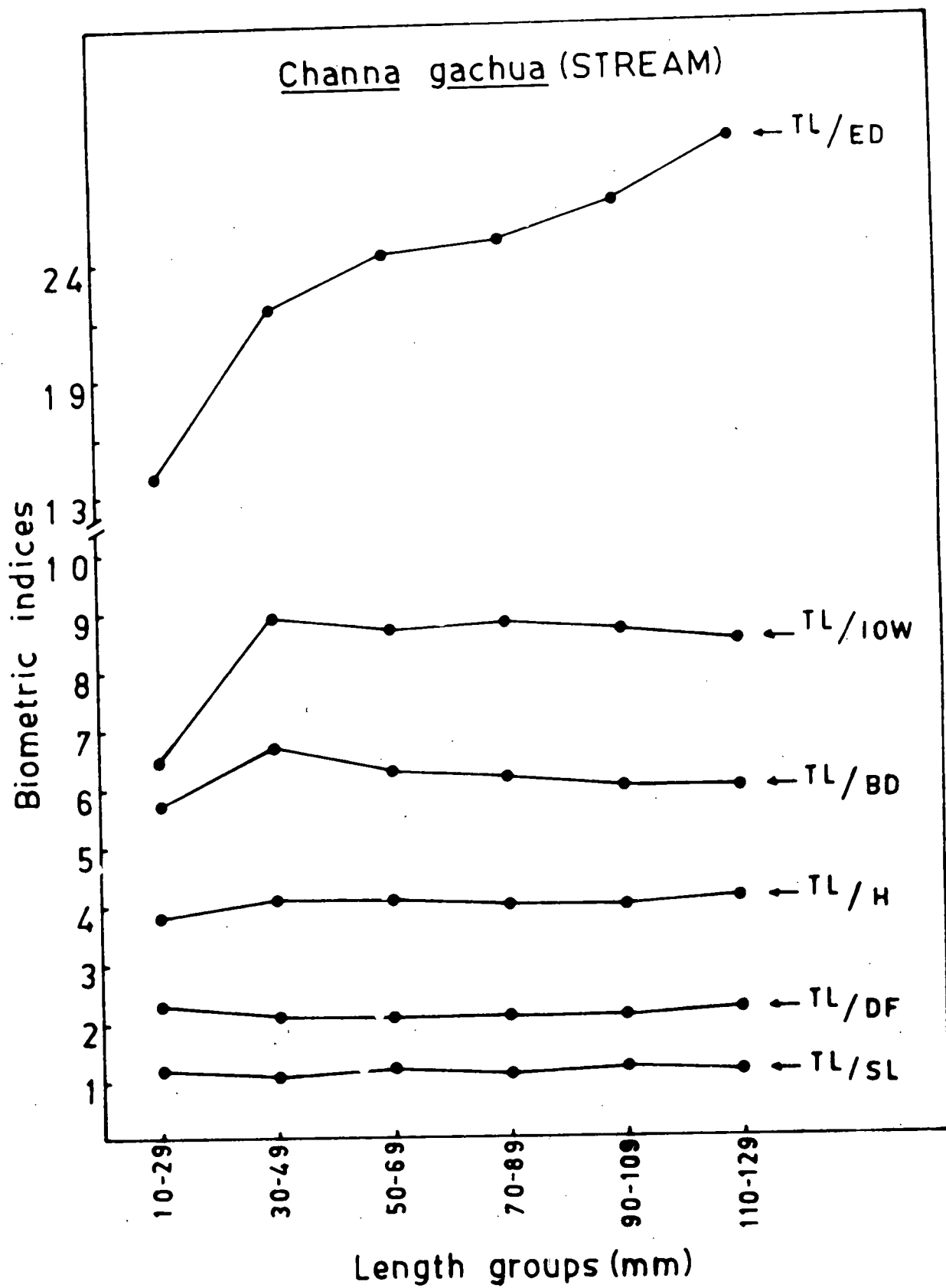


Fig.18: Biometric indices of C.gachua from the stream.

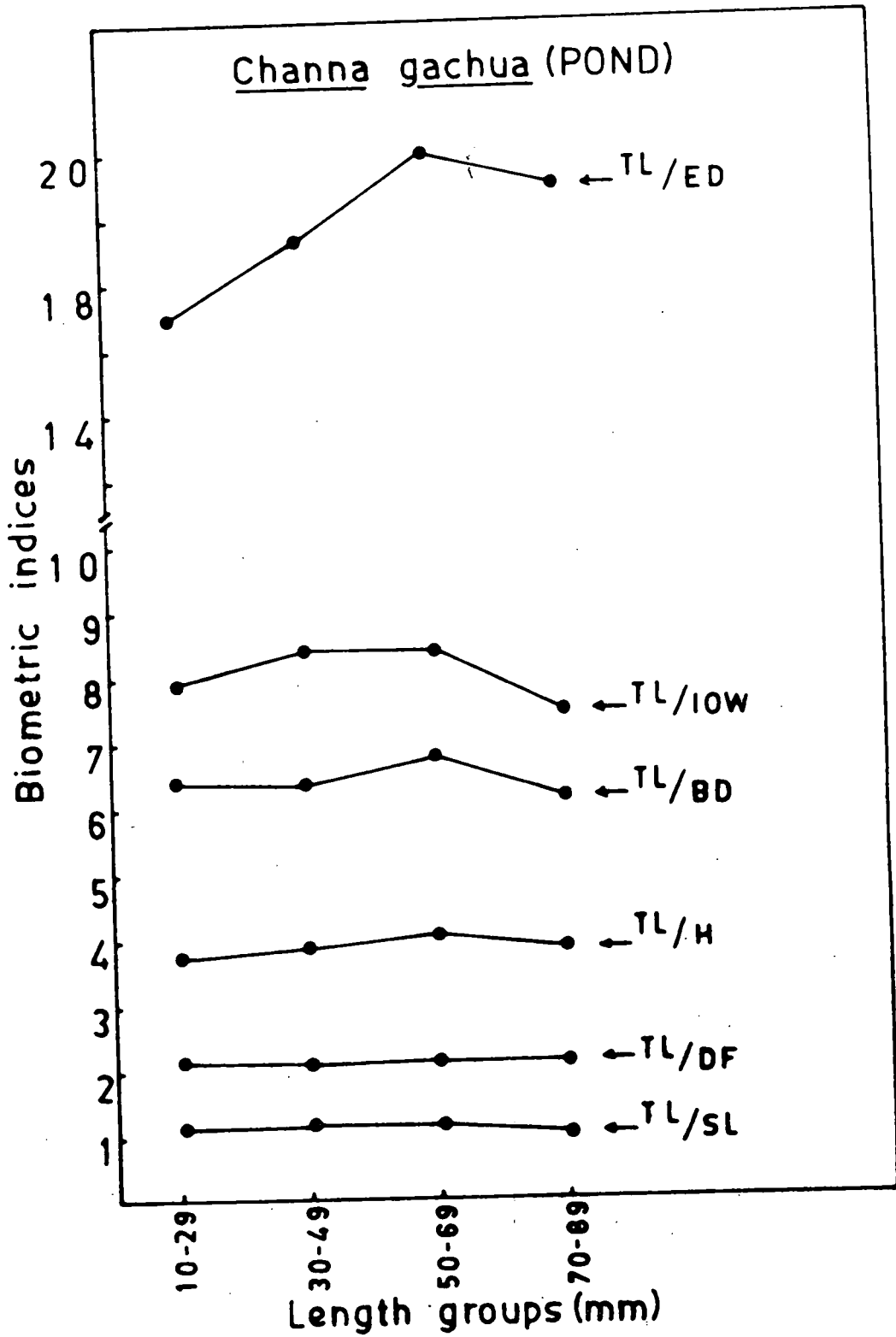


Fig. 19: Biometric indices of C. gachua from the pond.

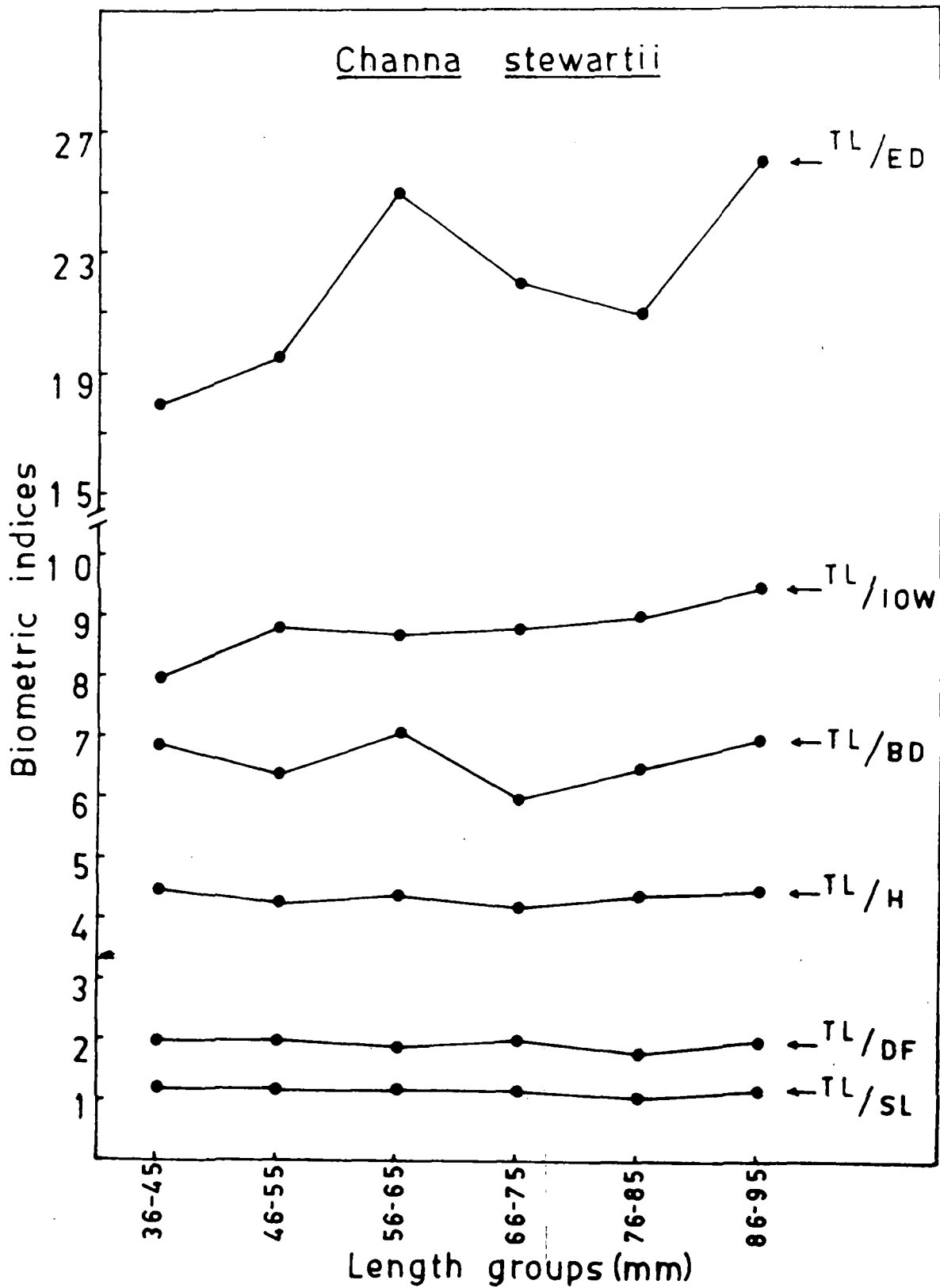


Fig. 20: Biometric indices of C. stewartii.

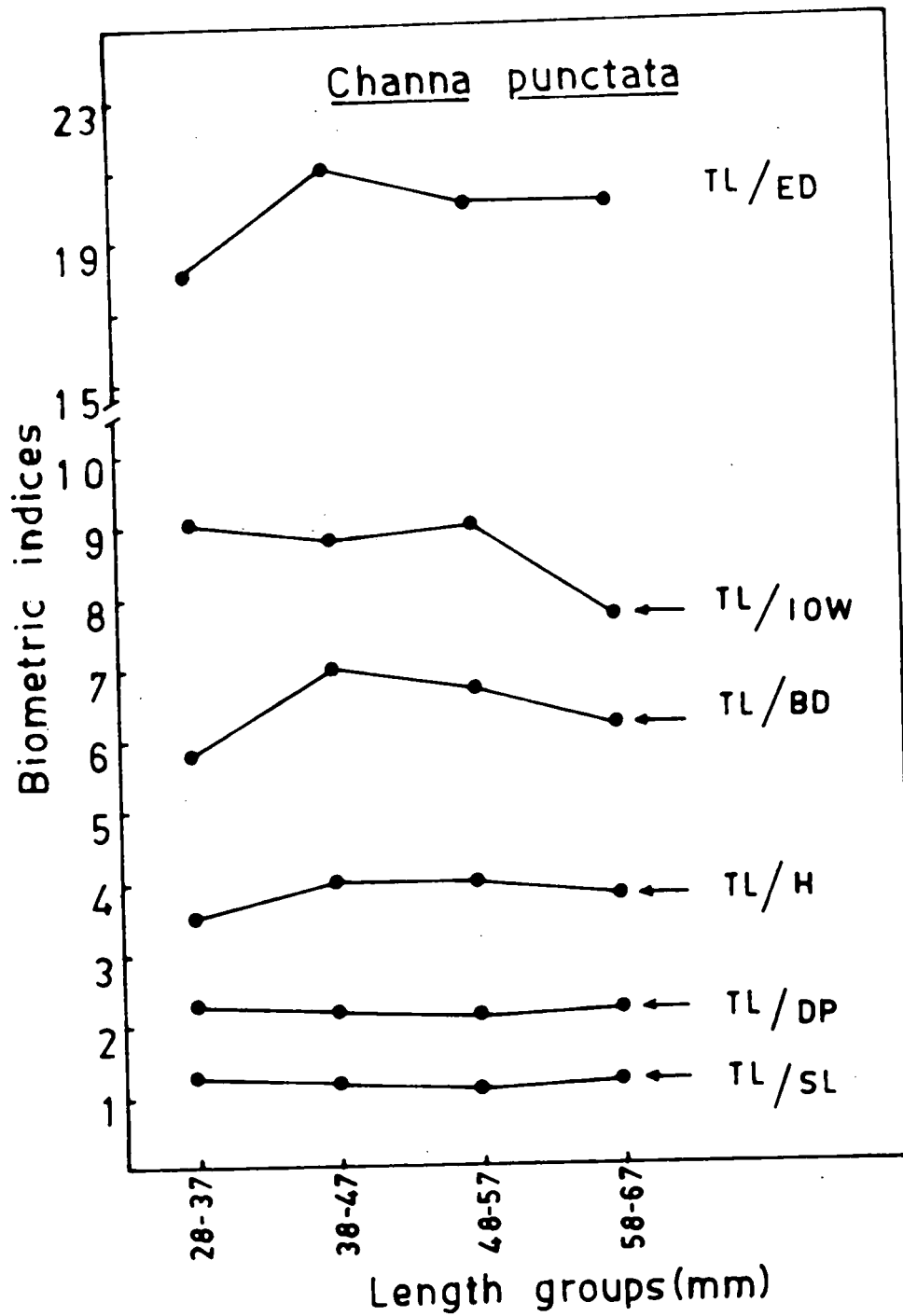


Fig. 21: Biometric indices of C. punctata.

LENGTH - WEIGHT RELATIONSHIP

From the studies on length-weight relationship, it is clear (Table 19) that there are interspecific variations in the exponential value. In the case of C. punctatus and C. stewartii. The values for "b" approximates to the cube law but are less than "3", thereby showing allometric growth. Das and Mitra (1958) have also obtained the value for "b" less than three, obtaining a parabolic equation of $W = 0.036775 L^{2.81112}$ in C. punctatus, based on specimens collected from West Bengal during March and April, 1956, which is quite similar to our result ($W = 0.00001172 L^{2.9701}$ in C. punctatus). In C. stewartii, Ganguly et al., (1963) reported the "b" value of 3.261, obtaining a parabolic equation as $W = 0.00447 L^{3.261}$, but in the present case, the "b" value was derived to be 2.452 ($W = 0.0001033 L^{2.4517}$). The change in the exponential value "b" is supposed to be under the influence of numerous factor 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 variation 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 two different types of ecosystems. The exponential values for C. qachua are found to vary in different seasons (summer and winter), during the juvenile and adult stages and also for the specimens collected from different systems. However, it is seen that the growth in all cases is allometric, except in the case of the specimens from the pond during summer which showed an isometric growth (Table 18).

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

According to Hile (1936) and Martin (1949) the value of exponent "b" usually range between 2.5 and 4.0. Allen (1938) suggested that the value for "b" remains constant at "3.0" for an ideal fish. In the present study, the value of "b" as determined for C. qachua is 3.1821 from the pond and 3.3942 from the stream whereas, it is 2.9701 and 2.4517 for C. punctatus and C. stewartii respectively.

It is important to determine atleast the orders of magnitude in the Ponderal index of the power function (b) of length in relation to body weight. It has been assembled in Table 34, to present the difference in the (b) value among different species of Channids. The table indicates that the values in almost all the species of Channids, approximates the cube law and hence according to Hile (1936) and Martin (1949), the fishes of this group can be considered as "Ideal".

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 carnivorous fish Trichiurus lepturus, which devour big prey. Accordingly Soni and

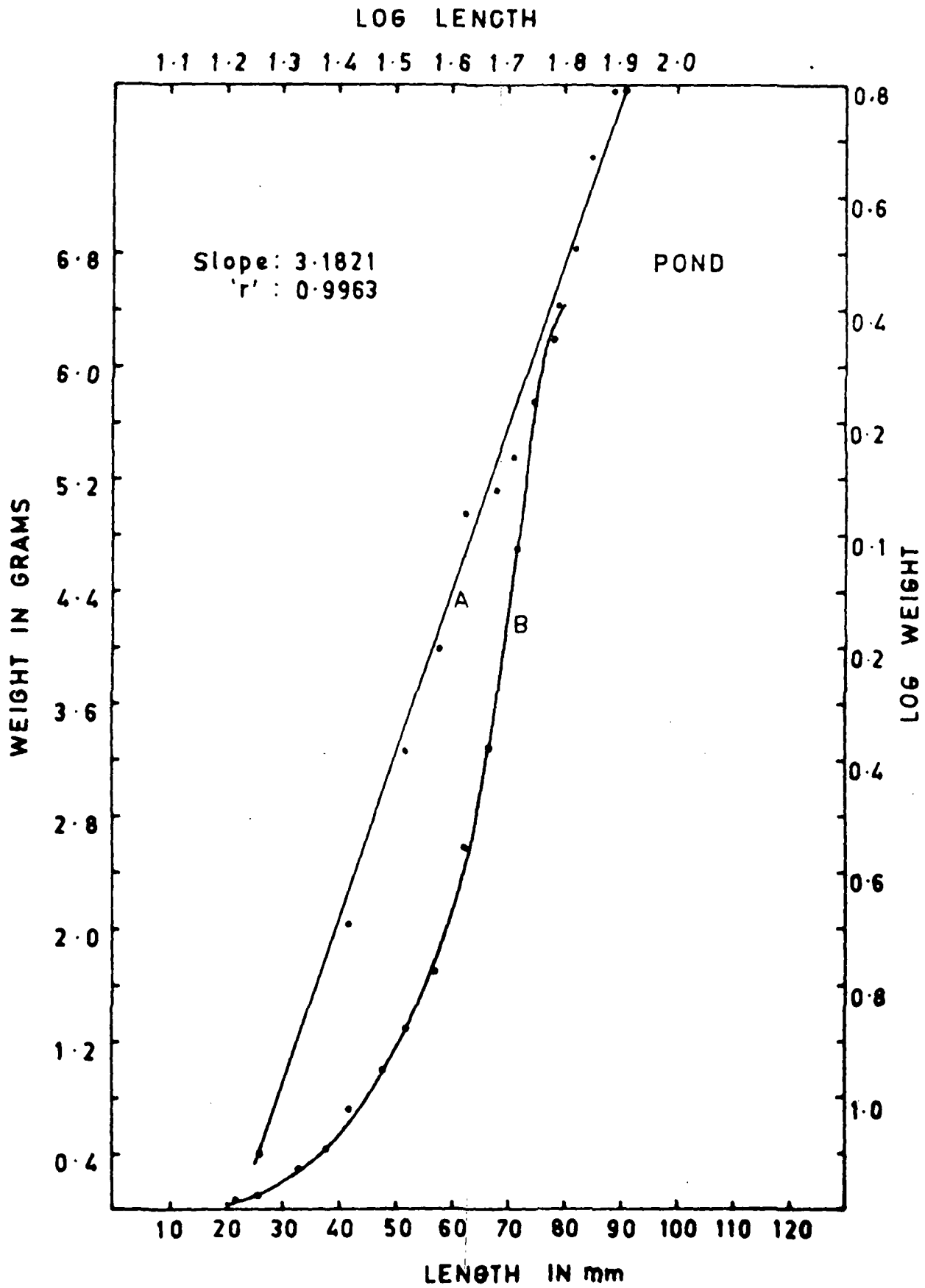


Fig. 22: Length-Weight Relationship A: Log-log - transformation B: Absolute values.

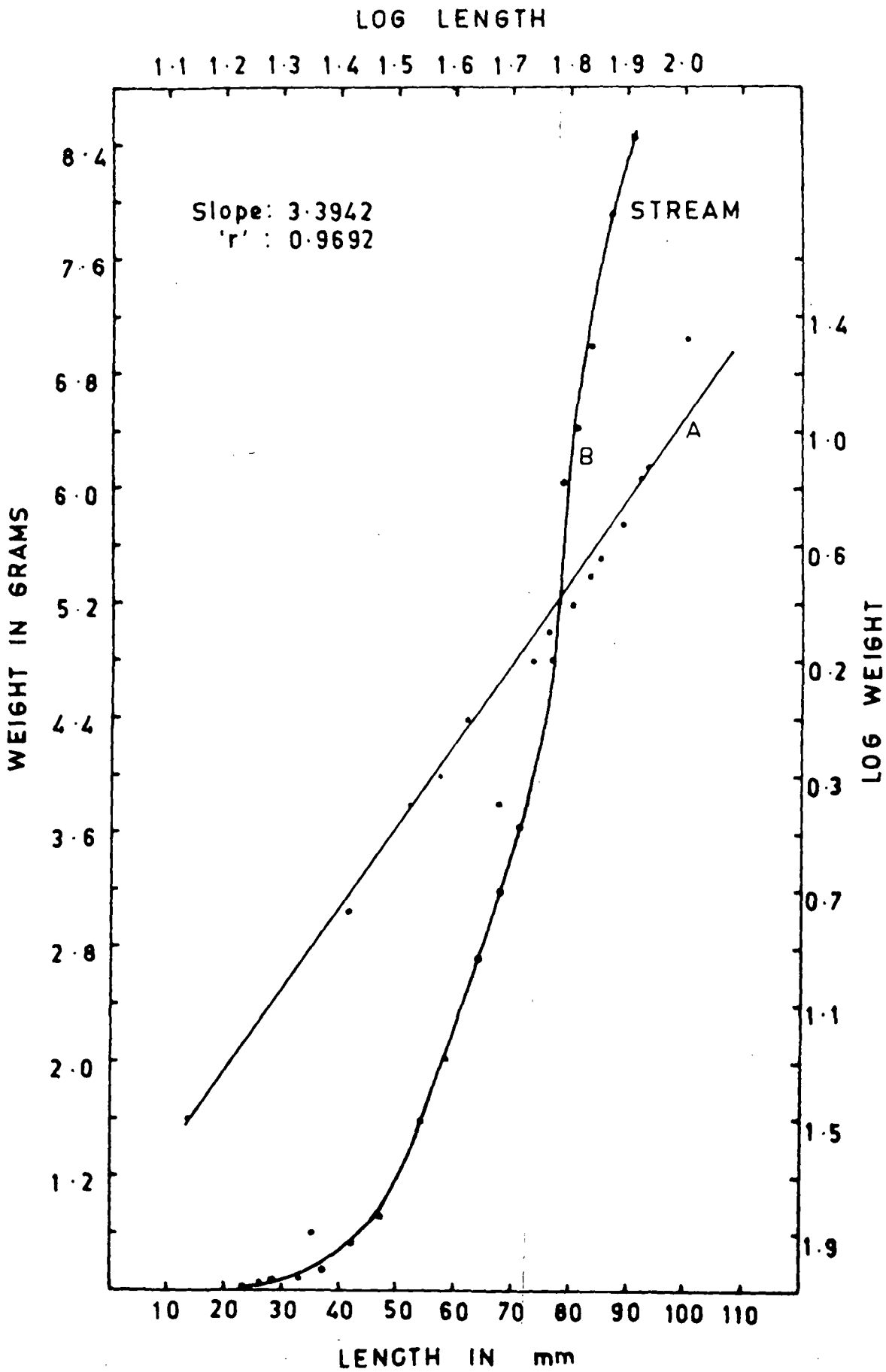


Fig. 23: Length-Weight Relationship. A: Log-log transformation, B: Absolute value.

TABLE 34

COMPARATIVE VALUES OF 'b' AS REPORTED FOR LOG BODY WEIGHT TO LOG BODY LENGTH IN VARIOUS AIR-BREATHING FISHES OF INDIA.

FISH SPECIES	VALDE FOR 'b'	REFERENCES
<u>Saccabanchus fossilis</u>	3.32	Hughes <u>et al.</u> (1974a)
<u>Heteropneustes fossilis</u>	3.10	Bandey <u>et al.</u> (1974).
<u>Heteropneustes fossilis</u> (male)	2.52	Bhatt (1968)
<u>Heteropneustes fossilis</u> (female)	2.94	Thakur and Das (1974).
<u>Heteropneustes fossilis</u> (juveniles)	3.16	Thakur and Das (1974).
<u>Macrognathus aculeatum</u>	3.36	Ojha (1974).
<u>Amphionous cuchia</u>	3.00	Hughes <u>et al.</u> (1974b).
<u>Clarias batrachus</u>	3.33	Sinha (1973). ^o
<u>Clarias batrachus</u>	3.08	Thakur (1974).
<u>N. notopterus</u>	2.96	Parameswaran and Sinha (1966).
<u>Ophicephalus marulius</u> (males)	2.99	Parameswaran (1974).
<u>Ophicephalus marulius</u> (females).	3.02	Parameswaran (1974).
<u>O. striatus</u> (males)	2.97	Parameswaran (1974).
<u>O. striatus</u> (females)	3.00	Parameswaran (1974).
<u>O. punctatus</u> (males)	3.07	Parameswaran (1974).
<u>O. punctatus</u> (females)	2.79	Parameswaran (1974).
<u>Channa qachua</u> (Pond)	3.18	Present Author.
<u>Channa qachua</u> (Stream)	3.39	Present Author .
<u>C. stewartii</u> (Stream)	2.45	Present Author.
<u>C. punctatus</u> (Pond)	2.97	Present Author.
<u>C. stewartii</u>	3.26	Ganguly <u>et al.</u> (1963).

