

STUDIES ON THE POPULATION STRUCTURE OF ZOOPLANKTON IN THE KOTMALE RESERVOIR

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Abstract: Plankton samples were collected from Kotmale reservoir, at approximately monthly intervals from August 1990 to August 1991. Investigations were focused on species composition, seasonal variation, vertical and horizontal distribution and the size class distribution in the population structure of zooplankton. Two species of cyclopoids, two species of calanoids, nine species of cladocerans and sixteen species of rotifers were recorded. Among these, the most abundant species during the study period were *Mesocyclops* sp., *Phyllodiaptomus annae*, *Ceriodaphnia cornuta*, *Keratella tropica*, *Filina longiseta*, *Brachionus caudatus* and *Tricocerca similis*. A location at the deepest region of the reservoir closer to the dam was selected as a representative station to investigate the vertical distribution of zooplankton. At this location, the vertical distribution patterns of all the zooplankton were almost similar throughout the year. As this location is situated at the down stream region of the river, it was expected to contain most of the zooplankton of the reservoir. The horizontal distribution of zooplankton did not show much variation. The nauplii stages and cyclopoids showed highest abundance in the population of zooplankton. However, during most of the months, the adult stages of calanoids and cladocerans were highly abundant.

Key words: Cyclopoids, calanoids, cladocerans, rotifers, seasonal variation, population structure, zooplankton.

INTRODUCTION

Kotmale reservoir is located at an elevation of 640 to 762m, 2100 feet above sea level with a geographical position of 7° 03' to 7° 05' N and 80° 36' to 80° 41' E. The morphometric features of the reservoir could be summarized as follows: surface area = 6.5 km², maximum depth = 90 m, volume = 174 mcm, mean depth = 26.8m, maximum length = 6.8 km and maximum width = 1.41 km.

Kotmale reservoir is the uppermost reservoir of an interconnected reservoir chain which is fed by a large number of tributaries from its catchment. The inlets of the catchment could therefore often influence the species diversity, seasonal variation and the population structure of the zooplankton in the reservoir.

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Much work has been already done on zooplankton in the water bodies of Sri Lanka. According to Fernando^{1,2} the limnetic zooplankton of Sri Lanka are typically tropical and poor in species diversity² and those with large body sizes were absent or rare in tropical waters.² Species composition in various water bodies of Sri Lanka is markedly different during different seasons of the year,³ which may be both short and long-term.^{4,5} Work on the composition of zooplankton species in Mahaweli reservoirs,⁶⁻¹⁰ indicated that the zooplankton component was represented by copepods, cladocerans & rotifers in the upland Mahaweli reservoirs and that the species richness of copepods was less than that of the rotifers and cladocerans.

The objective of the present work is to construct a complete picture of the species composition, seasonal fluctuations and the vertical and horizontal distribution patterns of the zooplankton and to describe the population of the zooplankton in the reservoir during the period of investigation from August 1990 to August 1991.

METHODS AND MATERIALS

Sampling procedure: Fig. 1 illustrates the locations of the sampling stations. St1 closer to the dam, is the deepest region in the reservoir and it was selected as a suitable location to investigate the vertical distribution pattern of zooplankton due to the following reasons: (1) As this location is situated at the down stream region, due to the direction of water flow, it was expected that this location would contain most of the representative zooplankton types of the reservoir. (2) As this is the deepest part of the reservoir its water level remains at a considerably higher level, even during severe droughts. (3) Therefore it allowed the comparison of the vertical distribution patterns of zooplankton during both high and low water levels. (4) Thus the results were comparable throughout the study.

For horizontal sampling, 10 locations (St1, St2, St3, A, B, C, D E, F & G) were selected from the dam site to the upstream region as illustrated in Fig. 1.

Vertical distribution: At major station 1, zooplankton samples were collected by filtering vertical columns of water from varying depth intervals from 0 – 10m, 10 – 20m, 20 – 30m etc. using a closing type net with 50 μ m mesh size which filtered 0.2011 m³ of water.

Sampling was done from 0900h to 1400 h, at monthly intervals for a period of one year from August 1990 to August 1991. Samples collected were transferred into sampling bottles and fixed in 5% formaline and transported to the laboratory for further investigations.

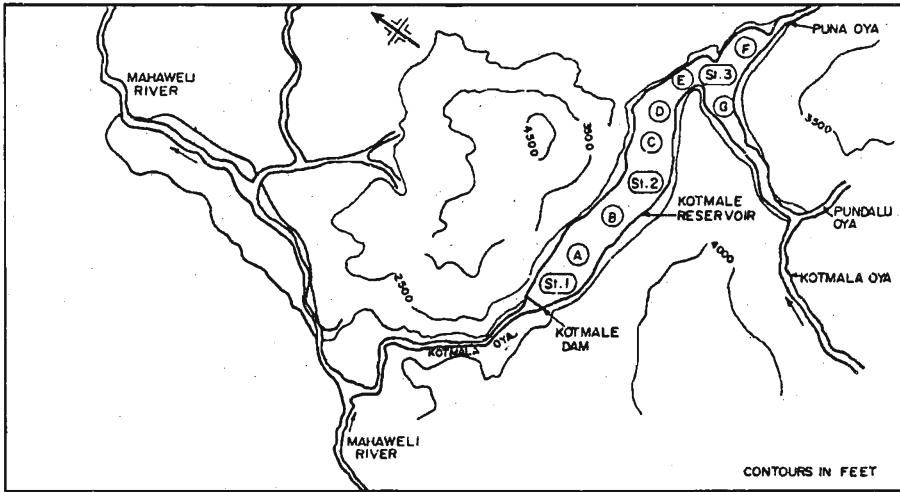


Figure 1: Kotmale reservoir with the locations of sampling. St1, indicates the location where the sampling was done along the vertical profile of the water column. At St 2 , St 3 , A, B, C, D, E, F & G stations, sampling was done at the surface & at 10m depths.

