LIMNOLOGICAL ASPECTS OF THREE MAN-MADE LAKES IN SRI LANKA

KUMARI DE SILVA

(Dr P. K. de Silva, Department of Zoology, University of Peradeniya, Peradeniya, Sri Lanka.)

Introduction

Sri Lanka, a tropical island with an area of 65,525 km^2 (Fig. 1), is situated to the south of the Indian sub-continent and separated from it by the narrow Palk Strait. Based on the amount of annual rainfall, two major climatic zones are usually recognised in the island: a wet zone covering the south-eastern quarter and a dry zone extending over the rest of the country (Fig. 1); the 2000 mm isohyet is usually the boundary between the two zones. The island contains no natural lakes, except for a few small floodplain lakes, but this absence is amply compensated by the creation of a large number of reservoirs for irrigating rice fields, most of which date back 800 to 2500 years. These are in the lowlands at altitudes below 200 m in the drier part of the country (Fig. 1), and they number more than 10,000 ranging in size from less than 2 ha to more than 2000 ha. Most of these reservoirs are small, shallow and seasonal, drying up completely or almost completely during the dry season by the end of the rice-growing period. Of the perennial reservoirs, only a few are large and exceed 300 ha at the full supply level (FSL), and others are medium-sized (10 to 300 ha) to small in area (<10 ha) (Table 1). In addition to these, a few large, deep reservoirs have been created recently in the uplands (200 to 1000 m above sea level) and highlands (>1000 m) primarily for hydroelectric purposes. Several of these reservoirs have been created by damming and diverting the River Mahaweli.

Little information is available on the limnology of these deep reservoirs or man-made lakes, although such aspects of many lowland, shallow, irrigation reservoirs have been studied (Fernando & De Silva 1984; De Silva 1988). Therefore, an investigation was undertaken to study mainly the important physicochemical characteristics, phytoplankton and fish fauna of three major deep lakes on the River Mahaweli, namely, Kotmalé, Victoria and Randenigala. The study was based on 10 randomly selected sampling stations in Kotmalé, 12 in Victoria and 12 in Randenigala (Fig. 1). These stations were sampled fortnightly during the period January 1988 to December 1990. Depth samples were taken using a Ruttner sampler of 1 litre capacity. Temperature, pH, dissolved oxygen concentration, electrolytic conductivity and turbidity were measured during sampling, using calibrated portable electronic meters. Alkalinity was estimated titrimetrically within 24 hours of collection. Concentrations of important anions such as nitrate, nitrite, phosphate and

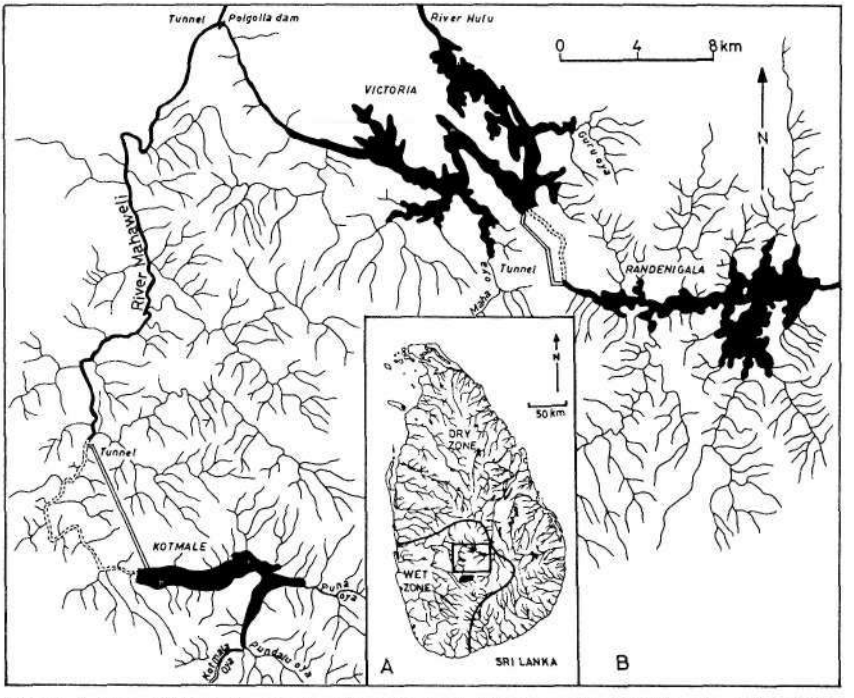

FIG. 1. A: Map of Sri Lanka showing the major rivers. The box sector indicates the region of the three Mahaweli lakes, and the curved line separates the wet zone in the south-west and the dry zone in the north and east. B: The three Mahaweli lakes – Kotmalè, Victoria and Randenigala.

Table 1. The estimated total surface areas of several types of lentic waterbodies in Sri Lanka.

Type of waterbody	Area (ha)
Major irrigation reservoirs (ancient) (>300 ha)	104,000
Medium-scale reservoirs (ancient) (10-300 ha)	19,000
Minor irrigation reservoirs (ancient) (>10 ha)	39,000
Floodplain lakes (natural) (mostly seasonal)	24,000
Upland (>300 m asl) hydroelectric reservoirs (recent)	11,000
Total area	197,000

