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LIMNOLOGY PROJECT AT MAHAWELI RESERVOIRS : I. SOME PHYSICAL PROPERTIES OF KOTMALE, VICTORIA AND RANDENIGALA RESERVOIRS

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Abstract

The Physical properties of Kotmale, Victoria and Randenigala reservoirs were studied since 1987 *upto now and this paper presents the data obtained during* 1987.

The transparency values changed with the reservoir and the season. The highest frequency percentage of Secchi depth observed at each reservoir were, Victoria 1.21—1.61*m, Randenigala* 2.51—3. 01*m and Kotmale* 2.10—2.30*m, indicating highest values at Randenigala and lowest values at Victoria. Accordingly the mean euphotic limits were* 5.00*m at Victoria,* 6.25*m at Randenigala and* 5.10*m at Kotmale. The highest differences in temperature gradients were observed from surface to about* 25*m depths in all three reservoirs, in the deeper layers the temperature gradient is distinctly low. The highest conductivity values were observed closer to the dams of all three reservoirs indicating the accumulation of dissolved ions towards the dams. Range of* 30—87*μs/cm at Kotmale,* 85—139 *μs/cm at Victoria and* 110—188 *μs/cm at Randenigala. The highest values were recorded from Randenigala. The highest conductivity values were correlated with the water rentenion levels of the reservoirs. Fluctuations in pH values with the seasons follow a similar pattern in all three reservoirs. The mean pH values of the three reservoirs were in between* 6.0 *and* 8.7. *In all three reservoirs, the pH gradient was higher above* 10*m depth whereas below this depth it remained more or less constant.*

The high dissolved Oxygen concentrations were closely linked with the euphotic zones of the three reservoirs. The mean Oxygen concentration calculated during 1987 *investigation period from surface to* 5*m depth were* 4.75—7.50 *mg/*1 *at Kotmale,* 4.70—6.60 *mg/*1 *at Victoria and* 4.70—6.65 *mg/*1 *at Randenigala reservoirs. Dissolved concentrations were very low below the depth of* 20*m in all three reservoirs. However there was no evidence for the presence of deoxy genated layers in all three reservoirs.*

Key words: Mahaweli Reservoirs Euphotic zone, Thermal regime, Oxygen isopleths and Conductivity.

1. Introduction

The Mahaweli is the longest river (330 km) in Sri Lanka with an annual discharge of 8.8 x 10m^3 of water into the sea. Several dams have been built across the river for the purpose of irrigation and hydroelectric power generation. The three major reservoirs of the "Accelerated Mahaweli Project" are Kotmale, Victoria and Randenigala.

In the last few decades, natural waters, lakes, rivers, reservoirs and marine coastal zones have received greater attention from national and international bodies concerned with the control of water quality. Particularly in tropical countries proper management of inland waters is essential due to acute population growth and gradual industrialization. As in many industrialized countries, the water bodies in the tropics too may subjected to dangers of increasing eutropication and pollution. Therefore, a complete and continuing limnological study of the Mahaweli reservoirs is necessary.

With the above intention, a project titled "Limnology project at Mahaweli reservoirs" is conducting since 1987 by the author of this paper to investigate the physical, chemical and biological properties of the three reservoirs to understand the tropic status and the trophic evolution of the reservoirs. This in turn helps to determine the suitability of waters for irrigation and drinking purposes and to protect the reservoirs from pollution. The scope of the present paper is to describe some of the physical properties observed in Kotmale, Victoria and Randenigala reservoirs during 1987 to 1988 investigation period.

1.1 The study area

The three reservoirs under investigation are at different altitudes. The main identification characteristics of the reservoirs are summarised in Fig 1 1a - 1c. The data on morphometry and hydrology are given in Table I.

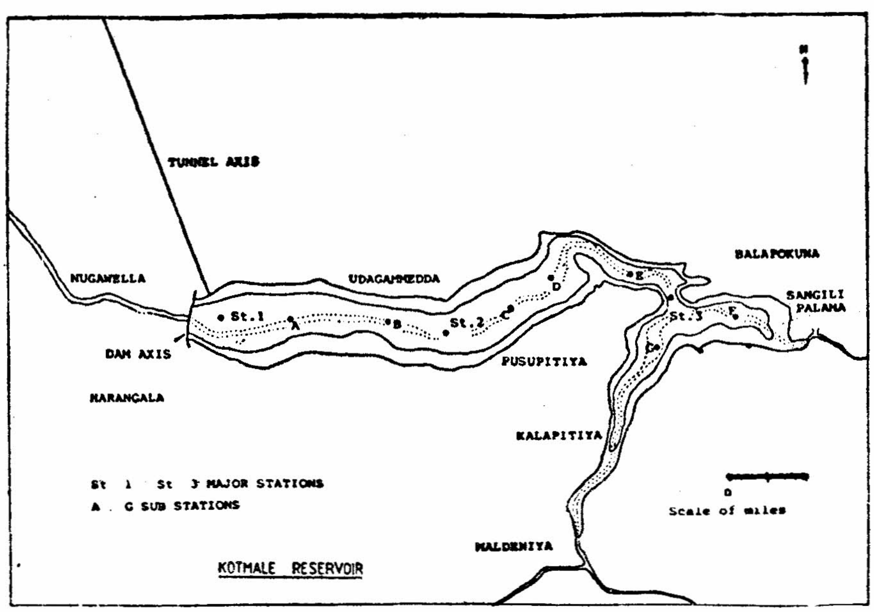

Fig. 1a: The main identificafion characteristics of Kotmale reservoir & the locations ef sampling St_1-St_3 are the three major sapling stations & A—G are the sub-stations.

