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WATER QUALITY OF THE MONASAVU RESERVOIR AND WAILOA RIVER IN 1985

INR TECHNICAL REPORRT NO. 86/3

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Report prepared for the Fiji Electricity Authority

March, 1986

1. INTRODUCTION

The Monasavu Hydro Power Project, for which statistics and maps are given in Table 1 and Figure 1 respectively, has been a major step forward in the development of Fiji. Undoubtedly, projects of this kind have certain, sometimes adverse, implications for the surrounding environment. However, this in itself is insufficient reason to halt development but developers must strive to ensure that every effort is made to assess the adverse effects, if any of the development on environment and to find appropriate means to overcome or minimise them. This often requires some sort of monitoring study.

The filling of the Monasavu reservoir started in 1982 and it was completely full following Cyclone Oscar in early 1983. Although numerous small-scale limnological studies were carried out by some USP scientists from the start of the project (Gibbons and Brodie, 1985) it was not until 1984 that any extensive regular monitoring of the water quality of the reservoir and the Wailoa River (into which the tail-race water is discharged) was initiated. The monitoring for 1985 was commissioned by the Fiji Electricity Authority and this report presents the results of the monitoring activities.

Section 2 which follows this introductory section gives details about the organisation of the monitoring programme together with location and description of sampling sites. The next two sections include data on the chemistry of the Monasavu reservoir and the Wailoa River and interpretations made from them. Section 5 deals with the vector-borne disease survey of the project area and the last section makes some concluding statements about the limnology of the Monasavu reservoir and the Wailoa River during 1985.

TABLE 1 : STATISTICS OF DAM AND RESERVOIR

Reservoir Length	18 km
Reservoir Width	Up to 1 km
Volume of Reservoir	142 million m^3
Area of Reservoir	670 Ha (6.7 km^2)
Head of Water above Wailoa	625 m
Generating Capacity	4 x 20 = 80 MW
Dam Height (Maximum)	85 m
Dam Height above Sea Level	750 m
Power Tunnel Length	5.4 km
Diversion Tunnel Length	11 km
Plateau Average Annual Rainfall	360 cm

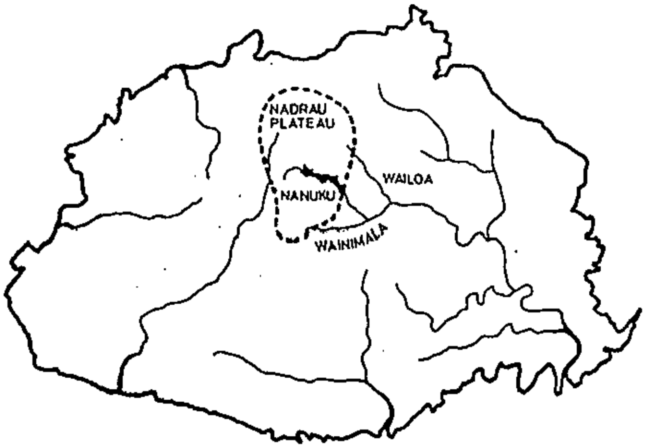
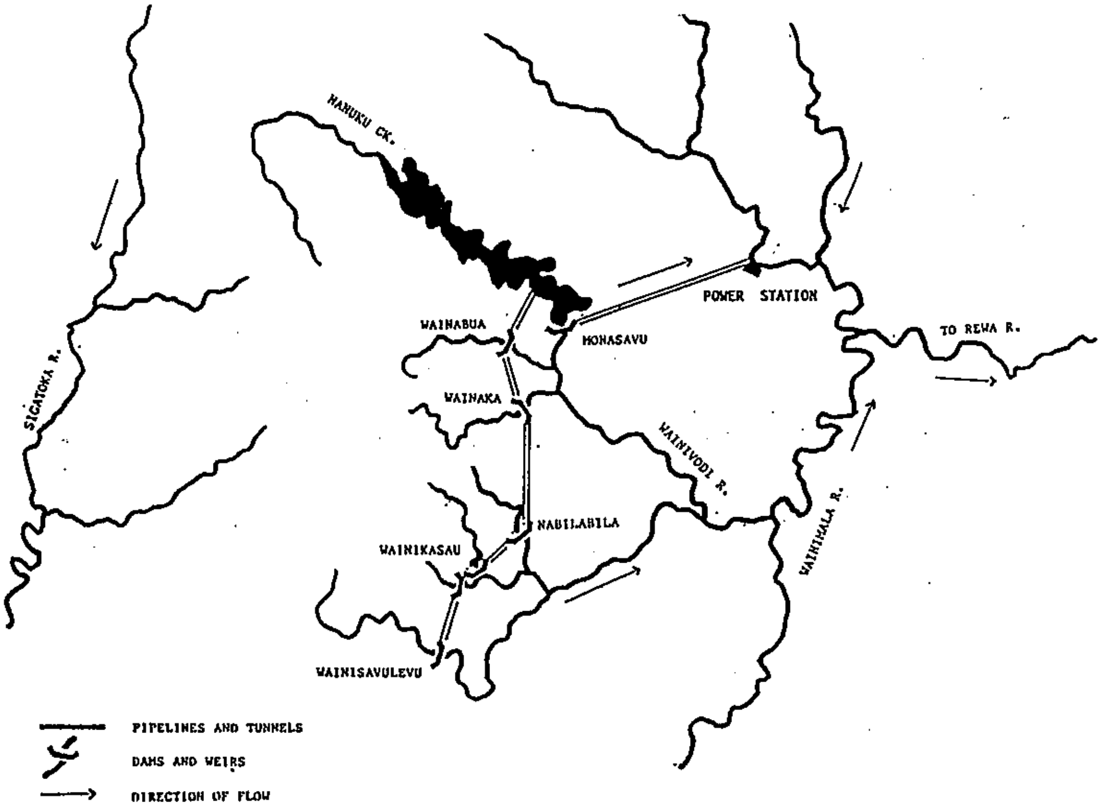


FIGURE 1 : Map showing the location of the Monasavu Hydro Power Project



2. THE MONITORING PROGRAMME

This section gives various aspects of the design of the monitoring programme.

2.1 The Organisation

The monitoring of the Monasavu Reservoir and the Wailoa River could not be started until April for reasons of inconvenience caused by the cyclones in the earlier months of 1985. Apart from this late start, the programme was carried out in general accordance with the proposal submitted to the Fiji Electricity Authority at the end of 1984. Accommodation for INR researchers while at Monasavu and boat facilities for sampling purposes were provided by FEA. Table 2 gives further details of the monitoring programme.

2.2 Sampling Sites

The sites chosen for sampling in 1985 remained the same as for 1984. Figure 2 which is an enlarged section of the Monasavu Reservoir shows the location of the three sampling stations within it. The sampling stations along the Wailoa River are given in Figure 3. Station 4 which is described as being 5 km from the power station in Figure 3 is actually located at the Laselevu village.