Kathal (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. However, in the present study, the value of "b" for C. gachua from the pond (Fig. 22) and stream (Fig. 23) was found to be 3.18 and 3.39 respectively, which is higher than 3.0. The departure of "b" values from 3.0 in the present case may be due to the feeding habits of the species (Mookerjee et al. 1950) and presence of good amounts of detritus along with vegetable matter in the stomach as obtained during the present study, which supports the view of Narasimhan (1970) and Soni and Kathal (1979).

CONDITION FACTOR

Monthwise averages of "Ponderal Index" or "K" values of entire one year period has been calculated to elucidate the seasonal fluctuations (Fig. 24) and have been tabulated in Table 20. The variation in the condition factor may be attributed to different factors, such as environmental condition, food availability and the gonadal maturity, as has also been suggested by many workers (Le Crén, 1951; Jhingran, 1972; Bashirullah, 1975). According to them, study on the changes in the condition values with length increase may yield evidence concerning the size at first maturity, while the seasonal fluctuations may reflect the spawning cycle of a fish as the "K" is the condition of fatness and condition of gonads. However, the present study has shown that the smallest size group of the species have higher condition values indicating that juveniles have better condition factor (Table 21). Many workers (Menon, 1950; Pillay, 1954;

Sarojini, 1957; and Varghese, 1961) have also observed a higher K_n value in juvenile of other fish species.

The results further suggests that the increase in the weight of the body due to the weight of maturing gonads followed by a decrease due to spawning, is also reflected in the condition factor of the fish (Table: 32). The results also support the view of Weatherley (1972) that even among the members of one population, samples on a single date, there may be considerable variation in condition with length (Fig. 24A). According to him, fish populations display considerable changes in average condition, reflecting normal seasonal fluctuations in their metabolic balance and in the pattern of maturation and subsequent release of reproductive products. Even the state of fullness of the alimentary canal may influence "K" factor.

Le Cren (1951) proposed a relative condition factor (K_n) and discussed its superiority over condition factor (K). According to him, the former measures all the variations not connected with length, which the latter fails to do (unless $n = 3$). Kesteven (1947) suggested that a true ponderal index should be obtained by comparison of volume of fish with its weight in which form it will be a measure of relative density or weight per unit volume, the latter being a function of the fish volume which is a cubic function of its linear dimensions.

In the present study, the condition factor was also found from the eviscerated specimens (Total weight of the fish - Weight of the gonad and gut) to eliminate the influence of gonad and food present in the alimentary canal. The pattern of fluctuations in these indices is almost similar to that of the indices

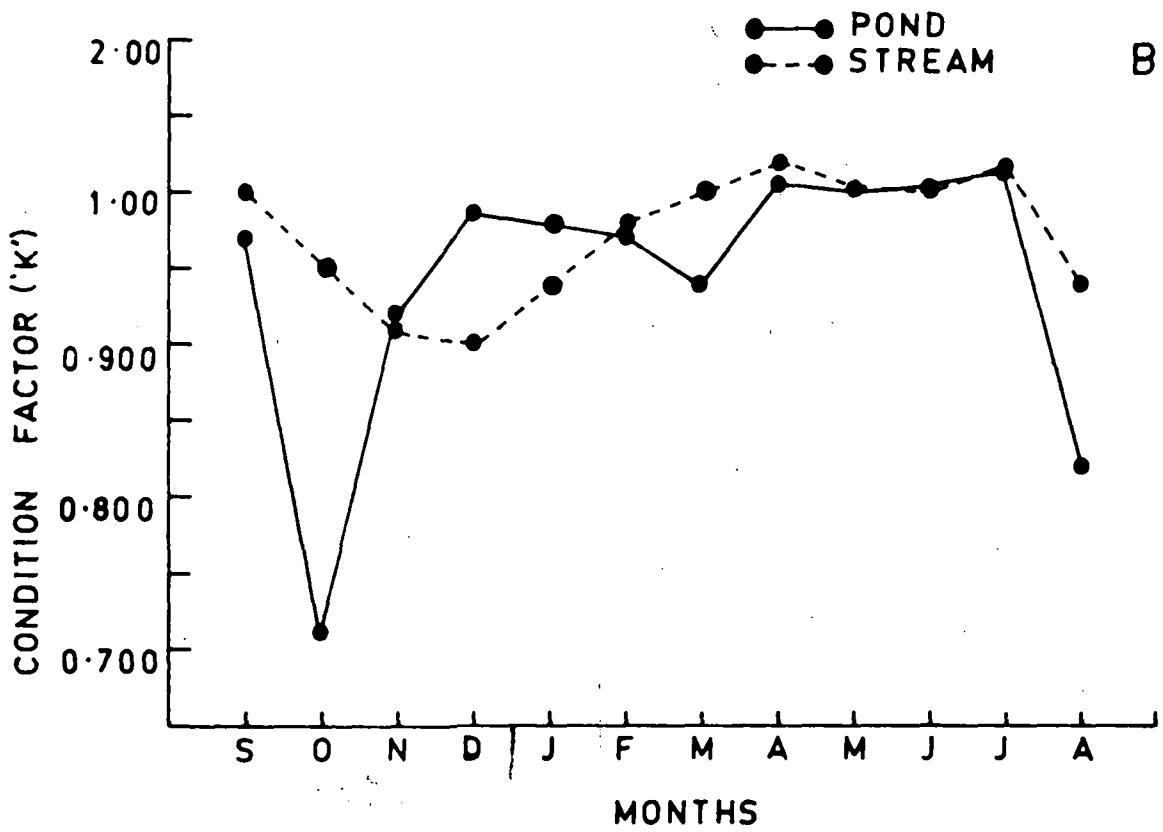
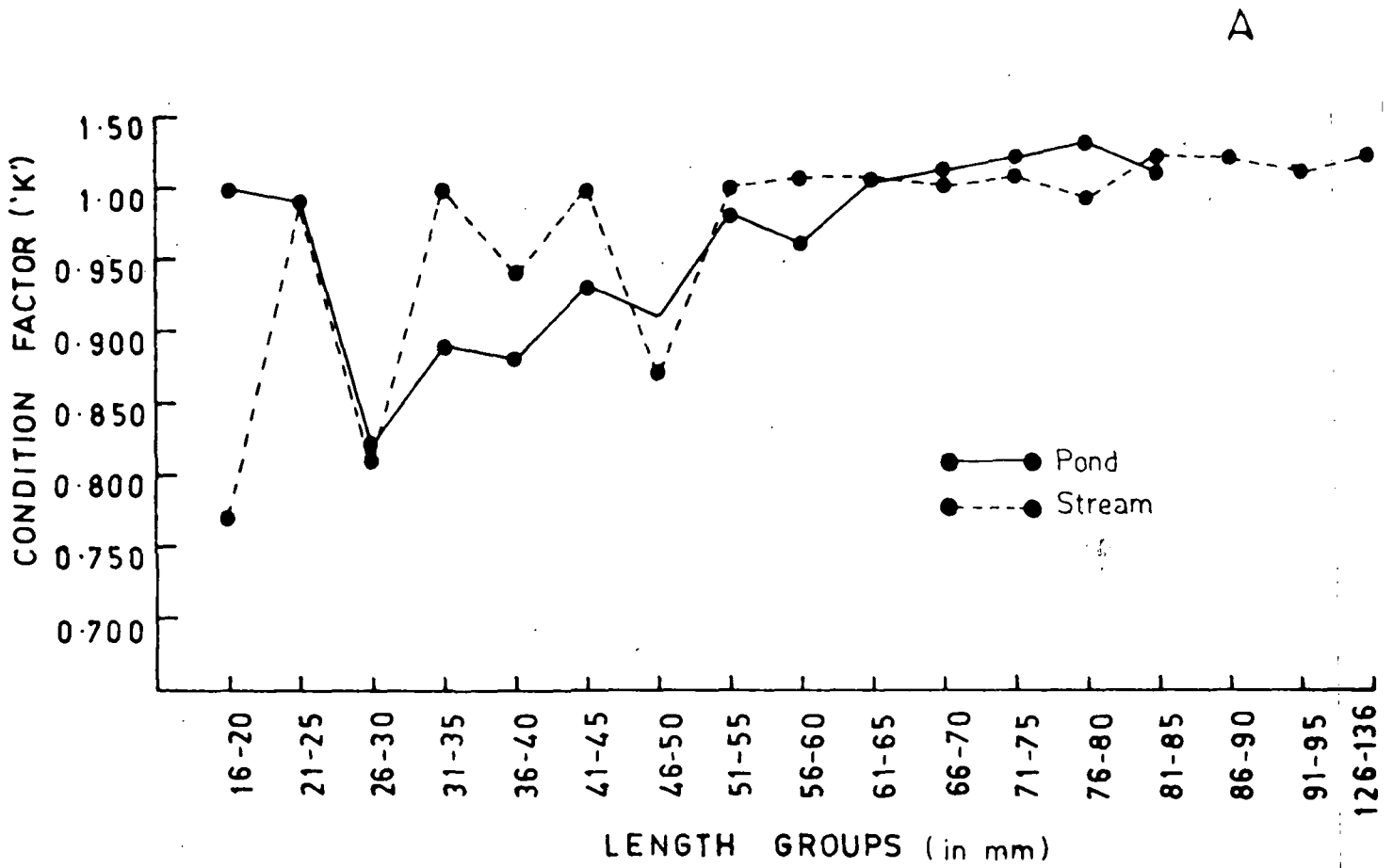


Fig. 24. K - factor in *C. gachua*. (A) Length wise
(B) Month wise.

of whole fish, the difference being only that of magnitude. This indicates that the condition factor is not only influenced by the maturation of the gonads and the food present in the alimentary canal but might also be due to certain other environmental factors too. Similar case has also been reported by Jhingran (1972) for Setipinna phasa. In the present study, adults of C. gachua from the pond are found to be heavier ($b = 3.6456$) in respect to their length, while the juveniles ($b = 2.8743$) were lighter in relation to their length.

MATURITY AND SPAWNING

Studies on maturity indicate that both the males and the females mature at the same time and have a similar breeding period (June-August) with just one spawning season in an annual cycle. The occurrence of ripe individuals during the months of June-August and its complete absence thereafter also supports that the spawning season lasts from late June to August. The condition factor or Ponderal Index (K) for the same individuals also indicates towards a similar trend in the spawning season as indicated by the results obtained for 'K' factor. 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, immature and mature. Similar observations have also been reported by Hickling and Rutenberg (1936), Prabhu (1956), Qasim and Qayyum (1961) and Natarajan and Jhingran (1963) as has also been found in the present study too. It has also been observed that the species (C. gachua) mature little earlier (length-wise)

in the pond population than the stream population and this can be attributed to the better food availability in the pond than the stream. This is also supported by the studies on the reproductive biology of the species in the present investigations.

Gonado-somatic index (Gn.S.I.) values when plotted against different body lengths (Fig. 26) indicated a tendency for the Gn.S.I. to increase with the increase in body length. It is also seen that the seasonal peaks (Fig. 25) 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. Such a case has also been reported by Kakuda and Nakai (1981). According to Kesteven (1942) the gonad maintained 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 weights will show an exponential with the length in the same way as does the length of the entire organisms. Jhingran (1961), Qasim and Qayyum (1963), Bagenal (1967) have studied the relationship between fecundity and fish length and reported that the exponent value to range around three. 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 2.5490 and 4.1752 for the specimens from the pond and the stream respectively. The value of exponent (2.5490) indicates that the fecundity of the pond population increases at a lower rate than that of the body weight, in relation to total length, as is also evident from the exponent value of 3.1821 (Table 19) obtained in the length-weight relationship during the

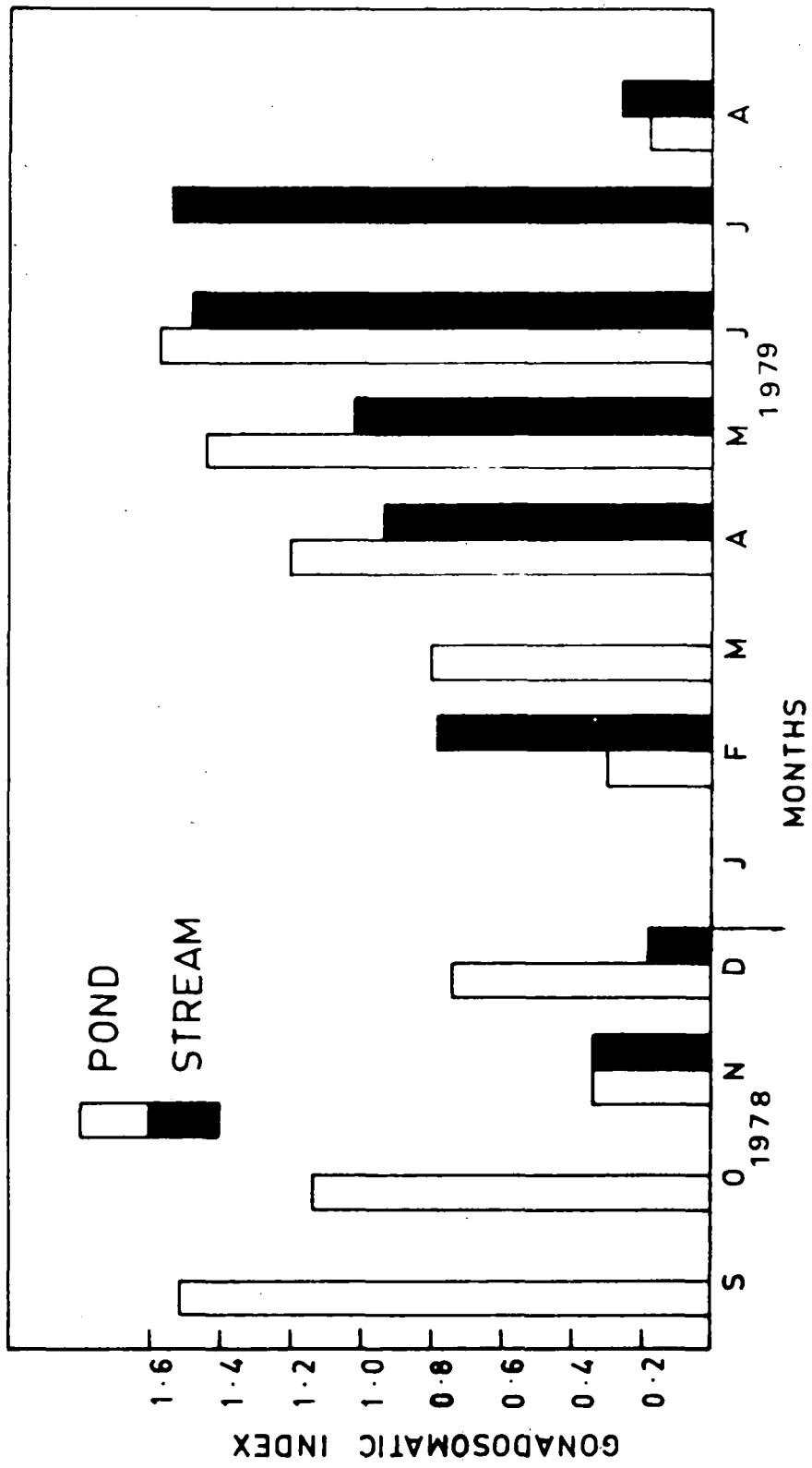


Fig. 25: (Gn.S.I.) of C gachua.

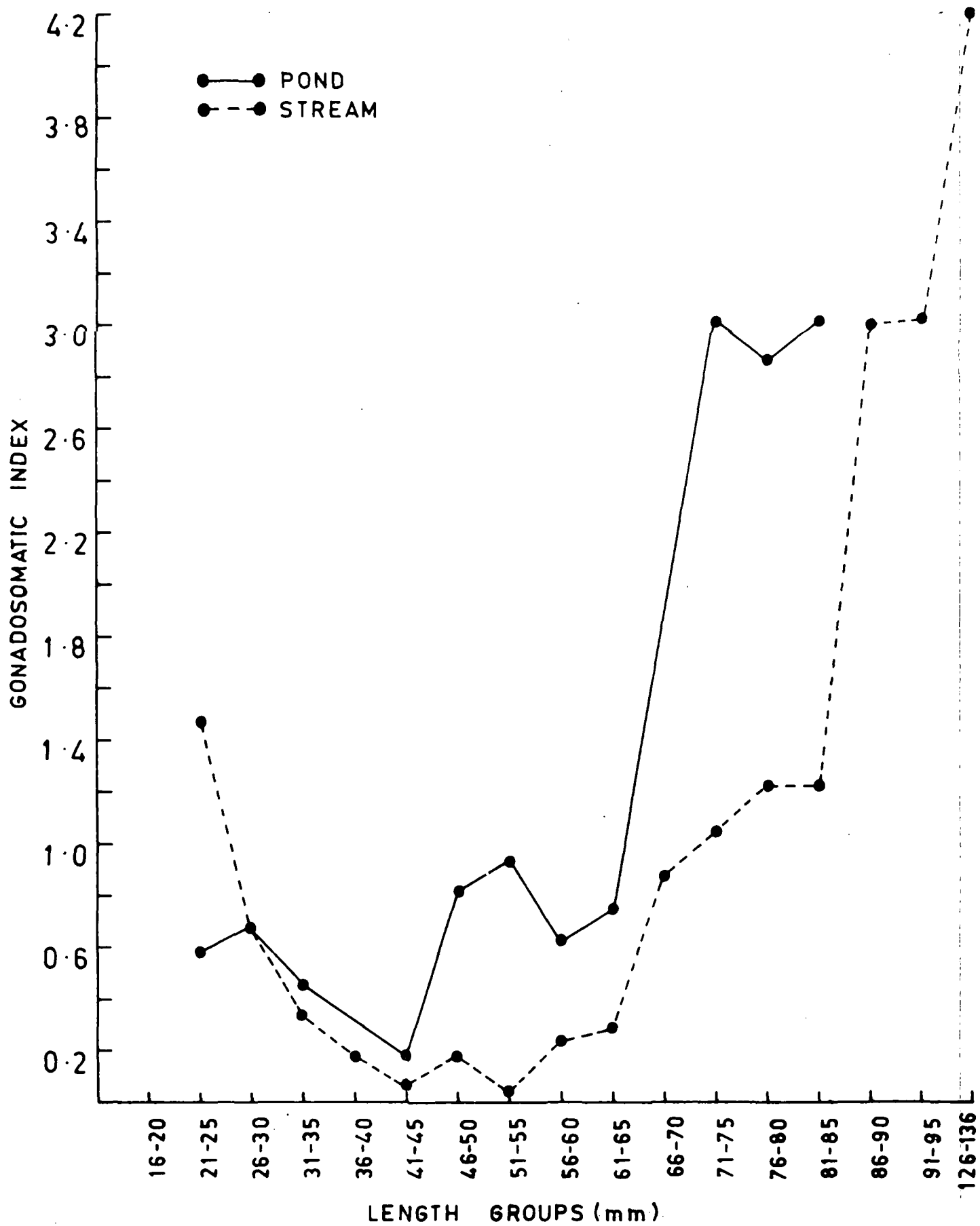


Fig. 26: (Gn.S.I.) of C. gachua.

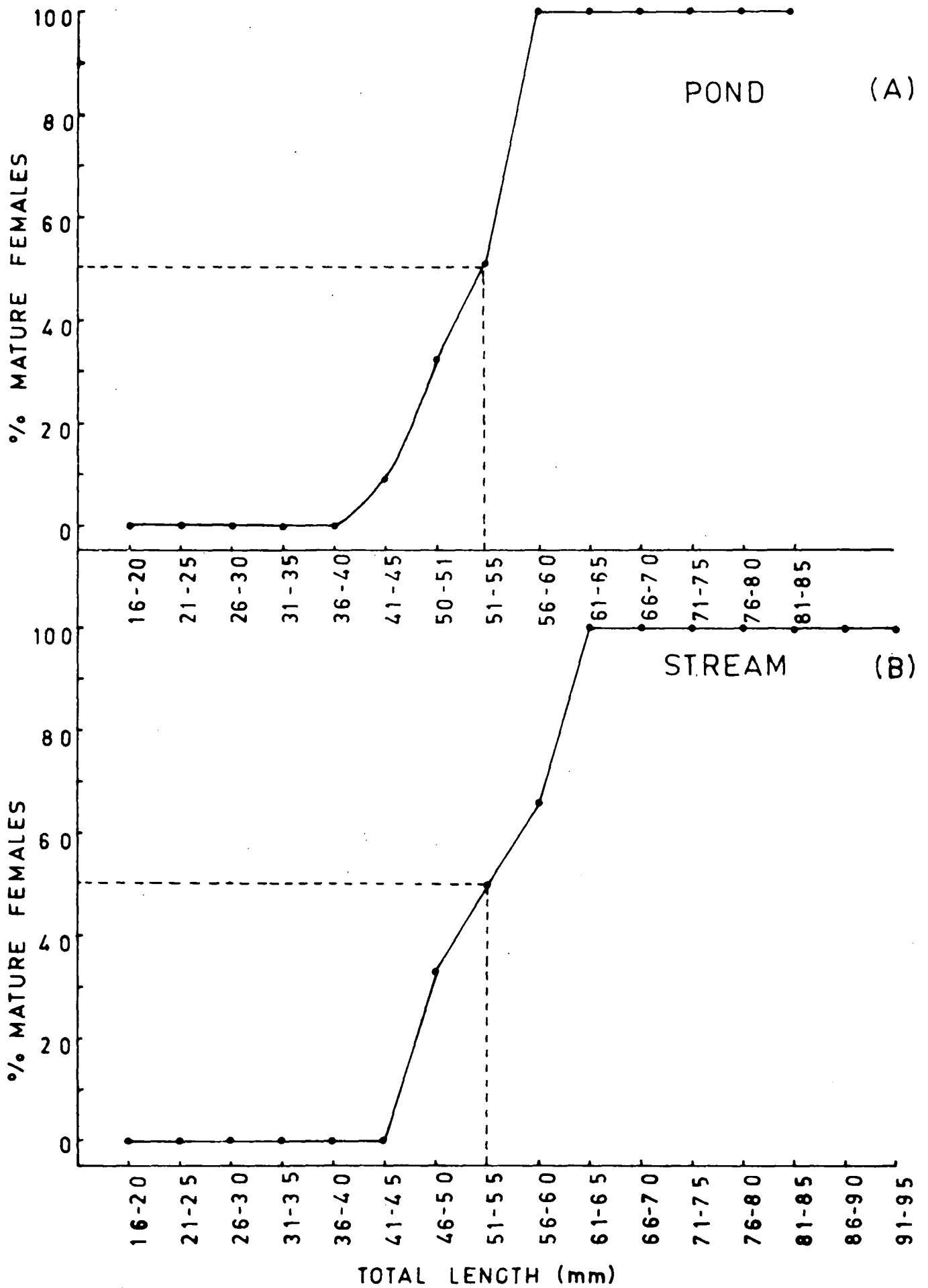


Fig. 27: Maturity of female, *C. gachua*. (A): Pond (B): Stream.

present study for individuals from the pond. From the value of exponent (3.3942) obtained in the length-weight relationship in the stream population (Table 19), it appears that the fecundity increases at a rate slightly faster than that of the body weight in relation to total length as the exponent value has been found to be 4.1752. The values of exponent obtained in the relationship between ovary weight and total length were found to be 2.7389 for pond population and 3.9540 for stream population which indicates that the ovary weight increase at a more rapid rate than the total weight in stream population, whereas in the pond population, the increase in ovary weight is lower than total weight.

It has been observed that the C. gachua specimens below 36.0 and 41.0 mm from the pond and stream respectively were immature. Fifty percent (M_{50}) individuals mature at 51.0 - 55.0 mm length group both in the pond and stream population (Fig. 27).

FECUNDITY

On plotting fecundity values against body length (Fig. 28E & F), it has been observed that the egg counts increased with the increase in length. It is also seen that there is an increase in the spread points describing this relationship with increasing size of the species. Similar case has also been reported by Habib (1979) in Puffer fish. According to Simpson (1951) fecundity is directly proportional to body weight. As pointed out by Bagenal (1967), since weight is more closely connected with the condition of fish than its length, Yuen (1955) found that relationship between fecundity and weight to be curvilinear as has also been recorded in the present study, which indicates that fecundity is more dependent on weights rather than length

as has also been reported by Manooch (1976) for Red Porgy. The logarithmic relationship between fecundity of the species and its length, body weight and ovary weight were found to be linear (Fig. 28). A comparative data on the fecundity of different air-breathing fishes from India, have been assembled in Table-35, which indicates that the fecundity of air-breathing teleosts appears low but when assessed in relation to their respective body sizes, the number of ova is considerable, as also reported by Dehadrai and Tripathi (1976).

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 found out to make comparisons between both the 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 fish (Bagenal, 1973). However, it is seen that the relative fecundity on average basis was found to be lower (97.04) in the stream population (Table 23), than the pond (Table 24) population (140.67), which may be attributed to the fact that the relative fecundity in the species may change markedly due to changes in the condition of the species and has also been mentioned by Le Cren (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 latter case, if the total weight remain constant and thus make the

calculation of relative fecundity meaningful. If the relative fecundity is related to length, it cannot be used alone to compare fecundity at different places and time (Bagenal, 1973).

The maximum fecundity values for C. qachua in the present study have been found to be 1170 and 1523 in the individuals from the pond and stream respectively (Tables 23 & 24) which is quite similar to the observations made by Mookerjee et al. (1950) that this species lay about 1500 and 2000 eggs. However, fecundity estimates suggest that the species is not very fecund in comparison to other species which might be due to the fact that a species that protects its eggs and young ones is usually less fecund, than the one that does not (Kryzhanoviskii, 1949). 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~~ of the mouth brooders were found to have fewer and larger eggs than the guarders. 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. Since, this species (C. qachua) is known to build nest and guard their young ones (Mookerjee et al. 1950), may be the reason of lower fecundity.

It is often assumed that fecundity and egg size are negatively correlated (Bagenal, 1971). The relationship is complicated by what appears to be a general tendency for fish which spawn later in the season to lay smaller than average eggs. Accordingly to him, since the egg size and parent length are usually positively correlated, suggest that the larger fish spawn first, however, this has been found to be true only for

some fishes but not for all. Simpson (1959) showed clearly that older plaice spawn first, but in contrast the older individuals of perch spawn later. In the present study too, it has been observed that the egg size and parent length are positively correlated.