Horizontal distribution: As the euphotic limit of the reservoir was less than 10 m as indicated in Piyasiri,^{11,12} for investigations on horizontal distribution, sampling was done at the top 10m-epilimnetic region where the zooplankton was highly abundant.

Samples collected in the field were transferred into sampling bottles and fixed in 5% formaline and transported to the laboratory for identification and enumeration.

Analysis of samples: All the plankton samples were diluted upto 100ml. Then 5 random sub samples (each representing 1ml with a coefficient of variation of 0.1 – 0.35) were used to analyse the zooplankton. For identification of zooplankton in the samples, keys of Streble & Krauter¹³ were used. Different types of zooplankton in each sub sample were counted using a Sedgewick Rafter counting chamber.

Life cycle stages and size class distribution: To study the population structure of the zooplankton community, the total lengths of different stages were measured in 80% of the counted individuals using an eye piece micrometer.

There were Nauplii of various stages with body lengths ranging from 0.09 to 0.33mm. N1 & N6 stages were identifiable and belonged to the size ranges of 0.09 to 0.12mm (N1) & 0.31 to 0.33mm (N6) respectively. As it was difficult to distinguish N3 to N5 stages, they were collectively considered in the size range

of 0.13 to 0.31mm in the population structure. The copepodite stages (C_1 to C_5) were identified using their morphological features and were categorized into different size classes accordingly. *Ceriodaphnia cornuta* were categorized into three size classes, which represented the embryonic stage (the smallest size class), the nymphs and the adults. For Rotifera, it was impossible to identify the stages and therefore analysis of life cycle stages was not attempted. For data analysis on size class distribution of plankton, related to their stages, zooplankton collected from epilimnetic waters along the horizontal axis of the reservoir was considered.

RESULTS

Seasonal fluctuation of zooplankton

Table 1 illustrates the richness of species in Kotmale reservoir. Sixteen species of rotifers, nine species of cladocerans, and three species of copepods were recorded during the present investigation. Fig. 2 illustrates the monthly variation in percentage occurrence of Cyclopoida, Calanoida, Cladocera & Rotifera of the epilimnetic waters of the reservoir. Copepods made a significant contribution to zooplankton population (Fig. 2). Calanoids were the least abundant and cyclopoids and rotifera dominated the population throughout the investigation. Cladocera occurred in fairly high percentages throughout the investigation.

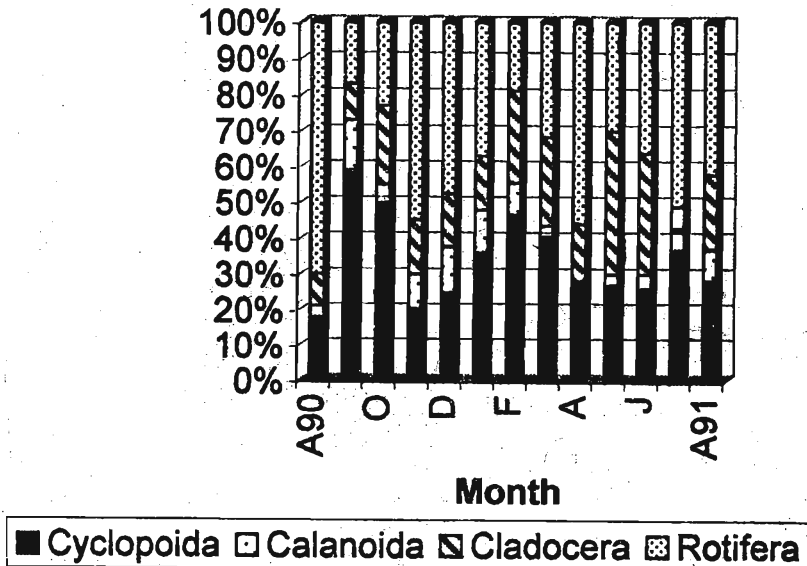


Figure 2: Percentage composition of Cyclopoida, Calanoida, Cladocera & Rotifera in the zooplankton community of the epilimnetic waters of Kotmale reservoir. For this analysis, samples collected from all the locations from surface to 10m depths during the investigation period were considered.

Table 1: Zooplankton in Kotmale reservoir during 1990 to 1992 investigation period. All the samples collected during the study period were analyzed.