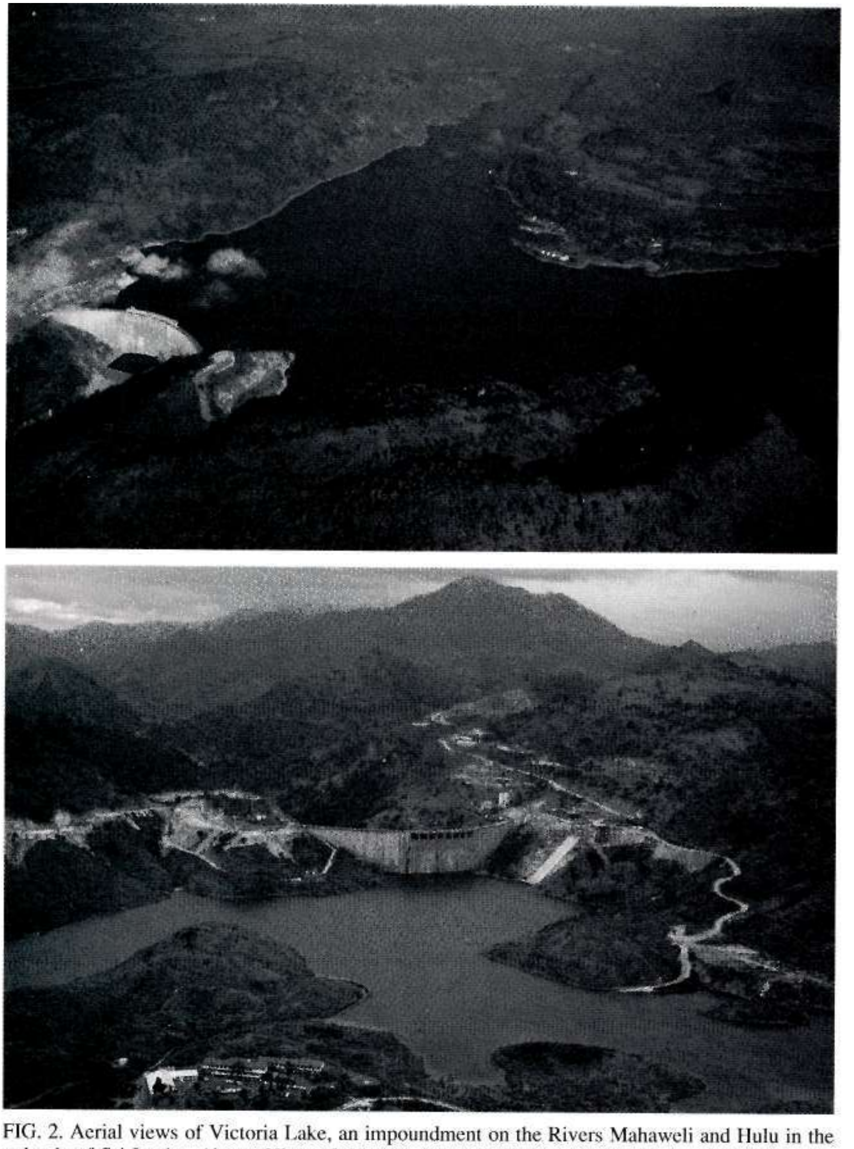

FIG. 2. Aerial views of Victoria Lake, an impoundment on the Rivers Mahaweli and Hulu in the uplands of Sri Lanka. *Above:* View of the dam (bottom left-hand corner of the picture) looking upstream (north-west; see Fig 1). *Below:* View of the dam, looking downstream (south-east) in the general direction of Randenigala Lake – out of the picture to the left.

silicate were estimated spectrophotometrically using appropriate colour reactions. The methods used in the study are those given by Golterman et al. (1978). The precautions given in the same work for collecting and testing various ions were carefully observed. Phytoplankters were collected using an Apstein net with an attached distance meter. They were counted in a Sedgewick-Rafter cell of 1 ml volume. Fish samples were obtained from the littoral as well as from the catches of local fishermen.

Table 2. Important morphometric features of Kotmalè, Victoria and Randenigala lakes (Mahaweli lakes). FSL = full supply level.

Lake features	Kotmalè	Victoria	Randenigala
Year of impoundment	1984	1984	1986
Storage capacity (10^6 m^3)	174	722	860
FSL (m asl)	703	438	232
Surface area at FSL (km^2)	6.3	23.7	23.5
Catchment area (km^2)	544	1891	2333
Maximum depth (m)	78	102	90
Mean depth (m)	27.6	30.8	36.6
Shore line (km)	32	115	73
Catchment area/lake area	86.4	79.8	99.3
Littoral zone at FSL (<3 m depth) (km^2)	0.4	1.6	1.0
Lowest drawdown level (m asl)	665	370	203
Useful storage capacity (10^6 m^3)	152	688	565
Dead storage capacity (10^6 m^3)	22	34	294
Surface area at dead storage (km^2)	1.6	1.8	13.0

Lakes Kotmalé, Victoria and Randenigala

These three deep lakes (Fig. 1) were created, mainly for hydroelectric purposes, during the period 1984 to 1986, by impounding the River Mahaweli at different elevations. Of the three lakes, Kotmalé is situated at the highest elevation (Table 2). It is an inverted L-shaped lake (Fig. 1) created by damming one of the uppermost branches of the river, the Kotmala Oya. The catchment of Kotmalé consists mainly of tea *(Camellia sinensis)* plantations in the hills, and paddy fields and human habitations at lower elevations, although in the hills there are also some forested areas with sub-montane evergreen vegetation.