McFadyen et al. (1965) found that trout from infertile streams had a lower egg production. Differences 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 hand locked salmon. The fecundity variations reported by Bagenal (1971), Raitt (1968) and Hodder (1965) were associated with food through population density. Nikolsky (1961; 1969) mentioned a number of Russian papers associating food supply and fecundity and the relationship of nutrition and fecundity were reviewed by Woodhead (1960). In the present study, variations in relative fecundity can be related to food availability, as the stream population had a lower relative fecundity than the pond population, since the stream is less productive in comparison to the pond, thus leading to lower relative fecundity in stream population than the pond population. Thus, relative fecundity can be associated with the food availability, which is also supported by certain experimental works (Scott, 1962; Hester, 1964; Bagenal, 1969; and Wottan, 1973) relating food to fecundity confirming the low food intake leading to lower number of eggs.

Several environmental effects on fecundity are believed to act through the food supply. Hodder (1965) suggested that the fecundity differences of grand banks Haddock were associated

TABLE 35

COMPARATIVE VALUES OF FECUNDITY IN DIFFERENT AIR-BREATHING
TELEOSTS FROM INDIA

FISH SPECIES	TOTAL NO. OF OVA (FECUNDITY)	AUTHORS
<u>Heteropneustes fossilis</u>	2843 - 44723	Bhargana (1971).
<u>Clarias batrachus</u>	11612	Mookerjee and Mazumdar (1950).
<u>Clarias batrachus</u>	1000 - 20000	Thakur (1974).
<u>Anabas testudineus</u>	4588 - 34993	Banerji and Prasad (1974).
<u>Netopterus notopterus</u>	175 - 1188	Parameswaran and Sinha (1966).
<u>Ophicephalus marulius</u>	1799 - 38375	Parameswaran (1974).
<u>O. striatus</u>	2794 - 28046	Parameswaran (1974).
<u>O. striatus</u>	4422 - 20070	Alikunhi (1953).
<u>O. striatus</u>	5970 - 31114	Srivastava (1977).
<u>C. gachua</u>	1500 - 2000	Mookerjee <u>et al.</u> (1950).
<u>Channa gachua</u> (Pond)	160 - 1170	Present Author .
<u>Channa gachua</u> (Stream)	243 - 1523	Present Author .

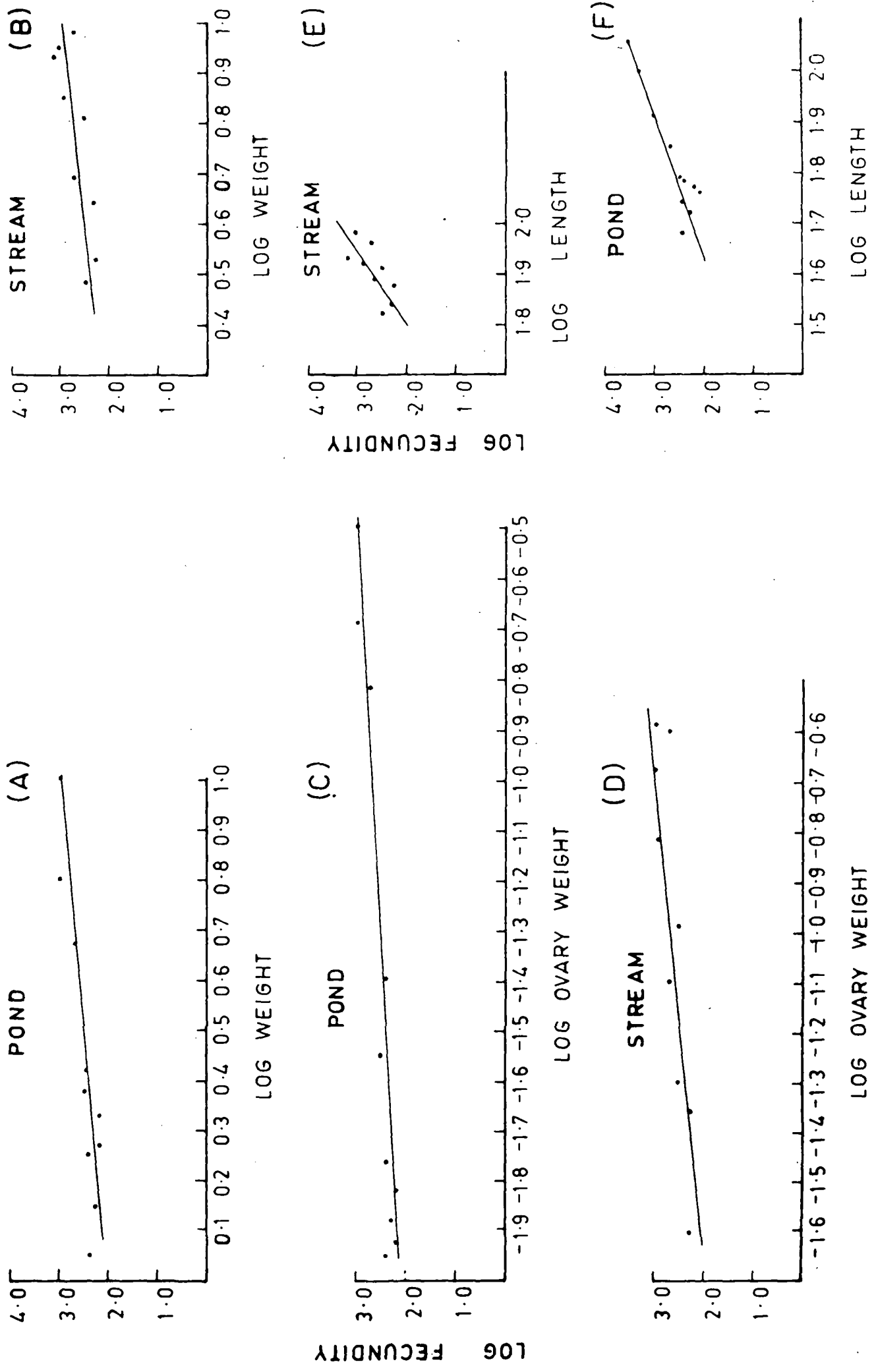


Fig.28: Log relationship in fecundity with various parameters in *G. gachua*.

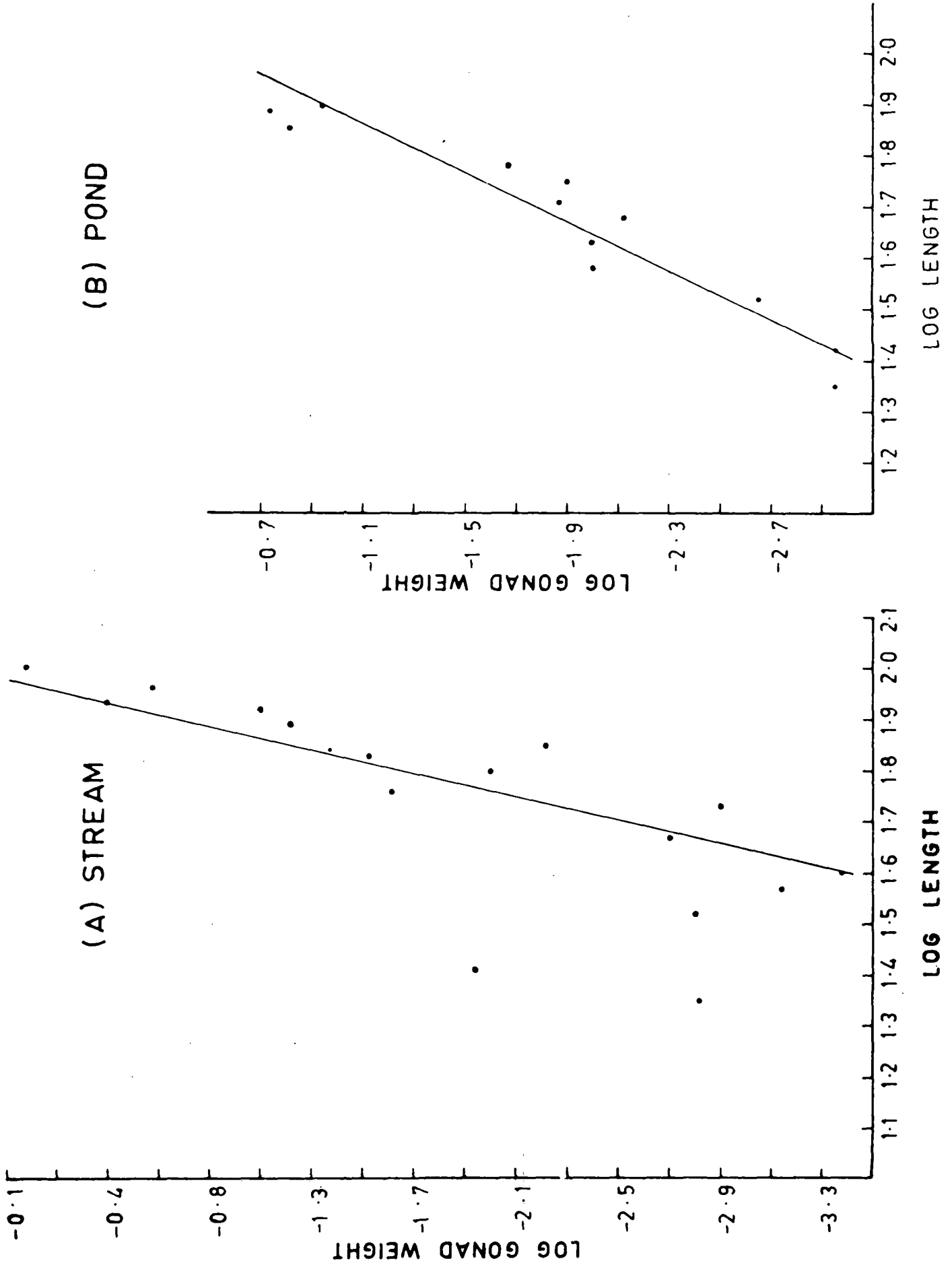


Fig.29: Log relationship between gonad and total length in *C. gachua*.

with water temperature as in cold water they concentrate along the edge of the banks resulting in overcrowding, which led to a food shortage and a lower fecundity. Accordingly in the present study, temperature could also be considered as a limiting factor affecting fecundity as throughout the study period, the species from both the systems were found to be concentrated along the edge of the banks among the marginal vegetation due to low water temperature, resulting in overcrowding. This might have led to a food shortage which in turn resulted in low fecundity.

FOOD AND FEEDING HABITS

Based on the numerical method and frequency of occurrence, the present study reveals that the composition of diet of C. qachua can be divided into the following broad categories :-

- (a) Detritus
- (b) Vegetable matter
- (c) Phytoplankton
- (d) Zooplankton

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

- (a) Basic food that normally eaten by the fish and comprising most of the stomach contents;
- (b) Secondary food - that which is frequently found in the stomach, but in smaller amounts; and
- (c) Incidental food - that which is found only rarely in the stomach contents.

Hence, the basic food of C. qachua as seen from the present study can be considered the detritus comprising of about 57-61% of the total gut contents. Consequently the secondary food of the species, as indicated by the results was vegetable

matter, which comprised 26.0% of the gut content. The remaining items were regarded as incidental food, due to the fact that phytoplankton and zooplankton form a very small fraction of the gut contents and occur without any regularity in the different months (Tables 26 & 27). This indicates that these are probably swallowed along with other food material accidentally.

A change in diet with increase in size with larger fish eating larger food items, has been widely reported by Keast (1966); Larsen (1967); De Silva (1937), Adams (1976), Kakuda and Matsumoto (1978) but in the present study no change in diet is observed except that the smaller length groups exhibited the presence of maximum numbers of species (Tables 28 & 29). The present study has also shown that the percentage of feeding individuals is higher among the smaller individuals, may be owing to the fact that metabolic activities are generally higher in young ones. Similar results have also been reported for heiring (Clupea harengus) and spent (C. sprattus) (Hardy, 1924; Marshall et al. 1939 and De Silva, 1973).

Feeding in relation to condition factor indicated a clear inverse relationship (Figs. 34 & 35) both on a seasonal basis and in the various length groups. An inverse relation is also observed between the feeding intensity (G.S.I.) and the gonadosomatic index (Table 32) which could be explained due to the spawning season of the fish, as reduced feeding has been reported during the spawning season by Wolfret and Miller (1978) for the northern pike and spawning brings about a sharp decrease in the condition factor (Jacobsen, 1974).

According to Jhingran (1971) the principal factor that

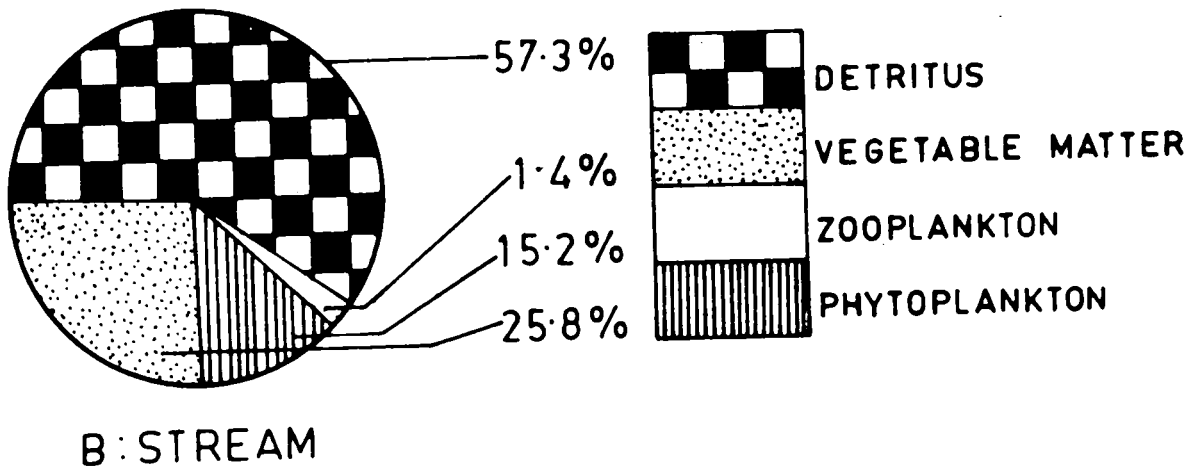
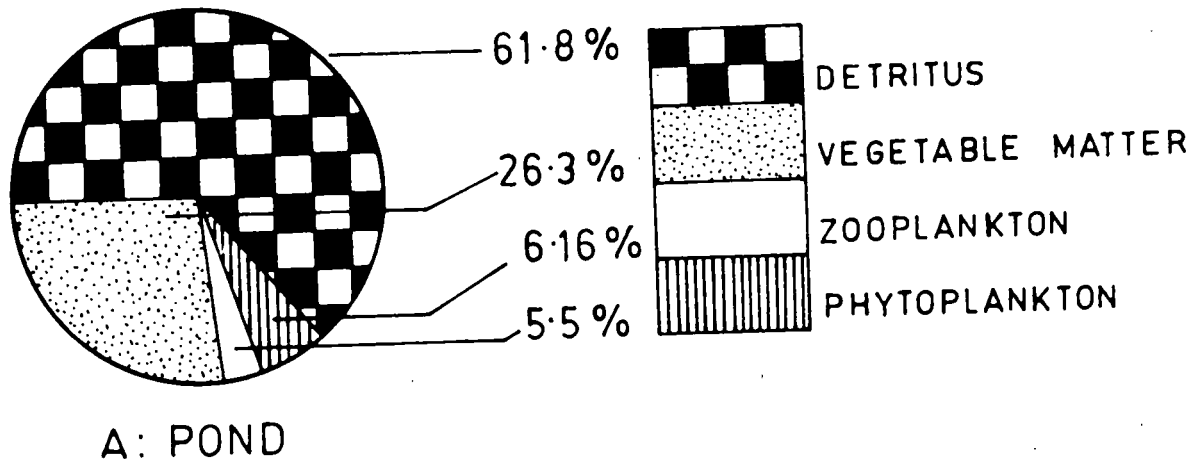


Fig.30: Relative importance of the major food items in the diet of C. gachua.

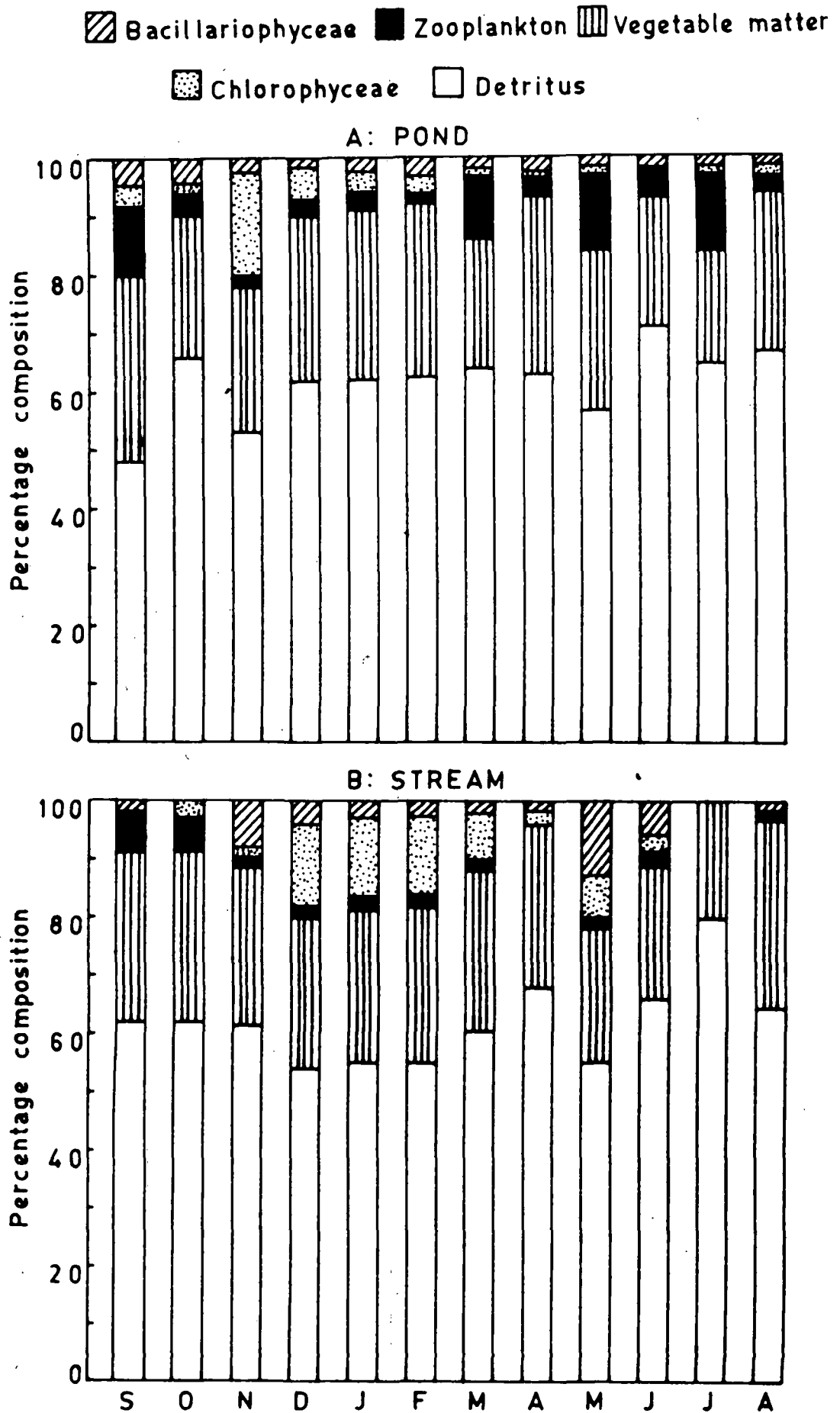


Fig. 31: Seasonal variation in major food items of C. gachua.

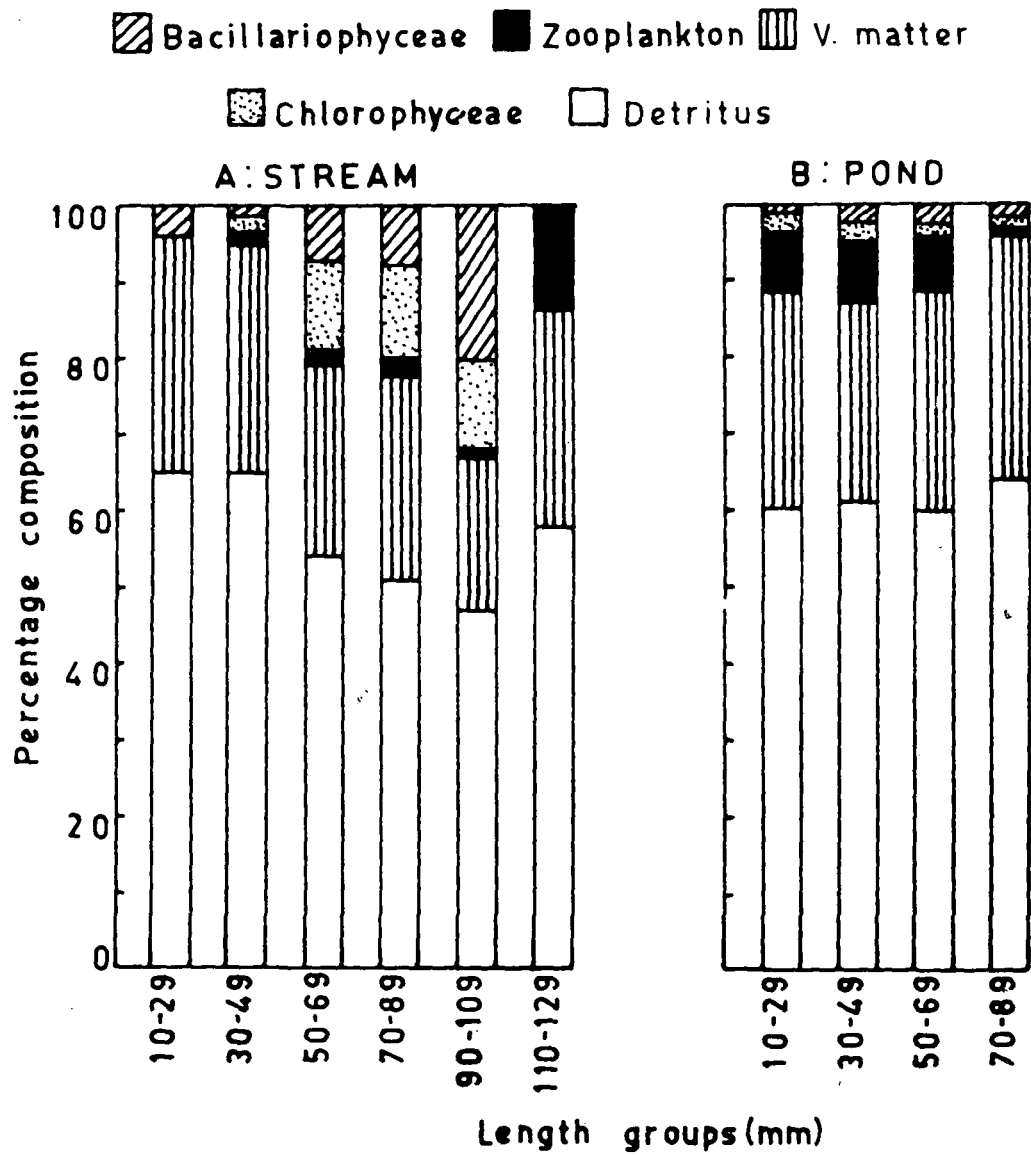


Fig. 32: Frequencies of occurrence of food items in *C. gachua*.

are likely to affect the monthly variations in the ponderal index are generally food and sexual maturity. The data of G.S.I. as obtained (Table 30) reflects the assessment of spawning season as has also been indicated by the monthly fluctuations in the condition factor (Table 20) of the species.

The feeding intensity declined (Table 30) with the progressive maturation of gonads (Fig. 25) from April to August in the case of individuals from the stream, whereas from February to July for pond specimens. Observations on the maturity and breeding season of the species (C. qachua) have shown that the fish breeds from June to August (Table 22) indicating that the periods of low feeding intensity coincides with the spawning season. The low feeding activity during peak breeding season may be attributed to the completely developed ovary, permitting limited space in the abdominal cavity for intake of food. Feeding intensity increased after the spawning period and attained peak in November and February in the case of stream population and October and November for pond individuals.

The coincidence of low feeding with peak breeding has been observed by many workers. Hardy (1924), Hickling (1933), Fage and Veillet (1938), Menon (1950) and Desai (1970) have reported a decrease in the rate of feeding and amount of food consumed with the maturation of gonads. Bhimachar and George (1952) have also referred to the reduced feeding in Indian mackerel, Rastrallia kannaqurta with the progressive maturation of 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 during its peak breeding season. Natarajan and Jhingran (1963) have noted the low level of breeding during maturation phase in the case of female Catla catla.

The observation of feeding intensity in different length groups in the present study also indicates that feeding intensity is higher in the smaller length groups, whereas larger (higher) length groups show a decline in the feeding intensity which could be due to the maturation of gonads.

The diet composition tends to show that the species feeds mainly on detritus and vegetable matter. However, contrasting opinion has been expressed regarding the food preference of this species though from different regions by Mookerjee et al. (1950) who classified it as a carnivore, rarely taking any vegetable matter, unlike the results of the present study.

According to Moitra (1956) food habits of fish varies in different environments, which may not only be due to the availability and abundance of particular food items, but also to the temperature and other ecological and geographical factor. This might be the reason of different feeding nature in the present case than the report of Mookerjee et al. (1950). The gut length of the species was found to range from 0.42 to 0.57 and 0.41 to 0.80 for the individuals from the pond and stream respectively. The adaptation of the alimentary canal of fish to their food are well known in regard to the relative length of gut (Sinha, 1972).