No.	Rotifera	No.	Cladocera	No.	Copepoda
	Family Brachionidae		Family Daphnidae		
1	<i>Brachionus caudatus</i>	1	<i>Ceriodaphnia cornuta</i>	1	<i>Mesocyclops</i> sp.
2	<i>Brachionus falcatus</i>	2	<i>Daphnia lumholtzi</i>	2	<i>Thermocyclops crassus</i>
3	<i>Brachionus angularis</i>	3	<i>Diaphanosoma aspinosum</i>	3	<i>Tropodiatomus australis</i>
4	<i>Brachionus calyciflorus</i>	4	<i>Diaphanosoma modigliani</i>		
5	<i>Brachionus forficula</i>		Family Moinidae		
6	<i>Anuraeopsis fissa</i>	5	<i>Moina micrura</i>		
7	<i>Keratella tropica</i>		Family Chydoridae		
	Family Tricocercidae	6	<i>Chydorus eurynotus</i>		
8	<i>Tricocera similis</i>	7	<i>Alona</i> sp.		
9	<i>Tricocerca birostris</i>		Family Bosminidae		
	Family Filinidae	8	<i>Bosmina</i> sp.		
10	<i>Filina opoliensis</i>		Family Macrothricidae		
11	<i>Filina longiseta</i>	9	<i>Macrothrix</i> sp.		
	Family Hexarthridae				
12	<i>Hexathra</i> sp.				
13	<i>Asplanchna</i> sp1				
14	<i>Asplanchna</i> sp2				
	Family Lampryidae				
15	<i>Lecane</i> sp1				
16	<i>Lecane</i> sp2				

Fig. 3 illustrates the monthly fluctuations in the abundance of different species of Cladocera, Rotifera and Copepoda at the surface epilimnetic waters of the reservoir. *C. cornuta* was the dominant species of the Cladocera population during most months whereas all the other cladoceran species appeared in low densities. There were two morphological forms in *C. cornuta* population.⁷

A thick bloom of *Microcystis aeruginosa* covered the Kotmale reservoir during the latter part of 1991 from Sept. to December 1991.¹² During this period, it was found that the *C. cornuta* with small body sizes were dominating the Cladocera population of the reservoir.

D. lumholtzi was the largest Cladocera (mean length = 1.38mm SD \pm 0.12) in the range of 1.98 mm to 2.34 mm. It had two morphological forms. The less common one was with a thin long spine-like process on the head region and a thin body while the common form had much shorter and stouter process on the head