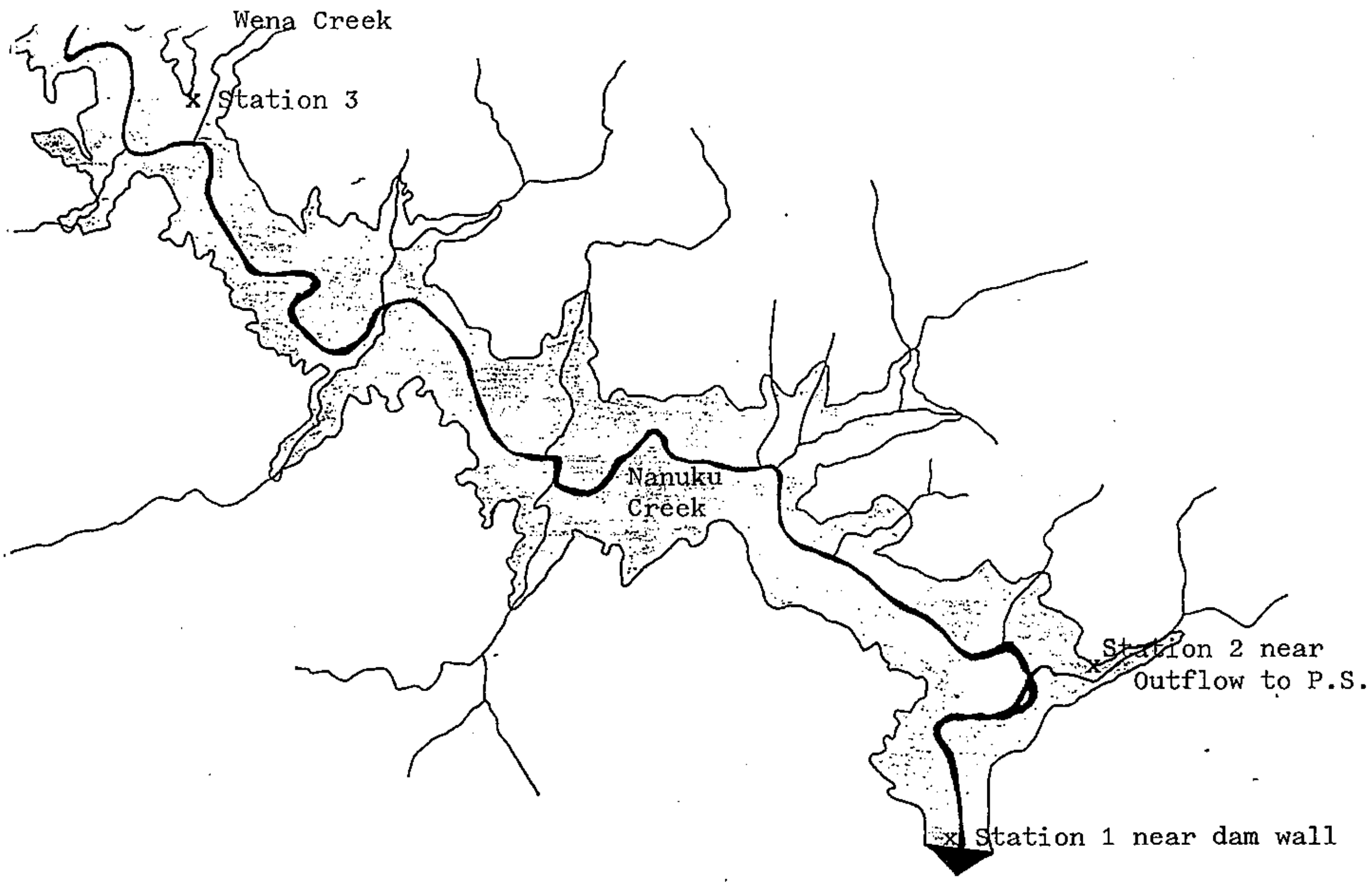


FIGURE 2 : Location of the sampling stations in the Monasavu Reservoir

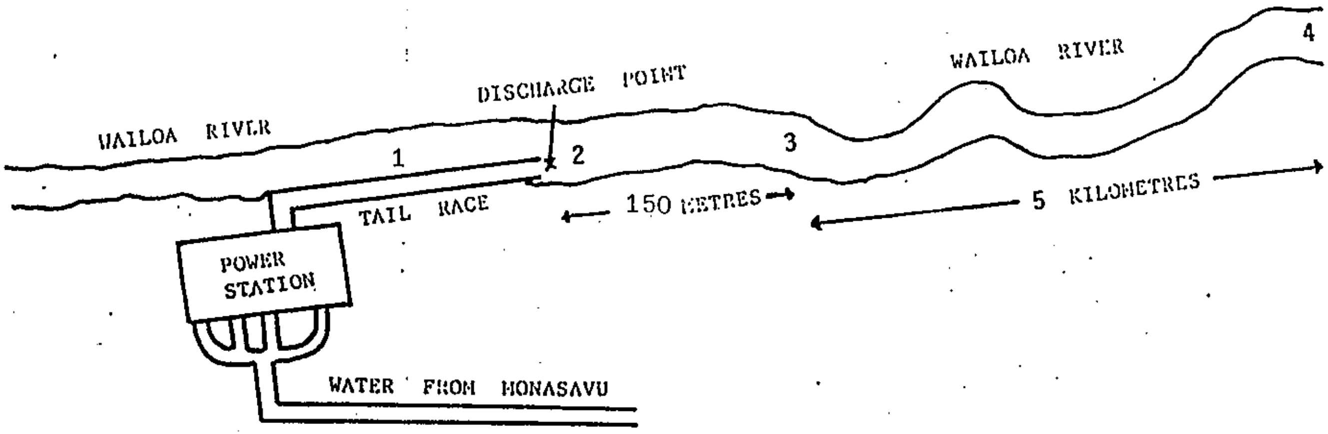


FIGURE 3 : Sampling sites along the Wailoa River

Site : 1 100 m above P.S. discharge
2 Tailrace

TABLE 2. Monitoring Programme of the Monasavu Reservoir and Wailoa River

	No of Sites Monitored	Monitoring Sequence	Parameters Measured
Monasavu Reservoir	3 stations each at 3 different depths	24/4/85 19/8/85 22/10/85 17/12/85	Temperature and dissolved oxygen profiles; pH, alkalinity; chlorophyll a,b and c; nutrients - nitrogen, phosphorus and sulphur; dissolved and total iron and manganese
Wailoa River*	4 stations near the Power Station and further downstream	27/4/85 24/6/85 19/8/85 22/10/85 14/11/85 17/12/85	As for above
Vector-borne disease survey	Examination of the entire project area	19/9/85 20/9/85 22/10/85	Possible disease hosts - Gastropods and mosquitoes

*The Wailoa River could be sampled at four stations only and not five as previously proposed because other parts of the river are virtually inaccessible by road. Also following the fencing of the Wailoa Power Station area access to the sampling site 150 m downstream from the station (see Figure 3) could not be obtained after October.

3. RECORD OF DATA

Apart from temperature and dissolved oxygen which were determined on site the rest of the measurements were made at the INR laboratory. Tables 3 to 8 give the results of the analyses carried on the samples. Interpretation of the data is given in the next section.