According to Das and Nath (1965) in a carnivore, the ratio is less than or equal to unity, whereas in herbivore and omnivore it is more than unity. Suyehiro (1941) and Beumer

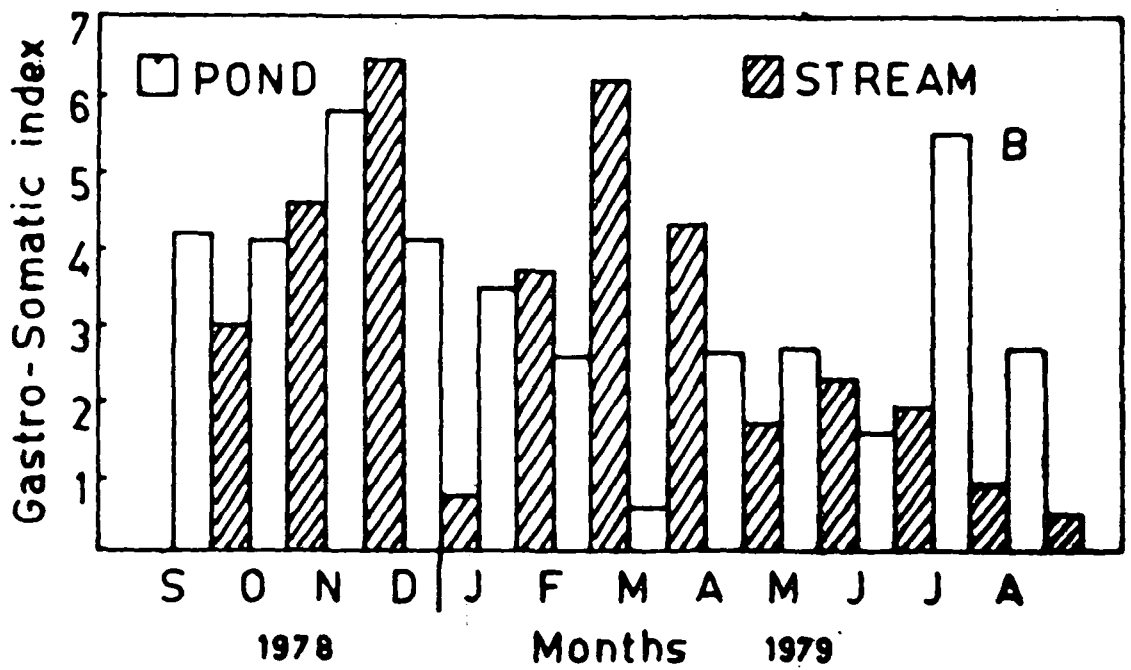
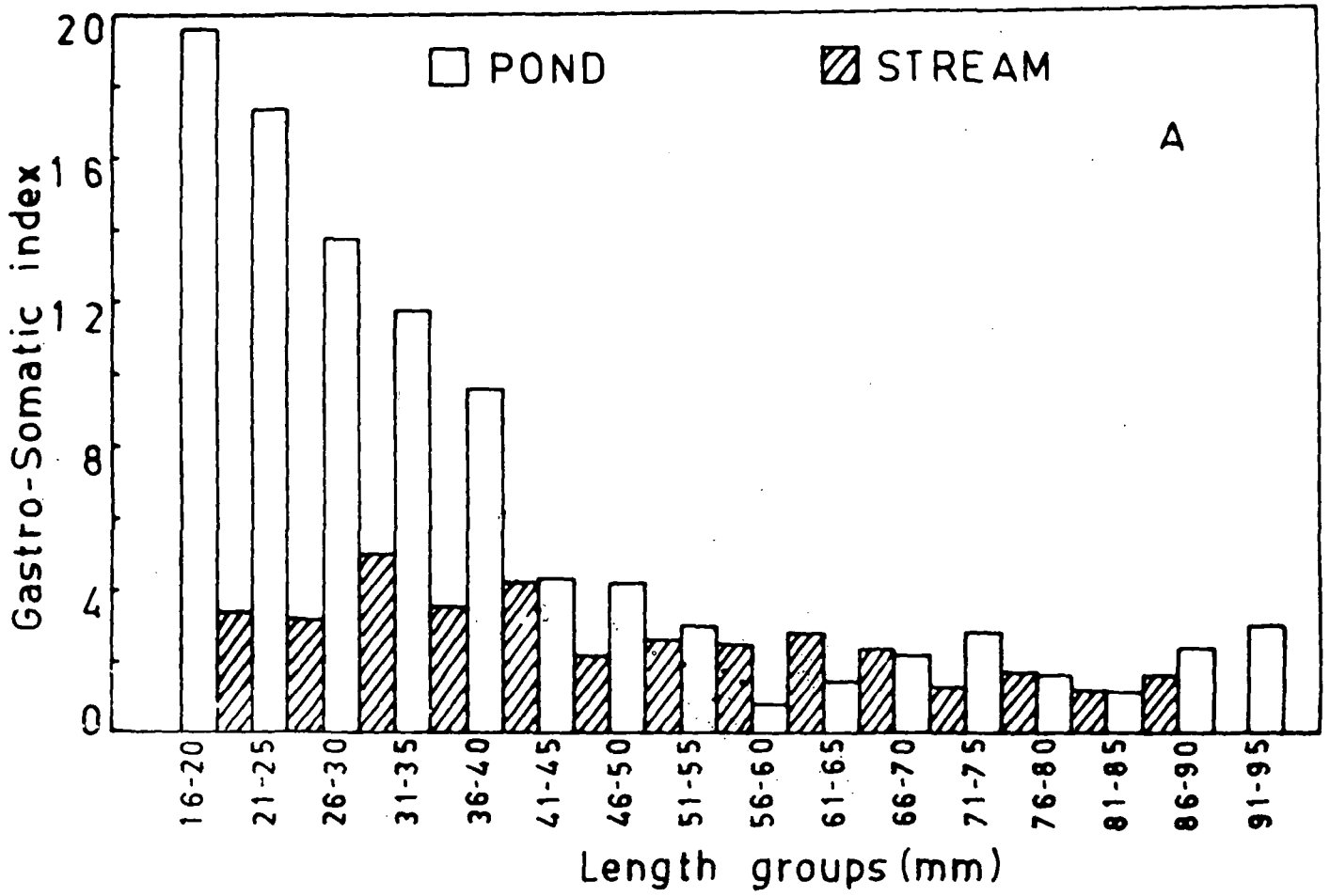


Fig.33: G.S.I of C. gachua.

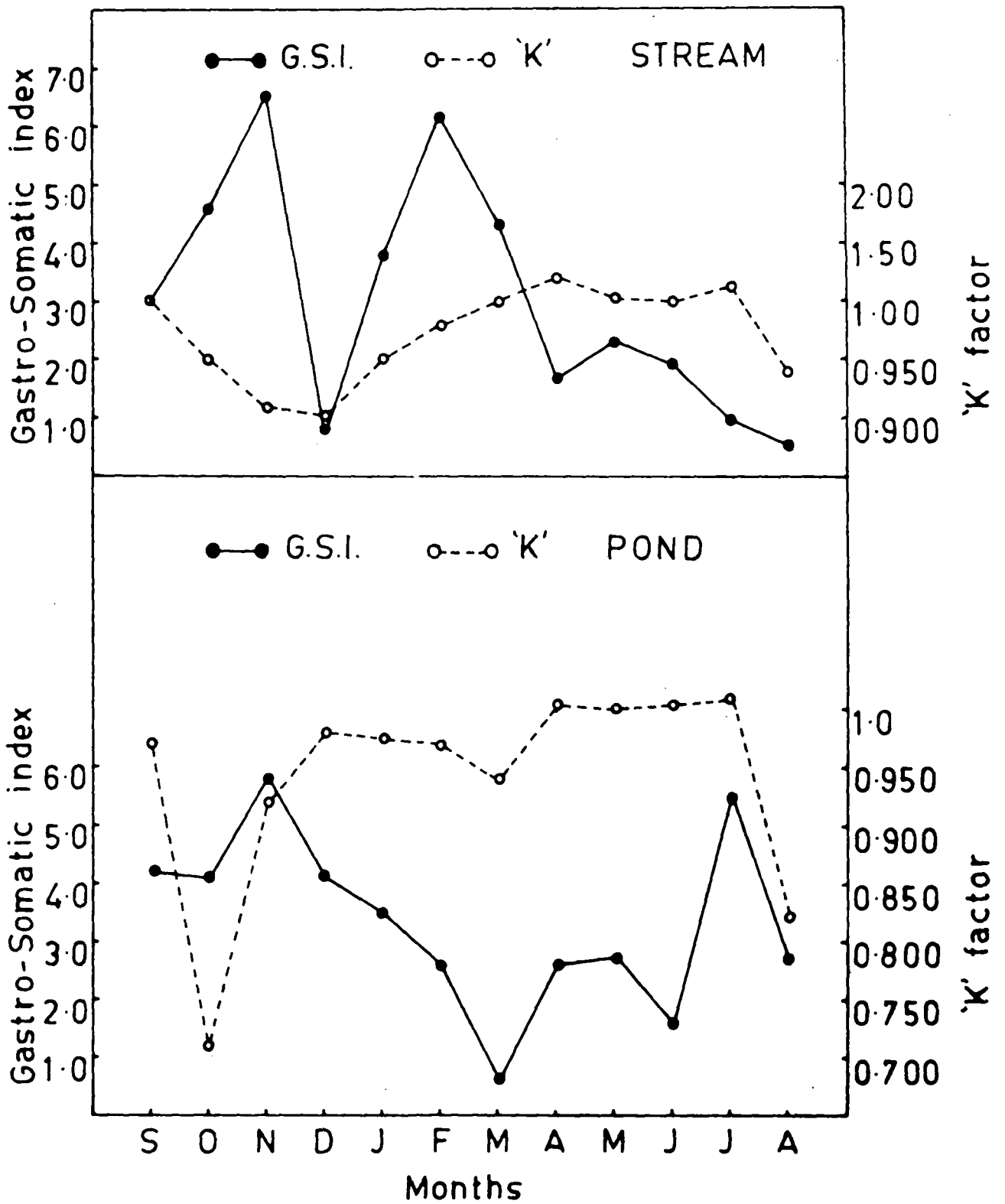


Fig. 34: Relationship between G.S.I. and 'K' factor.

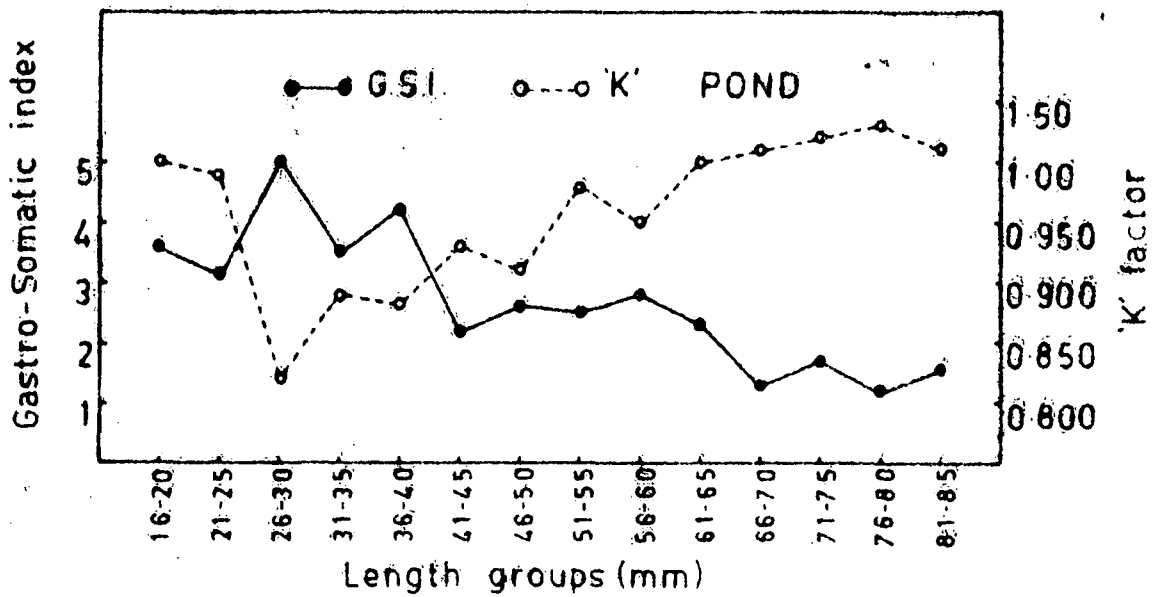
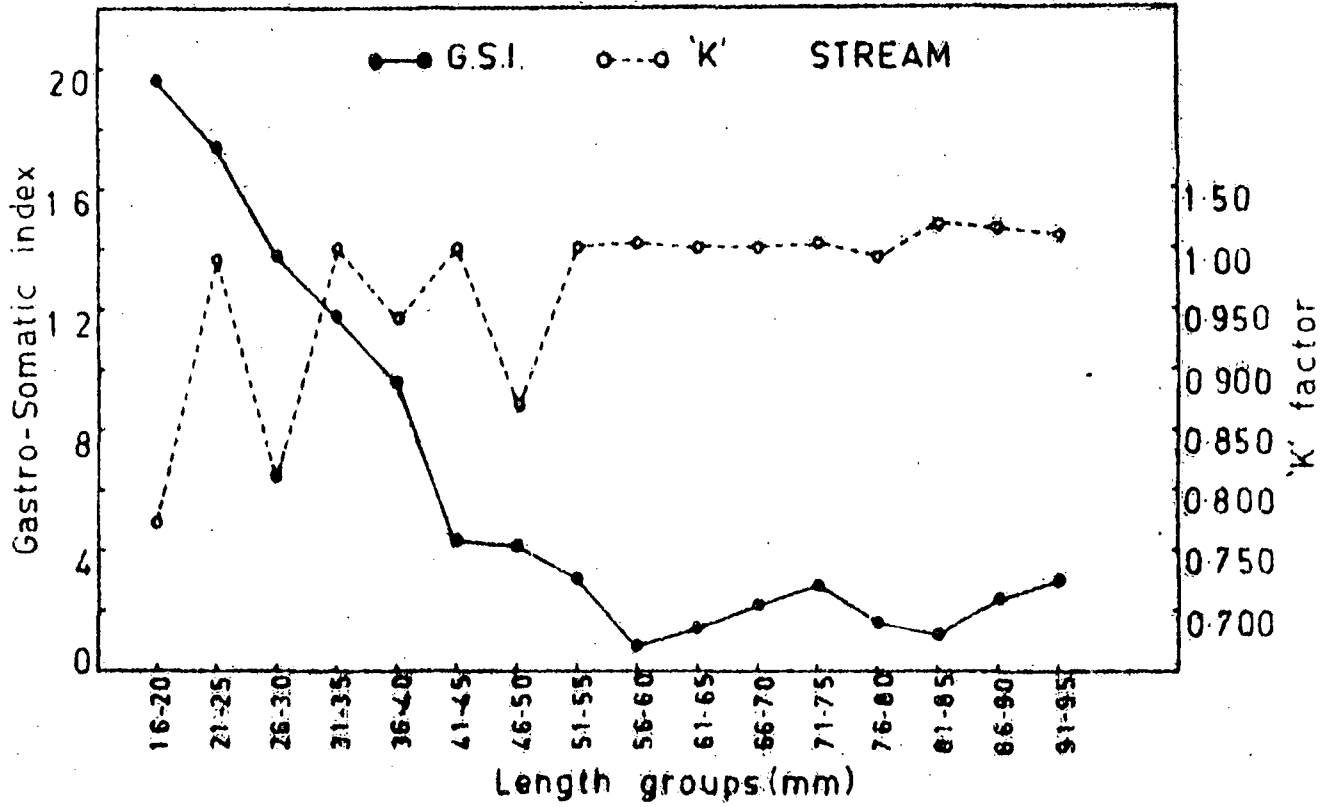


Fig. 35: Relationship between G.S.I. and 'K' factor at different size group

(1978) have also reported, low relative length of gut as typical of a carnivore. Accordingly, the ratios were calculated for C. gachua which showed a decrease in the relative gut length with the increase in length of the species. Das and Srivastava (1979) have reported a decrease in RLG values from fingerlings to adults in C. punctatus, Notopterus notopterus and Wallago attu and correlated this with the change in feeding habits in the same water bodies at different stages of life history in the same fish, but no such relation could be established in the present study, as the diet composition was found to be the same in different length groups of fishes.

In the present study the diet composition of C. stewartii showed that the most important food was Chlorophyceae (47.68%) followed by detritus (16.17%), Bacillariophyceae (9.61%) and Zooplankton (3.94%). Ganguly et al. (1963) have reported that C. stewartii is a surface feeder as well as carnivore. It prefers Protozoa, Insects and Crustacea along with a good quantity of both unicellular and multicellular algae, during early life stages, while insects, crustacea and fish fry form the main constituents of the diet of the adult.

In the present study, the diet of C. punctatus mainly consisted of detritus (54.83%), vegetable matter (18.51%), Chlorophyceae (14.84%) and Bacillariophyceae (8.66%) and Zooplankton (2.65%), whereas Mookerjee et al. (1950) have reported the same species to be a carnivore.

According to Dehadrai and Tripathi (1976) the murels are highly predatory and marked piscivorous. The fry in almost all cases feed heavily on zooplankton, whereas the fingerlings

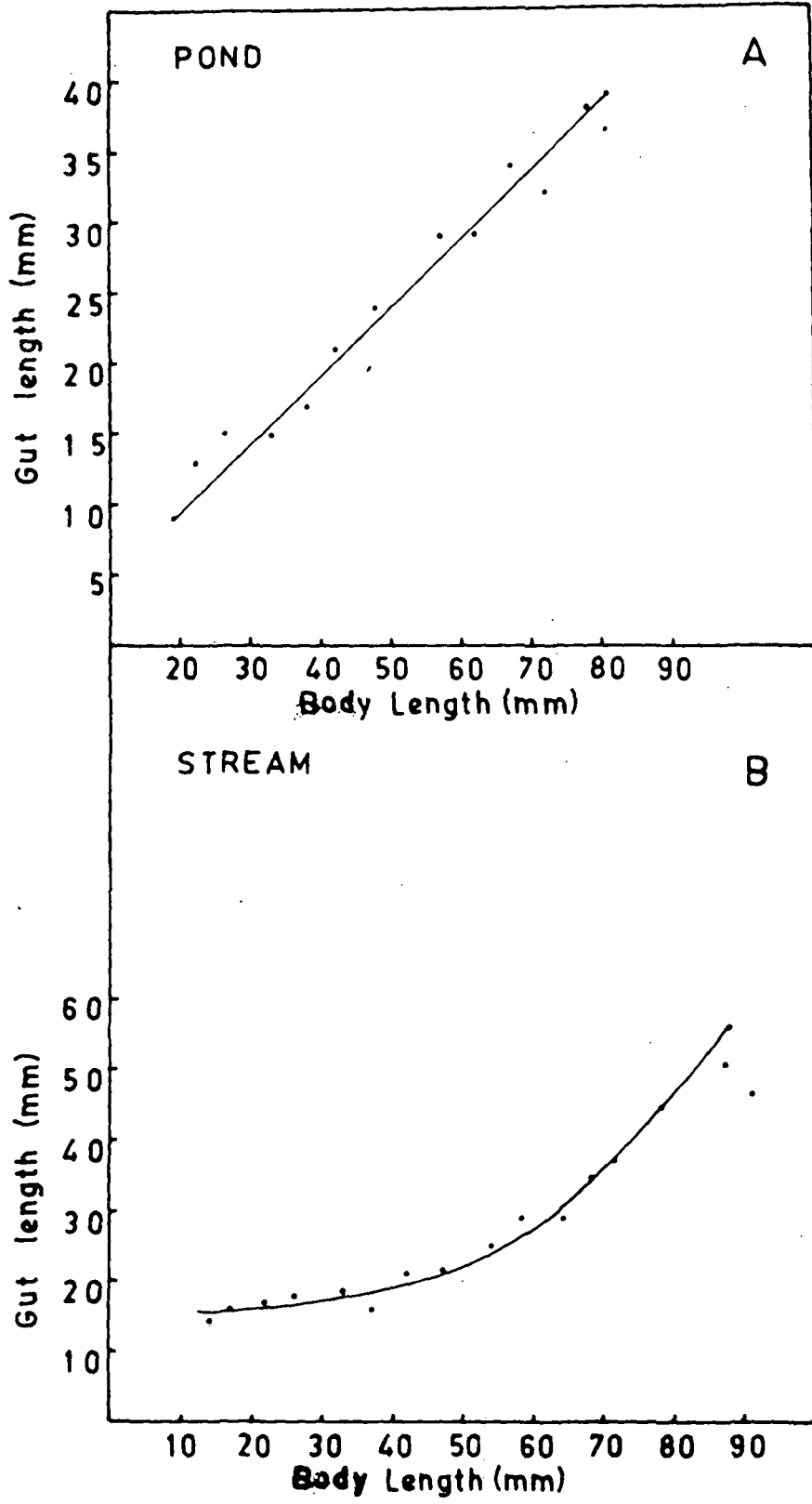


Fig. 36: Relationship between gut and total length of *C. gachua*.

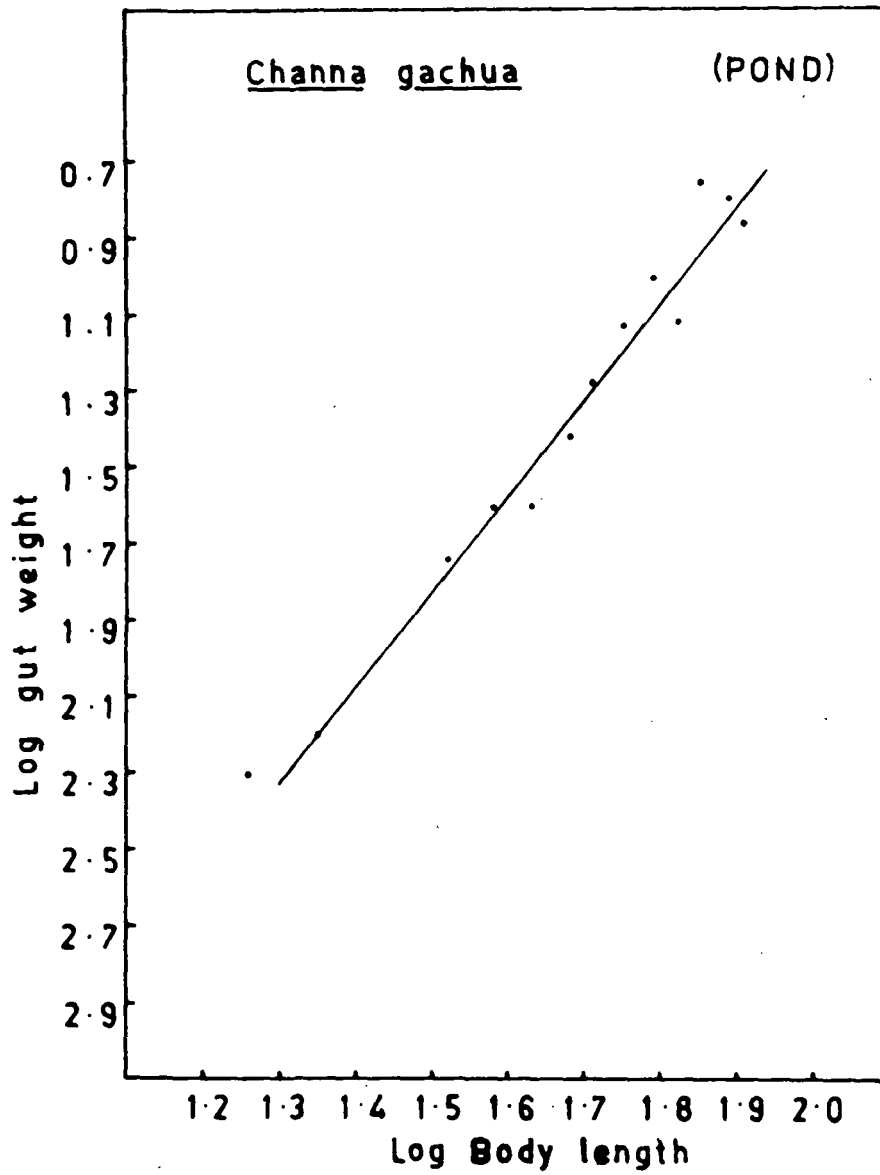


Fig: 37: Log relationship between gut weight and total length.

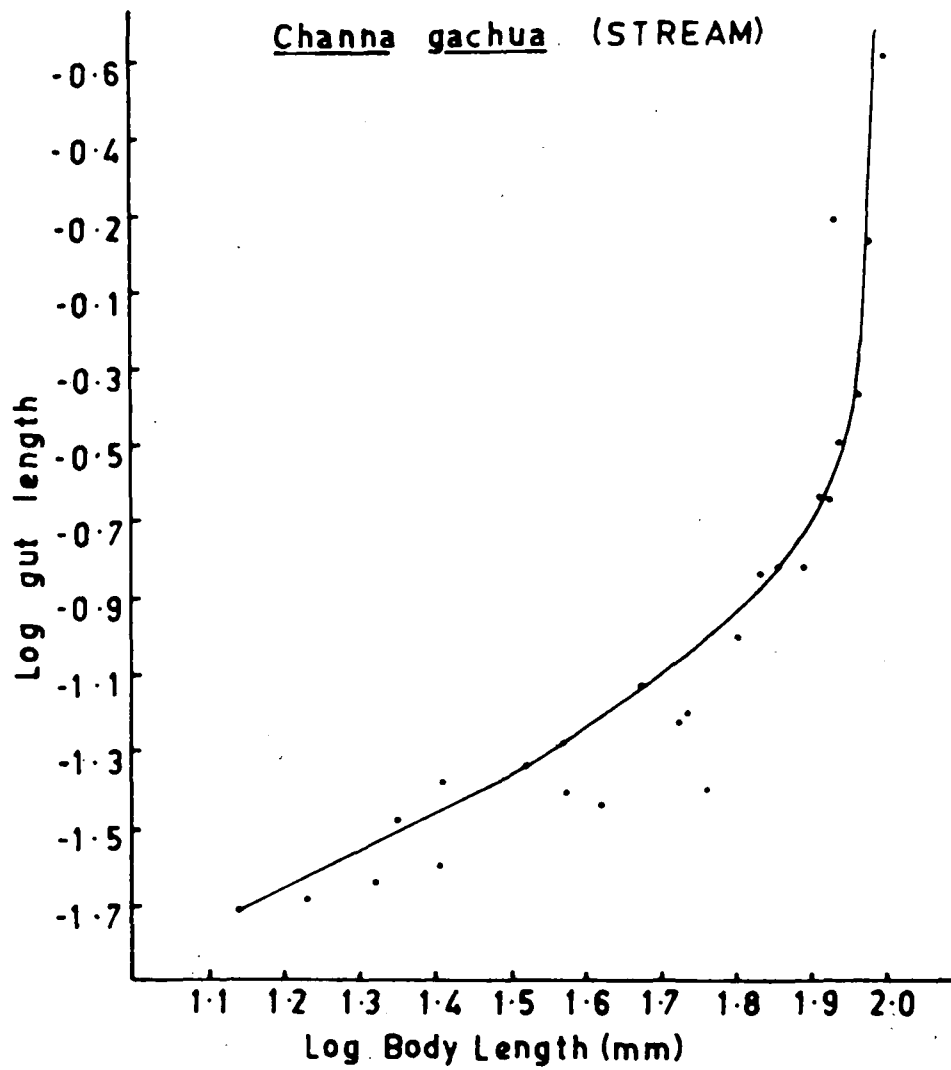


Fig. 38: Log relationship between gut length and total length.

on insect larvae, shrimps and fish fry. However, young of Ophi-
cephalus punctatus prefer phytoplankton (Banerjee, 1974). The
smaller species (O. punctatus and O. gachua) feed mainly on minn-
ows and other small fishes, shrimps, insects and occasionally
molluscs while the larger varieties (O. marulius and O. striatus)
feed mainly on fish, frogs, insects and other live food. All
these reports reveal that murrels are mainly carnivorous, but
the present study indicates that murrels of the highlands mainly
feed on detritus, though occasional presence of zooplankton and
phytoplankton are indicated.