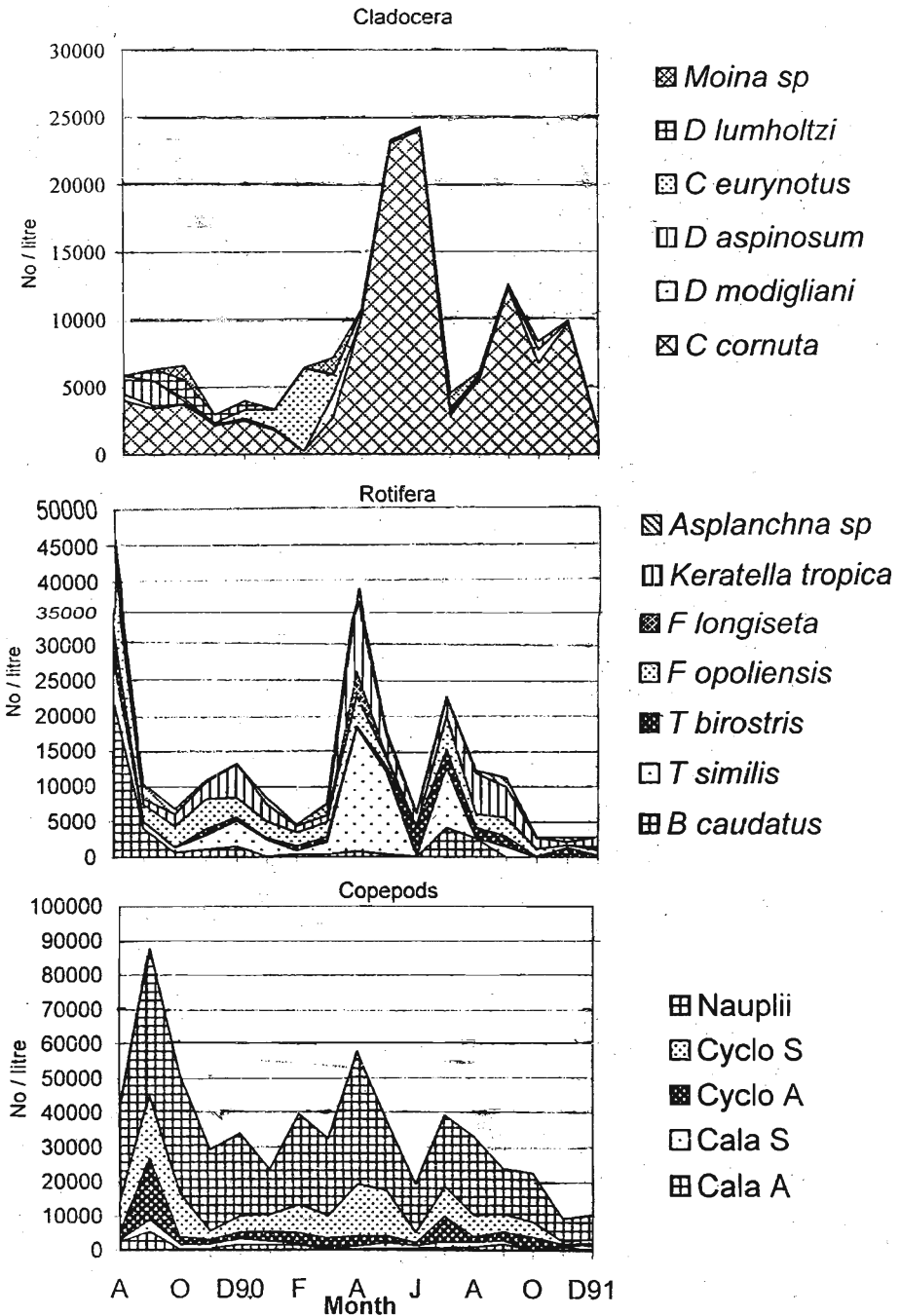


Figure 3: Seasonal variation and abundance of different species of Calanoida, Rotifera & Copepoda (as Number per litre) at the epilimnetic waters of the Kotmale reservoir.

and its body was stout. *C. eurynotus* species was generally abundant from December 1990 to March 1991. Other Cladocera species: *Moina* species, *D. aspinosum* and *D. modigliani* were found in low numbers during this study.

As shown in Fig. 3 the most abundant rotifer species was *B. caudatus*, *F. opoliensis*, *K. tropica*, *T. birostris* and *Asplanchna* species. The peaks in the rotifer population were observed from Aug. to Sept. 1990, April – May 1991 & July to Sept. 1991.

As illustrated in Fig.3 the copepods population was dominated by Nauplii stages throughout the investigation. Copepodite stages of cyclopoids (Cyclo S) also made a significant contribution. Considering the adults, cyclopoids (Cyclo A) dominated over the calanoids (Cala A). Copepodid stages of calanoids (Cala S) were low in number throughout the investigation period.

Distribution

Vertical distribution during high water level

Fig.4 A illustrates the general vertical distribution pattern of zooplankton at St1 recorded in August 1990 (when reservoir water level was high closer to the dam). When the reservoir water level was high, most of the zooplankton types were distributed throughout the water column. *B. caudatus* and *F. opoliensis* densities were high even at 30 to 40m depths. All the other rotifer species showed more or less uniform distribution along the water column.

Out of the cladocerans, *C. cornuta* was dominant from 30 to 40m depth range whereas *D. aspinosum* density was high upto 10 to 20m. *C. eurynotes* and *D. modigliani* were more or less uniformly distributed along the vertical profile.

Out of the copepods, Cyclopoid copepodites indicated highest densities from 20 to 40m whereas all the other copepods were approximately uniform along the water column. Nauplii stages were strikingly high from 20 to 40m.

Eggs and nymph stages of cladocerans did not show any similarity to the vertical distribution pattern indicated by the adults and other stages of zooplankton. The highest accumulation of zooplankton from 20m to 40m depth range was the general tendency of the vertical distribution pattern of zooplankton in Kotmale reservoir.

Vertical distribution during low water levels

Fig. 4B illustrates the vertical distribution pattern of zooplankton at the dam region in October 1990, (at low reservoir water level when power generation