TABLE 3 : Results of the April monitoring of the Monasavu Reservoir and Wailoa River   Date : 24/4/85

	Stn. 1 Surface	Stn. 1 Mid	Stn. 1 Bottom	Stn. 2 Surface	Stn. 2 Mid	Stn. 2 Bottom	Stn. 3 Surface	Stn. 3 Mid	Stn. 3 Bottom	Wailoa Above P.S.	Wailoa Tailrace	Wailoa 150m Below P.S.	Wailoa at Laselevu
kalinity CO_3)	18.0	14.6	36.3	18.1	15.8	15.8	17.8	17.4	18.0	33.0	15.1	21.9	26.1
y	1	1	42	1	2	64	1	1	16	1	1	2	1
lab	6.60	5.85	6.42	6.60	6.70	6.40	6.70	5.80	6.40				
site										7.01	6.75	7.38	7.34
(mg/l)	1.3	2.2	3.0	1.5	1.5	2.0	1.5	1.5	2.0	1.3	1.5	1.4	1.2
(μg/l)	28.0	33.2	14.0	55.2	95.2	70.0	24.0	55.6	72.0	84.0	55.6	55.2	56.0
(mg/l)	0.67	<0.3	3.84	1.00	<0.3	<0.3	1.84	0.83	2.67	1.47	1.00	0.33	<0.3
'l)	<0.01	0.66	0.10	0.04	0.42	0.36	0.01	0.11	<0.01	0.29	0.57	0.38	0.26
)	<10	<10	950	<10	<10	197	<10	76	360	<10	<10	<10	<10
yll mg/m^3 a	2.67	0.94	0.93	2.11	0.86	2.06	2.45	0.89	0.51	0.34	0.32	0.57	0.23
b	2.22	0.21	0.28	1.52	1.15	1.83	0.29	0.33	1.96	3.19	1.21	0.25	0.08
c	3.97	1.18	1.05	7.71	4.54	5.79	3.14	0.22	0	0	0	0	0
d Mn (mg/l)	<0.1	<0.1	1.8	<0.1	<0.1	1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
(mg/l)	<0.1	<0.1	1.8	<0.1	<0.1	1.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1
d Fe (mg/l)	<0.2	0.4	9.6	<0.2	0.2	2.2	0.2	0.4	2.0	<0.2	0.3	0.2	<0.2
(mg/l)	0.5	0.5	10.8	0.4	0.5	2.6	0.2	0.4	2.1	<0.2	0.4	0.3	<0.2
ure (°C)	23.0	21.0	20.0	23.5	22.0	21.5	24.5	22.5	22.0	23.5	22.5	23.0	
d O_2 (mg/l)	5.90	1.90	0	7.0	3.0	0.3	8.4	0.2	0	8.2	7.9	7.8	8.
l)	0	34	68	0	23	45	0	22	45	0	0	0	

TABLE 4. Results of the June monitoring of the Wailoa River

	Tail Race	L/Levu	100m above P.S.	150m below P.S.
pH	7.1	6.7	7.4	7.3
Turbidity	3.8	<2.0	2.0	2.2
Nitrates mg/l	0.1	0.25	0.40	0.19
Ammonia g NH_3/l	64	84	104	130
Phosphate g PO_4/l	<18	<18	61	<18
Total iron mg/l	0.4	<0.2	<0.2	0.2
Dissolved iron mg/l	0.4	<0.2	<0.2	<0.2
Total manganese mg/l	0.2	<0.1	<0.1	0.1
Dissolved manganese mg/l	0.2	<0.1	<0.1	0.1
Total nitrogen mg/l	2.0	2.5	1.6	2.1
Total sulphur mg/l	<1.0	1.0	<1.0	<1.0
Total alkalinity mg/l	30	31	46	32

TABLE 5 : Results of the August monitoring of the Monasavu Reservoir and Wailoa River Date : 19/8/85

	Stn. 1 Surface	Stn. 1 Mid	Stn. 1 Bottom	Stn. 2 Surface	Stn. 2 Mid	Stn. 2 Bottom	Stn. 3 Surface	Stn. 3 Mid	Stn. 3 Bottom	Wailoa Above P.S.	Wailoa Tailrace	Wailoa 150m Below P.S.	Wailoa at Laselevu
kalinity CO$_3$)	18	18	48	16	18	18	18	18	19	34	17	20	24
y	<2	<2	120	<2	<2	4	<2	<2	80	<2	<2	<2	<2
lab	7.15	7.20	7.20	7.11	7.21	7.20	7.21	7.30	7.10	8.15	7.20	7.59	8.0
site													
(mg/l)	2.1	1.8	3.5	2.4	1.5	1.8	1.5	1.8	1.9	1.4	1.8	1.6	1.4
(µg/l)	30	18	165	30	28	53	38	33	180	60	63	43	43
(mg/l)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
l)	0.05	0.12	0.53	0.04	0.11	0.10	0.18	0.56	0.12	0.23	0.56	<0.01	0.08
l)	<20	<20	1625	30	30	30	<20	30	30	30	20	20	20
yll mg/m^3 a	0.55	0.28	0.88	2.27	3.26	0.57	0.71	0.23	0.25	5.86	2.38	0.70	0.28
b	5.08	2.50	1.27	3.11	5.40	0.61	4.68	2.77	2.80	12.4	5.82	4.20	2.77
c	27.6	13.8	7.90	11.5	25.3	5.51	15.0	10.4	13.6	30.6	41.7	21.8	10.4
ed Mn (mg/l)	0.1	0.1	0.9	0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	<0.1
n (mg/l)	0.1	0.1	1.0	0.1	<0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ed Fe (mg/l)	0.2	0.2	0.9	0.2	0.2	0.3	0.3	0.2	0.6	0.4	0.3	0.3	0.3
e (mg/l)	0.5	0.2	0.9	0.5	0.4	0.6	0.5	0.7	1.4	0.4	0.4	0.3	0.4
ture (°C)	20	20	19.7	20	20	20	20	20	20	20	21	21	
ed O$_2$ (mg/l)	4.7	4.0	0	4.9	4.0	1.6	5.0	3.9	4.2	8.1	5.8	8.0	
n)	0	30	60	0	20	40	0	15	30	0	0	0	

TABLE 6 : Results of the October monitoring of the Monasavu Reservoir and Wailoa River Date : 23/10/85

		Stn. 1 Surface	Stn. 1 Mid	Stn. 1 Bottom	Stn. 2 Surface	Stn. 2 Mid	Stn. 2 Bottom	Stn. 3 Surface	Stn. 3 Mid	Stn. 3 Bottom	Wailoa Above P.S.	Wailoa Tailrace	Wailoa 150m Below P.S.	Wailoa at Laselevu
kalinity CO_3)		20	26	51	26	31	20	20	25	26	41	31	31	31
y		3.6	2.0	20.2	4.2	2.2	4.0	3.8	2.0	10.4	1.8	2.0	2.0	2.4
ab ite		8.10	6.85	6.60	8.22	6.91	6.89	7.85	7.12	6.81	7.92	7.10	7.10	7.85
(mg/l)		5.9	2.3	5.6	2.2	6.4	4.3	4.4	4.5	8.2	5.8	6.5	5.6	5.5
(µg/l)		38	40	190	32	34	26	36	40	120	58	32	46	56
(mg/l)		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.8	1.0
l)		0.04	0.35	0.02	0.02	0.07	0.12	0.03	0.08	0.05	0.14	0.07	0.15	0.14
)		20	27	800	20	53	60	33	27	275	35	75	94	33
yll mg/m^3	a	0.20	0.40	0.57	0.31	0.31	0.11	0.68	0.80	1.57	0.03	0.29	0.36	0.29
	b	0.46	2.10	0.84	0.67	0.67	0.17	0.96	1.22	2.42	0.82	0.89	3.02	0.89
	c	2.69	5.70	2.12	2.44	2.44	0.42	3.22	2.28	8.45	1.90	2.93	13.40	2.93
d Mn (mg/l)		0.10	0.10	1.10	0.10	0.10	0.22	0.10	0.10	0.20	0.10	0.40	0.20	0.10
(mg/l)		0.10	0.10	1.12	0.10	0.10	0.30	0.10	0.10	0.63	0.10	0.40	0.22	0.12
d Fe (mg/l)		0.30	0.20	0.40	0.30	0.20	0.60	0.20	0.30	1.5	0.20	0.90	0.20	0.40
(mg/l)		0.30	0.40	8.2	0.30	0.40	0.70	0.20	0.30	5.6	0.30	0.90	0.60	0.40
ure (°C)		25	19	19	24	21	20	26	21	20	22	22	22	
d O_2 (mg/l)		8.8	0.4	0	8.8	0.7	0	8.2	2.2	0	8.8	6.8	9.2	
)		0	30	59	0	16	32	0	12	23	0	0	0	