Beumer (1978) stated that there exists a relationship
between the nature of the stomach contents and the feeding str-
ucture, and according to Al-Hussainy (1947) the relative gut
index is also indicative of the diet. Low relative gut index
values are indicative of a carnivorous feeder (Suyehiro, 1941).

However, in the present study, a low relative gut length
has been observed which is indicative of carnivorous nature of
feeding (Suyehiro, 1941), but on the other hand C. gachua was
not found to be purely carnivorous, a large portion of the diet
was composed of detritus. Odum (1968) reported that high R.G.I.
is typical of a detritus feeder. Hence, it can be said that the
detritus feeding habits of Channids in the highlands of Shillong,
unlike the Channids of lower altitudes, might be an adaptation
to higher altitude owing to the absence or poor presence of
animal matter in these water bodies. However, the present resu-
lts supports the view of Nikolskii (1969) that the fish fauna
of high latitudes are usually adapted to eating various types
of food, on account of the high variability of the available

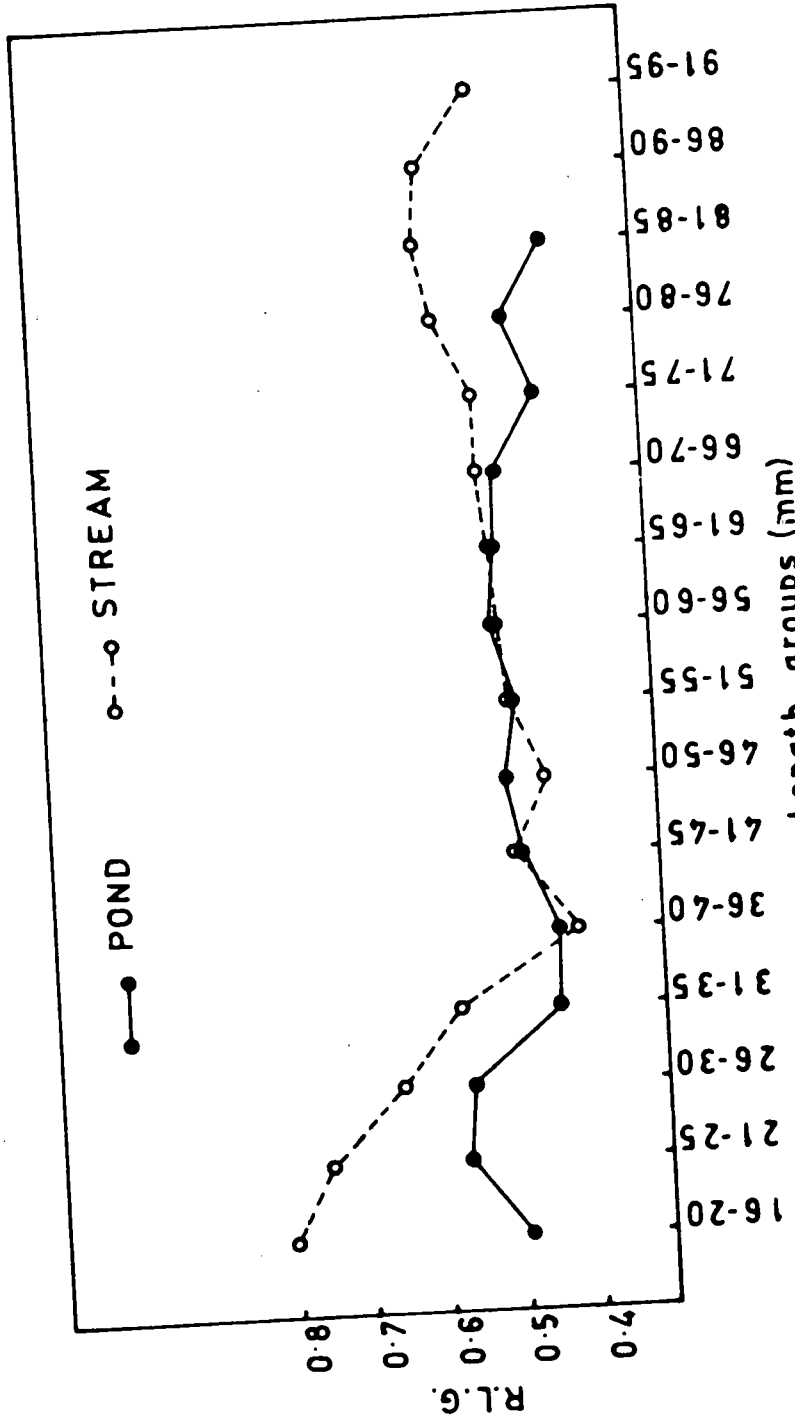
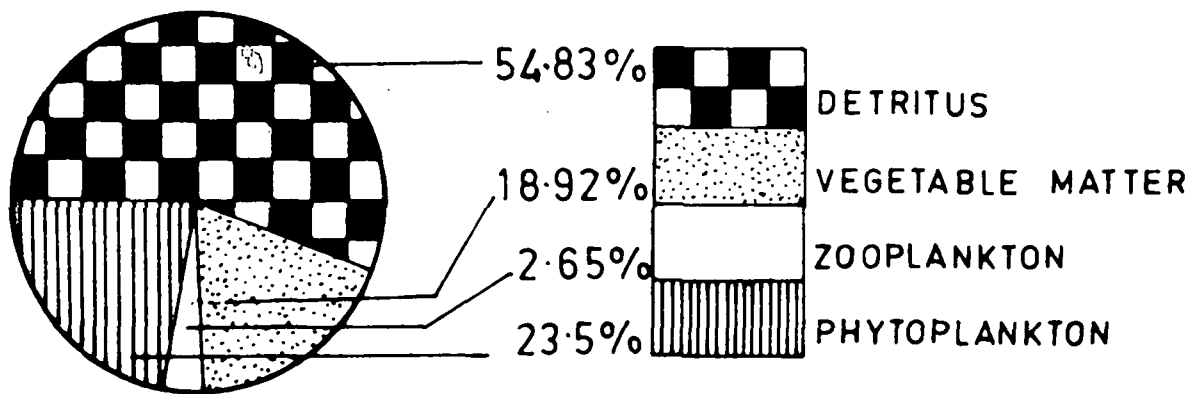
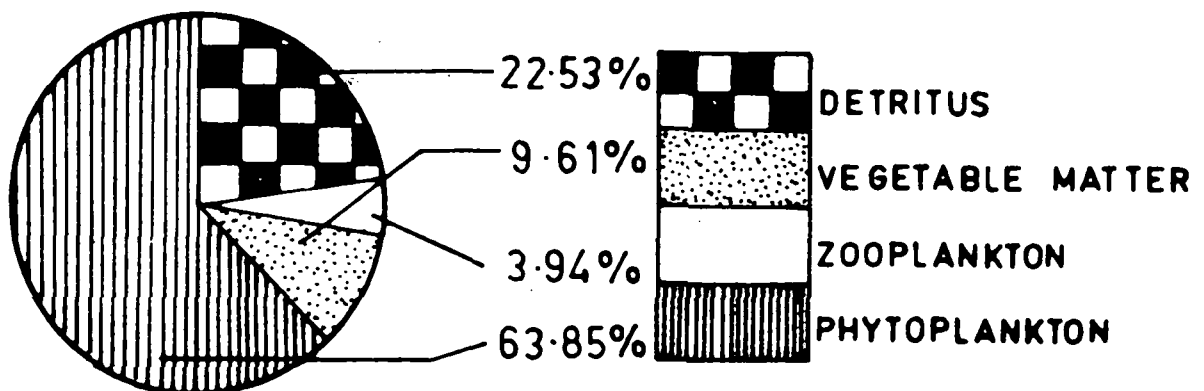


Fig. 39: R.L.G. values of C. gachua at different length groups.



A: Channa punctata



B: Channa stewartii

Fig. 40: Relative importance of the major food items.

food. The range of food organisms may vary greatly from area to area, even as regards to principal food, specially in freshwater conditions. Representative of associations from high altitudes are usually at an advantage when the food base is labile, since they tend to be euryphagous; conversely, those from the lower latitudes are so when the food base is stable.

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 have a knowledge on the structure of lotic and lentic ecosystems and on the biology of air breathing fishes adapted in such systems at higher altitude of the country, coupled with its great economic importance and also because of the fast gaining popularity of culturing air-breathing fishes, the present investigation has been undertaken. The thesis entitled "Studies on some aspects of the Biology and Ecology of Channa gachua (Ham.) and Channa stewartii (Playfair)" embodies the results obtained during the investigation, a summary and conclusion of which are presented below.

The water temperature in both the systems showed a close affinity with the atmospheric temperature. The conductivity

values fluctuated widely without showing any definite oscillation. Further, it has been observed that conductivity and alkalinity showed a somewhat direct relationship in the pond water unlike the stream water where the case was reverse. It has also been noticed that low pH values corresponded with high conductivity values. The pH values always remained below 7.0 or in other words, in the acidic range in both the systems. An inverse relationship has been observed between free CO_2 and pH. Higher pH value during winter and post winter season indicate higher photosynthetic activity than community respiration, which might be due to the availability of sufficient solar radiation resulting from cloudless sky.

The results indicate that the main source of free CO_2 of the water in both the systems seems to be the decomposing as well as respiratory processes of the organisms present in the system. It is also evident that CO_2 concentration of the water controls the pH, bicarbonate and carbonate alkalinity of the water.

The dissolved oxygen concentration were found to vary inversely with the temperature and free CO_2 . However, it may be concluded that oxygen content of these water bodies mainly depended on the following factors :-

- (a) Law of solubility of gaseous exchange;
- (b) Photosynthetic activities;
- (c) Respiration;
- (d) Intensity of illumination; and
- (e) Wind action.

The nutrient condition in both the systems was found to be quite poor. An inverse relationship has been observed between phosphate and dissolved oxygen concentration in both the

systems. 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 the ferric to the ferrous state, releasing phosphate into water. It may be assumed that the main source of nitrates in the systems may be the decomposing organic matter, not the plankton as the former was present in large quantities than the plankton. An inverse relationship has been observed between nitrate and temperature, which suggests that temperature has a profound effect on nitrate concentration in waters. The silicate content of the water was found to vary inversely with free CO_2 . It has also been observed that peaks of diatom population correspond with low levels of silicate in the systems.

In the present study 11 species of Chlorophyceae, 5 of Bacillariophyceae and 2 of Euglenophyceae in the pond and 15 of Chlorophyceae, 7 of Bacillariophyceae and 2 of Euglenophyceae in the stream have been recorded. Among Zooplankton, Rotifera comprised of 4 species in both the systems, whereas Copepoda was represented by 3 and 1 species in the pond and stream respectively. Cladocera was represented by 2 species and interestingly enough it could not be recorded from the pond. The study further reveals that the plankton peaks in freshwater bodies of high altitudes of India are quite comparable with the spring and autumn plankton peaks of the temperate regions.

In both the systems, phytoplankton showed a numerical superiority over the zooplankton. It is also apparent from the present study that certain species of plankton disappeared at certain periods only to reappear later and hence, at no time during the year, there was a total absence of plankton. The plankton productivity varied from season to season in both

the systems and qualitative variation particularly of zooplankton were quite identical.

It can be revealed from the present study that in some groups of plankton, the amplitude of rise and fall in quantity may not be large enough to produce more than minimal change in the total plankton population while in others, the change may be so great that a wave of development of a single group may be sufficient to dominate the whole population. Further, the period of quantitative increase and decrease of the individual may not in general, coincide with the seasonal minima and maxima of the total plankton. It is also clear that the rate of development of a pulse may vary greatly, some species may increase slowly and more or less uniformly to the maximum while others may show a burst of development rising from an apparent absence to a numerical dominance of the whole plankton population within a very short period. An inverse relationship between phyto- and zooplankton has been observed.

It is clear that plankton periodicity has been influenced by temperature and the seasonal variations were observed even amidst a fairly constant pH and oxygen content of the water. In the present study, a high phytoplankton population has been observed at low temperature in the stream, whereas, no such definite relationship could be observed in the pond suggesting that temperature alone is not always a limiting factor for the growth of plankton. Availability of food may be another important factor responsible for plankton growth which in turn depends on other abiotic factors.

It has been observed that whenever free CO_2 was at its minimum, percentage composition of zooplankton were found to be

in higher range, in other words zooplankton fluctuated almost inversely with free CO_2 . Therefore, it can be ascertained that presence of high quantities of free CO_2 have detrimental effect on zooplankton. Diatoms and silicates showed an inverse relationship with each other, owing to the fact that they 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. Apart from this, phosphate also seems to be a limiting factor controlling diatom periodicity.

In the present study, however, no very distinct periodicity in the total plankton could be observed, which might be due to the reason that the physico-chemical factors in freshwater bodies undergo frequent changes partially due to changes in the meteorological factors which in turn influences the plankton periodicity. Hence, it can be concluded that plankton population is directly or indirectly influenced by the seasonal variations in the complexes of abiotic and or biotic factors. It is also clear that the annual quantitative abundance of planktonic populations depends on the succession of appearance and disappearance of its component species.

It may be concluded that no ecosystem is static, which further supports the notion of Nasar (1975) that no one can step into the same ecosystem twice as the ecosystems is dynamic and the abiotic and biotic factors not only fluctuates seasonally and diurnally, but also each and every moment".

The result indicates that there exists an intraspecific difference in regression equations in various morphometric character of C. gachua which may be attributed to diverse ecolo-

gical and environmental conditions prevalent in both the systems. The various meristic counts of C. qachua made during the present study did not show marked intraspecific differences. The results of the biometric study for C. qachua reveal that Eye-diameter becomes smaller in relation to Head length and inter-orbital width as the species grows in length. With regard to C. stewartii and C. punctatus also, the eye diameter becomes progressively smaller in relation to head length and inter-orbital width as the fish grows. But pectoral fins unlike C. qachua do not exhibit any negative allometry in relation to head length.

From the results obtained on length-weight relationship it is evident that there exists an intraspecific variation in the exponential value ("b"). Since the "b" values in C. stewartii and C. punctatus approximates the cube law, but are less than three, thereby showing allometric growth, unlike C. qachua. The present result when compared with the results obtained by others for air-breathing fishes reveal that the "b" values in almost all the species of Channids approximates the cube law, hence, the fishes of this group can be considered as "ideal".

The condition factor of C. qachua at different length groups as well as during different months, has been calculated and fluctuations therein were discussed in relation to maturity and feeding rhythms. The results of condition factor indicates that the "K" value is much higher in smaller fishes than the bigger ones. It is also clear from the study that the limiting factors for "K" value are not only the gonadal maturity and gut contents, but some other environmental factors, also seems to be responsible.

Studies on maturity indicate that both the males and the females mature at the same time and hence the fish has a similar breeding period i.e. June to August with just one spawning season during an annual cycle. The occurrence of ripe specimens is restricted only during June to August which also clearly indicates about the spawning season of the species in this region. This is also supported by the results obtained on the Gn.S.I. of the fishes. It has been observed that 50% individuals (M_{50}) mature at 51.0-55.0 mm length group in both the systems. The Gn.S.I. values showed a tendency to increase with the increase in length. The seasonal peaks in the mean Gn.S.I. values coincided with the peaks in the present occurrence of mature individuals, hence, Gn.S.I. can be used as an index of gonadal development.

The fecundity of C. qachua was observed to range from 160 to 1170 eggs in the specimens of 60.0 to 96.0 mm in length from the pond, whereas it ranged from 243-1523 eggs in the specimens ranging 77.0 to 87.0 mm in length from the stream. Further, the logarithmic relationships between fecundity of C. qachua and its length, body weight and ovary weight were found to be linear. The relative fecundity on an average basis was found to be lower in the stream population than the pond population. Fecundity estimates suggests that C. qachua is not very fecund in comparison to other species which might be due to the fact that the species show parental care.

According to the present study, temperature could be considered as a limiting factor affecting fecundity as throughout the study period the fish in both the systems were found to be concentrated along the edge of the banks among the marginal

vegetation. This might be due to low water temperature resulting in overcrowding which led to a food shortage which in turn resulted in low fecundity.

Based on numerical and frequency of occurrence methods, the diet composition of C. gachua can be divided into the following four broad categories : (a) Detritus (b) Vegetable matter (c) Phytoplankton and (d) Zooplankton. The low feeding intensity coincided with the spawning season and such a case 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 C. gachua is higher in the smaller length groups than the higher length groups. The present study reveals that the detritus feeding habits of Chanids in the highlands of Shillong unlike the lower altitudes might be an adaptation of the species to higher altitude owing to the relatively poor presence of animal matter in these water bodies.

From the results obtained during the present investigation and the breeding discussions, 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 especially trophic interrelationships which supports the view of Weatherley, 1972. Temperature of the water, therefore, is of enormous significance in the life of a fish. Fishes being poikilotherms, are more dependent on the temperature of their habitat and their

surrounding water than homoithermal animals. According to Nikol-sky (1963), in majority of fishes, the body temperature differs from that of the surrounding water by only 0.5-1°C and 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 a 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 particularly stream fishes it is an important one which limits both broad 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 Channids. If the total amplitude of the temperature at which a species of 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 condition. The timing and extent of temperature changes are also important, as they often control breeding. Hence, the optimal temperature to which a fish adapt can also be considered a species characteristics.

The present study further corroborates the view of Weatherley (1972) that fishes of higher latitudes have evolved a metabolic type which enables them to feed successfully at very low temperatures unlike the fishes of lower latitudes. Within the 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 life 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 very strong.

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, Pütter (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 by rivers, particularly during the flood period, ensures a rich development of the various organisms which form the food of fishes in the estuarine region.

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, processing of mineral ores, and so on, has become particularly important to fishes. The effects of other dissolved compounds which enter the water, both organic and inorganic, are also rather variable in fact the majority of them effect primarily the course of respiration.

Like all other animals, fishes cannot live without the access of oxygen to the organism through its blood, which ensures the 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. Only a few species, living in waters in which for various reasons, there frequently develops an oxygen deficit, are adapted to breathing atmospheric air. In the Murrels (*Ophicephalidae*), the epibranchial organ is represented by paired outgrowths in the pharynx. The walls of these outgrowths are very rich in blood capillaries. According to Nikolsky (1963), the Snake-head *Ophicephalus striatus* Bl. dies from lack of oxygen in 30-197 minutes when prevented from reaching the surface. Apparently young snake heads die sooner from suffocation than older ones. The majority of fishes which are adapted to breathing atmospheric air are inhabitants of subtropical and tropical latitudes, and only few live in the waters of temperate and high latitudes.

Apart from oxygen, other gases are also of considerable importance to fishes. It is well known that CO_2 even in relatively small doses causes the death of fishes which might be the reason of poor population of the fish (Channids) in these systems as the CO_2 (free) concentration was quite high than the water bodies of lower latitudes in general. The mechanism of the action of carbon-dioxide upon fish like other animals consists of the reduction of the bloods capacity to absorb oxygen. The amount of CO_2 in the water is directly proportional to the pH, changes in which also have a severe effect upon fishes. As the acidity of the water increases, the rate of metabolism falls, although the respiratory rhythm increases in more acid water compared to either neutral or alkaline.

Fishes are adapted to moving through both still and flowing water and the body shape, fin structure and certain other features in the structure of the fish are connected with this. Fishes of the family Channidae are snake-shaped i.e. the body is much elongated, transverse section almost circular and are usually inhabitants of weeds.

Forms belonging to the same species, but living in flowing and stagnant waters, differ in their adaptation to currents. River currents affect the fish organism not only mechanically, but through the medium of other factors. 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 plenty of oxygen and conversely fishes which inhabit slowly flowing a stagnant waters are usually adapted to a different oxygen regime and can withstand an oxygen deficit better.

Not all the fishes of rapid water are swimmers, many maintain themselves close to the bottom or in shelter under and behind stones (Hynes, 1970). In the present study too, the Channa species from the stream were found to maintain themselves close to the bottom and in sheltered areas under stones and marginal vegetation. These fishes living on the bottom or stony substrata are dark coloured and more usually (boldly) mottled so that they blend into the background. Hynes (1970) reported that fishes can exert some control over their colour, becoming paler on pale coloured backgrounds and no stream fish can match the spectacular performance of the plaice, which can adjust fairly rapidly.

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 and the length of the feeding season in turn is affected by the onset of unfavourable conditions. The food supply is, therefore, governed by the conditions for obtaining and utilising the food and it is also dependent on abiotic conditions during the feeding period, such as temperature, illumination, winds and changes in the size of feeding area.

The ichthyo-fauna of high altitudes are usually adapted to eating various types of food, on account of the high variability of the available food. The range of food organisms may vary greatly from area to area, even as regards principal food, especially in freshwater conditions (Nikolsky, 1969).

LITERATURE CITED

L I T E R A T U R E C I T E D

- Adams, S.M. 1976. Feeding ecology of Eelgrass fish communities. Trans. American Fish. Soc. 105(4) : 514-519.
- Alderdice, D.F. 1972. Factor combinations: Responses of marine poikilotherms to environmental factors acting in concert. In: Marine Ecology. Vol. I, Environmental factors, part 3. Ed. O.Kinne. Willey (Interscience), New York, U.S.A.
- Al-Hussainy, A.H. 1947. The anatomy and histology of the alimentary tract of the plankton feeder, Atherina forskali Rupp. J. Morph. 80 : 251-286.
- Al-Hussainy, A.H. 1949. On the functional morphology of the alimentary tract of some fishes in relation to differences in their feeding habits. Quart. J. Micro Sci. 90(2) : 190-240.
- Alikunhi, K.H. 1953. Notes on the Bionomics, Breeding and Growth of the murrel, Ophiocephalus striatus Bloch. Proc. Indian Acad. Sci. 38 : 10-20.
- Alikunhi, K.H. 1957. Fish culture in India. Farm. Bull. 20, I.C.A.R., New Delhi.
- Alikunhi, K.H., N. Choudhary and V. Ramachandra.. 1955. On the mortality of carp fry in nursery ponds and role of plankton on their survival and growth. Indian J. Fish. 2 : 257-313.

- *Allegeier, R.J., W.H. Peterson, C. Juday and E.A. Bridge. 1932. The anaerobic fermentation of lake deposits. Int. Rev. d. ges. Hydrobiol. u. Hydrogi. 26 : 444-461.
- Allen, K.R. 1938. Some observations on the biology of the trout (Salmo trutta) in Windermere. J. Anim. Ecol. 7 : 333-349.
- Allen, O.N. 1930. Methods in quantitative research on marine microplankton. Bull. Scripps. Inst. Oceanogr. Tech. Sci. 2 : 319-329.
- American Public Health Association. 1965. Standard methods for the determination of water and waste water (12th edition), New York.
- *Anderson, H.H. 1889. Notes on Indian rotifers. J. Asiat. Soc. Bengal, Calcutta. 58 : 345-348.
- Anees, M.A. 1978. Hepatic pathology in a fresh water teleost Channa punctatus (Bloch) exposed to sublethal and chronic levels of 3 organophosphorus insecticides. Bull. Environ. Contam. Toxicol. 19(5) : 524.
- Anon, 1962. The wealth of India. Raw materials. Fish and Fisheries. 4 : 1-132.
- Arora, G.L. 1931. Fauna of Lahore. 2. Entomostraca (water fleas) of Lahore. Bull. Dept. Zool. Punjab Univ. 1 : 79.
- Arora, H.C. 1962. Studies on Indian Rotifera - Part I. J. Zool. Soc. India. 14 : 33-44.
- Arora, H.C. 1963a. Studies on Indian Rotifera. Part IV. On some species of sessile Rotifera from India (with a description of a new species of Genus Sinantherina). Arch. Hydrobiol. 59 : 502-507.
- Arora, H.C. 1963b. Studies on Indian Rotifera. Part II. J. Zool. Soc. India. 15 : 112-121.
- Arora, H.C. 1965. Studies on Indian Rotifera. Part VI. On a collection of Rotifera from Nagpur, India with four new species and a new variety. Hydrobiologia. 26 : 444-456.
- Arora, H.C. 1966a. Studies on Indian Rotifera. Part V. Arch. Hydrobiol. 61 : 482-493.
- Arora, H.C. 1966b. Cyclomorphosis (Four variations) in some species of Indian planktonic Rotatoria. Int. Rev. ges. Hydrobiol. 51 : 623-632.
- Atkins, W.R.G. 1926. Seasonal changes in the silica content of natural waters in relation to the phytoplankton. J. Mar. Biol. Ass. U.K. 14 : 89-99.
- Atkins, W.R.G. and G.T. Harris. 1924. Seasonal changes in the water and helioplankton of freshwater ponds. Sci. Proc. Roy. Dublin Soc. 18 : 1-21.
- Bagenal, T.B. 1963. The fecundity of Witches in the Firth of Clyde. J. Mar. Biol. Ass. U.K. 43 : 401-407.
- Bagenal, T.B. 1967. A short review of fish fecundity. In: Biological basis of freshwater fish production. Ed. S.O. Gerking. Oxford. pp. 89-111.

- Bagenal, T.B. 1969. The relationship between food supply and fecundity in brown trout, Salmo trutta. J. Fish. Biol. 1 : 167-182.
- Bagenal, T.B. 1971. The interrelation of the size of fish eggs, the date of spawning and the production cycle. J. Fish. Biol. 3 : 207-219.
- Bagenal, T.B. 1973. Fish fecundity and its relations with stock and recruitment. Rapp. P.V. Reun. Com. perm. int. Explor. Mer. 164 : 186-198.
- Bagenal, T.B. 1978. Aspects of Fish Fecundity. In: Ecology of freshwater fish production. Ed. S.D. Gerking. Blackwell Scientific Publ. Oxford. pp. 75-101.
- *Baird, W. 1859. Description of some new recent Entomostraca from Nagpur collected by the Rev. S. Hislop. Proc. Zool. Soc. London. 39 : 231.
- Banerjee, S.R. 1974. Hypophysation and life history of Channa punctata (Bloch). J. Inland. Fish. Soc. India. 6 : 62-73.
- Bardach, J.E. 1978. The growing science of Aquaculture. In: Ecology of Freshwater Fish Production. Ed. S.D. Gerking. Blackwell Sci. Publ., Oxford. pp. 424-426.
- Barlow, G.W. 1961. Causes and significance of morphological variation in fishes. Syst. Zool. 10 : 105-117.
- Bayagbona, E.O. 1963. Biometric study of two species of Pseudotalithus from the Lagos trawling ground. Bulletin de Ifan. T. XXV. Ser. A.1.
- Bashirullah, A.K.N. 1975. Biology of Lutjanus griseus (L.) of the Cubagua Island, Venezuela. I. Length-weight, Body, Length gut, Length relationships and condition factor. Biol. Inst. Oceanogr. Univ. Oriente. 14(1) : 101-107.
- *Ber, K.M. 1854. History of fishing in Russia and the adjacent seas. Uch. Zap. Akad. Nauk. 2. No. 4.
- Bernice, R. 1970. Studies on the biology of Streptocephalus. Ph.D. Thesis, University of Madras.
- Bernice, R. 1971a. The succinic dehydrogenase activity of Streptocephalus dichotomus Baird. Hydrobiol. 38(3-4) : 463-471.
- Bernice, R. 1971b. Food, feeding and digestion in Streptocephalus dichotomus Baird. (Crustacea : Anostraca). Hydrobiol. 38(3-4) : 507-520.
- Bernice, R. 1972a. Ecological studies on Streptocephalus dichotomus Baird. Hydrobiologia. 39(2) : 217-240.
- Bernice, R. 1972b. Biochemical composition of Streptocephalus dichotomus Baird and Branchinella kuqenumoensis (Ishikawa) (Crustacea : Anostraca). Hydrobiol. 39(2) : 155-164.
- Bernice, R. and R.T. Srinivasagam. 1967. On the succinic dehydrogenase activity of the fairy shrimp, Branchinella kuqenumoensis (Ishikawa). Curr. Sci. 36(4):103-104.