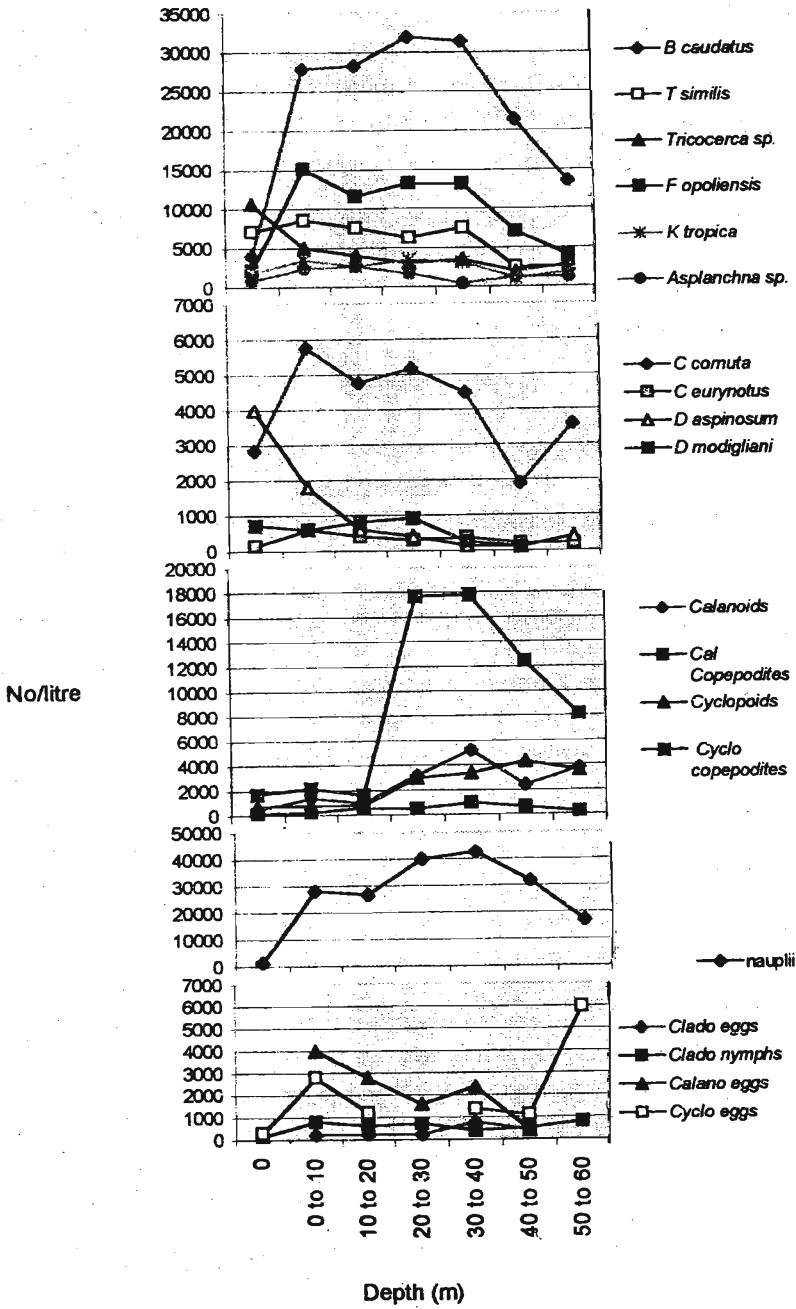


Figure 4A: General vertical distribution pattern of zooplankton at St1 recorded in August 1990, when the water level of the reservoir was high closer to the dam.

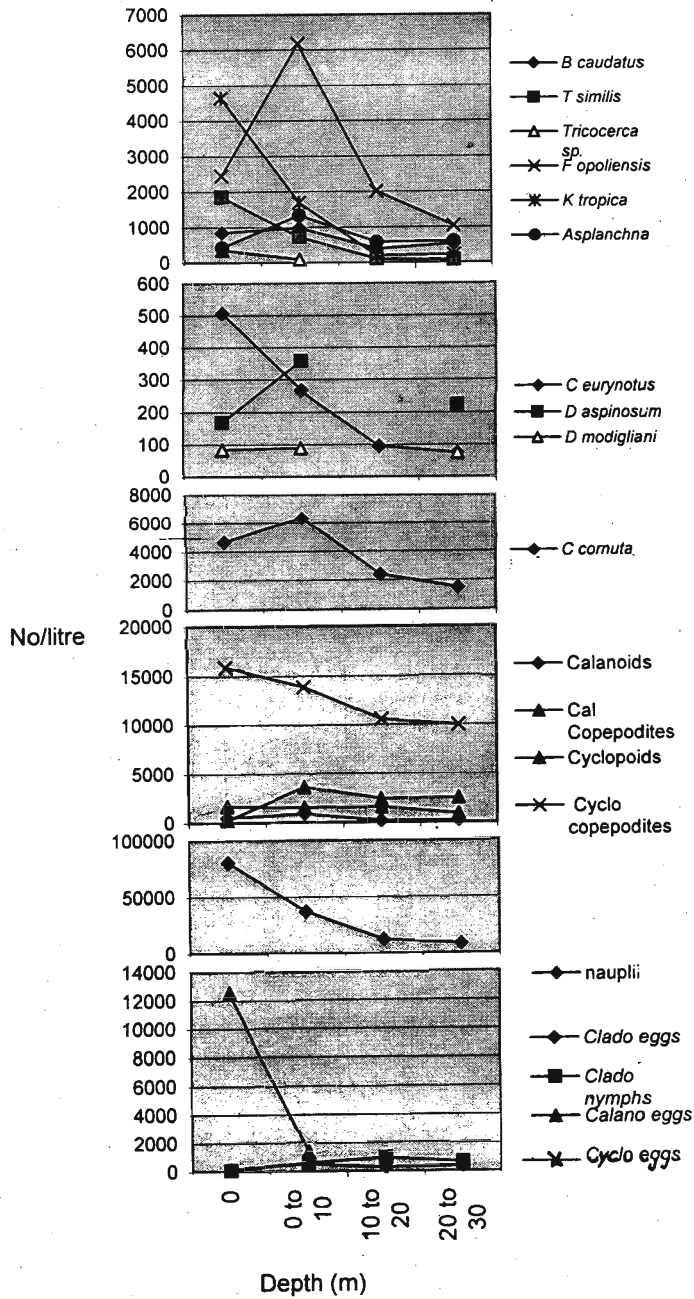


Figure 4B: General vertical distribution pattern of zooplankton at St1 recorded in October 1990 when the water level of the reservoir was low.

was limited). This pattern shows that the zooplankton was high in abundance from the surface to 10m depths and decreases in density with increasing depth. This was the general trend found in the vertical distribution pattern of zooplankton at St1 during the other months of the investigation period during low reservoir water levels.