TABLE 6 : Results of the October monitoring of the Monasavu Reservoir and Wailoa River   Date : 23/10/85

	Stn. 1 Surface	Stn. 1 Mid	Stn. 1 Bottom	Stn. 2 Surface	Stn. 2 Mid	Stn. 2 Bottom	Stn. 3 Surface	Stn. 3 Mid	Stn. 3 Bottom	Wailoa Above P.S.	Wailoa Tailrace	Wailoa 150m Below P.S.	Wailoa at Laselevu
lkalinity aCO$_3$)	20	26	51	26	31	20	20	25	26	41	31	31	31
ty	3.6	2.0	20.2	4.2	2.2	4.0	3.8	2.0	10.4	1.8	2.0	2.0	2.4
lab site	8.10	6.85	6.60	8.22	6.91	6.89	7.85	7.12	6.81	7.92	7.10	7.10	7.85
(mg/l)	5.9	2.3	5.6	2.2	6.4	4.3	4.4	4.5	8.2	5.8	6.5	5.6	5.5
(µg/l)	38	40	190	32	34	26	36	40	120	58	32	46	56
(mg/l)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.8	1.0
/l)	0.04	0.35	0.02	0.02	0.07	0.12	0.03	0.08	0.05	0.14	0.07	0.15	0.14
/l)	20	27	800	20	53	60	33	27	275	35	75	94	33
hyll mg/m^3 a	0.20	0.40	0.57	0.31	0.31	0.11	0.68	0.80	1.57	0.03	0.29	0.36	0.29
b	0.46	2.10	0.84	0.67	0.67	0.17	0.96	1.22	2.42	0.82	0.89	3.02	0.89
c	2.69	5.70	2.12	2.44	2.44	0.42	3.22	2.28	8.45	1.90	2.93	13.40	2.93
ved Mn (mg/l)	0.10	0.10	1.10	0.10	0.10	0.22	0.10	0.10	0.20	0.10	0.40	0.20	0.10
Mn (mg/l)	0.10	0.10	1.12	0.10	0.10	0.30	0.10	0.10	0.63	0.10	0.40	0.22	0.12
ved Fe (mg/l)	0.30	0.20	0.40	0.30	0.20	0.60	0.20	0.30	1.5	0.20	0.90	0.20	0.40
Fe (mg/l)	0.30	0.40	8.2	0.30	0.40	0.70	0.20	0.30	5.6	0.30	0.90	0.60	0.40
ature (^{o}C)	25	19	19	24	21	20	26	21	20	22	22	22	
ved O$_2$ (mg/l)	8.8	0.4	0	8.8	0.7	0	8.2	2.2	0	8.8	6.8	9.2	
(m)	0	30	59	0	16	32	0	12	23	0	0	0	

TABLE 7. Results of the November monitoring of the Wailoa River

		Wailoa Above P.S.	Wailoa Tailrace	Wailoa at Laselevu
Total Alkalinity mg/l $CaCO_3$		29	19	24
Turbidity		2.8	4.0	3.0
pH on site				
lab		7.90	7.15	7.05
Total N (mg/l)		2.7	2.8	3.3
Total P (g/l)		60	44	50
Total S (mg/l)		1.0	1.0	1.0
NO^{3-} (mg/l)		0.15	0.05	0.14
NH_3 (g/l)		20	124	30
Chlorophyll mg/m^3	a	0.86	0.63	0.23
	b	1.70	1.38	0.33
	c	5.10	4.20	0.85
Dissolved Mn (mg/l)		0.10	0.18	0.10
Total Mn (mg/l)		0.10	0.52	0.10
Dissolved Fe (mg/l)		0.20	1.0	0.60
Total Fe (mg/l)		0.20	1.0	0.64
Temperature (°C)				
Dissolved O_2 (mg/l)		8.5	8.0	
Depth (m)		0	0	

TABLE 8 : Results of December monitoring of the Monasavu Reservoir and Wailoa River Date : 18/12/85

	Stn. 1 Surface	Stn. 1 Mid	Stn. 1 Bottom	Stn. 2 Surface	Stn. 2 Mid	Stn. 2 Bottom	Stn. 3 Surface	Stn. 3 Mid	Stn. 3 Bottom	Wailoa Above P.S.	Wailoa Tailrace	Wailoa 150m Below P.S.	Wailoa at Laselevu
kalinity CO_3)	20	31	51	51	31	20	27	20	20	41	25		20
y	2	2	4	4	2	8	4	2	2	2	2		2
lab site	8.6	7.2	7.0	7.5	7.1	6.9	7.5	6.9	6.8	7.6	7.0		7.5
(mg/l)	6.2	3.1	7.5	6.4	6.2	2.8	2.6	2.5	6.6	3.2	4.2		5.3
(μg/l)	35	6	180	43	<6	35	18	25	25	50	43		50
(mg/l)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0		<1.0
l)	0.02	<0.01	<0.01	<0.01	<0.01	0.04	<0.01	<0.01	<0.01	<0.01	<0.01		0.09
	50	260	1700	110	110	95	75	65	250	<20	85		25
yll mg/m^3 a	2.3	1.1	1.6	0.57	0.43	0.28	0.57	6.5	0.57	0.57	0.57		0.28
b	3.3	1.2	3.6	0.84	1.9	2.8	5.8	11	0.84	0.61	0.84		7.5
c	8.4	11	8.8	2.1	4.6	10	18	51	2.2	5.5	2.1		29
d Mn (mg/l)	0.1	0.1	<0.1	0.1	0.1	0.4	<0.1	0.1	0.4	<0.1	0.2		0.1
(mg/l)	0.1	0.1	0.1	0.1	0.1	0.5	0.1	0.1	0.4	<0.1	0.2		0.1
d Fe (mg/l)	<0.2	<0.2	3.2	<0.2	<0.2	4.6	0.4	<0.2	<0.2	<0.2	0.4		0.3
(mg/l)	<0.2	<0.2	3.5	<0.2	<0.2	4.8	0.5	0.3	<0.2	<0.2	0.5		0.3
ure (^{o}C)	23.0	20.0	20.0	23.0	21.0	20.0	24.0	20.5	20.0	23.5	23.5		
d O_2 (mg/l)	7.6	0	0	8.4	2.6	0.8	7.6	0.2	0.1	7.8	6.1		
)	0	36	62	0	16	32	0	16	32	0	0		

4. INTERPRETATION OF RESULTS FOR WATER QUALITY

4.1 The Monasavu Reservoir

As far as the physical state of the reservoir is concerned, the surface of the water is becoming relatively free from dead tree branches and visual observations made during sampling trips have indicated the water at the bottom of the reservoir is getting clearer. The turbidity measurements for 1985 reported in Table 9, although not suggesting any major trend with time of the year show that turbidity still increases with depth, resulting mainly from decaying organic matter and possibly from the action of the bottom waters on loose sediments.