- Beumer, J.P. 1978. Feeding ecology of four fishes : from a mangrove creek in North Queensland, Australia. *J. Fish. Biol.* 12 : 475-490.
- Beverton, R.J.H. and S.J. Holt. 1957. On the dynamics of exploited fish populations. *Fish. Invest. London. Sci. II.* 19 : 533.
- *Bhatia, B.L. 1936. Fauna of British India. Protozoa : Chilophora. Taylor & Francis, London. 23 : 493.
- Bhatnagar, G.K. and Karamchandani, S.J. 1970. Food and feeding habits of Labeo fimbriatus (Bloch) in river Narbada near Hoshangabad (M.P.). *J. Inland Fish. Soc. India*, 2 : 30-50.
- Bhattacharya, R. 1946. On the life history of Ophicephalus striatus Bloch. *Proc. 33rd Ind. Sci. Congr. Part 3.*
- Bhattacharya, S., D. Mukherjee and S. Sen. 1979. Role of synthetic mammalian thyrotropin releasing hormone on fish thyroid peroxidase activity. *Indian. J. Exp. Biol.* 17(10) : 1041-1043.
- Bhimachar, B.S. and P.C. George. 1952. Observations on the food and feeding of the Indian mackerel, Rastrelliger kanagurta (Cuvier). *Proc. Indian Acad. Sci. (B)*. 36 : 105-108.
- *Birge, E.A. and C. Juday. 1911. The inland lakes of Wisconsin. The dissolved gases and their biological significance. *Bull. Wis. Geol. Nat. Hist. Surv.* 22 : 259.
- Biswas, S. 1964. A new species of the Cladoceran genus Latona straus 1820 from Rajasthan, India. *Proc. Zool. Soc. Calcutta.* 17 : 149-152.
- *Bleeker, P. 1853. Nalezingen op de Ichthyologische fauna Van Bengalen en Hindustan. *Verh. batavia Genoot.* 25:1-164.
- *Bloch, M.E. 1785. *Naturgeschichte der ausländischer Fische*, Berlin, 9 parts in 2 and atlas (3 vols.).
- Blum, J.L. 1956. The ecology of River algae. *Bot. Rev.* 22(5) : 291-341.
- *Blyth, E. 1860. The Cartiliginous fishes of lower Bengal. *J. Asiat. Soc.*, 29 : 35-45.
- Bose, K.C. and A.K. Sinha. 1979. Histopathology of the stomach wall of the fish Channa gachua (Ham.) (Channidae). Attributable to the digenetic hematode Generchopsis goppo (Ozaki) (Hemiuridae). *Curr. Sci. India.* 48(16) : 474.
- Brehm, V. 1936. Yale North India Expedition. Mem. Connecticut Acad. Ants. Sci. 10 : 283-297.
- Brehm, V. 1950. Freshwater Fauna of India - Part II. *Rec. Ind. Mus.*, Calcutta. 48 : 9-28.
- Brett, J.R. 1979. Environmental factors and growth. In fish physiology, Vol. 8. Eds. W.S. Hoar & D.J. Randall. Academic Press, New York, U.S.A.

- Butcher, R.W. 1964. The biological detection of pollution. J. Inst. Sew. Purif. 2 : 92.
- Carlander, D.K. 1970. Handbook of Freshwater Fishery Biology. Vol. I. The Iowa State Univ. Press. Amer. Iowa.
- Carl, G.C. 1953. Limnology of Cowcha lake, British Columbia. J. Fish. Res. Bd. Canada. 9 : 417-449.
- Carpenter, E.J. 1971. Annual phytoplankton cycle of the Carps Fear River Estuary, N.C. Ches. Sci. 12 : 95-104.
- Carpenter, P.L. 1941. Bacterial counts in deep deposits of Trout lake, Wisconsin. Symp. Hydrobiol., Univ. Wis. Press. 393-394.
- Causton, F.G. 1948. Pollution of rivers. S.Afr. med. 7. 22: 475.
- Chacko, P.I. and G.K. Kuriyan. 1948. Survey of the fisheries of Tungabhadra river. Proc. Indian Acad. Sci. 28(5) : 165-176.
- Chacko, P.I. and J.B. Krishnamurthy. 1954. On the plankton of three freshwater fish ponds in Madras City, India. Symp. Mar. Freshwater Plank. Indo-Pacific. Fish. Count. (UNESCO) : 103-107.
- Chakraborty, R.D., P. Roy and S.P. Singh. 1959. A quantitative study of the plankton and the physico-chemical conditions of the river Jamna at Allahabad in 1954-55. Indian J. Fish. 6(1) : 186-203.
- Chaturvedi, M.C. 1976. Water second India studies. Macmillan Co. India Ltd. 94.
- Chitra, T. and J.V.R. Rao. 1979. Observations on some haematological factors in Channa punctatus (Bloch) and Clarias batrachus (Linnaeus). Comp. Physiol. Ecol. 4(3) : 138-139.
- Clark, F.N. 1934. Maturity of the Californian sardine (Sardina casrulea) determined by ova diameter measurements. Calif. Fish and Game Fish. Bull. 42 : 49.
- Cole, G.A. 1979. Text book of Limnology. The E.V. Mosby Co., Toronto. London. 426 pp.
- Conover, S.M. 1956. Oceanography of long island sound, 1952-54. Part IV. Phytoplankton. Bull. Bingham Ocean. Coll. 15 : 62-112.
- Corbin, P.G. 1948. On the seasonal abundance of young fish. IX. The year 1947. J. Mar. biol. U.K. 27 : 718.
- Corbin, P.G. 1952. The seasonal abundance of young fish IX. The year 1949. J. mar. biol. U.K. 30 : 271.
- *Cuvier, G. and A. Valenciennes. 1828-49. Historic naturelle des poissons. 22 Vols. Paris, 653 plates.
- Dalela, R.C., M.C. Bhatnagar and S.R. Verma. 1978. Histochemical studies on the effect of regor and thiodon on activity of acid phosphatase in liver, muscles and kidney of Channa gachua. India. J. Exp. Biol. 16(10): 1095-1096.

- *Das, B.K. 1927. The bionomics of certain air breathing fishes of India together with an account of the development of their air-breathing organs. Phil. Trans. Roy. Soc. Lond. 216 : 183-219.
- Das, S.C. and G. Mitra. 1958. Length-weight relationship of Ophicephalus punctatus Bloch. Sci. & Cult. 24 : 178-179.
- Das, S.M. 1961. Hydrogen-ion concentration, plankton and fish in freshwater Eutrophic lakes of India. Nature, London. 191 (4787) : 511-512.
- Das, S.M. 1970. Organic production in Kashmir lakes, IHF (PF) Report, Symposium in Poland. 1 : 67-75.
- Das, S.M. and A.K. Srivastava. 1979. On the relative length of gut (RLG) in some food fishes of Uttar Pradesh with changes from fingerling to adult stage. J. Inland. Fish. Soc. India. 11(1) : 6-11.
- Das, S.M., H.S. Daftari, S. Akhtar, S. Choudhuri and N. Ahmad. 1969. Studies on organic production in high altitude lakes of India. Part I. The general ecology and zooplankton of Kashmir lakes. Kashmir Sci. 6 : 12-22.
- Das, S.M. and J.C. Upadhyay. 1979. Studies on qualitative and quantitative fluctuations of plankton in two Kumaon lakes, Nainital and Bhimtal (India). Acta. Hydrobio. 21(1) : 9-17.
- Das, S.M. and S. Akhtar. 1976. A survey of rotifers of Kashmir with new records of Palaeartic genera and species. Rotifer News. 3 : 9-12.
- Das, S.M., S. Choudhury, N. Ahmad, S. Akhtar, S. Peer and M. Rashid. 1976. Studies on organic production in high altitude lakes of India. Part 2. The zooplankton, phytoplankton and pedon of high altitude of Kashmir lakes, Kounsarnag and Alpathar. Kashmir Sci. 7 : 119-132.
- Das, S.M. and S. Nath. 1965. The comparative anatomy of the alimentary tract and its modifications in relation to the food and feeding habits in some fishes of Jammu Province (India). Ichthyologica. 4(1-2) : 63-78.
- Das, S.M. and V.K. Srivastava. 1956a. Quantitative studies on freshwater plankton. II. Correlations between plankton and hydrological factors. Proc. Nat. Acad. Sci. India. B 26 : 243-254.
- Das, S.M. and V.K. Srivastava. 1956b. Some new observations on plankton from freshwater ponds and tanks of Lucknow. Sci. & Cult. 21(8) : 466-467.
- Das, S.M. and V.K. Srivastava. 1959. Studies on freshwater plankton. III. Qualitative composition and seasonal fluctuations in plankton components. Proc. Nat. Acad. Sci. India 29 : 174-189.
- Datta Munshi, J.S. 1962. On the accessory respiration organs of Ophiocephalus punctatus (Bloch) and O. striatus (Bl.). J. Linn. Soc. Lond. (Zoo). 44 : 616-626.

- Datta Munshi, J.S. 1976. Gross and fine structure of the respiration organs of air breathing fishes. In: Respiration of Amphibious vertebrates. Ed. G.M. Hughes, Academic Press, London. pp. 73-104.
- Datta Munshi, J.S. 1980. The structure and function of the respiratory organs of air breathing fishes of India. Presidential address, Sec. Zool. Entomol. Fish. 67 Indian Science Congress, pp. 31-70.
- *Day, F. 1878. The fishes of India: Being a Natural History of the Fishes known to inhabit the Seas and Freshwaters of India, Burma and Ceylon. Reproduced in 1958. William Dawson and Sons, London. 778 pp.
- *Day, F. 1889. The fauna of British India, including Ceylon and Burma. Fishes. Vols. 1 & 2 : 548 & 509 pp.
- *De, K.C. 1910. Reports on the fisheries of Bengal and Assam.
- Deb, M. 1972. Two new species of Stenocypris Sars, 1889 (Crustacea : Ostracoda : Cypridae) from India. J. Zool. Soc. India, 24(1)2 : 91-95.
- Deb, M. and S.A.K. Nasar. 1977. Cypricercus munshii sp. nov. (Crustacea : Ostracoda) from India. Zool. Beiterg. 23 : 455-457.
- Dehadrai, P.V. and S.D. Tripathi. 1976. Environment and Ecology of freshwater air-breathing teleosts. In: Respiration of Amphibious vertebrates. Ed. G.M. Hughes. Academic Press, London. pp. 39-72.
- Dehadrai, P.V., S.R. Banerjee, N.K. Thakur and N.K. Das. 1973. Sexual dimorphism in certain air-breathing teleosts. J. Inland Fish. Soc. India. 5 : 71-77.
- Deraniyagala, P.E.P. 1929. The Labyrinthici of Ceylon. Ceylon J. Sci. 15(2) : 79-111.
- Desai, V.R. 1970. Studies on the fishery and biology of Tor tor (Hamilton) from river Narmada. I. Food and feeding habits. J. Inland Fish. Soc. India. 2 : 101-112.
- Desikachary, T.V. 1959. Cyanophyta. Indian Council of Agricultural Research Monographs on Algae : 686.
- DeSilva, S.S. 1973. Food and feeding habits of the herring Clupea harengus and the sprat C. sprattus in inshore waters of the west coast of Scotland. Mar. Biol. 20 : 282-290.
- De Witt, H.H. 1960. A contribution to the ichthyology of Nepal. Stanford. Ichth. Bull. 7(4) : 63-88.
- Dhanapathi, M.V.S.S.S. 1973. On the occurrence of the rare rotifer Rotaria neptunia (Ehrenberg) in India. Curr. Sci. 42 : 770.
- Dhanapathi, M.V.S.S.S. 1974. Rotifers from Andhra Pradesh, India. I. Hydrobiologia. 45 : 357-372.
- Dhanapathi, M.V.S.S.S. 1975. Rotifers from Andhra Pradesh, India. J. Linn. Soc. (Zool.). 57 : 85-94.
- Dhanapathi, M.V.S.S.S. 1976a. Rotifers from Andhra Pradesh, India. III. Family Lecanidae including two new species. Hydrobiologia. 48 : 9-16.

- Dhanapathi, M.V.S.S.S. 1976b. A new lecanid rotifer from India. *Hydrobiologie*. 50 : 191-192.
- Dhanapathi, M.V.S.S.S. 1978. New species of rotifer from India belonging to the family Brachionidae. *J. Linn. Soc. (Zool)*. 62 : 305-308.
- *Donner, J. 1949. Horabella brehmi nov. gen. sp. eine neue Rader-tier aus Indien. *Hydrobiologia*. 2 : 304-328.
- Dubale, M.S. 1955. Paucity of oxygen in the medium as a factor in the evolution of air-breathing habit among teleosts. *J. Univ. Baroda*. 4 : 63.
- Dubale, M.S. 1959. A comparative study of the oxygen carrying capacity of the blood in water and air-breathing teleosts. *J. Anim. Morph. Physiol*. 6 : 48-54.
- Dutta, S. and P.B. Reddy. 1974. On the head scales of Channa sp. (Fishes : Channidae). *Sci. Cult.* 41 : 529-531.
- Dutt, S. and P.B. Reddy. 1978. On the snake head fishes of Andhra Pradesh. *Mem. Soc. Zool. Gunther I* : 103-108.
- Eddy, S. 1934. A study of freshwater plankton communities. *Biol. Monogr*. 12 : 1-93.
- *Edmondson, W.T. and G.E. Hutchinson. 1934. Report on Rotataria, Article IX. Yale North India Expedition. *Mem. Conn. Acad. Arts. Sci.* 10 : 153-186.
- *Einsele, W. 1936. Über die Beziehungen des Eisenkreislaufs zum Phosphat-kreislauf in eutrophen. *Arch. Hydrobiol.* 29 : 664-686.
- Elton, C.S. 1927. *Animal Ecology*. Sidgwick and Jackson, London.
- *Fage, L. 1958. Croissance, races, migrations. *Traite de zoologie de p.p. Grosse*, Paris, Masson et Cie. Edit. 73 : 1835-1849.
- *Fage, L. and A. Veillet. 1938. Sur quelque problèmes biologique lies a l Etude de la Croissance de poissons. *Cons. Perm. Internat. Pour. L'Expl. de la Mer*. 108 : 46-48.
- Farran, G.P. 1938. On the size and number of ova of Irish herring. *J. cons. int. Explor. Mer*. 13 : 91-100.
- Fritsch, F.E. 1907. A general consideration of the subaerial and freshwater algal flora of Ceylon. A contribution to the study of tropical ecology. Part I. Subaerial algae of the inland freshwaters. *Proc. Roy. Soc.* 129 : 197-254.
- Fritsch, F.E. 1931. Some aspects of the ecology of freshwater algae, with special reference to static waters. *Ecology*. 19 : 235-272.
- Fry, F.E.J. 1947. Effects of the environment on animal activity. *Univ. Toronto, Stud. Biol.* 55. *Pub. Ont. Fish. Res. Lab.* 68 : 62 pp.
- Fry, F.E.J. 1957. The aquatic respiration of fish. *The Physiology of Fishes*. Vol. I. Metabolism (M.E. Brown, ed.), Academic Press, New York. 1-63.

- Fry, F.E.J. 1971. The effect of environmental factors on the physiology of fish. In: Fish Physiology, VI (W.S. Hoar and D.J. Randall, eds.): Academic Press, New York. 1-98.
- Fry, F.E.J. 1976. Comments. J. Fish. Res. Bd. Canada. 33:332-335.
- Fryer, G. and T.D. Isles. 1972. The Cichlid fishes of the Great Lakes of Africa. Oliver & Boyd, London.
- Gambryar, M.E. 1963. The role of biological processes in the present oxygen cycle of Lake Senen. Izvest. Akad. Nauk. Armynsk. S.S.R. Biol. Nauk. 16 : 7-16.
- Ganapati, S.V. 1940. The ecology of the temple tank containing a permanent bloom of Microcystis aeruginosa (Kutz.) Henfr. J. Bombay. Nat. Hist. Soc. 42(1) : 65-77.
- Ganapati, S.V. 1941. Studies on the chemistry and biology of ponds in the Madras City. J. Madras Univ. 13: 55-69.
- Ganapati, S.V. 1943. An ecological study of a garden pond containing abundant zooplankton. Proc. Ind. Acad. Sci. 17 : 41-58.
- Ganapati, S.V. 1949. The hydrobiology of three summer pools in the rocky stream bed at Mettur Dam with special reference to certain abnormal congregation of fish. J. Zool. Soc. India. 1 : 44-48.
- Ganapati, S.V. 1955. Diurnal variations in dissolved gases, hydrogen-ion concentration and some of the important dissolved substances of biological significance in three temporary rock pools in stream bed at Mettur dam. Hydrobiologia. 7 : 285-303.
- Ganapati, S.V. 1960. Ecology of tropical waters. Proc. Symp. Algol. New Delhi. 200-218.
- Ganapati, S.V. 1963. An ecological study of a garden pond containing abundant zooplankton. Proc. Indian Acad. Sci. 17 : 51-58.
- Ganapati, S.V. and A. Sreenivasan. 1970. Energy flow in natural aquatic ecosystems in India. Arch. Hydrobiol. 66 : 458-498.
- Ganguly, D.N., S.P. Sarkar and B. Mitra. 1963. On the biology of Ophiocephalus stewartii Playfair. Proc. Zool. Soc. 16(2) : 195-200.
- Garg, V.K. 1978. Site and rate of sugar and amino acid transport in intestine and pyloric caeca of teleost fishes. Indian J. Exp. Biol. 16(10) : 1095-1096.
- Garg, V.K. and K.V. Sastry. 1976. Intestinal transport of fructose and glycine in Ophiocephalus punctatus. Acta. Physiol. Acad. Sci. Hungary. 48(1) : 135.
- *Garmer, J.H., F.M. Brown and M. Lovett. 1936. Chemical and biological survey of the river Holme. Rep. W. Riding Riv. Bd.
- Gaufin, A.R. and C.M. Tarzwell. 1956. Aquatic invertebrates as indicators of organic pollution in Lythe Creek. Sewage and Indust. Wastes. 28 : 906.

- George, M.G. 1961. Observations on the rotifers from shallow ponds in Delhi. *Curr. Sci.* 30 : 268-269.
- George, M.G. 1961b. Diurnal variations in two shallow ponds in Delhi, India. *Hydrobiologia.* 18 : 265-273.
- George, M.G. 1966a. Comparative plankton ecology of five fish tanks in Delhi, India. *Hydrobiologia.* 27(1-2):81-108.
- George, M.G. 1966b. Cyclomorphosis in a planktonic rotifer Keratella tropica apstein. *Curr. Sci.* 35 : 67-68.
- Gill, T.S. and S.S. Khanna. 1976. Effect of glucagon on the principal insects of a freshwater fish, Channa punctatus (Bloch). *Acta. Anatomica.* 95 : 93.
- Goel, K.A. and V. Garg. 1980. Histopathological changes produced in the liver and kidney of Channa punctatus after chronic exposure to 2,3,4-triaminoazobenzene. *Bull. Environ. Contam. & Toxicol.* 25(2) : 330-334.
- Gonzalves, E.A. and D.B. Joshi. 1946. Freshwater algae near Bombay. I. The seasonal succession of the algae in a tank at Bandra. *J. Bombay nat. Hist. Soc.* 46(1) :: 154-176.
- Gould, S.J. 1966. Allometry and size in ontogeny and phylogeny. *Biol. Rev. Cambridge Philos. Soc.* 41 : 587-640.
- Grant, C.J. and A.V. Spain. 1977. Variation in the body shape of three species of Australian Mulletts (Pisces : Mugilidae) during the course of development. *Aust. J. Mar. Freshwater Res.* 28 : 723-738.
- Greenwood, P.H. M.D.E. Rosen, S.N. Weitzman and G.S. Myers. 1966. Phyletic studies of teleostean fishes with a provisional classification of living forms. *Bull. American Mus. nat. Hist. New York.* 131 : 341-455.
- *Griffiths, B.M. 1923. The phytoplankton of bodies of freshwater and the factors determining its occurrence and composition. *J. Ecol.* 2 : 184-213.
- Crossman, G.D., R. Coffin and P.B. Moyle. 1980. Feeding ecology of the Bay Goby (Pisces : Gobiidae). Effects of behavioural, ontogenetic and temporal variation on diet. *J. Exp. mar. Biol. Ecol.* 44 : 47-59.
- Grover, I.S., S.S. Kalra and S. Puri. 1978. Hydrobiological studies of two fish ponds of Ludhiana. *Phykos.* 17: 39-48.
- *Gunther, A.C.L.G. 1859. Catalogue of the Fishes of the British Museum. 8 vols. London.
- *Gunther, A.C.L.G. 1861. Catalogue of the Acanthopterygian fishes in the collection of British Museum. London. 3 : 478-479.
- Habib, G. 1979. Reproductive biology of the puffer fish, Uranastoma richei (Plectognathi : Lagocephalidae) from Lyttelton Harbour. *New Zealand Jour. of Mar. and Freshwat. Res.* 13(1) : 71-78.
- Hakim, A., J.S. Datta Munshi and G.M. Hughes. 1978. Morphometrics of the respiratory organs of the Indian green snake headed fish, Channa punctatus. *J. Zool.* 184(4) : 519-543.

- Hamilton, B. 1822. An account of the fishes found in the River Ganges and its Branches. Edinburgh, 405 pp.
- Hannan, H.H., I.R. Fuchs and D.C. Whitenberg, 1979. Spatial and temporal patterns of temperature, alkalinity, dissolved oxygen and conductivity in an oligo-mesotrophic, deep storage reservoir in Central Texas. *Hydrobiologia*. 66(3) : 209-221.
- Hannan, H.H. and L. Broz. 1976. The influence of a deep storage and an underground reservoir on the physico-chemical limnology of a permanent Central Texas river. *Hydrobiologia*. 51(1) : 43-63.
- Hannan, H.H. and W.C. Young. 1970. Physico-chemical limnology of the gaudalupe river, Texas. Report to the Texas water quality board. 152.
- Hannan, H.H. and W.J. Young. 1974. The influence of a Deep-storage Reservoir on the Physico-chemical limnology of a Central Rexas River. *Hydrobiologia*. 44(2) : 177-207.
- Hanumante, M.M. and S.S. Kulkarni. 1979. Acute toxicity of 2 molluscicides mercuric chloride and pentachlorophenol to a freshwater fish (Channa gachua). *Bull. Environ. Contam. Tox.* 23(6) : 725-727.
- Hardistry, M.W. 1964. The fecundity of lampreys. *Archive fur Hydrobiologie*. 60(3) : 340-357.
- *Hardy, A.C. 1924. The herring in relation to its marine environment. Part I. The food and feeding habits of the herring with special reference to the east coast of England. *Fish. Invest., London, Ser. 2*(7) : 1-53.
- Hardy, A.C. 1936. Plankton ecology and the hypothesis of animal exclusion. 148th Proc. Linn. Soc. London. 64-70.
- Hardy, A.C. and E.R. Gunther. 1935. The plankton of the South Georgia whaling grounds and adjacent waters. 1926-1927. *Discovery Reports*. 11 : 1-456.
- *Hart, T.J. 1942. Phytoplankton periodicity in Antarctic surface waters. *Discovery Reports*. 21 : 261-356.
- Harvey, H.W. 1934. Annual variation of planktonic vegetation, *Jour. Marine Biol. Ass., U.K.* 19 : 775-792.
- Harvey, H.W., L.H.N. Cooper, M.V. Lebour and F.S. Russell. 1935. Plankton production and its control. *J. mar. biol. Ass. U.K.* 20 : 407-422.
- Hasler, A.D. 1947. Eutrophication of lakes by domestic drainage. *Ecology*. 28 : 383-395.
- *Hauer, J. 1936. Neue Rotatorien aus Indien I. *Zool. Anz.* 116 : 77-80.
- *Hauer, J. 1937a. Neue Rotatarien aus Indien II. *Zool. Anz.* 119 : 284-288.
- *Hauer, J. 1937b. Neue Rotatorien aus Indien. III. *Zool. Anz.* 120 : 17-19.
- Herse, A.W.C. and G.S. Myers. 1937. A contributions to Malayan Ichthyology. *Bull. Raffles Mus.* 13 : 5-74.

- Hester, F.J. 1964. Effects of food supply on fecundity in the female guppy, Lebistes reticulatus (Peters). J. Fish. Res. Bd. Canada. 21 : 757-764.
- Hickling, C.F. 1933. The natural history of the lake IV. Age determination and growth rate. Fish. Invest. Ser. II. 13(2) : 120.
- Hickling, C.F. and E. Rutenberg. 1936. The ovary as an indicator of spawning period of fishes. J. mar. biol. ass. U.K. 21 : 311-317.
- Hile, R. 1936. Age and growth of the Cisco. Bull. U.S. Bur. Fish. 48 : 211-317.
- Hodder, V.M. 1963. Fecundity of grand Bank Haddock. J. Fish. Res. Bd. Canada. 20 : 1465-1487.
- Hodder, V.M. 1965. The possible effects of temperature on the fecundity of grand Bank haddock. ICNAF Spec. Publ. 6 : 515-522.
- Hodgkiss, I. John and S.H.H. Man. 1978. Reproductive biology of Saratheradon mossambicus (Cichilidae) in Ploner cone Reservoir, Hong Kong. Env. Biol. Fish. 3(2) : 287-292.
- Holt, S.J. 1967. The contribution of freshwater fish production to human nutrition and well being. In: The Biological Basis of Freshwater Fish Production, Ed. S.D. Genking, Oxford, Blackwell : 455-467.
- Hora, S.L. 1935. Physiology, bionomics and evolution of the air-breathing fishes of India. Proc. nat. Inst. Sci. India. 1(1) : 1-16.
- Hora, S.L. 1944. On the Malayan affinities of the freshwater fish fauna of Penninsular India and its bearing on the probable age of the Garo-Rajmahal gap. Proc. nat. Inst. Sci. India. 10(4) : 423-439.
- Hora, S.L. 1951a. Knowledge of the ancient Hindus concerning fish and fisheries of India. Matsyavinoda or a chapter on angling in the Manosoltara by King Somesvara (1127 A.D.). J. Asiat. Soc. 17(2) : 145-169.
- Hora, S.L. 1951b. Freshwater Fauna. Handbook Indian Fish. 4:34-39.
- Hora, S.L. 1955. Fish geography of India. J. Zool. Soc. India. 3(1) : 183-187.
- Hora, S.L. 1956. Fish paintings of third millennium B.C. from Nal (Baluchistan) and their zoogeographic significance. Mem. Indian Mus., 14(2) : 78-84.
- Howland, L.J. 1931. A four years investigation of a Hertfordshire pond. New Phytol. 30(4) : 321-365.
- Hubbs, C. 1922. Variation in the number of vertebrate and other meristic character of fishes correlated with the temperature of the water during development. Amer. Nat. 56.
- Hughes, G.M., B.R. Singh, G. Guha, S.C. Dube and J.S. Datta Munshi. 1974. Respiratory surface area of an air-breathing siluroid fish Saccobranchus (= Heteropneustes) fossilis in relation to body size. J. Zool. Lond. 172 : 215-232.