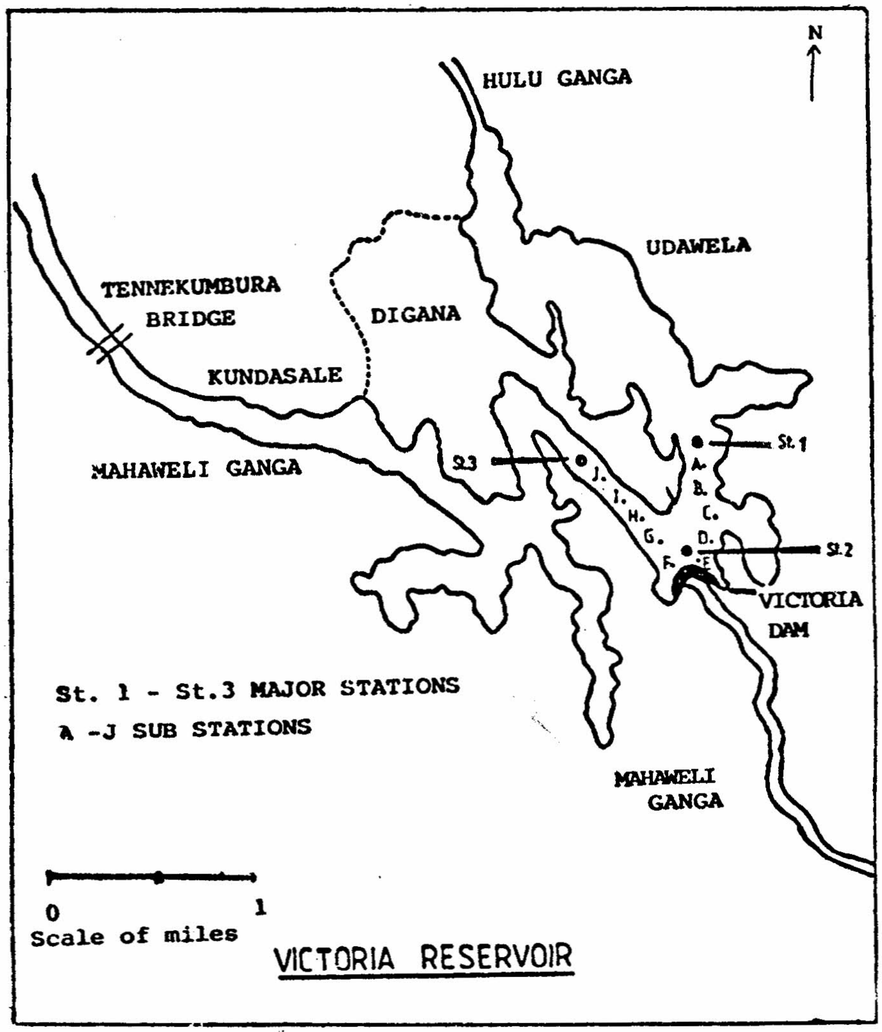

Fig. 1b: The main identification characteristics of Victoria reservoir & the locations of sampling. St_1-St_3 are the major sampling stations & A—J are the substations.

1.2 Climate

In general, the climate of Sri Lanka is governed by the monsoons according to the direction of the wind. Monsoons occur twice a year as the south west monsoon and the North east monsoon with intermonsoonal seasons. Therefore, the year can be divided into four seasons.

(1) The first intermonsoon season from March to mid-May, (2) the south west Monsoon season from May to September, (3) the second intermonsoon season from October to November and (4) the North East Monsoon from December to February. In the study area the general climate is determined by the SW Monsoon (Yala) and by the NE Monsoon (Maha).