TABLE 9. Turbidity in the Monasavu Reservoir in 1985

Sampling Date		April	August	October	December
STATION 1	SFC	1	<2	4	2
	MID	1	<2	2	2
	BTM	42	120	20	4
STATION 2	SFC	1	<2	4	4
	MID	2	<2	2	2
	BTM	64	4	4	8
STATION 3	SFC	1	<2	4	4
	MID	1	<2	2	2
	BTM	16	80	10	2

a) Temperature and dissolved oxygen profiles.

The temperature and the dissolved oxygen profiles for the three stations for each of the sampling trips are given in Figures 4, 5 and 6. The profiles for the summer months are characterised by a distinct temperature gradient with virtually no oxygen below 20 to 30 m whereas during the cooler months the reservoir is almost homothermal with oxygenated waters at depth. Comparison with 1984 measurements (Figure 7) shows that the reservoir behaved in a similar fashion in 1985 with one turnover during the cooler months. However, the zero oxygen level has increased from 10 to 20 m in 1984 to 20 to 30 m in 1985 indicating decreasing amounts of organic matter left at these levels for decomposition. This could also be due to the aerator in the viccinity of Station 2. The temperature and oxygen profiles can be rationalised generally in terms of the local weather conditions, water movements, the morphometry of the reservoir and the biological activity within it.

Perhaps the most important parameter that influences in fundamental ways the physical, chemical and biological cycles of lakes is temperature and therefore needs to be discussed first. Whilst there can be a number of sources of heat in a lake the most significant is that from solar radiation absorbed directly by the water. The absorbed heat can then be distributed in the water column through either conduction or turbulance. However, the thermal conductivity of water is very low and is not adequate to explain the observations made. Turbulance or mixing is therefore the major factor affecting temperature distribution in lakes. The marked thermal stratification in the summer months