Victoria (Fig. 2), a W-shaped lake, was built by constructing a dam immediately downstream of the point of confluence of the main branch of the River Mahaweli and a major tributary, the River Hulu (Fig. 1). Victoria receives its water mostly from the Hulu, because water from the main branch of the Mahaweli is usually diverted immediately upstream of the lake into the dry zone lakes which lie to the north. The headwaters of the River Hulu are in

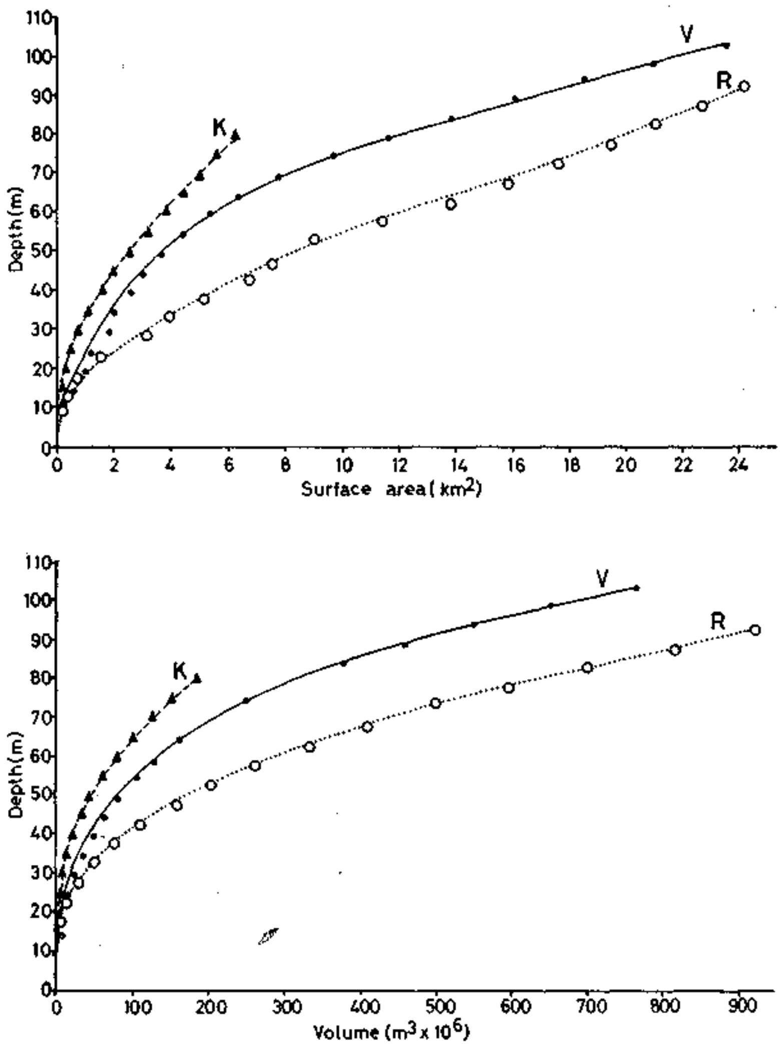

FIG. 3. Curves relating depth (m) and surface area (km²), and depth and volume (m³ x 10⁶) in the three Mahaweli lakes: Kotmalè (K, ▲), Victoria (V, ●) and Randenigala (R, ○).

the forested Knuckles hills (with moist semi-evergreen forest vegetation), which form the Knuckles forest reserve, but at lower elevations there are tea and cardamon *(Elettaria cardamomum)* plantations and at still lower elevations there are paddy fields and human habitations.

Randenigala is hatchet-shaped (Fig. 1) and is the third lake on the River Mahaweli, situated immediately below Victoria. Although it has several streams flowing into it, the main supply of water to Randenigala comes from Victoria. Therefore, the water level of the lake is mostly controlled by the outflow of the Victoria lake. The streams flowing into Randenigala originate in forested areas (with moist semi-evergreen forest-type vegetation), which form the Victoria-Randenigala sanctuary. More recently, another small lake was created immediately downstream of Randenigala to catch the outflow of the latter.

Morphometric features of the three Mahaweli lakes

As the three lakes are situated in the hilly region, their banks are steep and the littoral zone is narrow along most of the shoreline, in contrast to wide littoral regions of the shallow irrigation lakes in the dry zone. The frequent fluctuations of the water level, resulting from the high outflow rate during periods of greater hydropower production, change the position and extent of the lake littoral zone frequently. The littoral area, taken as less than 3 m deep, is only 6.1% of the total area at full supply level in Kotmalé, 6.6% of Victoria and 4.1 % of Randenigala.

Major morphometric and hydrological features of the three lakes are listed in Table 2. The area and capacity curves (Fig. 3) show that Kotmalé has the lowest ratios of area/depth and capacity/depth, indicating that its basin is the narrowest and most steep-sided of the three lakes; Randenigala, on the other hand, is the least steep.

Physicochemical characteristics of the Mahaweli lakes

Table 3 gives the ranges of temperature, pH, dissolved oxygen concentration, conductivity, turbidity, and the concentrations of important anions in the Mahaweli lakes. The monthly variation of temperature, pH, dissolved oxygen concentration, conductivity, turbidity, rainfall, water level, inflow and Secchi disc depth in Victoria are shown in Fig. 4. In all three lakes, thermoclines are present during most months of the year, but these appear to be not very stable. They tend to disappear during January-February but are well established in August-November (Fig. 5). Heavy rains occur in January and July, and during these months the lake temperature varies gradually from top to bottom rather than establishing a thermocline. May to July are windy months, and the thermocline is not well marked during this period. The depth of the