Horizontal distribution

Fig. 5 illustrates the horizontal distribution of copepods, cyclopoids, *C. cornuta* and *Keratella* sp. at the epilimnetic water layer from the dam site to the upstream region along the longitudinal axis of the reservoir. Population densities of all these forms were generally low at the dam site. However at the middle part of the reservoir, highest abundance of these types were recorded. At the upstream region their abundance was generally high. There was no variation in horizontal distribution pattern of Nauplii at the surface and at 10m depths. For all the samples collected during the investigation period at ten sites, the mean number of Nauplii per litre present at the surface was 32.2 SD \pm 13.6, CV 0.42 and at 10m depths it was 35.3, SD \pm 17.95, CV 50. As illustrated in Fig.5, the cyclopoids were observed throughout the reservoir with a mean abundance of 12.78 per litre, SD \pm 9.5, CV 0.74. During the investigation period, they were more abundant in St2, St3, and at F locations. There was no difference in the horizontal distribution of *C. cornuta*, but their abundance was slightly higher in St3 than the other stations on most of the sampling occasions.

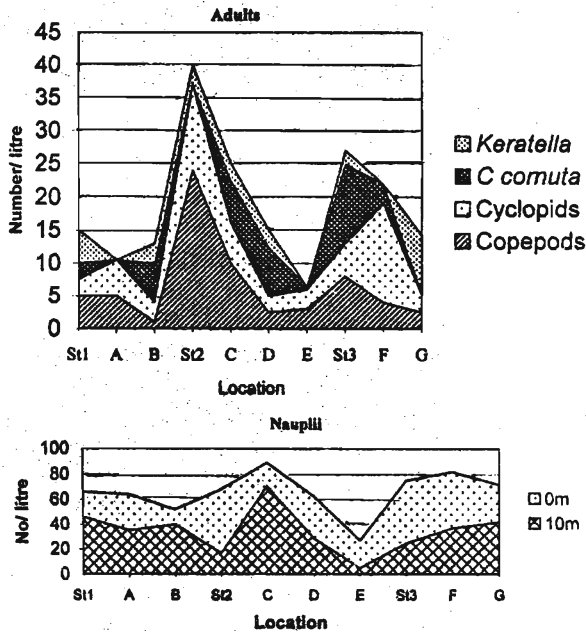


Figure 5: Abundance of *Keratella*, *C. cornuta*, Cyclopoids, copepods (as no. per litre) & Nauplii (number per litre) along the horizontal axis of the reservoir. Analysis was based on the samples collected from all the stations at the surface to 10m depths.