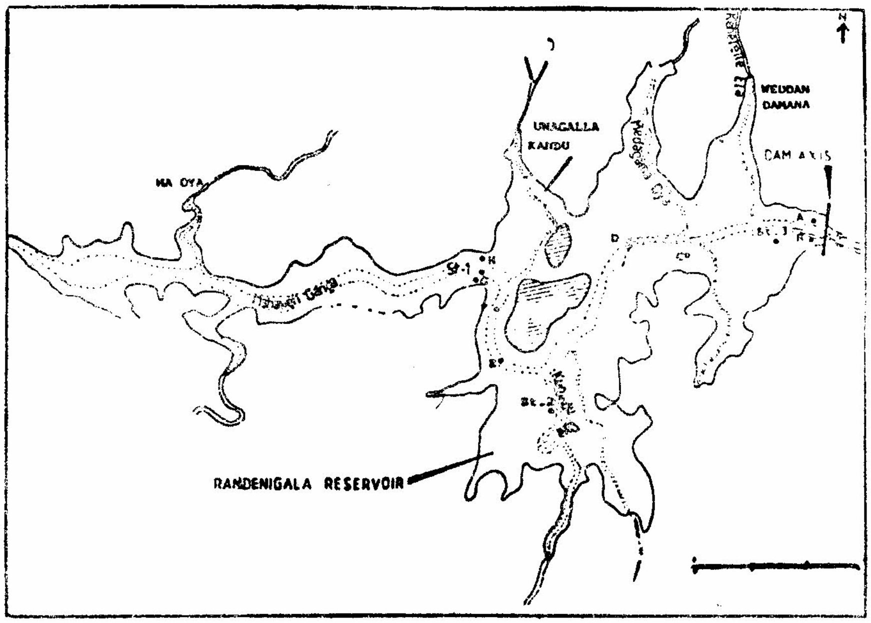

Fig. 1c: The main identification characteristics of Randenigala reservoir and the locations of sampling. St_1 - St_3 are the three major sampling stations & A - J are the sub stations.

2. Materials and Methods

2.1 Sampling

Samples were collected from three major stations and from several substations at each reservoir, using a RUTTNER'S sampler (11 capacity) operated from a boat and attached to a winch and an integrated depth meter.

At each major station samples were collected from the bottom to the top at 5m intervals whereas at substations the samples were taken only on the surface and at 10m depth. This sampling procedure was used in order to study the vertical and horizontal distribution of parameters described below. Sampling was carried out once a month at Kotmale and Randenigala and every fortnight at Victoria.

2.2. Transparency measurements

Secchi depth measurements were taken at each sampling station (at major and sub stations) between 10 a.m.—2 p.m. The times at which the secchi disc measurements were taken were recorded. The secchi depth gives an indication of the euphotic limit of the reservoirs which is the depth at which irradiance is 1% of the surface at about 2.5 the secchi depth (ZsD X 2.5=Zeu). As calculations of the Zeu from photocell readings in different spectral regions is very laborious, the above equation was used in the present study to determine the euphotic limit (see Dokulil et al., 1983).

TABLE 1. Morphometric and Hydrological data of Kotmale, Victoria and Randenigala

	Kotmale	Victoria	Randenigala
Geography—Location	Nuwaraeliya District	Kandy District	Badulla District
Altitude			
Full supply level (asl) (m)	703.0	438.0	232.0
Extreme flood level (m)	704.3	441.2	236.2
Minimum operating level (m)	665.0	370.0	205.0
Latitude	7°03'-705°'N	7°15'-7°19'N	7°10.-7°14'N
Longitude	80°36'-80°41'E	80°39.-80°48'E	80°49-80°56'E
Geology Catchment areas	Predominent rock at the dam site is Charnokite overlain by soil & boulders & underlain by lime stone.	Lime stone, Bed rock is precambrian rock mainly gniess associated with quartzites & bands of limestone.	Lime stohe, consist of precambrian crystaline rocks (Charnokite) & quartzites with some crystaline limestone.
Morphology			
Surface Area (A°) km2	6.5	23.7	23.5
Maximum depth	703-613m as 1 (90m)	438-340m asl (98m)	232-152m asl (80m)
Volume at FSL	174 mcm	722 mcm	860 mcm
Mean depth	26.8m	30.5m	36.6m
Shore line (SL)	45Km	165 km	74 Km
Shore line development DL	4.979	9.561	4.306
Maximum length	6.8 Km	6.8 Km	9.6 Km
Maximum width	1.41 Km	2.41 Km	1.21 Km
Hydrology Catchment area	550 Km^2	1891 Km^2	2330 Km^2
Mean river flow	96 m^3/sec	105 m^3/sec	123.55 m^3/sec
Climatology Seasons	Climate is characterized by SW Monsoon (Yala) from May-October & by NE Monsoon (Maha) from December—February.		
Outlet—Power tunnel	133 m^3/sec	140 m^3/sec.	180 m^3/sec.
Bottom outlet (low level)	110 m^3/sec.	760 m^3/sec.	315 m^3/sec.
Spilway	5560 m^3/sec.	7900 m^3sec.	8085 m^3/sec.

Water temperature, dissolved Oxygen concentration and conductivity were measured in each water sample collected from each major station and from each substation using a thermometer, a type 300 chemtrix Oxygen meter and a type 300 chemtrix conductivity meter (automatically corrected to 20°C by internal thermister network in probe).