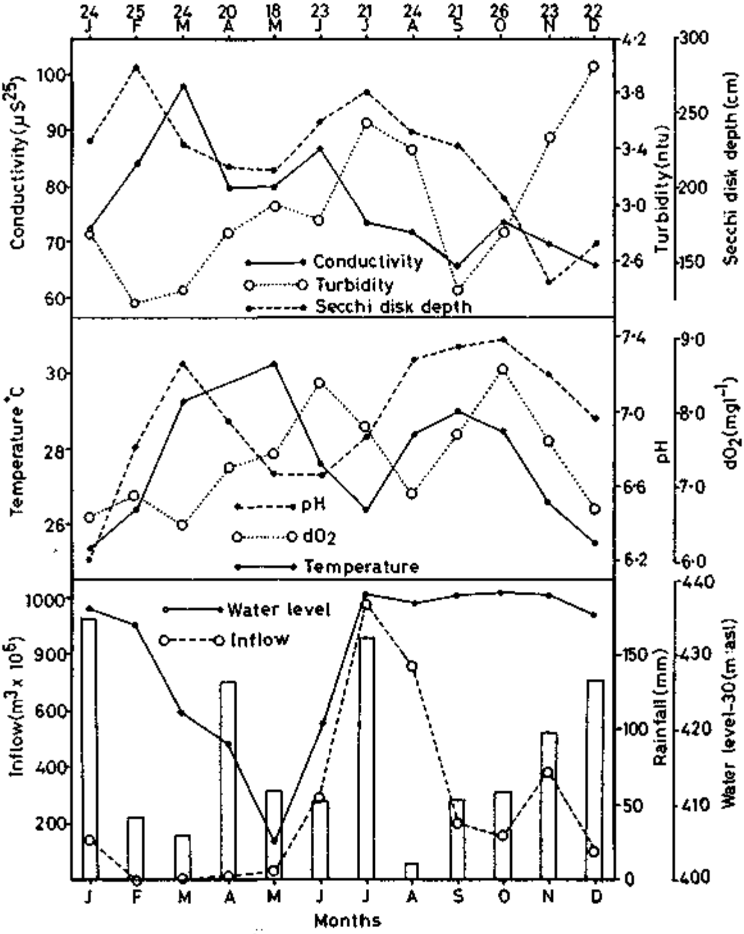

FIG. 4. Monthly variation of some physicochemical variables in Victoria Lake during 1989. Top panel: conductivity (uS/cm at 25°C), turbidity (nephelometric turbidity units), Secchi-disc depth (cm). Centre panel: pH, dissolved oxygen (mg/1), temperature (°C). Bottom panel: water level (metres above sea level), rainfall (mm), inflow volume (m^3 x 10^6).

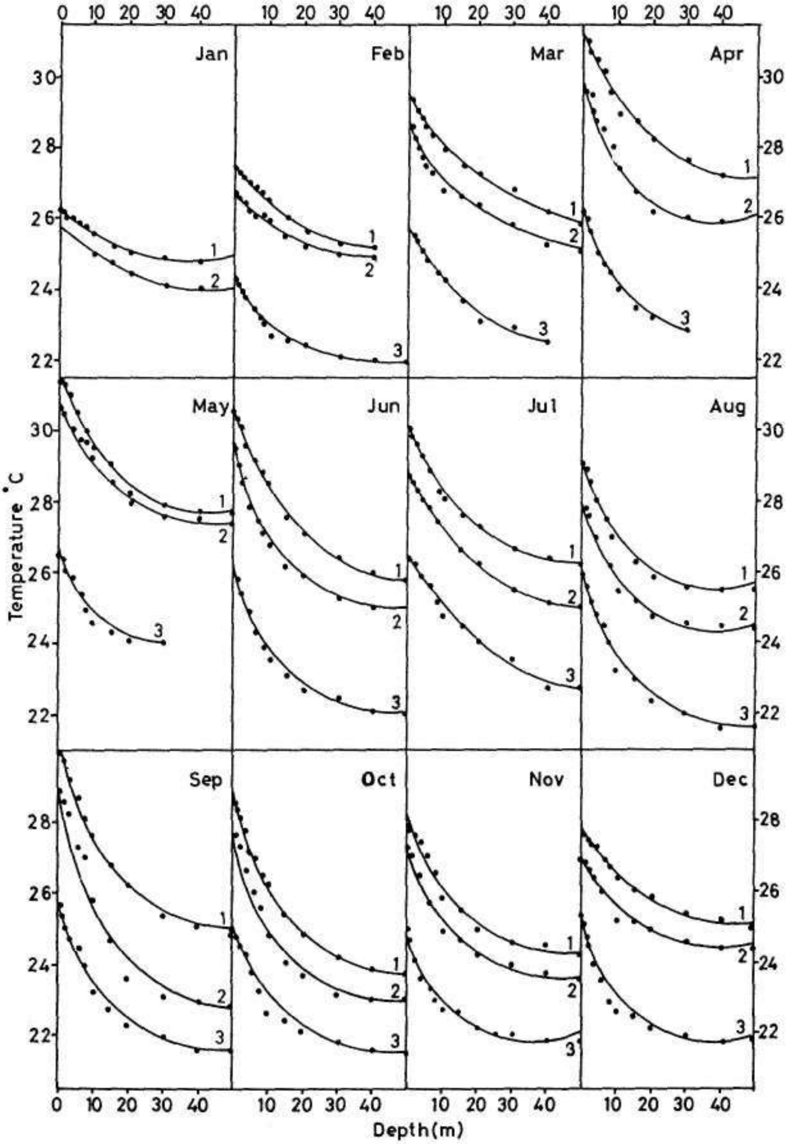

FIG. 5. Variation of water temperature with depth in the three Mahaweli lakes during 1989. 1 = Randenigala; 2 = Victoria, 3 = Kotmalè (not sampled in January 1989).