FIGURE 4 : Dissolved oxygen and temperature profiles for station 1 in 1985

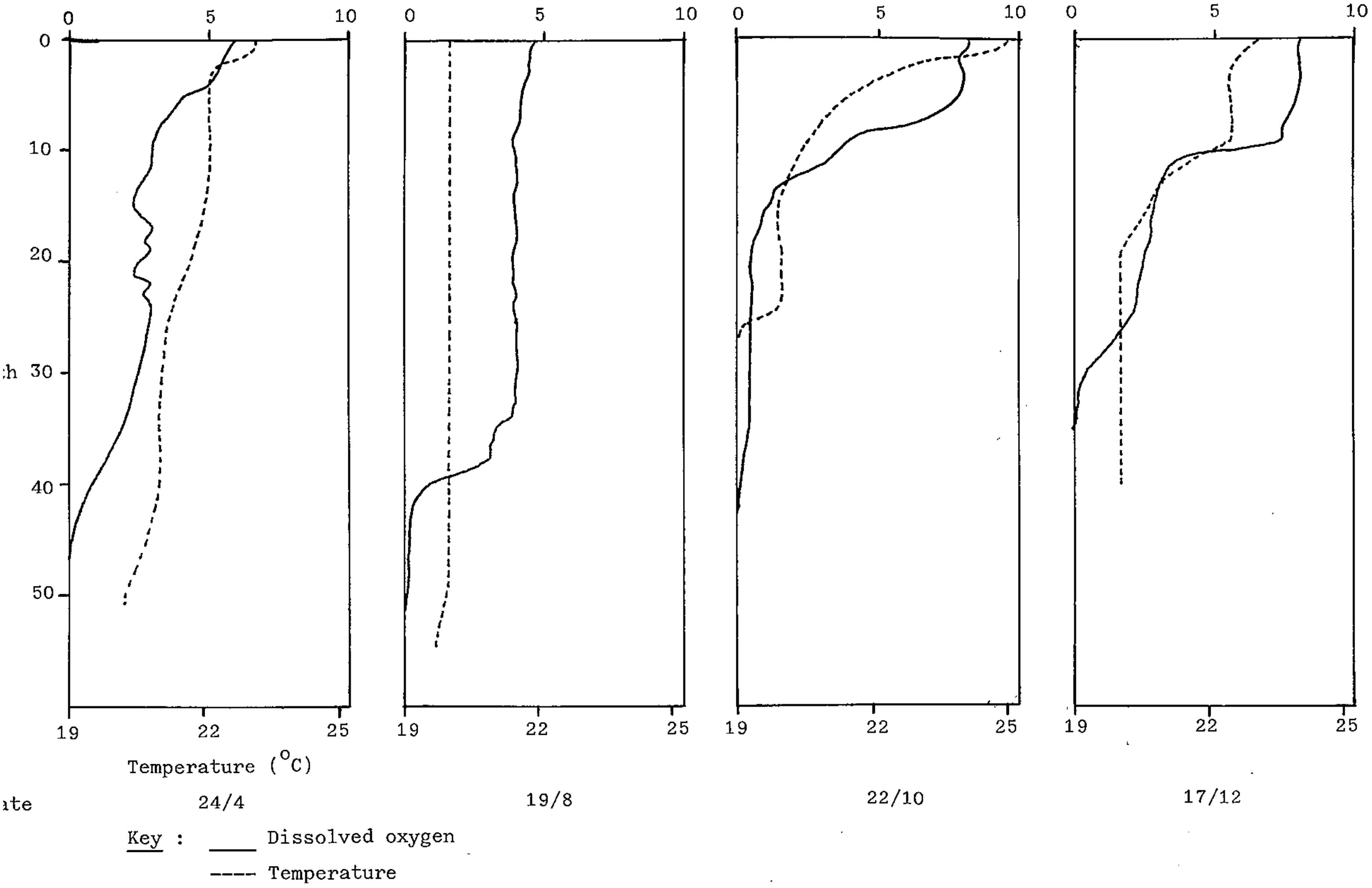


FIGURE 5 : Dissolved oxygen and temperature profiles for station 2 in 1985

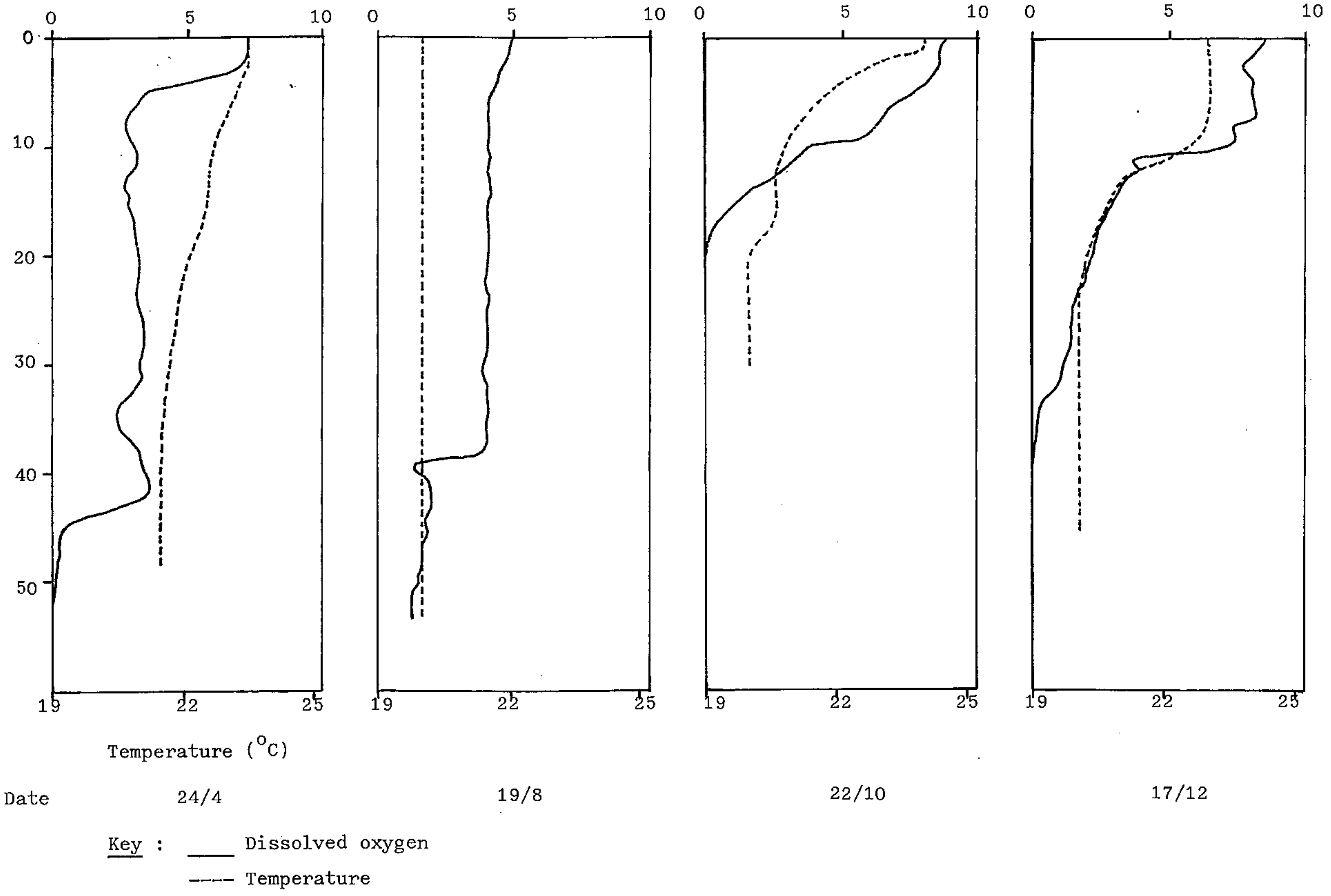


FIGURE 6 : Dissolved oxygen and temperature profiles for station 3 in 1985

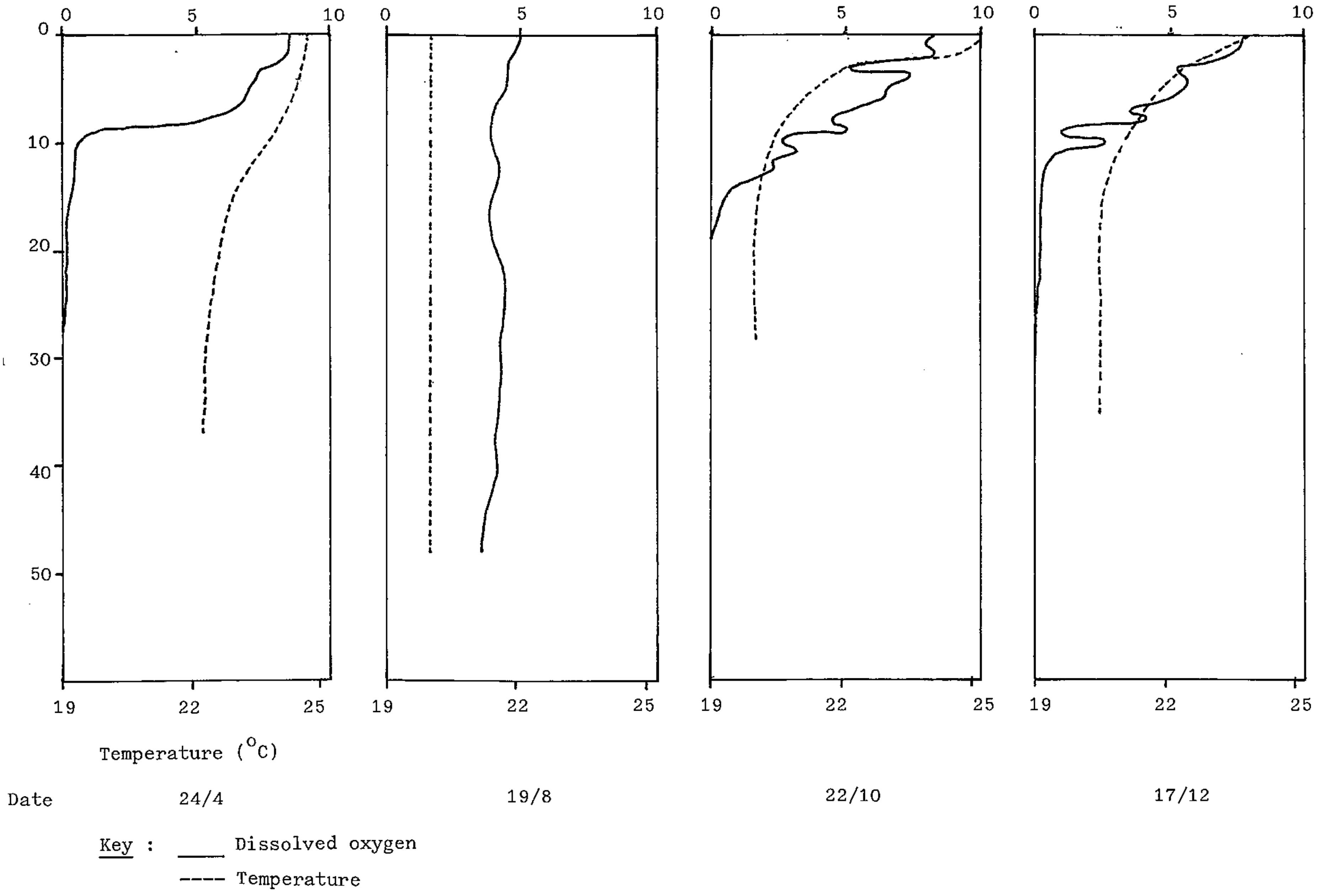
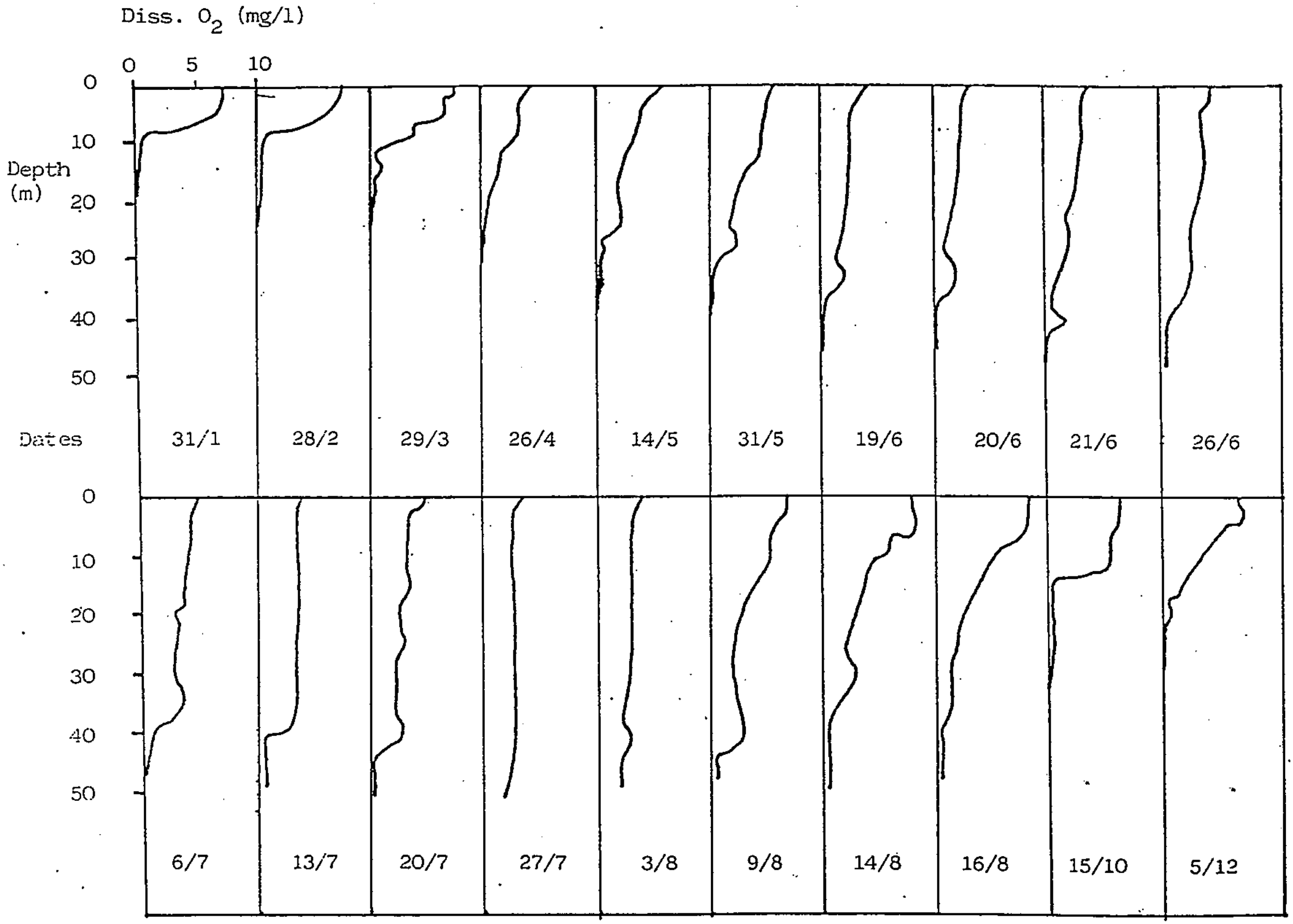