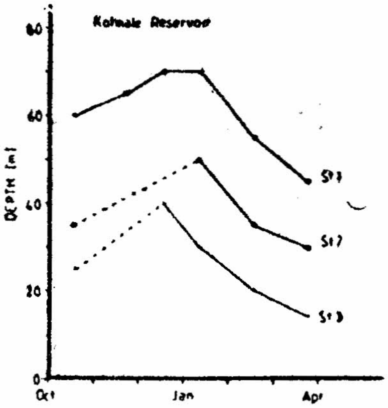

Fig. 2a

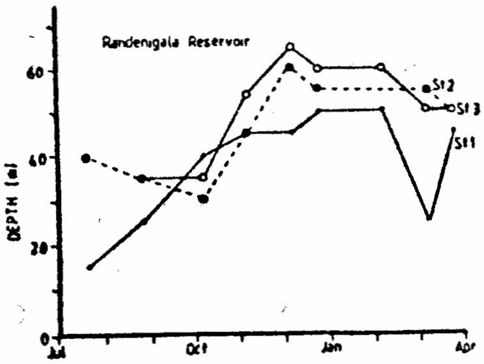

Fig.2b

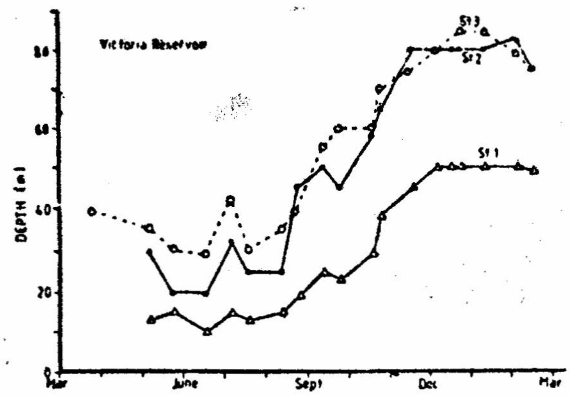

Fig.2c

Fig. 2a - 2c Seasonal water level fluctuations at Kotmale, Victoria & Randenigala reservoirs (elevation a.s.l).

3. Results

The reservoirs under investigation are often subjected to water level fluctuations mainly due to hydroelectric power generation and rainfall and to a lesser extent due to evaporation. Figure 2 illustrates the water level fluctuations in the three major stations of the three reservoirs during March 1987 to Feb. 1988.

Table : II Monthly mean values of secchi depth and mean depth of Euphotic zones at Kotmale, Victoria and Randenigala reservoirs 1987/1988.

Month	*No. of Observations*	*No. of Locations*	*Mean secchi depth*	*SD*	*Mean Euphotic limit (m) Zeu*	*Vertical attentuation* coefficient *Ev (m)*
Kotmale						
October (1987)	10	10	2.26	0.38	5.65	0.84
November	01	01	1.36	—	3.40	1.39
December	10	10	1.53	0.11	3.83	1.24
January (1988)	10	10	2.15	0.16	5.38	0.88
February	10	10	2.25	0.19	5.65	0.84
March	10	10	2.07	0.42	5.18	0.92
Oct. 1987 March 1988	51	51	2.04	0.39	5.10	0.93
Victoria						
March (1987)	01	01	2.25	—	5.63	0.84
May (early)	03	03	1.75	0.66	4.38	1.08
May (late)	03	03	1.77	0.48	4.43	1.07
June	03	03	1.72	0.06	4.30	1.10
July	06	03	1.69	0.27	4.23	1.12
August	16	13	2,10	0.27	5.25	0.91
September	26	13	1.86	0.42	4.65	1.02
October	26	13	1.34	0.38	3.35	1.42
November	13	13	1.49	0.14	3.73	1.28
December	39	13	1.68	0.32	4.20	1.13
January (1985)	13	13	1.80	0.41	4.50	1.06
February	26	13	3.02	0.37	7.55	0.63
March	13	13	2.37	0.30	5.93	0.80
March 1987- March 1988	198	117	2.00	0.64	5.00	0.85
Randenigala						
July (1987)	02	02	2.75	—	6.88	0.69
August	03	03	2.52	0.29	6.30	0.75
October	11	11	2.45	0.23	6.13	0.73
November	11	11	1.76	0.34	4.40	1.08
December	22	11	2.40	0.65	6.00	0.79
February (1988)	11	11	3.30	0.26	8.25	0.58
March	19	11	2.56	0.35	6.40	0.30
July - March 1988 ×	79	60	2.50	0.59	6.25	0.76

Fig.3

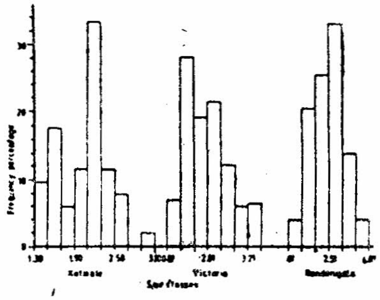

Fig. 3 The relationship between frequency, percentage & size classes of secchi depth values of the Kotamale, Voctoria and Randenigala reservoirs.