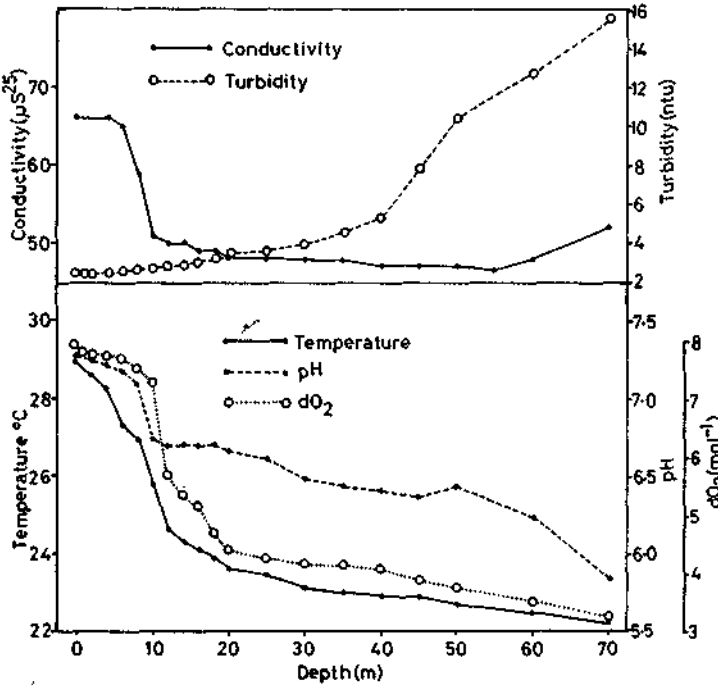

FIG. 6. Variation of conductivity, turbidity, temperature, pH and dissolved oxygen with depth of Victoria Lake on 21 September 1989.

Table 3. Important phsyicochemical characteristics of the subsurface waters (measured at 5 to 10 cm below the water surface) of the three Mahaweli lakes during 1988 to 1990. The ranges given are for the means of samples at all stations; ntu = nephelometric turbidity units.

Characteristics	Kotmalè	Victoria	Randenigala
Water temperature (°C)	24.0–27.6	24.8–30.1	26.2–30.6
Dissolved oxygen concentration (mg/l)	7.5–8.9	6.0–8.0	6.4–8.8
pH	6.8–7.2	6.7–7.8	6.8–7.6
Conductivity (μS/cm)	40–55	53–92	78–100
Turbidity (ntu)	1.0–4.6	1.0–4.5	1.0–4.2
Secchi-disc transparency (cm)	136–226	160–283	251–301
Total alkalinity (mequiv./l)	0.23–0.43	0.45–0.82	0.68–0.97
Nitrate (mg/l)	2.9–45.6	2.7–22.8	5.1–38.5
Nitrite (mg/l)	0.01–0.1	0.01–0.1	0.01–0.1
Orthophosphate (μg/l)	<5–12.4	<5–9.1	<5–10.5
Silicate (μg/l)	0.1–8.5	0.5–9.1	0.5–10.6

thermocline also changes somewhat during different months but usually it is present at depths between 5 and 15 m. The epilimnion is not very deep. Bauer (1983) is of the opinion that the shallow low-country reservoirs in Sri Lanka are unlikely to develop and retain for long periods of time strong thermoclines and chemical stratification. Sreenivasan (1970) showed that thermal stratification is rare even in much deeper reservoirs in southern India.

Down the thermocline, dissolved oxygen concentrations decreased rapidly but conductivity and pH declined more gradually (Fig. 6). Turbidity increased with depth. Concentrations of nitrates were highest at the thermocline, but nitrates and phosphates, especially the latter, were relatively low in all three lakes (Table 3). The rapid turnover of water is one of the factors which tend to work against the accumulation of these ions in the lakes.

All three lakes have a rapid turnover. The yearly inflows of Kotmale, Victoria and Randenigala are respectively about 480, 1850 and 2070 million cubic metres for the period 1987 to 1990. The catchments of the lakes receive high rainfall; during 1987 to 1990 annual rainfall at Kotmale, Victoria and Randenigala respectively ranged between 2216 and 3365 mm, 1033 and 1860 mm, and 1264 and 1590 mm. Since the capacities of the three lakes are, respectively, 174, 722 and 860 million cubic metres, it appears that, at least theoretically, the water in each lake could be completely replaced in periods of only three to four months. The constant heavy outflow at a considerable depth (intake gates are located 38, 52 and 29 m below FSL, respectively, in Kotmalé, Victoria and Randenigala lakes (Table 2)), as well as the frequent fluctuations of the water levels, also could affect the establishment of stable thermoclines.

In general, the physicochemical parameters considered above are all higher in the irrigation reservoirs situated elsewhere, at low elevations in the dry zone (Table 4).

Macrophytes and phytoplankton

Aquatic macrophytes, floating or rooted, were not observed in any of the Mahaweli lakes, and the primary productivity was almost entirely due to phytoplankton. The frequent changes of water level affect the establishment of rooted macrophytes.

The net phytoplankton consisted of all three major groups, namely, Cyanobacteria, Chlorophyta and Bacillariophyta, but Chlorophyta dominated all three lakes in terms of the number of taxa present. Desmids were the most common, mainly species of *Staurastrum* and *Cosmarium.* Table 5 gives a list of phytoplankters identified from the Mahaweli lakes.

Cyanobacteria

Fifteen species of blue-green algae belonging to 14 genera were identified (Table 5). The common genera were: *Microcystis, Gomphosphaeria,*

Table 4. Physicochemical characteristics of some important perennial reservoirs in the dry zone (Fig. 1) of Sri Lanka. (Note: wewa = reservoir and samudra = sea, in Sinhalese. Authors: 1 = Amarasinghe et al. (1983); 2 = Gunantilleke (1983); 3 = Gunawardene & Adikari (1981); 4 = Schiemer (1983).