FIGURE 7 : Dissolved oxygen profiles for station 1 in 1984



suggests strong resistance of the water column to mixing and is mainly density related. Summer temperatures are normally higher and cause surface waters to heat up more rapidly than the distribution of heat by mixing. As the surface waters heat and become less dense with respect to underlying waters, the relative thermal resistance to mixing increases markedly. Figure 8 which shows density as a function of temperature for distilled water at 1 atmosphere indicates clearly that density difference per °C increases with increasing temperature. A difference of only a few degrees is sufficient to prevent complete circulation of the entire water column (Wetzel, 1975).

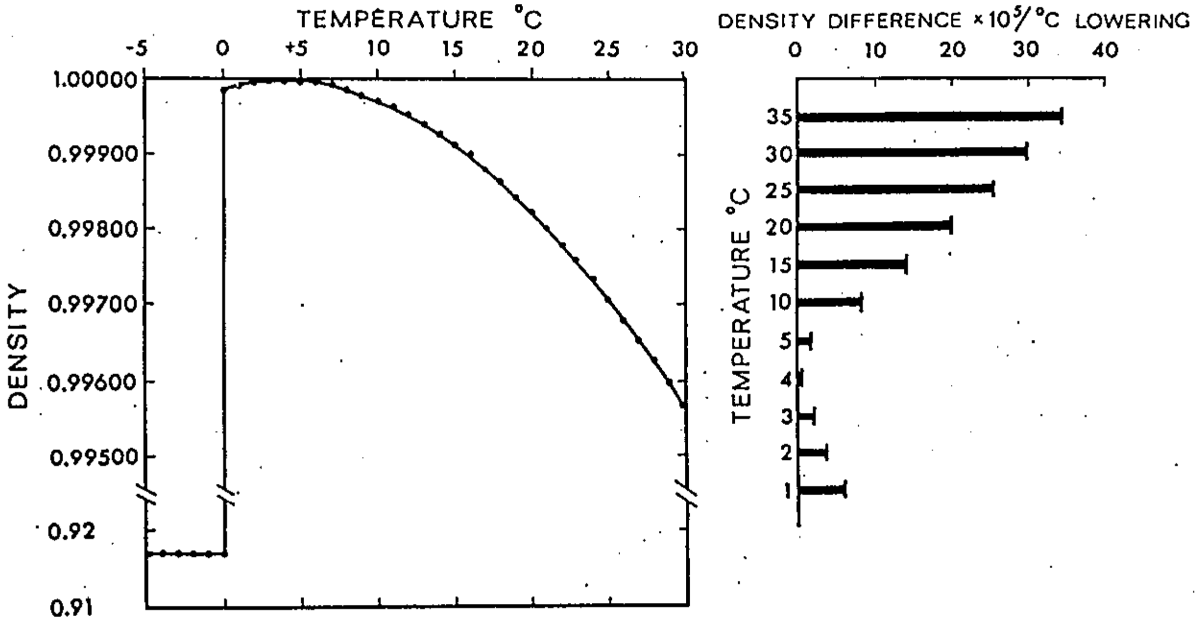


FIGURE 8 : Density as a function of temperature for distilled water at 1 atm. The density difference per °C lowering is shown in the righthand portion of the figure at various temperatures. (Origin : Wetzel, 1975).

The water is then divided into three regions of different temperatures which resist mixing with each other as shown in Figure 9. The temperature difference between the epilimnion and the hypolimnion in the Monasavu reservoir can be as high as 6°C during the summer months and thus marked thermal stratification during these months is observed. In late summer and in the cooler months falling air temperatures cause loss of heat from the surface waters more rapidly than inputs from solar radiation. Surface water get cooler and their temperatures and therefore densities approach those of the underlying waters. There is little thermal resistance to mixing and complete circulation of the water column is achieved through convection currents and wind energy resulting in effectively a homothermal water column. This explains the profiles observed in the month of August.