Fig.4

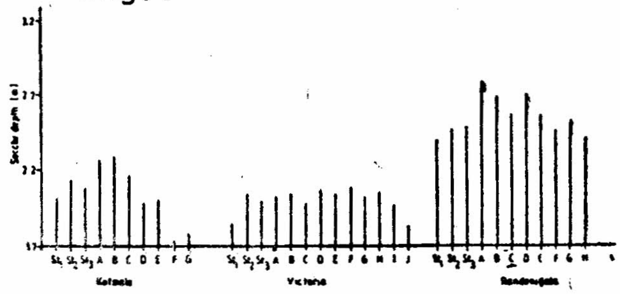

Fig. 4 The main secchi depth values (m) at different locations (major and substations) of Kotmale, Victoria & Randenigala reservoits.

3.1 Secchi depth measurements

Figure 3 illustrates the percentage frequency distribution of secchi depth values in the three reservoirs. Size classes of the secchi depth for the highest frequency percentages of such measurements recorded from each reservoir are as follows; Victoria 1.21m—1.61m, Randenigala 2.51m-3.01m and Kotmale 2.10-2.30m indicating that the highest transparency values are at Randenigala and the lowest at Victoria. This fact is further reflected in the secchi depth values measured at different stations of the three reservoirs (Fig 4). The highest values are recorded at Randenigala and the lowest at Kotmale.

3.2 Euphotic zone

The euphotic limit at different seasons and at different stations of the three reservoirs are summarised in Table II. The mean secchi depth values at each reservoir are 2.00 m for Victoria, 2.50m for Randenigala and 2.04 for Kotmale. The mean euphotic limits calculated from the mean secchi depth values are 5.00m at Victoria, 6.25m at Randenigala and 5.10m at Kotmale. These values were calculated from the mean secchi depth values obtained during the investigation period. Below these values primary productivity is usually considered to be nil.

3.3 Water temperature

Temperature is an important parameter which affects the life processes of fish and other organisms in the reservoirs, the solubility of Oxygen in water, the equilibrium between Carbon dioxide and Bicarbonate in water and the taste of water etc. According to the present investigations made in 1987, the highest surface temperatures recorded in the three reservoirs are 28.8°C at Kotmale, 32°C at Victoria & 31°C at Randenigala and the lowest bottom temperatures are 21.5°C at Kotmale, 24°C at Victoria & 25.3°C at Randenigala, respectively, indicating temperature gradients of 7.3°C at Kotmale, 8°C at Victoria & 5.7⁰C at Randenigala.

3.4 Thermal regime and stratification

According to the classification of Hutchinson and Löffler (1956), the present reservoirs under investigation are oligomictic. This oligotrophy has changed to eutrophic hypertrophic condition due to external nutrient loading taking place increasingly along the water path due to usage of agrochemicals.

The time-depth diagram of isotherms of the three reservoirs during 1987/1988 in the stations closer to the dams of the reservoirs are given in Fig. 5a-5c. The thermal behaviour is identical for all three reservoirs. Unlike in the reservoirs in the temperate countries, vertical heterogenity occurs throughout the year in the reservoirs under observation. The epilimnetic water temperatures are around 26°C at Kotmale, 27°C at Victoria and 28°C at Randenigala. However the epilimnetic water temperatures may often vary due to weather conditions such as wind action and rain. Below 20m, the temperature gradient for all three reservoirs are below 0.03°C/m (Table III). The daily density changes in the upper 15-20m strata of waters of the reservoirs cause relocation of these strata even during windless days. However, such changes in the upper water strata do not disturb the firmly established thermocline.

Thermal stratification has a pronounced influence on the distribution & concentration of several elements, primarily Oxygen. Due to thermal stratification, Oxygen concentrations near the bottom start to decrease resulting in a clinograde Oxygen curve. However due to hydroelectric power generation and the runoff of water at the bottom layers, the upper oxygenated water layers get mixed with the bottom layers, thus causing oxygenation of the bottom strata as well.

3.5 The temperature gradient

The larger differences in temperature gradient were observed from surface to about 20m. Below 20m depth the temperature decreased readily but at a lower rate (Table III). However in the deeper layers, the gradient is even

Fig.5a

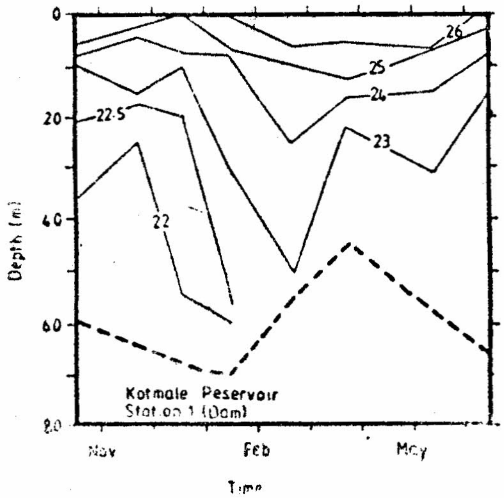

Fig. 5a: Isotherms closer to the dam of Kotmale reeervoir.