Reservoir	Surface area (ha)	Mean depth (m)	Teperature (°C)	pH	O_2 (mg/l)	Conductivity (µS/cm)	Total alkalinity (meq/l)	Secchi depth (cm)	PO_4–P (µg/l)	Author
Kala wewa	2598	4.8	27–32	7.5–8.4	7.9–9.4	82–400	1.0–2.4	41–94	8.4–15.7	1, 3
Parakrama Samudra	2262	5.3	28–30	8.3–9.6	0.5–1.0	218–243	1.8–3.2	–	70–167	2, 4
Hurulu wewa	2195	6.2	27–32	7.2–8.5	6.3–10.5	140–300	1.2–3.3	40–111	–	1
Mahavilachchiya wewa	1784	4.2	28–34	7.5–8.5	7.6–9.3	400–800	1.6 –3.0	42–78	–	1
Nachchaduwa wewa	1748	3.1	29–33	7.5–8.5	7.7–9.9	350–570	1.0–3.0	40–90	–	1
Rajangana wewa	1599	6.2	26–32	7.5–8.6	4.8–9.0	455–650	2.5–3.8	65–151	–	1
Mahakandara wewa	1457	5.8	23–32	7.9–8.5	7.1–13.0	402–910	2.3–3.8	40–95	–	1
Nuwara wewa	1196	6.4	28–31	8.2–8.6	6.7–10.1	300–850	1.5–2.9	22–54	–	1

Table 5. Phytoplankton recorded in the three Mahaweli lakes during 1988 to 1990.

Cyanobacteria	Bacillariophyta	Chlorophyta Non-desmid green algae	Desmids
Anabaena sp.	*Amphora* sp.	*Ankistrodesmus* sp.	*Closterium* sp.
Coelospharium sp.	*Fragilaria* sp.	*Cladophora* sp.	*Cosmarium antilopeum*
Dactylococcopsis sp.	*Gomphonema* sp.	*Closteriopsis* sp.	*C. circulare*
Gloeocapsa sp.	*Gyrosigma* sp.	*Coelastrum* sp.	*C. contractum*
Gomphosphaeria sp.	*Melosira granulata*	*Coleochaete* sp.	*C. moniliforme*
Lyngbya sp.	*M. undulata*	*Dictyosphaerium* sp.	*C. tetraophthalmum*
Merismopedia punctata	*Navicula* sp.	*Eudorina* sp.	*Euastrum pulchellum*
M. tenuissima	*Pinnularia* sp.	*Golenkinia* sp.	*E. verrucosum*
Microcystis aeruginosa	*Synedra* sp.	*Gonium* sp.	*Micrasterias* sp.
Nostoc sp.	*Tabellaria* sp.	*Mougeotia* sp.	*Staurastrum apiculatum*
Oscillatoria sp.		*Oedogonium* sp.	*S. arachne*
Rivularia sp.		*Pandorina* sp.	*S. arctiscon*
Scytonema sp.		*Pediastrum biradiatum*	*S. brachiatum*
Spirulina sp.		*P. clathratum*	*S. chaetoceras*
Tolypothrix sp.		*P. duplex*	*S. dickiei*
		P. simplex	*S. forficulatum*
		Scenedesmus bijuga	*S. gracile*
		S. brasiliensis	*S. grande*
		S. quadricauda	*S. inflexum*
		Sphaerocystis sp.	*S. leptocladum*
		Tetraedron sp.	*S. ophiura*
		Treubaria sp.	*S. paradoxum*
		Trochiscia sp.	*S. psuedopelagicum*
		Ulothrix sp.	*S. sebaldi*
		Volvox sp.	*S. subcruciatum*
			Tetmemorus sp.
			Triploceras sp.

Merismopedia, Coelosphaerium, Dactylococcopsis, Lyngbya and *Oscillatoria. Microcystis* and *Merismopedia* were present continuously throughout the year and, being colonial and large forms, they imparted a bluish colour to the surface waters when present in abundance: *Microcystis* was the dominant genus and contributed more than 50% to the numbers in all months.

Species of *Anabaena, Microcystis* and *Oscillatoria* appear to be widespread in Sri Lanka and were present in all three Mahaweli lakes as well as in irrigation reservoirs of the dry zone (Mendis 1965; Rott 1983) and in Beira Lake in the lowland wet zone (Costa & De Silva 1978). However, genera such as *Anabaenopsis, Chroococcus* and *Pseudanabaena,* which were recorded in Parakrama Samudra reservoir, were not collected in the three Mahaweli lakes. Seenyya (1971) found that blooms of green algae, especially blooms of *Microcystis,* are antagonistic to the development of Volvocales. Thus *Microcystis,* which was present in significant numbers throughout the study period in all three lakes, may have affected the growth of Volvocales, which were present only in very low numbers. Costa & De Silva (1978) also reported similar observations in Lake Beira in Colombo. *Aphanocapsa* and *Gleotheca,* recorded from Beira, were not found in the Mahaweli lakes or in Parakrama Samudra.

In general, the Cyanobacteria are known to predominate the phytoplankton biomass in shallow tropical waters (Sreenivasan 1970). Holsinger (1955) reported Cyanobacteria (Myxophyceae) as the dominant phytoplankton group in Lake Beira, but Costa & De Silva (1978) found that Chlorophyta formed the major part of phytoplankton in this lake. Dokulil et al. (1983) reported that the phytoplankton assemblage in Parakrama Samudra reservoir is dominated by Cyanobacteria and Bacillariophyta; chlorophyte species occurred in low numbers. However, by number of taxa, Chlorophyta (which includes 30 species), dominate in Parakrama Samudra; Cyanobacteria are represented by 22 species (Rott 1983).