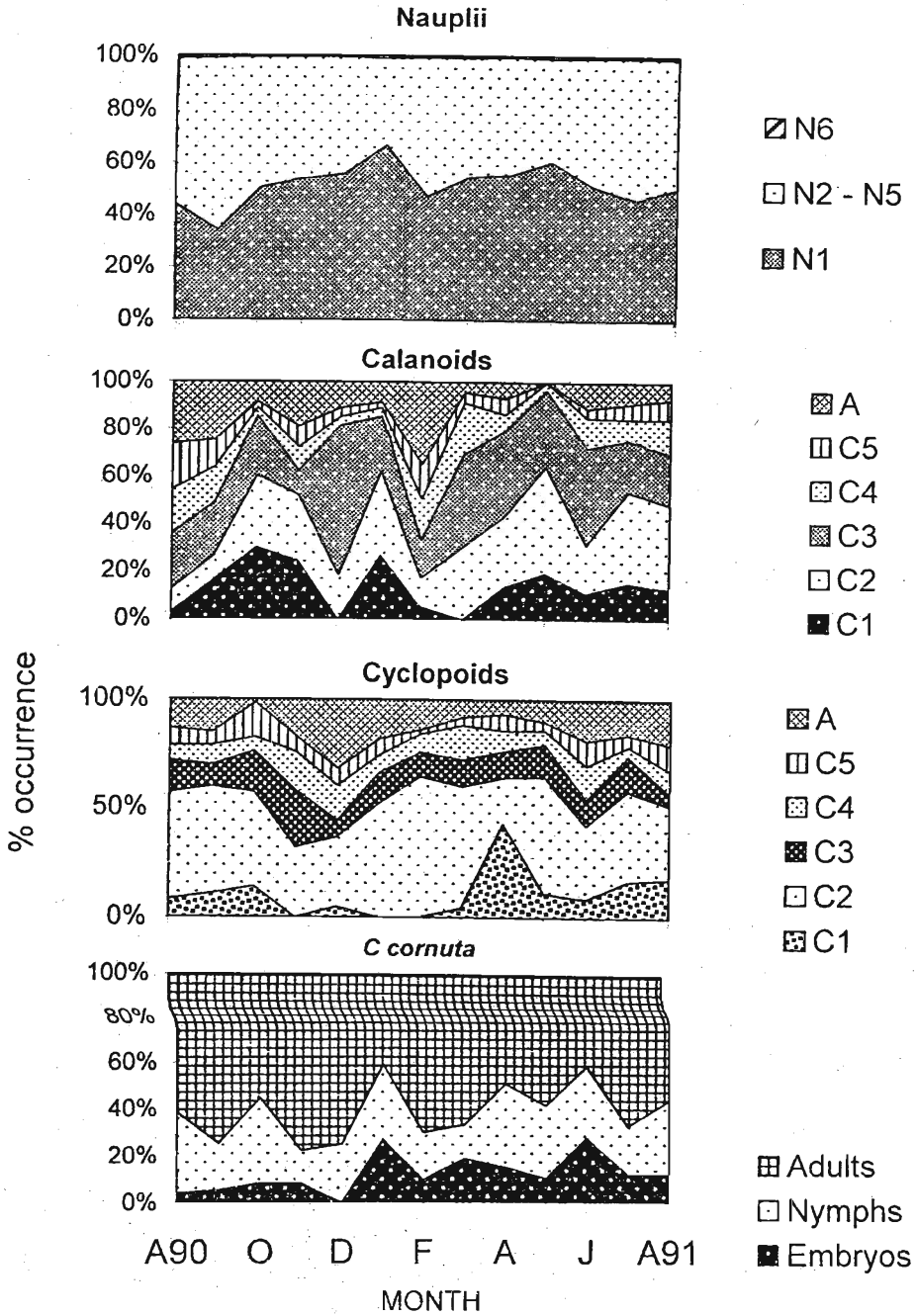


Figure 6: Seasonal variation of occurrence of Nauplii, Calanoids, Cycloids C, cornuta at the surface to 10m depth; at the epilimnetic waters of the reservoir during the investigation period

Population structure

Nauplii

Fig.6 illustrates the distribution of Nauplii stages of Copepoda in the reservoir. Data from all sites at surface to 10m depths, (horizontal sampling locations) were utilized to compare these results. Plankton population was composed of Nauplii of various stages and their body lengths varied between 0.09 to 0.33mm. The smallest size range (N1 stage) was 0.09 – 0.12mm which comprised 34% - 67% (mean of 50.6%, SD \pm 0.84, CV = 0.017) of the Nauplii stages. The total number of individuals decreased gradually with increase of the size range (with the stage). Comparatively few numbers of individuals were present in the higher size classes of 0.31 – 0.33mm which represent the N6 stage (Fig.6). From Oct. – Nov. 1990 & Feb. – March 1991 large Nauplii (N6) with length classes of 0.31 to 0.33mm were present in the population, but were very few in number and negligible compared to other stages as indicated in Fig.6.

Copepodite stages of cyclopoids

In the copepod population, the copepodite stages of cyclopoids and calanoids were identifiable. The smallest Cyclopoid copepodite stage (C1 stage) recorded had a body length of 0.27mm and the smallest calanoid copepodite stage had a length of 0.36mm.

Fig 6 illustrates the distribution of different copepodite stages of cyclopoids in different months collected from epilimnetic waters of the entire reservoir. The increase in their body length is a measure of their stage. Different copepodite stages belonged to different size class ranges as C1: 0.27 – 0.35mm, C2: 0.36 - 0.44mm, C3: 0.45 - 0.53mm, C4: 0.54 - 0.62, and C5: 0.63 - 0.71mm and the Adults: 0.72 - 1.34. Early copepodite stages were high in number compared to that of Nauplii of the final stages, which indicate molting of Nauplii to the copepodite stages. In May 1991, the lowest size class (0.27 to 0.35mm) became most abundant and in the same month lowest water level (35m at dam site) was recorded with high temperature which could be considered as favourable conditions for hatching of eggs. During this period, abundance of Nauplii and copepodite stages were also fairly high. However the density of the adult cyclopoids decreased to low levels. The population of copepodite stages decreased gradually with the increase in body size (stage). The adults (body size > 0.63 mm) were always numerically lower than the copepodite stages. During high water levels, the adults were numerically high in the population.

In Aug. to Sept. 1990, Oct. to Dec. 1990 and in March 1991, the adults of calanoid population were more numerous. This situation was different from cyclopoids population where copepodites dominated throughout the investiga-

tion period. However both copepodite stages and adults were lower in numbers in calanoids than that of cyclopoids throughout the year. According to Fig.6 there was a fluctuation in percentage contribution of different stages with different size classes to the population of calanoids. Percentage of C4, C5 and adults of calanoids were less than the smaller copepodite stages of the population.

Cladocera

As illustrated in Fig. 2, cladocerans contributed significantly to the zooplankton community of the epilimnetic waters of the reservoir during most months of the year.

C. cornuta dominated the samples throughout the study (Fig.3) except in Feb .1991. As illustrated in Fig.6, Cladocera community of the epilimnetic waters of the reservoir contained various stages of *C. cornuta* (with different size class ranges). There were rare occasions where larger individuals with a body length between 0.87 to 0.90mm were recorded. The individuals belonging to the first size class range were considered as embryos (not properly developed) and generally they were present in low numbers. The second size range (0.33 to 0.41mm) which was considered as nymphs, were abundant in the epilimnetic waters. The percentage abundance of *C. cornuta* adults was higher in the population than the nymphs and the embryos in the limnetic zone. The population structure and the dominant size class varied monthly.