Fig.5b

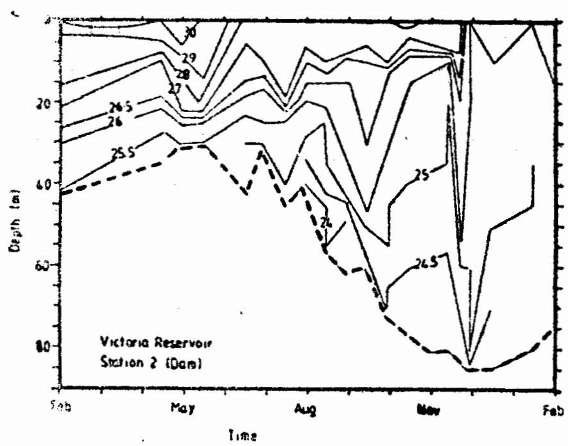

Fig. 5b: Isotherms closer to the dam of Victoria reservoir.

Fig.5c

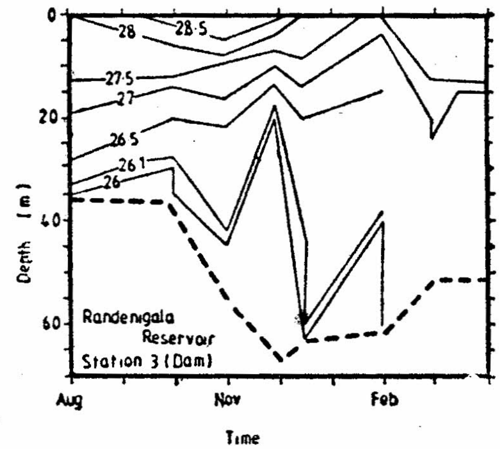

Fig. 5c Isotherms closer to the dam of Randenigala reservoirs

Fig.6a

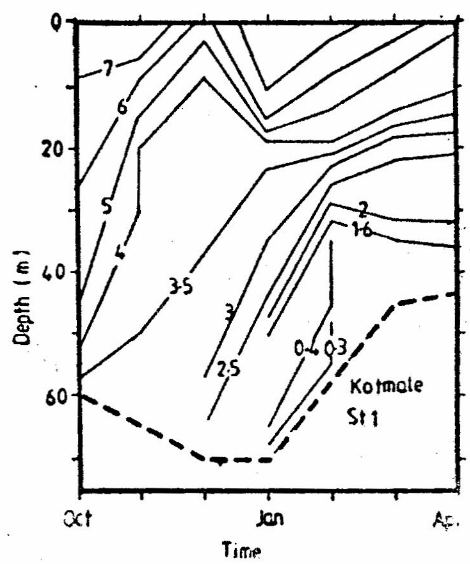

Fig. 6a: Oxygen isoplerhs closer to the dam of Kotmale reservoir.

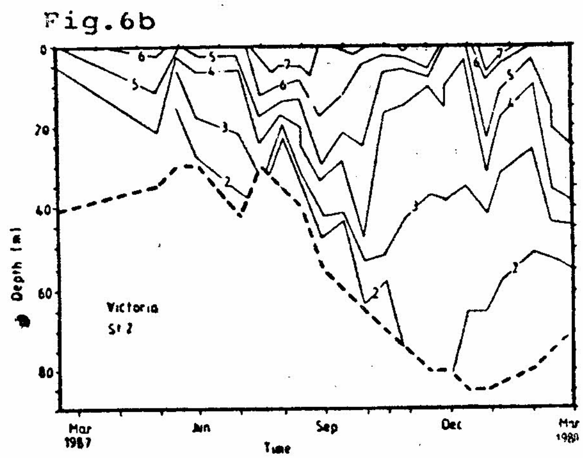

Fig. 6b Oxygen isopleths closer to the dam of Victoria reservoir.

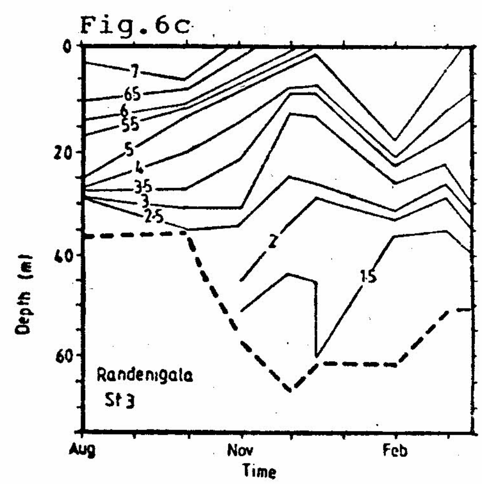

Fig. - 6c Oxygen isopleths closer to the dam of Randenigala reservoirs.

Table : III Changes in the mean temperatures of different water layers during day time and mid night at different stations of Kotmale, Victoria and Randenigala reservoirs during the 1987/1988 investigation period.