Chlorophyta

The three Mahaweli lakes contained 27 species (seven genera) of desmids and 25 species (20 genera) of non-desmid green algae. Desmids were the dominant group and the mean number of desmids per litre was much higher than the total counts of other Chlorophyta and Cyanobacteria taken together. *Staurastrum,* with 16 species, was the dominant desmid genus by the number of taxa. The common species were *S. sebaldi, S. arctiscon* and *S. pseudopelagicum.* These three species respectively contributed 75%, 8% and 5% by numbers, while all other species of *Staurastrum* contributed only 12%. *Cosmarium* was represented by 5 species (Table 5) and was more abundant than *Staurastrum* by numbers.

Staurastrum, Cosmarium and *Pediastrum* (Chlorophyta), which were present in the dry zone irrigation reservoirs as well (Mendis 1965), appear to be widespread in Sri Lanka. Genera such as *Botryococcus, Crucigeniella, Franceia, Monoraphidium, Quadricoccus* and *Tetrastrum,* which were present in Parakrama Samudra (Rott 1983), were not collected in the three Mahaweli lakes during the present study. Some of the nannoplanktonic species may not have been collected because the mesh size of the net used (55 μm) is too large.

Mougeotia and *Closteriopsis* were common among non-desmid Chlorophyta. The rest of the green algal species did not add much quantitatively to the phytoplankton abundance of the three lakes.

The phytoplankton in the Mahaweli lakes is dominated by Chlorophyta, by number of taxa, and this compares well with the situation in Lake Beira, Colombo.

Bacillariophyta

Ten species (nine genera) of diatoms were identified in the Mahaweli lakes, of which the two filamentous species *Melosira granulata* and *M. undulata* were dominant. The remaining eight diatom species were non-filamentous forms and were not of much quantitative significance. The diatom *Melosira* was also present in Parakrama Samudra, but Costa & De Silva (1978) did not record it in Lake Beira. *Cyclotelld,* which is a common diatom in both Parakrama Samudra and Beira, and *Synedra,* which is common in Parakrama Samudra (Rott 1983) and other dry zone irrigation reservoirs (P. K. de Silva, unpublished data), were not observed in the three Mahaweli lakes.

Zooplankton

An investigation on the zooplankton of the three lakes was undertaken subsequent to that of the phytoplankton, and is still not complete. However, it appears that rotifers (six genera), cladocerans (nine genera) and copepods (five genera) are common, as they are in lowland irrigation reservoirs. These common species are as follows.

Rotifera: *Asplanchna brightwelli, Brachionus caudatus, Keratella tropica, Notholca* sp., *Lecane* spp., *Trichocerca* sp.

Cladocera: *Alona* sp., *Bosmina* sp., *Bosminopsis* sp., *Ceriodaphnia cornuta, Diaphanosoma exisum, Leptodora* sp., *Moina* sp., *Moinadaphnia* sp., *Simocephalus* sp.

Copepoda: *Diacyclops* sp., *Ergasilus* sp., *Eudiaptomus* sp., *Mesocyclops leuckarti, Thermocyclops* sp.

Fish fauna

As in other lakes and rivers in Sri Lanka, the Family Cyprinidae dominated the fish fauna by number of species, but by biomass the exotic cichlids (tilapias) were dominant.

Table 6. The fish fauna of three Mahaweil lakes in the period 1988 to 1990.

Family/Species	Status in Sri Lanka
Anguillidae	
Anguilla nebulosa	Common
Cyprinidae	
Cyprinus carpio	Exotic, restricted to some reservoirs
Danio malabaricus	Common
Esomus thermoicos	Common
Labeo fisheri	Endemic, restricted to Victoria-Randenigala region
Puntius dorsalis	Common
P. filamentosus	Common
P. sarana	Common
Rasbora daniconius	Common
Tor khudree	Common
Bagridae	
Mystus vittatus	Common
Siluridae	
Ompok bimaculatus	Common
Heteropneustidae	
Heteropneustes fossilis	Common
Chichlidae	
Etroplus maculatus	Common
Oreochromis mossambicus	Exotic, very common
O. niloticus	Exotic, common
Tilapia rendalli	Exotic, rare
Gobiidae	
Glossogobius giuris	Common
Belontiidae	
Belontia signata	Endemic, frequent
Channidae	
Channa gachua	Common
C. marulius	Rare
Mastacembilidae	
Mastacembelus armatus	Common

Twenty-two species of fish were recorded from the three Mahaweli lakes (Table 6), most of which are small, riverine species. The absence of natural lakes in Sri Lanka is reflected in the absence of indigenous lacustrine fish. The species found in lowland irrigation reservoirs are also riverine fishes, together with a few estuarine species. The absence of lacustrine species may be one of the reasons why the exotic tilapia *Oreochromis mossambicus* became well established in lentic waters in a short period of time after its introduction in 1952.

The conversion of the River Mahaweli into a series of lakes has affected populations of the endemic fishes *Garra ceylonensis* and *Labeo fisheri,* the latter being restricted to the Victoria and Randenigala areas. This riverine fish has become rare since the creation of Victoria and Randenigala, and *L. fisheri* should be considered as an endangered species. *G. ceylonensis,* which is strictly a riverine fish, has disappeared with the change of habitat, but is still present in feeder streams. In any case, it is a common species found in all major river catchments in Sri Lanka. The creation of the lakes also affects the upstream spawning migration of the mahseer *Tor khudree.* But, since other streams suitable for spawning are present both upstream and downstream of the lakes, their creation has effectively isolated populations present in different locations. *Channa marulius* is usually present in rivers but spawns at low altitudes; the juveniles then often migrate up to an altitude of about 600 m. This fish will disappear from the River Mahaweli above Randenigala because the lake is a barrier to its migration. The catadromous *Anguilla nebulosa* will also disappear from the lakes and upper regions of the river because the downward migration of the adults for spawning and the upward migration of juveniles for feeding and growth are both prevented by the dams of the series of lakes built along the Mahaweli.