- Hughes, G.M. and J.S. Datta Munshi. 1973. Nature of the air-breathing organs of the Indian fishes Channa, Amphiprurus, Clarias and Saccobranchus as shown by electron microscopy. J. Zool. Lond. 170 : 245-270.
- Hughes, G.M. and J.S. Datta Munshi. 1979. Fine structure of the gills of some Indian air-breathing fishes. J. Morphology. 160(2) : 169-194.
- Hulburt, E.M. 1964. Succession and diversity in the plankton flora of the Western North Atlantic. Bull. Mar. Sci. Sci. 14 : 33-44.
- Hussainy, S.V. 1967. Studies on the limnology and primary production of a tropical lake. Hydrobiol. 30 : 335-352.
- Hutchinson, G.E. 1967. A treatise on limnology. Vol. I. John Wiley & Sons; Inc; New York. 105 pp.
- Hynes, H.B.N. 1950. The food of freshwater stickbacks (Gasterosteus aculeatus and Pygosteus puniigitius) with a review of the food and fishes. J. Anim. Ecol. 19 : 36-58.
- Hynes, H.B.N. 1970. The Ecology of running waters. Univ. Toronto Press, Toronto. 555 pp.
- Jacobsen, O.J. 1974. Feeding habits of the population of white fish (Coregonus lauretus) in Hangatjerna eutrophic Norwegian Lake. Nov. J. Zool. 22 : 295-318.
- Jana, B.B. 1970. On the study of limnology and bacteriology of the thermal springs of Bakreswar. Ph.D. Thesis. Visva Bharati Univ., Shantiniketan, India.
- Jana, B.B. 1973a. Seasonal periodicity of plankton in a freshwater pond in West Bengal, India. Int. Revue. ges. Hydrobiol. 58(1) : 127-143.
- Jana, B.B. 1973b. The thermal springs of Bakreswar, India. Physico-chemical conditions, Flora and Fauna. Hydrobiologia. 41(3) : 291-307.
- Jana, B.B. and H.L. Sarkar. 1971a. The limnology of "Swetganga" a thermal spring of Bakreswar, West Bengal, India. Hydrobiologia. 37 : 33-47.
- Jana, B.B. and H.L. Sarkar. 1971b. On the variation of limnobiological conditions along a hot spring thermal gradient. Curr. Sci. 40 : 491-493.
- Jhingran, A.G. 1961. Studies on the maturity and fecundity of the gangetic anchovy, Setipinna phasa (Hamilton). Indian J. Fish. 8 : 291-311.
- Jhingran, A.G. 1971. Validity of scale as age indicator in Setipinna phasa (Ham.) and interpretation of "salmonoid bands" and spawning marks. Proc. Ind. Nat. Sci. Acad. (B). 37(4) : 1-62.
- Jhingran, A.G. 1972. Fluctuations in the ponderal index of the gangetic anchovy Setipinna phasa (Ham.). J. Inland Fish. Soc. India. 4 : 1-9.
- Jhingran, A.G. 1976. Systems of polyculture of fishes in the Inland waters of India. J. Fish. Res. Bd. Canada. 33(4) : 905-910.

- Job, T.J. 1951. Problems of freshwater fisheries. Handbook Indian Fish. 8 : 71-78.
- Joshi, B.N. and A.G. Sathyanesan. 1979. Adrenal histochemistry histoenzymology of the teleost Channa punctatus (Bloch). *Monitore Zoologico Italiano*. 13(2-3) : 77-82.
- Joshi, B.N. and A.G. Sathyanesan. 1980. Annual cyclical changes in the monoamine oxides (MAO) activity in the testis of the teleost. Channa punctatus (Bloch). *Gen. Comp. Endocrinol.* 41(2) : 240-242.
- *Juday, C. 1922. Quantitative studies of the bottom fauna in the deeper waters of lake Mendota. *Trans. Wis. Acad. Sci. Arts. Litt.* 20 : 461-493.
- Kakuda, S. and K. Matsumoto. 1978. On the food habits of the white Croaker Argyrosomus argentalus. *J. Fac. Fish. Anim. Husb., Hiroshima Univ.* 17 : 133-142.
- Kakuda, S. and K. Nakai. 1981. On the maturity and spawning of Nibea albiflora. *Bull. Jap. Soc. Scient. Fish.* 47(1), 17-25 : 17-25.
- Karekar, P.S. and D.V. Bal. 1958. The food and feeding habits of Polynemus indicus (Shaw) *Indian J. Fish.* 5 : 77-94.
- Kaul, V. 1971. Production and ecology of some macrophytes of Kashmir lakes. *Hydrobiol. (Romania)*. 12 : 63-70.
- Keast, A. 1966. Trophic interrelationships in the fish fauna of a small stream. *Proc. 9th Conf. Great Lakes Res. Div., Univ. Michigan.* 51-79.
- Kerr, S.R. 1980. Niche Theory in Fisheries Ecology. *Trans. Amer. Fish. Soc.* 109 : 254-260.
- Kesteven, G.L. 1942. Studies on the biology of Australian mullets. Part I. Account of the fishery and preliminary statement of biology of Mugil dobula Gunther. *Cour. Sci. Indus. Res. Bull.* 157.
- Kesteven, G.L. 1947. Studies on the economic biology of the Australian mullet (Mugil dobula Gunther). D.Sc. Thesis, Univ. Sydney.
- Khan, M.H. 1924. Observations on the breeding habits of some freshwater fishes in Punjab. *J. Bombay nat. Hist. Soc.* 29 : 958-962.
- Khan, M.H. 1925. Early stages in the development of some freshwater fishes in the Punjab. *Jour. Bombay Nat. Hist. Soc.* 30(3) : 531-540.
- Khan, A.A. and A. Qayyum. 1966. On the ionic composition of five tropical fish ponds of Aligarh (U.P.), India. *Hydrobiologia*. 28 : 195-202.
- Khan, A.A. and A.Q. Siddiqui. 1971a. Primary production in a tropical fish pond at Aligarh, India. *Hydrobiol.* 37 : 447-456.
- Khan, A.A. and A.Q. Siddiqui. 1971b. Water, Nitrogen and Phosphorus in freshwater plankton. *Hydrobiol.* 37:531-536.
- Khanna, S.S. and T. Singh. 1971. Studies on the glucose level in Channa punctatus (Bl.). *Acta. Zool. Stockh.* 52:91-101.

- Klein, L. 1956. The problems of river pollution in industrial areas. Roy. Soc. Prov. Hut. 76 : 348-357.
- Kothare, P.V. and D.V. Bal. 1975. Length-frequency distribution in Sphyraena obtusata (C.&V.). J.Biol. Sci. 18: 1-4.
- Krishnamurthy, K.P. and G. Visweswara. 1965. Hydrobiological studies in Gandhisagar (Jumna tank), Diurnal variations in plankton. Hydrobiologia. 25(1-2) : 99-118.
- Kryzhanovsky, S.G. 1949. Ecological-morphological principles in the development of cyprinid, cobitid and silurid fishes. Trudy Inst. Morf. Univ. 1 : 5-332.
- Kumaraiah, P., V.K. Murugesan and P.V. Dehadrai. 1978. A new record of a bacterium causing eye disease and mortality in Channa marulius (Ham). J. Inland Fish. Soc. India. 9 : 214-215.
- Laal, A.K. and S.A.K. Nasar. 1977. Rotifer fauna of Bihar, India. Bangladesh J. Zool. 5 : 127-128.
- *Lacepede, B.G.E. 1798-1803. Historie naturelle des poissons. Tome Premier, Paris.
- Lal, M.S. and A.S. Dwivedi. 1965. Studies on the Biology and Fishery of some freshwater fishes of U.P., Length-Weight relationship of Rita rita. Ichthyol. 4:21-26.
- Larsen, K. 1967. Studies on the biology of Danish stream fishes II. The food of pike (Esox lucine L.) in trout streams. Meddr. Dan. Fisk. Havundess. 4 : 271-326.
- LeCren, E.D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). J.Anim. Ecol. 20 : 201-219.
- Leggett, W.C. and G. Power. 1969. Differences between two populations of land locked Atlantic salmon (Salmo salar) in Newfoundland. J. Fish. Res. Bd. Canada. 26 : 1585-1596.
- Lindsay, C.C. 1954. Temperature controlled meristic variation in the Paradise fish Macropodus opercularis (L). Can. J. Zool. 32 : 87-98.
- Lowe-McConnell, R.H. 1971. Identification of freshwater fishes. In: Methods for Assessment of Fish production in Freshwaters. Ed. W.E. Ricker: Blackwell Scientific Publications. Oxford and Edinburgh : 45-81.
- Lowe-McConnell, R.H. 1975. Fish communities in Tropical Freshwaters - Their distribution, ecology and evolution. Longman, London and New York : 1-337.
- Mackereth, P.J.M. 1957. Some methods of water analysis for limnologists. Freshwater Biol. Ass. Publ.
- Madhavi, R. 1980. Life history of Allocreadium handiai Pande, 1937 (Trematoda, Allocreadiidae) from the freshwater fish Channa punctatus Bloch. Z. Parasitenkunde. 63(1) : 89.
- Mahajan, C.L. and J.S. Dheer. 1979a. Seasonal variations in the blood constituents of an air-breathing fish, Channa punctatus Bloch. J. Fish. Biology. 14(4) : 413-418.

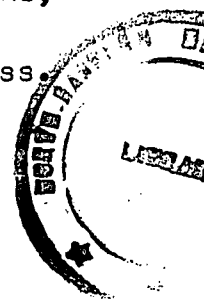
- Mahajan, C.L. and J.S. Dheer. 1979b. Cell types in the peripheral blood of an air breathing fish Channa punctatus. J. Fish. Biol. 14(5) : 481-488.
- Mahajan, C.L. and J.S. Dheer. 1979c. Autoradiography and differential hemoglobin staining as aids to the study of fish haematology. Experientia. 35(6) : 834-835.
- Mahajan, C.L. and N.K. Agarwal. 1979. Vitamin C deficiency in Channa punctatus Bloch. Curr. Sci. India. 47(21):835.
- Mahajan, C.L., N.K. Agarwal, M.J. John and V.P. Katta. 1978. Parasitigation of Isoparorchis hypselobaqri (Billet) in Channa punctatus Bloch. Curr. Sci. India. 47(21) : 835.
- Mahajan, C.K., N.K. Agarwal, M.J. John and V.P. Katta. 1979. Effect of the digenean Isoparorchis hypselobaqri (Billet, 1978) on an air breathing fish Channa punctatus (Bloch) with particular reference to biochemical and haematological changes. J. Fish. Dis. 2(6) : 529-542.
- Malhotra, Y.R. and P.L. Duda. 1970. n.sp. (Anostraca : Branchi-rectidae) from Indian Crustaceana. 18 : 173-176.
- Mandal, B.K. and S.K. Moitra. 1975. Seasonal variations of benthos and bottom soil edaphic factors in a freshwater fish pond at Burdwan, West Bengal. Trop. Ecol. 16 : 43-48.
- Manooch, C.S. 1976. Reproductive cycle, fecundity and sex ratios of the Red Porgy, Pagrus pagrus (Pisces : Sparidae) in North Carolina, Fishery Bulletin. 74(4).
- *Mare, M.F. 1940. Plankton production of Plymouth and the mouth of the English channer in 1939. Jour. Marine. Biol. Assn. U.K. 24 : 461-482.
- Marshall, S.K., A.G. Nicholls and A.P. Orr. 1939. On the growth and feeding of young herring in the Clyde. J. Mar. Biol. Assoc. U.K. 23 : 427-435.
- Martin, W.R. 1949. The mechanics of environmental control of body form in fishes. Univ. Toronto Stud. Biol. 58 (Publ. Ont. Fish. Res. Lab. 70) : 1-91.
- Mathur, R. 1979. The effect of porcine calcitonin on plasma calcium in Channa punctatus Bloch. J. Fish. Biol. 15(3) : 329-336.
- *McClelland, J. 1839. Indian Cyprinidae. In: Asiatic Researches. 19(2) : 217-465.
- McFadyen, J., E.L. Cooper and J.K. Andersen. 1965. Some effects of environment on egg production in brown trout (Salmo trutta). Limnol. Oceanogr. 10 : 88-95.
- *McGregor, E.A. 1922. Observations on the egg yield of Klamath River King salmon. Calif. Fish. Game. 3 : 160-164.
- Menon, A.G.K. 1951. The role of the Eastern Ghats in the distribution of the Malayan fauna and flora to Peninsular India. Proc. Nat. Inst. Sci. India. 17(6) : 475-497.

- Menon, M.D. 1950. Bionomics of the Pool Cod (Gadus minutus L.) in the Plymouth area. J. mar. biol. Ass. U.K. 29 : 185-239.
- *Michael, R.G. 1965. Ph.D. Thesis. Calcutta University, India. 165.
- Michael, R.G. 1966. A new rotifer, Conchilus madurai sp. nov., from an astatic pool in Madurai, South India. Zool. Anz. 177 : 439-441.
- Michael, R.G. 1968. Studies on zooplankton of a Tropical fish pond. Hydrobiologia. 32(1-2) : 47-68.
- Michael, R.G. 1969. Seasonal trends in physico-chemical factors and plankton of a freshwater fish pond and their in fish culture. Hydrobiologia. 33(1) : 144-160.
- Michael, R.G. 1973. A guide to the study of freshwater organisms. 2. Rotatoria. J. Madurai Univ., Suppl. 1 : 23-36.
- Michael, R.G. 1980. A historical resume of Indian Limnology. Hydrobiol. 72 : 15-20.
- Michael, R.G. and M.R. Chandran. 1967. On the biochemical composition of the conchostracan Caenestheriella annandaji Daday. Biolog. Zent. 86(4) : 495-499.
- Michael, R.G. and V.M. Anselm. 1978. Role of nannoplankton in primary productivity studies in tropical ponds. Verh. Internat. Verein. Limnol. 20 : 2196-2201.
- Mishra, A.K. and B.R. Singh. 1979. Effect of thermal stress on oxygen consumption through water of the air-breathing fish Channa gachua (Bl.). Indian J. Exp. Biol. 17 : 892-894.
- Mishra, K.D. 1978. The anatomy of the synopsis in the central nervous system of Channa gachua (Ham.). Teleostomi: Pisces. Indian J. Zool. 6(2) : 72-76.
- Misra, K.S. 1959. An aid to the identification of the Common Commercial fishes of India and Pakistan. Rec. Indian Mus., 57(1-4) : 1-320.
- Mitra, G.N. 1956. Reclamation of swamps for fishery development in Orissa. Progr. Fish. Develop. India : 54-62.
- Mohr, J.L. 1952. Protozoa as indicator of pollution. Sci. Mon. N.Y. 74:1.
- Moitra, S.K. 1956. On the food habits of some fishes of Lucknow. Proc. Zool. Soc. Bengal. 9(2) : 89-91.
- Moitra, S.K. and B.K. Bhattacharya. 1965. Some hydrological factors affecting plankton production in a fish pond in Kalyani, W.Bengal, India. Ichthyol. 4 : 8-12.
- Moitra, S.K. and M.L. Bhowmick. 1968. Seasonal cycles of rotifers in a freshwater fish pond in Kalyani, West Bengal, India. Proc. Symp. Recent Adv. Trop. Ecol. 1 : 359-367.
- Moitra, S.K. and S.K. Mukherji. 1972. Studies on the freshwater plankton of a fish pond in Kalyani, W.Bengal, India. Vest. Cs. spol. zool. 36(1) : 23-28.

- Moyle, P.B., R.E. Andrews, R.M. Jenkins, R.L. Noble, S.B. Saila and W.O. Wick. 1979. Research Needs in Fisheries. Trans. 44th Amer. Wildlife & Nat. Resour. Conf. Publ. by Wildlife Management Institute, Washington D.C. 176-187.
- Mookerjee, H.K. 1946. Life histories of some carnivorous fishes of Bengal. Sci. & Cult. 11 : 102-103.
- Mookerjee, H.K., D.N. Ganguly and M. Islam. 1946. On the composition of Ophicephalus punctatus Bloch. Proc. 33rd Indian Sci. Cong. 3 : 131.
- Mookerjee, H.K., D.N. Ganguly and R.N. Bhattacharya. 1948. On the bionomics, breeding habits and development of Ophicephalus striatus Bl. Proc. Zool. Soc. Bengal. 1 : 58-64.
- Mookerjee, H.K., D.N. Ganguly and S.C. Mallick. 1950. On the life history of Ophicephalus gachua Ham. Proc. Zool. Soc. Beng. 3 : 169-179.
- Mulford, R.A. 1972. Phytoplankton of Chesapeake Bay. Ches. Sci. 13 : 74-81.
- Munawar, M. 1970. Limnological studies on freshwater ponds of Hyderabad, India. I. The Biotope. Hydrobiol. 35 : 127-162.
- Munawar, M. 1970. Limnological studies of freshwater ponds of Hyderabad, India. II. The Biocenose. Distribution of unicellular and colonial phytoplankton in polluted and unpolluted environments. Hydrobiol. 36(1) : 105-128.
- Murugesan, V.K. 1978. The growth potential of the murrels, Channa marulius (Ham.) and Channa striatus (Bloch). J. Inland Fish. Soc. India. 10 : 169-170.
- Mustafa, S. 1979. RNA and synthesis of protein in relation to biological condition of freshwater teleost, Channa punctatus. Comp. Physiol. and Ecol. 4(3) : 118-120.
- Mustafa, S. and A.K. Jafri. 1977. RNA and protein contents in the flesh of the teleost Channa punctatus Bloch during growth. Annales de Biologie Animale Biochimie Biophysique. 17(6) : 991.
- Myers, G.S. and L. Shapovalov. 1931. On the identity of Ophicephalus and Channa, two genera of labyrinth fishes. Peking nat. Hist. Bull. 6(2) : 33-37.
- Naidu, K.V. 1962. Studies on the freshwater protozoa of South India- I: Euglenoidina. J. Zool. Soc. India. 14(1) : 88-92.
- Naidu, K.V. 1966. Studies on the freshwater protozoa of South India. III: Euglenoidina. 2. Hydrobiologia. 27:23-32.
- Naidu, K.V. 1967. A contribution to the Rotatarian fauna of South India. J. Bombay nat. Hist. Soc. 64 : 384-388.
- Nair, K.K.N, and C.K.G. Nayar. 1971. A preliminary study of the rotifers of Irinjalakuda and neighbouring places. J. Ker. Acad. Biol. 3 : 31-43.

- Narasimhan, K.A. 1970. On the length-weight relationship and relative condition in Trichurus lepturus (Linnaeus). Indian J. Fish. 17(1-2) : 90-96.
- Nasar, S.A.K. 1973. The zooplankton fauna of Bhagalpur : Rotifer. J. Bh. U. 6(1) : 55-62.
- Nasar, S.A.K. 1975. Studies on some aspects of pond ecosystem at Bhagalpur. Ph.D. Thesis. Bhagalpur University.
- Nasar, S.A.K. 1977a. Diurnal variations in some physico-chemical factors in a pond in Bhagalpur, India. Comp. Physiol. Ecol. 2(3) : 145-149.
- Nasar, S.A.K. 1977b. Observations on a planktonic Ostracoda - Cypricercus munshii. J. Res. Crustacea. 8 : 32-36.
- Nasar, S.A.K. 1977c. Investigations on the seasonal periodicity of zooplankton in a freshwater pond in Bhagalpur, India. Acta. Hydrochim. Hydrobiol. 5(6) : 577-584.
- Nasar, S.A.K. 1977d. The zooplankton fauna of Bhagalpur (Bihar): Cladocera. Research in Crustacea. Japan. 8 : 32-36.
- Nasar, S.A.K. 1978. Studies on certain chemical properties of soil in a freshwater pond of Bhagalpur, India. Indian J. Soil Conserv. 6(1) : 24-27.
- Nasar, S.A.K. 1979a. Seasonal periodicity of zooplankton in a tropical freshwater swamp in Bhagalpur. Tropical Ecology. (supl.). In Press.
- Nasar, S.A.K. 1979b. Effect on certain organochlor insecticides on primary production in a freshwater pond. Prog. Water. Tech. 11(6) : 247-251.
- Nasar, S.A.K. 1980a. Primary productivity studies on freshwater fish ponds of Bhagalpur, India. Acta. Hydrochim. Hydrobiol. 8(6) : 569-582.
- Nasar, S.A.K. 1980b. Limnology in India - What should we do next? Paper presented at the 1st Workshop on the promotion of Limnology in the developing countries. 21st SIL Congress, Kyoto, Japan.
- Nasar, S.A.K. and J. Datta Munshi. 1971. Studies on the macrophytic biomass production and fish population in an abandoned pond of Bhagalpur, Bihar. J. Bh. U. 4(1) : 8-16.
- Nasar, S.A.K. and J. Datta Munshi. 1974. Seasonal variations in the physico-chemical and biological properties in a tropical freshwater pond. Jap. J. Ecology. 24(4) : 255-259.
- Nasar, S.A.K. and J. Datta Munshi. 1975. Studies on the primary production of a freshwater pond. Jap. J. Ecology. 25(1) : 21-23.
- Nasar, S.A.K. and J. Datta Munshi. 1976. Studies on the biomass production of Spirodela polyrhiza schleid. Geobios. 3(4) : 134-135.
- Nasar, S.A.K. and J. Datta Munshi. 1978. Biomass production of Potamogeton crispus. L. Limnologica (Berlin). 11(2) : 457-461.

- Nasar, S.A.K. and J. Datta Munshi. 1980. Studies on the seasonal variations in the fungal population of a freshwater pond of Bhagalpur, India. *Limnologica*. 12(1) : 137-139.
- Nasar, S.A.K. and M. Deb. 1979. Cypridopsis ochracea Sars, 1924 (Crustacea : Ostracoda). A new record from India. *Curr. Sci.* 44(8) : 271-272.
- Nasar, S.A.K. and M. Sharma. 1980. Primary productivity in relation to the abiotic factors in a temporary freshwater pond. *Acta. Hydrochim. Hydrobiol.* 8(5):435-442.
- Nasar, S.A.K. and Sukhbeer Kaur. 1979. Culturable fishes of India. *Science Reporter*. 16(8) : 486-488.
- Nasar, S.A.K. and Sukhbeer Kaur. 1981. Observations on the abiotic factors and planktonic periodicity in a shallow pond from the highland of Shillong (India). *Acta Hydrochim. Hydrobiol.* 9 : (in Press).
- Nath, B. 1966. Prehistoric animals of India and their bearing on early Indian culture. *Proc. All India Congr. Zool.* 2(2) : 6-13.
- Natarajan, A.V. and A.G. Jhingran. 1963. On the biology of Catla catla (Ham.) from the river Jumna. *Proc. nat. Inst. Sci. India (B)* : 29(3) : 326-355.
- Nayar, C.K.G. 1964. Morphometric studies on the rotifer Brachionus calyciflorus Pallas. *Curr. Sci.* 33 : 469-470.
- Nayar, C.K.G. 1965a. Taxonomic notes on the Indian species of Keratella (Rotifera). *Hydrobiologia*. 26 : 457-462.
- Nayar, C.K.G. 1965b. Three new species of conchostraca (Brachiozoa : Crustacea) from Rajasthan. *Bull. Syst. Zool.* 1(1) : 18-23.
- Nayar, C.K.G. 1965c. Cyclomorphosis of Brachionus calyciflorus Pallas. *Hydrobiologia*. 25 : 538-544.
- Nayar, C.K.G. 1968. Rotifer fauna of Rajasthan. *Hydrobiol.* 31 : 168-185.
- Nayar, C.K.G. 1970. Studies on the Rotifer population of two ponds at Pilani, Rajasthan. *J. Zool. Soc. India*. 22(1-2) : 21-34.
- Nayar, C.K.G. 1971. Cladocera of Rajasthan. *Hydrobiol.* 37 : 509-519.
- Nayar, C.K.G. and K.K.N. Nair. 1969. A collection of brachionid rotifers from Kerala. *Proc. Indian Acad. Sci.* 69 : 223-233.
- Nikolsky, G.V. 1961. On some adaptations to the regulation of population density in fish species with different types of stock structure. The exploitation of natural animal populations (B.D. LeCren & H.W. Holdgate, Eds.). Blackwell Scientific Publications, Oxford.
- Nikolsky, G.V. 1963. *The Ecology of Fishes*. Academic Press. London and New York.