Depth Profile	Mean Temperature gradient C /m			Mean temperature gradient C /m			Mean temperature gradient C /m			Temperature gradient C-/m at mid night	
	Kotmale			Victoria			Randenigala			Vict.	Randen
	St1	St2	St3	St1	St2	St3	St1	St2	St3	St2	St3
0- 5	0.052	0.052	0.069	0.033	0.032	0.019	0.016	0.023	0.014	0.076	
0-10	0.038	0.052	0.045	0.018	0.031	0.022	0.038	0.048	0.038	0.080	0.004
10-15	0.017	0.016	0.019	0.022	0.012	0.012	0.015	0.014	0.018	0.020	0.020
15-20	0.017	0.014	0.025	0.012	0.016	0.011	0.010	0.018	0.011	0.008	0.050
20-25	0.012	0.014	0.019	0.003	0.016	0.014	0.009	0.008	0.005	0.028	0.000
25-30	0.001	0.003		0.006	0.008	0.006	0.009	0.002	0.008	0.016	0.001
30-35	0.005	0.009	0.018	0.005	0.008	0.000		0.005	0.003	0.012	0.004
35-40	0.003	0.002		0.010	0.002	0.004	0.006	0.006			0.006
40-45	0.001	0.004		0.000	0.005	0.006			0.006		
45-50	0.002				0.005		0.006	0.001	0.001	0.012	0.016
50-55	0.002				0.005				0.006		0.004
55-60	0.026				0.004			0.003	0.008		
60-65						0.001			0.008		
65-70					0.002						
70-75						0.008					
75-80						0.018					

disinctly lower. The patterns of stratification in all three reservoirs seem to be identical. Temperature profiles taken during midnight on 30th & 31st March 1988 at Victoria & on 27th and 28th March 1988 at Randenigala also show slight differentices in temperature gradient below 20m at Victoria and Randenigala. The highest gradient of 0.08°C/m occurs between 5-10m depth at Victoria and that of 0.05°C/m occurs between 15-20m at Randenigala. The highest gradient of 0.08°C/m occurs between 5-10m depth at Victoria and that of 0.05°C/m occurs between 15-20m depth at Randenigala. The highest gradient of 0.08°C/m occurs between 5-10m depth at Victoria and that of 0.05°C/m occurs between 15-20m depth at Randenigala.

3.6 Dissolved Oxygen

Dissolved Osygen content of water bodies reflect the balance between Oxygen consuming and producing processes. The dissolved Oxygen content of the reservoir is determined and controlled by the plankton biomass, temperature, ight intensity and wind action, water turbulence etc.

3.7 Oxygen isopleths

Fig. 6a-6c illustrates the Oxygen isopleths in major stations closer to the dams of the three reservoirs. Oxygen stratification follows a similar pattern of variation in the three reservoirs. Due to thermal stratification described earlier, Oxygen concentrations closer to the bottom decrease resulting in a clinograde Oxygen curve. There is no evidence of complete deoxygenated layers at the bottom of any reservoir under observation. The high Oxygen concentrations are closely linked with the euphotic zones of the three reservoirs where photosynthetic activity is high. The mean Oxygen concentrations calculated for the investigation period for the surface waters, closer to the dam are 7.5 $\pm$1.76, at Kotmale, 6.5 $\pm$1.06 at Victoria and 6.4 $\pm$1.03 at Randenigala, Oxygen depletion is markedly cobserved below the depth of 20m in all three reservoirs where mixing of surface waters with the deeper layers are limited.

3.8 Conductivity

Conductivity is a measure of the total dissolved salts (TDS) in water. The salts dissolved in fresh waters consist mainly of the carbonates of Calcium, Magnecium and Sulphates and Chlorides of Calsium, Sodium and Potassium. So that increase or decrease of the conductivity measurements of the waters of the reservoirs indicate any increase or decrease in the ionic concentrations.

3.9 The highest conductivity values

The mean conductivity changes in the vertical profiles of the waters of three major stations of the three reservoirs during these investigations are illustrated in Fig. 7a-7c.