Three tilapias, *Oreochromis mossambicus, O. niloticus* and *Tilapia rendalli,* were present in Victoria and Randenigala, but the last species was not caught in Kotmale. The three tilapias together constituted 67%, 59% and 69% of the fishermen's catch (by netting) on Kotmale, Victoria and Randenigala. *O. mossambicus* dominated the catches and this fish usually forms about 90% of the catch in lowland irrigation reservoirs (De Silva 1988).

The moipho-edaphic index (MEI) (the ratio of water conductivity to mean depth) is a good indicator of fish production in many lakes and reservoirs (Henderson & Welcomme 1974). The three Mahaweli lakes have low conductivities and large depths, and therefore they have low values for the MEI: 2.2, 2.8 and 3.0, respectively for Kotmale, Victoria and Randenigala. These ratios are much lower than those of Sri Lankan lowland irrigation reservoirs, which range from 12.7 (Udawalawe reservoir) to 251.9 (Yodhawewa reservoir) (De Silva 1988). Thus, only a low fish yield per hectare could be expected from an upland lake, in comparison to that of shallow, lowland irrigation reservoirs. In fact, the respective annual fish yields of 38 and 70 kg per hectare in Kotmale and Victoria and a potential annual fish yield of 70 kg per hectare in Randenigala (de Silva 1992) show that these large, deep lakes do indeed have a relatively low fish productivity compared with that of the shallow irrigation reservoirs at low elevations (De Silva 1988).

Acknowledgements

Thanks are due to Mr R. M. D. Somarathna for his help in collecting the samples and carrying out some of the chemical analyses, and Mr T. S. B. Alagoda for preparing the text-figures. I am very grateful to the Manager of the Mahaweli Power Complex of the Ceylon Electricity Board for providing a research grant enabling me to carry out this project, and to the Chief Engineer and other officials at the CECB Victoria office for their kind help during the study. I am very much indebted to Dr J. F. Tailing and Dr D. W. Sutcliffe for reading the manuscript carefully and making valuable suggestions to improve the text.

References

Amarasinghe, U. A., Costa, H. H. & Wijeratna, M. J. S. (1983). Limnology and fish production potential of some reservoirs in Anuradhapura district, Sri Lanka. *Journal of Inland Fisheries, Sri Lanka, 2,* 14-29.

Bauer, K. (1983). Thermal stratification, mixis and advective currents in the Parakrama Samudra reservoir, Sri Lanka. In *Limnology of Parakrama Samudra, Sri Lanka* (ed. F. Schiemer), pp. 27-34. W. Junk, The Hague.

Costa, H. H. & De Silva, S. S. (1978). Seasonal fluctuations of phytoplankton. *Spolia Zeylanica,* 32, 35-53.

de Silva, K. H. G. M. (1992). Limnology and fishery of three recently impounded reservoirs in Sri Lanka. In *Reservoir Fisheries of Asia* (ed. S. S. De Silya), pp. 12-22. International Development Research Centre, Ottawa.

De Silva, S. S. (1988). Reservoirs of Sri Lanka and their Fisheries. *FAO Fisheries Technical Papers,* **298.** FAO Rome, 128 pp.

Dokulil, M., Bauer, K. & Silva, I. (1983). An assessment of the phytoplankton biomass and primary productivity of Parakrama Samudra, a shallow man-made lake in Sri Lanka. In *Limnology of Parakrama Samudra, Sri Lanka* (ed. F. Schiemer), pp. 49-76. W. Junk, The Hague.

Fernando, C. H. & De Silva, S. S. (1984). Man-made lakes: ancient heritage and modern biological resource. In *Ecology and Biogeography in Sri Lanka* (ed. E. H. Fernando), pp. 431-451. W. Junk, The Hague.

Golterman, H. L., Clymo, R. S. & Ohnstad, M. A. M. (1978). *Methods for Physical and Chemical Analysis of Fresh Waters.* IBP Handbook No. 8. Blackwell, Oxford, 213 pp.

Gunatilleke, A. (1983). Phosphorus and phosphate dynamics in Parakrama Samudra based on diurnal observations. In *Limnology of Parakrama Samudra* (ed. F. Schiemer), pp. 35-47. W. Junk, The Hague.

Gunawardene, H. D. & Adikari, A. M. K. R. (1981). Studies on the quality of irrigation waters in Kalawewa area. *Journal of the National Science Council of Sri Lanka*, 9, 121-148.

Henderson, H. F. & Welcomme, R. L. (1974). The relationship of yield to morpho-edaphic index and number of fishermen in African inland fisheries. *C1FA Occasional Papers,* 1, 19 pp.

Holsinger, E. C. T. (1955). The distribution and periodicity of phytoplankton of three Ceylon lakes. *Hydrobiologia,* 7, 25-35.

Mendis, A. S. (1965). A preliminary study of 21 Ceylon lakes. 2. Limnology and fish production potential. *Bulletin of the Fisheries Research Station, Ceylon*, 18, 7-16.

Rott, E. (1983). A contribution to the phytoplankton species composition of Parakrama Samudra, an ancient man-made lake in Sri Lanka. In *Limnology of Parakrama Samudra, Sri Lanka* (ed. F. Schiemer), pp. 209-226. W. Junk, The Hague.

Schiemer, F. (Editor) (1983). *The Limnology of Parakrama Samudra, Sri Lanka.* W. Junk, The Hague, 192 pp.

Seenyya, G. (1971). Ecological studies in the plankton of certain freshwater ponds of Hyderabad, India. II. Phytoplankton-1. *Hydrobiologia,* 37, 55-88.

Sreenivasan, A. (1970). Limnology of tropical impoundments, a comparative study of major reservoirs in Madras State, India. *Hydrobiologia,* 36, 443-459.