- Nikolsky, G.V. 1969. Theory of fish population dynamics as the biological background for Rational Exploitation and Management of Fishery Resources. Oliver and Boyd, Edinburgh.
- Odum, H.T. 1957. Trophic structure and productivity of Silver Springs, Florida. Ecol. Monogr. 27 : 55-112.
- Odum, W.E. 1968. The ecological significance of fine particle selection by the striped mullet, Muqil cephalus L. Linn. Oceanogr. 13 : 92-98.
- Pahwa, D.V. and S.N. Mehrotra. 1966. Observations on fluctuations in the abundance of plankton in relation to certain Hydrological conditions of River Ganga. Proc. Nat. Acad. Sci. India. 36 : 157-189.
- Parameswaran, S. 1975. Investigations on the biology of some fishes of the genus Channa Gronavius 1763. Ph.D. Thesis. Magadh Univ.
- Parameswaran, S. and V.K. Murugesan. 1976. Breeding season and seed resources of murrels in swamps of Karnataka State. J. Inland Fish. Soc. India. 7 : 60-67.
- Pasha, S.M.K. 1961. On a collection of freshwater rotifers from Madras. J. Zool. Soc. India. 13 : 50-55.
- Patil, S.G. 1978. New records of Rotatoria from Northeast India. Sci. Cult. 44 : 279-281.
- Patrick, R. 1967. Diatom communities in estuaries. In: Estuaries (G.H. Lauff, Ed.). Am. Assoc. Adv. Sci. Publ. No. 83. Washington D.C. : 311-315.
- Patrick, R. and P. Ruth. 1950. Biological measure of stream conditions. Sewage Industs. Wastes. 22 : 926.
- *Pearsall, W.H. 1923. A theory of diatom periodicity. J. Ecol. 11-12 : 165-183.
- Pearsall, W.H. 1930. Phytoplankton in the English lakes. I. The proportion in the water of some dissolved substances of biological importance. J. Ecol. 18 : 306-320.
- Pearsall, W.H. 1932. Phytoplankton in the English lakes. II. The composition of the phytoplankton in relation to dissolved substances. J. Ecol. 20 : 241-262.
- *Pearson, J.C. 1928. Natural history and conservation of Red Fish and other commercial sciaenids on Texas coast. Bull. U.S. Bur. Fish Washington. 44 : 129.
- Pennak, R.W. 1949. Annual limnological cycle in some Colorado reservoirs and lakes. Ecol. Monogr. 19 : 233-267.
- Pennak, R.W. 1957. Species composition of limnetic zooplankton communities. Limnol. Oceanogr. 2 : 222-232.
- *Petersen, C.G.T. 1922. On the stocks on plaice and plaice fisheries in different waters. A survey Repts. Danish. Biol. Stn. 29 : 1-36.
- Philipose, M.T. 1959. Freshwater phytoplankton of Inland fisheries. Proc. Symp. Algal. I.C.A.R. New Delhi:272-291.
- Philipose, M.T. 1967. Chlorococcales. Indian Council of Agricultural Research. Monographs of Algae. 365 pp.

- Pillay, T.V.R. 1954. The biology of grey mullet, Muqil tade Forskal with notes on its fishery in Bengal. Proc. Nat. Inst. Sci. India. 17 : 187-217.
- Prabhu, M.S. 1956. Maturation of the intra-ovarian eggs and spawning periodicities in some fishes. Indian J. Fish. 3 : 582-590.
- Prashad, B. 1916. The seasonal conditions governing the pond life in the Punjab. J. Asiat. Soc. Beng. 12 : 142-145.
- Pringsheim, E.G. 1946. Pure cultures of algae. Cambridge.
- Pruthi, H.S. 1933. Studies on the bionomics of freshwaters in India. I. Seasonal changes in the physical and chemical conditions of the water of the tank in the Indian Museum Compound. Int. Rev. Hydrobiol. 28 : 46-67.
- Qasim, S.Z. and A. Qayyum. 1961. Spawning frequencies and breeding seasons of some freshwater fishes with special reference to those occurring in plains of Northern India. Indian J. Fish. 8 : 24-43.
- Qasim, S.Z. and A. Qayyum. 1963. Fecundities of some freshwater fishes. Proc. Nat. Inst. Sci. India. 29 : 373-382.
- Qayyum, A. and S.Z. Qasim. 1962. Behaviour of the Indian murrel, Ophicephalus punctatus during brood care. Copeia. 2 : 465-467.
- Raitt, D.F.S. 1968. The population dynamics of the Norway part in the North Sea. Mar. Res. 1968 (5) : 1-24.
- Rahimullah, M. 1966. Observations on the breeding habits of Ophicephalus striatus Bloch. Proc. 33rd Ind. Sci. Congr.
- Raj, B.S. 1916. Notes on the Freshwater Fish of Madras. Recd. Indian Mus. 12 : 249-294.
- Rajendran, M. 1971. On a new species of Conochilus Rousselet (Rotifera : Monogononta, Conochilidae) from Madurai, S. India, with a key for the known species of the genus. Proc. Indian Acad. Sci. 73 : 8-14.
- Ramanathan, K.R. 1964. Ulotrichiales. Indian Council of Agricultural Research. Monographs on Algae. : 188.
- Ramaswamy, M. and T.G. Reddy. 1978. Bimodal oxygen uptake of an air-breathing fish Channa gachua (Hamilton). Indian J. Exp. Biol. 16(6) : 693.
- Rana, A.K., J. Ojha and J.S. Datta Munshi. 1978. Morphometrics of the olfactory rosette in relation to body weight in a freshwater murrel Channa (= Ophiocephalus) punctatus Bloch. Archives de Biologie. 89(4) : 403-418.
- Rao, C.B. 1955. On the distribution of algae in a group of six small ponds. II. Algal periodicity. J. Ecol. 43 : 291-308.
- Ray, A.K. and A.K. Medda. 1976. Effect of thyroid hormones and analogues on ammonia and urea excretion in lata fish (Ophicephalus punctatus) Gen. Comp. Endocrin. 29:190.

- Regier, H.A. 1974. Fish ecology and its application. Mitl. Internat. Verein. Limnol. 20 : 273-286.
- Reid, G.K. 1961. Ecology of Inland waters and estuaries. Reinhold Book Corp., New York.
- Ricker, W.E. 1971. Methods for Assessment of Fish Production in Freshwaters, 2nd ed; Blackwell Scientific Publications, Oxford and Edinburgh. pp. 216-218.
- Riley, G.A. 1943. Physiological aspects of spring diatom flowerings. Bingham Oceanog. Coll. Bull. 8(4) : 1-53.
- Riley, G.A. 1946. Factors controlling phytoplankton population on Goerges Bank. J. Mar. Res. 6 : 54-73.
- Riley, G.A. 1967. The plankton of estuaries. In: Estuaries (G.H. Lauff, ed.) : 316-326.
- *Royan, J. 1972. Ph.D. Thesis. Madurai University. Madurai. pp. 108.
- Russel, P. 1803. Description and figures of 200 fishes collected from Vizagapatnam on the coast of Coromandel. 2 Vols; London.
- Ruttner, F. 1953. Fundamentals of Limnology. (Trans. by D.G. Frey and F.E.J. Fry). Univ. of Toronto Press, Toronto, Canada.
- Ryther, J.H. 1954. Ecology of phytoplankton blooms in Meriches and great South Bay, L.I. Biol. Bull. Woods Hole. 106 : 198-209.
- Saha, G.N., K.L. Sehgal, E. Mitra and N.C. Nandy. 1971. Studies on the seasonal and diurnal variations in physico-chemical and biological conditions of a perennial freshwater pond. J. Inland Fish. Soc. India. 3:74-102.
- Saha, K.C., D.P. Sen and J.C. Sengupta. 1959. Note on the biochemical stratification in pond fisheries and their productivity. Sci. Cult. 25(3) : 216-218.
- Sahai, R. and A.B. Sinha. 1969. Investigations on bio-ecology of inland waters of Gorakhpur (U.P.), India. I. Limnology of Ramgarh Lake. Hydrobiologia. 34:433-447.
- Samuels, W.B., A. Uzzo and R. Nuzzi. 1979. Correlations of phytoplankton standing crop, species diversity and dominances with physical-chemical data in a coastal salt pond. Hydrobiologia. 64(3) : 233-237.
- Sarojini, K.K. 1957. Biology and fisheries of the grey Mulletts of Bengal. I. Biology of Mugil parsia (Ham.) with notes on its fishery in Bengal. Indian J. Fish. 4(2) : 254-283.
- Sastry, K.V. and S.K. Sharma. 1978. Effect on endrin on histopathological changes in liver of Channa punctatus. Bull. Environ. Contam. & Tox. 20(5) : 674-677.
- Sastry, K.V. and S.K. Sharma. 1979. In vivo effect of endrin on 3 phosphatases in kidney and liver of the fish Ophiocephalus punctatus Bull. Environ. Contam. Toxicol. 21(1-2) : 185-189.

- Sastry, K.V. and S.K. Snarma. 1980. Diazinon effect on the activities of brain enzymes from Ophiocephalus (Channa) punctatus. Bull. Environ. Contam. Toxicol. 24(3) : 326-332.
- Saxena, O.P. and B.K. Sharma. 1978. Flame photometry and photo-colorimetric determination of electrolytes of plasma of Channa punctatus (Bl.) and Notopterus notopterus (Ham.). Curr. Sci. India. 47(11) : 391.
- Saxena, P.K. and K. Mani. Ovarian recrudescences in freshwater teleost Channa punctatus (Bl.) during thiourea treatment. Indian J. Exp. Biol. 17(12) : 1301-1304.
- Schindler, D.W. 1971. A hypothesis to explain differences and similarities among lakes in the experimental lakes area, North-Western Ontario. J. Fish. Res. Bd. Canada, 28 : 295-301.
- Schmidt, J. 1921. Racial investigations. VII. Annual fluctuations of racial characters in Loarces vivipares L. C.R. Lab. Carlsberg. 14 : 1-20.
- Schoener, T.W. 1974. Resource partitioning in ecological communities. Science. N.Y. 185 : 27-39.
- Scott, D.P. 1962. Effect of food quantity of fecundity of rainbow trout Salmo gairdneri. J. Fish. Res. Bd. Canada. 19 : 715-731.
- Seetharamaiah, P. 1966. Studies on the ecology of a freshwater pond community. Hydrobiologia. 27 : 529-547.
- Seenayya, G. 1971. Ecological studies in the plankton of certain freshwater ponds of Hyderabad, India. I. Physico-chemical complexes. Hydrobiologia. 37 : 7-31.
- Sekheran, K.V. 1968. Length-weight relationship in Sardinella albella (Val.) and S. gibbosa (Bleak). Indian J. Fish. 15 : 166-174.
- Sen, N.S. 1979, Ph.D. Thesis. Ranchi University, Ranchi.
- Sewell, R.B.S. 1935. Studies on the bionomics of freshwater in India. II. On the fauna of the tank in the Indian Museum Compound and seasonal changes observed. Int. Rev. ges. Hydrobiol. 31 : 203-238.
- Shaffi, S.A. 1978. Biochemical compartmentation of fish tissues. I. Brain energy reserves and its metabolic products. Acta. Physiologica Acad. Sci. Hungary. 52(4) : 435-440.
- Shanbhag, A.G. and V.B. Nadkarni. 1979. Histological and histochemical studies on the testicular cycle of a freshwater teleost Channa gachua (Ham.). Anat. Anz. 146 (4) : 381-389.
- Sharma, B.K. 1976. Rotifers collected from North-West India. Newsl. Zool. Surv. India. 2 : 255-259.
- Sharma, B.K. 1977. On a small collection of rotifers (Class : Rotifera) from Orissa. Newsl. Zool. Univ. India. 3 : 189-190.
- Sharma, B.K. 1978. Two new lecanid Rotifers from India. Hydrobiologia. 60 : 191-192.

- Sharma, B.K. 1979. Rotifers from West Bengal. III. Further studies on the Eurotatoria. *Hydrobiologia*. 64:39-47.
- Sharma, S.K. 1978. Endrin toxicity on liver of Channa punctatus (Bloch). *Indian J. Exp. Biol.* 16(3) : 327.
- Sharma, S.K., L.D. Chaturvedi and K.V. Sastry. 1979. Acute endrin toxicity on oxidases of Ophiocephalus punctatus (Bloch). *Bull. Environ. Contam. and Toxicology*. 23(1-2) : 153-157.
- Shaw, G.E. and E.O. Shebbeare. 1937. The fishes of Northern Bengal. *J. Roy. Asiatic. Soc. Bengal*. 3 : 1-137.
- Shelford, V.H. 1973. "Animal Communities in Temperate America, as illustrated in the Chicago Region, a study in Animal Ecology". Chicago University Press, Chicago.
- Simpson, A.C. 1951. The fecundity of plaice. *Fish Invest.* London. 17(27) : 1-29.
- Simpson, A.C. 1959. The spawning of the plaice in the North Sea. *Fish. Invest.* London. Sci. 2(22) : 1-111.
- Singh, R.L. 1971. India. A Regional Geography : 676-697. National Geographical Society of India.
- Singh, R.N. 1955. Limnological relations of Indian inland waters with special reference to water blooms. *Proc. Int. Assoc. Limnol.* 12 : 831-836.
- Sinha, A.L. 1973. Length-weight relationships of a freshwater catfish, Clarias batrachus (Linn). *Indian J. Zool.* 14 : 97-102.
- Sinha, M. 1972. Observations on the biology of Puntius sarana (Hamilton) of Loni reservoir (M.P.). *J. Inland Fish. Soc. India*. 4 : 122-131.
- Sinha, M. 1975. Observations on the Biology of Puntius sarana (Hamilton) of Loni reservoir (M.P.). II. Maturity and Fecundity. *J. Inland Fish. Soc. India*. 7: 49-57.
- Sinha, N.D.P. and J.S. Datta Munshi. 1979. Muscle fluid compartments and electrolyte distribution in relation to gonadal cycle in the freshwater teleost Channa punctatus. *Indian J. Exp. Biol.* 17(9) : 885-887.
- Sladecsek, V. 1958. A note on the phytoplankton-zooplankton relationship. *Ecology*. 39 : 547-549.
- Smith, S.M. 1945. Freshwater fishes of Siam or Thailand. 465-466.
- Soni, D.D. and M. Kathal. 1979. Length-weight relationship in Cirrhina mrigala (Val.) and Cyprinus carpio (Hamilton) *Matsya* 5 : 69-72.
- Spence, R. and H.S. Prater. 1933. Game fishes of Bombay, the Deccan and the neighbouring districts of the Bombay Presidency. *J. Bombay nat. Hist. soc.* 36(1) : 29-66.
- Sreenivasan, A. 1963. Primary production in three upland lake of Madras State, India. *Curr. Sci.* 32 : 130-131.
- Sreenivasan, A. 1964a. Limnological features of and primary production in polluted moat at Vellore, Madras State. *Environ. Health*. 6 : 237-245.

- Sreenivasan, A. 1964b. Limnological studies and fish yield in three upland lakes of Madras State, India. *Limnol. Oceanogr.* 9 : 564-575.
- Sreenivasan, A. 1966. Limnology of tropical impoundments. I. Hydrological features and fish production in Stanley reservoir. *Int. Rev. Ges. Hydrobiol.* 51(2) : 295-306.
- Sreenivasan, A. 1968. Limnology of Tropical Impoundments. IV. Studies of two hard water reservoirs in Madras State. *Arch. Hydrobiol.* 65(2) : 205-222.
- Sreenivasan, A. 1970. Limnology of tropical impoundments. A comparative study of the major reservoirs in Madras State (India). *Hydrobiologia.* 36(3-4) : 443-467.
- Sreenivasan, A. 1971. Shallow aquatic biotopes as limnological models. *Hydrobiologia.* 37(3-4) : 553-564.
- Srivastava, A.K. and N.N. Singh. 1980. Observations on hyperglycemia in the murrel (Channa punctatus) after acute exposure to methyl parathion. *Comp. Physiol. Ecol.* 5(2) : 100-101.
- Srivastava, G.D. 1950. The pH tolerance of an aquatic plant community. *Curr. Sci.* 19 : 66.
- Srivastava, S. 1977. Some observations on the fishery and biology of the murrel Channa striatus (Bloch) of Ramgarh lake (Gorakhpur). *Zeitschrift für Angewandte Zool.* 403-408.
- Srivastava, V.M.S. and P.K. Gupta. 1979. Lobal distribution of free amino acids in the brain of Channa punctatus (Bloch). *Comp. Physiol. Ecol.* 4(4) : 223-224.
- *Steedmann Nielsen, E. 1937. On the relation between the quantities of phytoplankton and zooplankton in the sea. *Cons. Perm. Int. p. 1'Explo. de la mer. J. du. Cons.* 12 : 147-154.
- Subbarao, O. and B.V. Govind. 1964. Hydrology of Tungabhadra reservoir. *Indian J. Fish.* 11(1) : 321-344.
- Sumitra, V. 1971. Seasonal variation in Primary Productivity in Three Tropical ponds. *Hydrobiol.* 38(3-4) : 395-408.
- Suryavanshi, S. and J.S. Chakraborty. 1972. Studies on the blood glucose and pancreatic islets of the teleost. Channa striatus (Bloch). *Proc. Indian Sci. Cong. Abs.* 59 : 487.
- Suyehiro, Y. 1941. A study of the digestive system and feeding habits of fish. *Jap. J. Zool.* 10 : 1-303.
- Suzuki, R. and M. Yamaguchi. 1980. Meristic and morphometric characters of fine races of Cyprinus carpio. *Japanese Jour. of Ichthyol.* 27(3) : 199-206.
- Swale, E.M.F. 1964. A study of the phytoplankton of a calcareous river. *J. Ecol.* 52(2) : 433-446.
- Swarup, K. and S.R. Singh. 1979. Limnological studies of Sursha lake (Ballia). I. Variations in the water quality. *J. Inland Fish. Soc. India.* 11(1) : 22-33.

- Swarup, K. and S. Srivastava. 1975. Occurrence of collagenous capsules in the testes of Channa striatus and C. marulius. J. Inland Fish. Soc. 7 : 88-90.
- *Sykes, W.H. 1839. On the fishes of the Deccan. Proc. Zool. Soc. London. 93 : 157-165.
- *Sykes, W.H. 1841. On the fishes of the Duphun. Trans. Zool. Soc. London. 2 : 349-378.
- Tandon, K.K. 1964. Absence of the right pelvic fin in Channa punctatus (Bloch). Res. Bull. Punjab Univ. 15 : 351-352.
- Tandon, K.K. and P. Kaur. 1979. Taxonomic value of Tori longitudinales and Valvula cerebelli in Channa punctatus (Bloch) and Channa marulius (Ham.). Curr. Sci. India. 48(11) : 511.
- Taning, A.V. 1944. Experiments on meristic and other characters in fishes. I. On the influence of temperature on some meristic characters in sea trout and the fixation period of these characters. Medd. Dan. Fisk. Havunders. 11(3) : 1-66.
- Taylor, M.P. and E.B. Welch. 1970. Morris Reservoir study. Part II. Effects of thermal stratification and nutrient availability on the production of reservoir phytoplankton : 34.
- Tiwari, K.K. and B.K. Sharma. 1977. Rotifers in the Indian Museum tank, Calcutta. Sci. Cult. 43 : 280-282.
- Tobor, J.G. 1974. A contribution to the study of Lates nilaticus Nile Perch in Lake Chad. Federal Ministry of Information Printing Division, Lagos. Occasional Paper No. 17 : 1-23.
- Unni, K.S. 1971a. An ecological study of the macrophytic vegetation of the Doodhadhari lake, Raipur, M.P., India. Hydrobiologia. 37 : 139-155.
- Unni, K.S. 1971b. An ecological study of the macrophytic vegetation of the Doodhadhari lake, Raipur, M.P., India. 2. Physical Factors. Hydrobiologia. 38(3-4):479-487.
- Varghese, T.J. 1961. Some observations on the biology of Ceilia borneensis. Indian J. Fish. 8(2) : 312-325.
- Vashisht, H.S. 1968. Limnological studies of Sukhna Lake, Chandigarh (India). Proc. Symp. Rec. Adv. Trop. Ecol. 316-325.
- Vasisht, H.S. and B.L. Dawar. 1968. The male of the Rotifer Cupelopagis vorax (Leidy). Cur. Sci. 37 : 466-467.
- Vasisht, H.S. and C.L. Gupta. 1967. The rotifer fauna of Chandigarh. Res. Bull. (N.S.) Punjab Univ. 18 : 495-496.
- Vasisht, H.S. and S.K. Bhattish. 1969. The Rotifer fauna of North India. I. Scaridium longicaudum Ehrenberg. Res. Bull. (N.S.) Punjab Univ. 20 : 593-594.
- Vasisht, H.S. and S.K. Bhattish. 1970. The rotifer fauna of North India. II. Trichocerca porcellus. Res. Bull. (N.S.) Punjab Univ. 21 : 515.

- Vasisht, H.S. and S.K. Bhattish. 1971. The rotifer fauna of North India. Brachionus. Res. Bull. (N.S.). Punjab Univ. 22 : 179-186.
- Vasisht, H.S. and S.K. Bhattish. 1971b. The rotifer fauna of North India. Lepadella and Colurella. Res. Bull. (N.S.). Punjab Univ. 22 : 189-192.
- Vaas, K.K. and D.P. Zutshi. 1979. Limnological studies on Dal Lake, Kashmir. I. Morphometry and Physical features. J. Inland. Fish. Soc. India. 11(1) : 12-21.
- Venkataraman, G.S. 1961. Vaucheriaceae. Indian Council of Agricultural Research. Monographs on Algae : 112.
- Venkateswarlu, T. and T.V. Jayanti. 1968. Hydrobiological studies of the River Sabarmati to evaluate water quality. Hydrobiologia. 31 : 442-448.
- Verma, M.N. 1967. Diurnal variations in a fish pond in Sconi, India. Hydrobiologia. 30(1) : 129-137.
- Verma, S.R., M.C. Bhatnagar and R.C. Dalela. 1978. Biocides in relation to water pollution. 2. Bioassay studies of few biocides to a freshwater fish, Channa gachua. Acta. Hydrochim. Hydrobiol. 6(2) : 137.
- Verma, S.R., A.K. Tyagi, N. Pal and R.C. Dalela. 1979. In vivo effect of the syndets IDET-5L and SWANIC-6L on ATPase activity in the teleost, Channa punctatus. Arch. Environ. Contam. & Tox. 8(2) : 241-246.
- *Vladykov, V.D. 1934. Environmental and taxonomic character of fishes. Trans. R. Can. Inst. 20 : 99-140.
- *Vollenweider, R.A. 1968. Scientific fundamentals of eutrophication of lakes and flowing water with particular reference to nitrogen and phosphorus as factors in eutrophication. Water Manag. Res.
- Vyas, L.N. and H.D. Kumar. 1968. Studies on the phytoplankton and other algae of Indrasagar tank, Udaipur, India. Hydrobiologia. 31 : 421-434.
- Walford, C.A. 1932. The California Barracuda Sphyraena argentea. Calif. Div. Fish & Game. Fish. Bull. 37.
- Weatherley, A.H. 1972. Growth and Ecology of Fish Populations. Academic Press, London. pp. 293.
- Welch, P.S. 1948. Limnological Methods. McGraw-Hill Book Co., Inc., New York.
- Welch, P.S. 1952. Limnology. McGraw-Hill, New York. 538 pp.
- *Whipple, G.C. and H.N. Parker. 1902. On the amount of oxygen and carbonic acid dissolved in natural waters and the effect of these gases upon the occurrence of microscopic organisms. Trans. Amer. Microscop. Soc. 23 : 103-144.
- Wiebe, A.H. 1927. Biological survey of Upper Mississippi with special references to pollution. Bull. U.S. Bur. Fish. 43(2) : 137-167.
- Willey, A. 1910. Observation on the nest, eggs and larvae of Ophicephalus striatus. Spol. Zeyl. Colombo. 6 : 108-123.

- Wimpenny, R.S. 1936. The distribution, breeding and feeding of some important plankton organisms of the South-West North Sea in 1934. Fish. Invest. Gt. Britain. Ser. II, 15(3), 53 pp.
- Winberg, G.G. 1963. The primary production of bodies of water. U.S. Atomic Energy Comm., Transl. AEC-tr-5692, Biol. Med. Off. Tech. Serv., Washington D.C. pp. 601.
- Wolfret, D.R. and T.J. Miller. 1978. Age, growth and food of Northern pike in Eastern Lake Ontario. Trans. Am. Fish. Soc. 107(5) : 696-702.
- Woodhead, A.D. 1960. Nutrition and reproductive capacity in fish. Proc. Natr. Soc. 19 : 23-28.
- Wootton, R.J. 1973. The effect of size of food ration on egg production in the female three spined stickleback. Gasterosteus aculeatus L. J. Fish. Biol. 5 : 89-96.
- Worthington, E.B. 1943. Freshwater fisheries in British Colonial Empire. Nature. 141 : 353-355.
- *Wulfert, K. 1966. Rotatorian aus dem Stausee Ajua und der Trinkwasser Aufbereitung der Stadt Baroda (Indian). Limnologica. 4 : 53-93.
- Wycliffe, M.J. and R.G. Michael. 1968. Pseudoembata acutipoda gen. et. sp. nov. (Rotifera : Bdelloridae) an epizoic rotifer. Cur. Sci. 37 : 106-108.
- Yazdani, G.M. and S.K. Chanda. 1971. Identity of Channa stewartii (Playfair) with some observations on abnormal specimens (Channiformes : Channidae). Sci. Cult. 37 : 580-581.
- *Yousuf, A.R. 1979. Ph.D. Thesis. Kashmir University, Srinagar.
- Yaen, H.S.H. 1955. Maturity and fecundity of big eye tuna in the Pacific. Spec. Sci. Rep. U.S. Fish Wildl. Serv. Fish. 150 : 30.
- Zafar, A.R. 1955. On the periodicity and distribution of algae in certain fish ponds in the vicinity of Hyderabad, India. Ph.D. Thesis, Osmania University.
- Zafar, A.R. 1959. Taxonomy of lakes. Hydrobiol. 13(3):287-299.
- Zafar, A.R. 1964a. On the ecology of algae in certain fish ponds of Hyderabad, India. I. Physico-chemical complexes. Hydrobiologia. 23 : 179-195.
- Zafar, A.R. 1964. On the ecology of algae in certain fish ponds of Hyderabad, India. II. Distribution of unicellular and colonial forms. Hydrobiol. 24(4) : 556-566.
- *Zafar, A.R. 1966. Limnology of Huesain sagar lake, Hyderabad, India. Phykos. 5(1&2) : 115-126.

* Original not consulted.

IBHU Library
 Acc. No. 101360
 Acc. by... Woolley
 Class by.....
 Sub. Head.....
 Cata. by.....
 Transcribed by.....

APPENDIX

AUTHOR'S LIST OF PUBLICATIONS

(A) : Paper(s) presented at the Congress(s)/Seminar(s) :

1. Studies on the abiotic factors of a shallow pond during winter in Shillong (Meghalaya). 67th Indian Science Congr., Sec. Zool. Entomol. Fish., Abs.No. 160 : pp. 157 (1980).
2. On the ecology of the fishes of the family Channidae with special reference to their abiotic environment. IInd All India Seminar on Ichthyology, Abs. No. 55 : pp. 38 (1979).
3. Some limnological observations on a shallow pond in Shillong (India): Physico-chemical factors and planktonic periodicity. 21st (SIL) International Congress of Limnology, Japan, Abs. No. C2-Wpm - 5 : pp. 110 (1980).

(B) : Paper published :

1. Observations on the abiotic factors and planktonic periodicity in a shallow pond from the highlands of Shillong (India). Acta. Hydrochim. Hydrobiol. 9, 1981 (In Press).
2. On the length-weight relationship and condition factor of Channa gachua (Ham.). Arquivos do Museu Bocage., 1981 (In Press).
3. Culturable fishes of India. Sci. Rept. 16(17): 486-488 (1979).