Fig. 7a

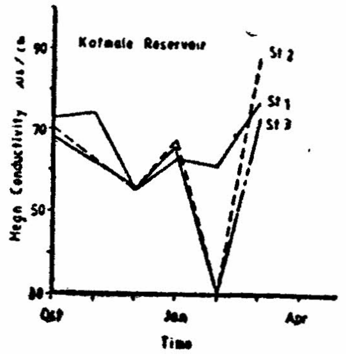

Fig.7c

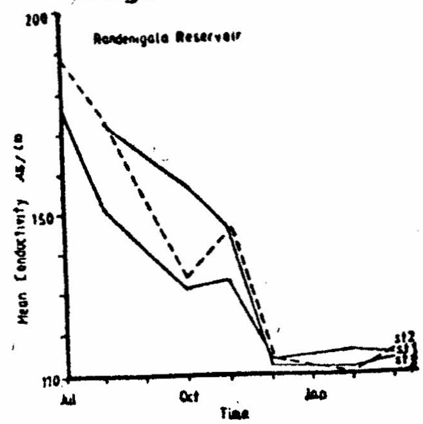

Fig. 7b

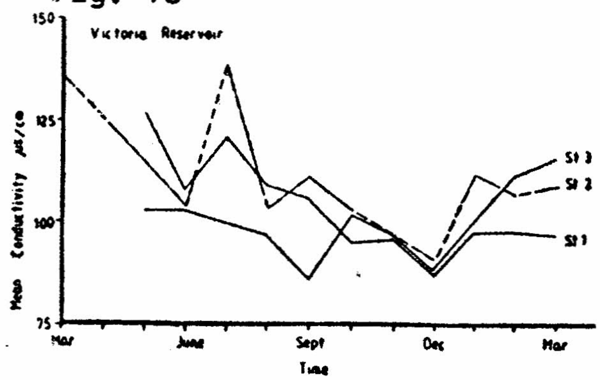

Fig. 7a - 7c The seasonal variation of conductivity (µs/cm) at Kotmale, Victoria and Ran denigala reservoirs at the three major stations.

Fig. 8

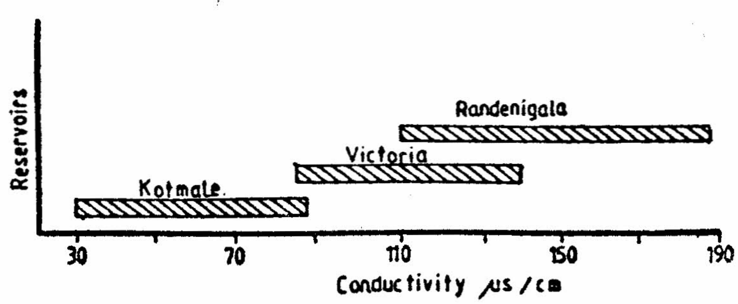

Fig. 8 The ranges of mean conductivity values at Kotmale, Victoria & Randenigala reservoirs observed in 1987.

The highest conductivity values are recorded for waters closer to the dams of the three reservoirs indicating an accumulation of dissolved ions towards the dams.

3.10 Ranges of conductivity values in the three reservoirs

The mean conductivity values of the vertical profiles of the waters recorded from the three reservoirs fall into the ranges of 30-87 micromohs/cm at Randenigala (Fig. 7 & 8). The highest values are recorded from Randenigala, the lowest at Kotmale with an intermediate value at Victoria. This may be due to the fact that Kotmale is situated at the highest elevation of these three reservoirs. This would mean that the waters dissolve more and more salts as they descend. However the conductivity values of all three reservoirs are below 250 micromohs/cm at 20° C which belong to the category of low salinity water according to the grouping of irrigation water setup as a standard given by US salinity laboratory (FAO/UNESCO irrigation, drainage & salinity). Therefore, the water from Randenigala reservoir is suitable for irrigation with most crops on most soils with little likelihood that a salinity problem will develop.

4. Discussion

The Kotmale, Victoria and Randenigala are the chain of deep hydro-electric reservoirs resulted due to damming of river Mahaweli. These reservoirs are newly built and vary from their morphometry and from their nutrient status. The data obtained from this limnology project revealed that there is a tendency to accumulate nutrients with decreasing altitude. (Piyasiri, 1987). The transparency measurements of the three reservoirs indicate that the highest values at Kotmale and lowest at Randenigala and an inbetween values at Victoria. Conductivity values also show increasing values from Kotmale to Randenigala indicating an accumulation of nutrients at the reservoirs in lower elevations. Therefore, using agrochemicals or fertilizers at upper reservoirs or at Kotamale could effect the reservoirs at the lower elevations immediately and causing high growth rates of algae at lowland reservoirs.

The isotherms of the three reservoirs closer to the dam indicate thermal stratification in the three reservoirs. The highest temperature gradient of 6°C has been recorded for Victoria reservoir & 4°C for Kotmale & 3°C for Randenigala. Presence of the stratification in the three reservoirs indicate that the waters of the reservoirs develop stratification even with circulation due to hydroelectric power generation by using the waters from the bottom layers of the water body. Even the Oxygen isopleths indicate depletion of Oxygen at the bottom strata of the reservoirs. These may be the surface water layers which flushed through and became low in Oxygen content due to oxidising process of organic matter accumulated in the deeper layers of the reservoir.

This cause accumulation of Ammonia, Hydrogen Sulphide like toxic substances at the bottom of the reservoir. Therefore, as a precaution, it is advisible to stop debris of the cut trees etc. entering into the reservoirs which get accumulated at the bottom causing Oxygen depletion. Organic pollution and accumulation of toxins in the reservoirs may cause poor quality drinking water and water borne diseases. According to the results obtained from this study, It is advisable to control excessive use of fertilizers and agrochemicals in the catchment area. Also it is important to make a system for the sewage effluents to by pass the reservoirs in order to avoid eutrophication of the reservoirs.

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