DISCUSSION

During the present investigation, twenty eight zooplankton species were found in the epilimnetic waters of the Kotmale reservoir. The highest number of species was found in Rotifera in which sixteen species were recorded, whereas it was low in Copepoda and Cladocera. Fernando¹⁴ has also found similar results for three taxonomic groups of zooplankton present in the water bodies of Sri Lanka. Out of the three major taxonomic groups, the Copepoda and Rotifera have dominated the zooplankton population at the epilimnetic waters of the reservoir. Piyasiri & Jayakody⁶ for Victoria reservoir & Pathmalal & Piyasiri⁸ for Randenigala have also found copepods as the most dominant zooplankton type as in the present case. Rajapakse & Fernando¹⁵ have found copepods in high percentages in the littoral zones of the water bodies of Sri Lanka. The calanoids population was comparatively smaller than the cyclopoids population in the epilimnetic waters of the reservoir. Large number of copepodite stages than the adults represented calanoids and cyclopoids. Vijverberg¹⁶ has found copepodite I and II stages and the adults as the most abundant stages in the zooplankton population of temperate lakes. In the present study, as illustrated in fig. 3, copepodite I, II & III stages and the adults were the most abundant in the calanoids population of the epilimnetic waters. In cyclopoids population (Fig. 3), the copepodite stage II was the most dominant compared to other stages.

Nauplii of the crustaceans have dominated the copepod population of the Kotmale reservoir.⁷ The crustaceans Nauplii were most noticeable among zooplankton in Colombo lake.¹⁷

The Nauplii density found in the epilimnetic waters of the reservoir indicated very low densities of late Nauplii stages (N6) compared to the smaller stages. This could be related to many reasons. The development time of the 6th Nauplii stage to adult may be very fast under warmer conditions and also due to their large sizes, they may become a prey for larger invertebrates and fish larvae which cause the high mortality rates.

C. cornuta was the most abundant Cladoceran type in the epilimnetic waters of the Kotmale reservoir. Fernando¹ also found *C. cornuta* as a dominant limnetic species and according to Rajapakse & Fernando,¹⁵ it is found in every habitat type. *C. cornuta* is the most dominant Cladocera in the Victoria reservoir as in the present study.¹¹

Presence of two morphological forms in *C. cornuta* has been previously recorded.^{18, 19} Both had equal body sizes but one was with tiny protuberances on the head region and a small eye and the other was without any protuberance but with a large eye.^{18, 19} Rajapakse & Fernando¹⁵ also described a cyclomorphosis in *C. cornuta* with horn like projections on the head and pointed beak like rostrum with similarities to the forms found in the Kotmale reservoir. The unhelmeted form of *D. lumholtzi*²⁰ was not recorded in the Kotmale reservoir and the two morphological types found in the Kotmale reservoir were with processes on the head.

As mentioned earlier, it is a known fact that the general trend of the body sizes of zooplankton in tropical waters is smaller sizes than that of temperate waters. Vidal²¹ based on his detailed ecophysiological experimental work has explained body size related patterns of geographical and vertical distribution in species of zooplankton. That is, oligotrophic tropical and sub tropical regions with deep thermoclines are characterized by the dominance of small sized species, while richer temperate and boreal regions with shallower thermoclines are noted for the abundance of larger species. In a fresh water lake in the Netherlands,¹⁶ the length of the copepods was inversely related to the temperature. This caused relatively small sized copepods in summer.¹⁶ Piyasiri²² found similar results for a tropical Calanoid, *Phyllodiaptomus annae*, which suggests that the body sizes of the zooplankton are smaller in tropical waters, compared to that of temperate waters.

D. lumholtzi found in the present study was the largest Cladocera of the reservoir with a mean length of 1.38mm SD \pm 0.12 in the range of 1.98 to 2.34 mm. According to Brooks,²³ the species found in the temperate zones reached body

lengths of 2.5 to 5.0mm. The mean body length recorded for cyclopoids in the Kotmale reservoir was well within the length range recorded by Fernando.¹⁴ However *C. cornuta* found in the Kotmale reservoir was fairly big (0.36 to 0.84mm) compared to body lengths recorded for *C. cornuta* in the Netherlands by Zaret²⁰ and the body lengths (0.32 – 0.34mm) recorded by Rajapakse & Fernando¹⁵ in Sri Lanka. When the Kotmale reservoir was covered with a thick bloom of *M. aeruginosa* in Sept. to Dec. 1991, *C. cornuta* with smaller body size dominated the zooplankton population. There is no scientific explanation for this. However a similar situation has been recorded in a sub tropical lake in South Africa.²⁴

In the present investigation different zooplankton types have shown differences in their vertical distribution pattern (Fig.4). However most of the zooplankton experienced high densities from 20 to 40m region. At the St1, when the water level dropped during drought and when the power generation was limited, the densities of most of the zooplankton decreased with increasing depth. Piyasiri & Jayakody⁶ found similar patterns for the Victoria reservoir. Accumulation of most zooplankton types in the water column from 20m to 40m indicates that they may have found the thermocline established¹¹ at 20m depth as a barrier for upward migration. Welch²⁵ described a similar situation for many other water bodies. However it is difficult to generalize the vertical distribution of zooplankton as a whole.²⁵ The controlling circumstances being so involved and so variable a general statement is not possible.

As described by Welch,²⁵ the distribution behaviour of zooplankton may be very different in different kinds of water. It may be influenced by combined factors such as (i) physico chemical stratification, (ii) light, (iii) food (iv) dissolved oxygen (v) temperature (vi) wind, (vii) gravity and (viii) age of individuals of a species. The Kotmale reservoir is thermally stratified¹¹ and dissolved oxygen is low in the deeper hypolimnion compared to the epilimnetic region. These factors together with high density of phytoplankton and better light conditions might have influenced high abundance of certain zooplankton types in the surface water layers of the Kotmale reservoir.

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