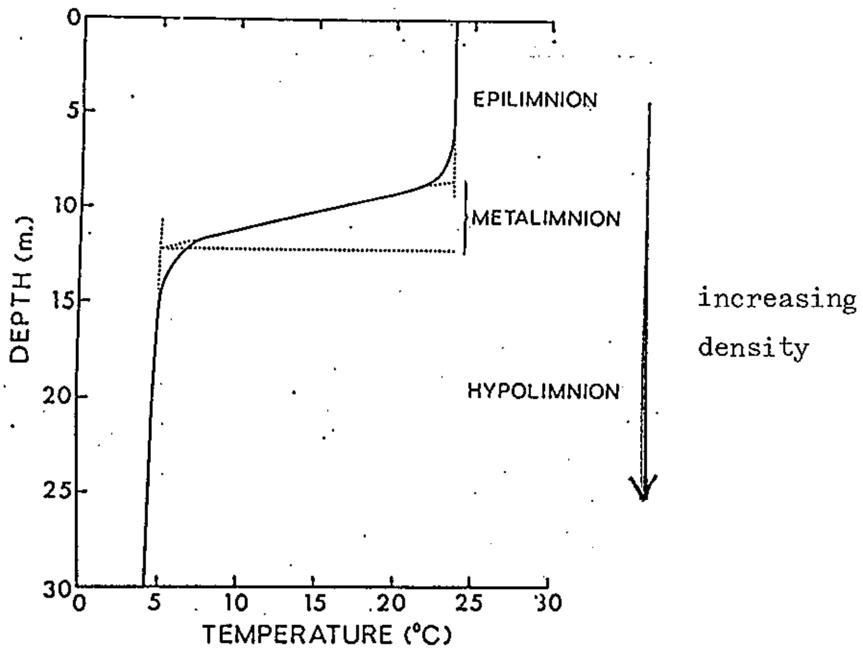


FIGURE 9 : Typical thermal stratification of a lake into the epilimnetic, metalimnetic and hypolimnetic water starta. (Origin : Wetzel, 1975).

The oxygen profiles can be explained essentially in terms of the temperature profiles. The solubility of oxygen in water decreases with increasing temperature. However, higher dissolved oxygen contents in the surface waters are noted in the summer months because resistance to mixing of the different layers leads to oxygen concentration in the upper layer or the epilimnion. Diffusion of oxygen in water is a very slow process and does not play a major role in oxygen distribution. Any oxygen present in the hypolimnion is used for bacterial respiration and oxidative processes in decomposition of the underlying organic matter. The hypolimnetic oxygen content of highly eutroptic lakes is depleted within a few weeks after summer stratification begins and the bottom layers remain anaerobic throughout the summer months.

The mixing of the different layers in the cooler period ensures a redistribution of the dissolved oxygen throughout the entire water column.

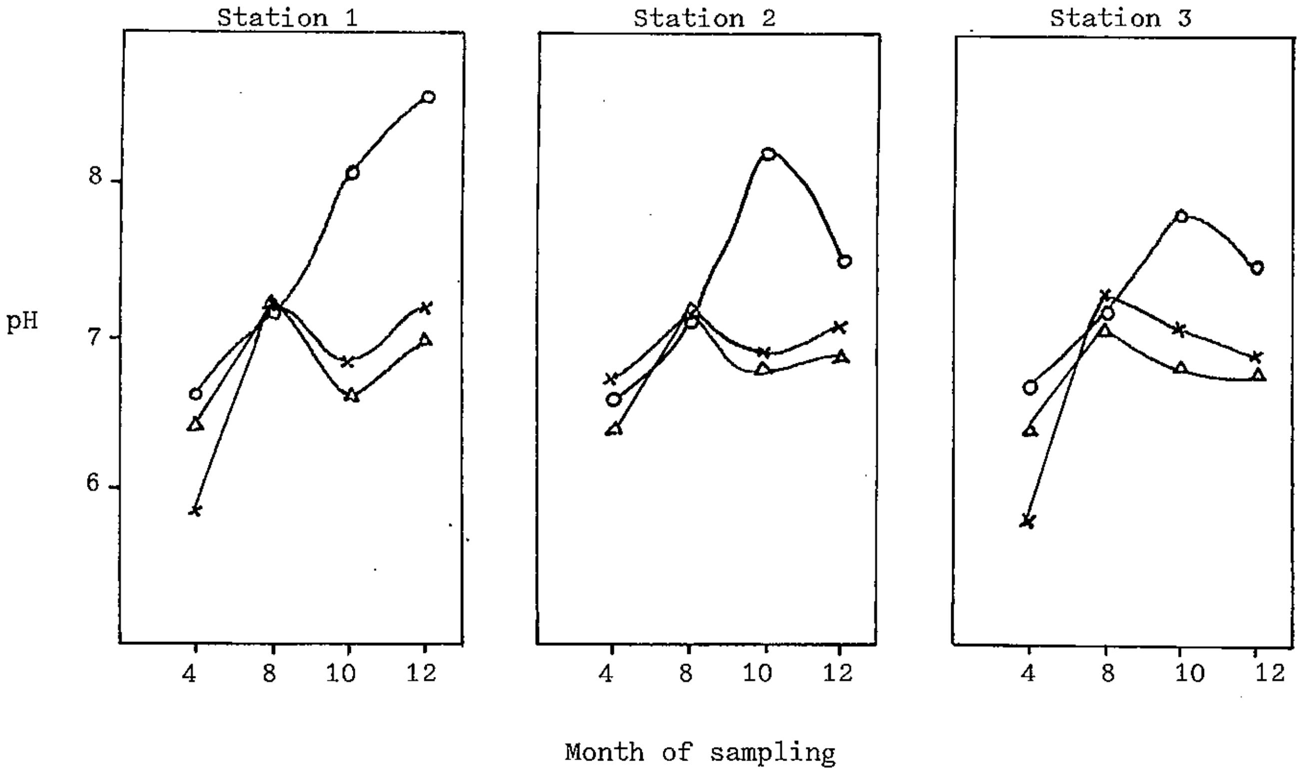
b) pH in the Monasavu Reservoir

The pH of fresh water systems is closely related to the carbon content. A majority of the carbon in fresh fresh water systems occurs as equilibrium products of carbonic acid. The pH of these waters results from the H+ ions of the dissociation of carbonic acid and OH- ions of the hydrolysis of bicarbonate ions. Although the exchange of carbon dioxide of the water with that of the atmosphere is rapid and relatively complete in aerated open water of lakes, the distribution of carbon dioxide and pH with depth is altered by microbial metabolism in stratified zones of lakes.

The range of pH for the Monasavu lake is between 6 and 9 as shown in Figure 10. This would make it a bicarbonate type lake, regulated by the carbon dioxide-bicarbonate-carbonate buffering system.

The total inorganic carbon, which is derived by the equilibrium established between atmospheric carbon dioxide, the bicarbonate-carbonate system, contributions from metabolic respiration and decomposition and utilization in photosynthesis, is distributed evenly with depth during periods of circulation (in the winter months) thus explaining little variability in pH with depth at this time of the year.

FIGURE 10 : Variation of pH with time of year during 1985 in the Monasavu River



Key

o surface

x mid

Δ bottom

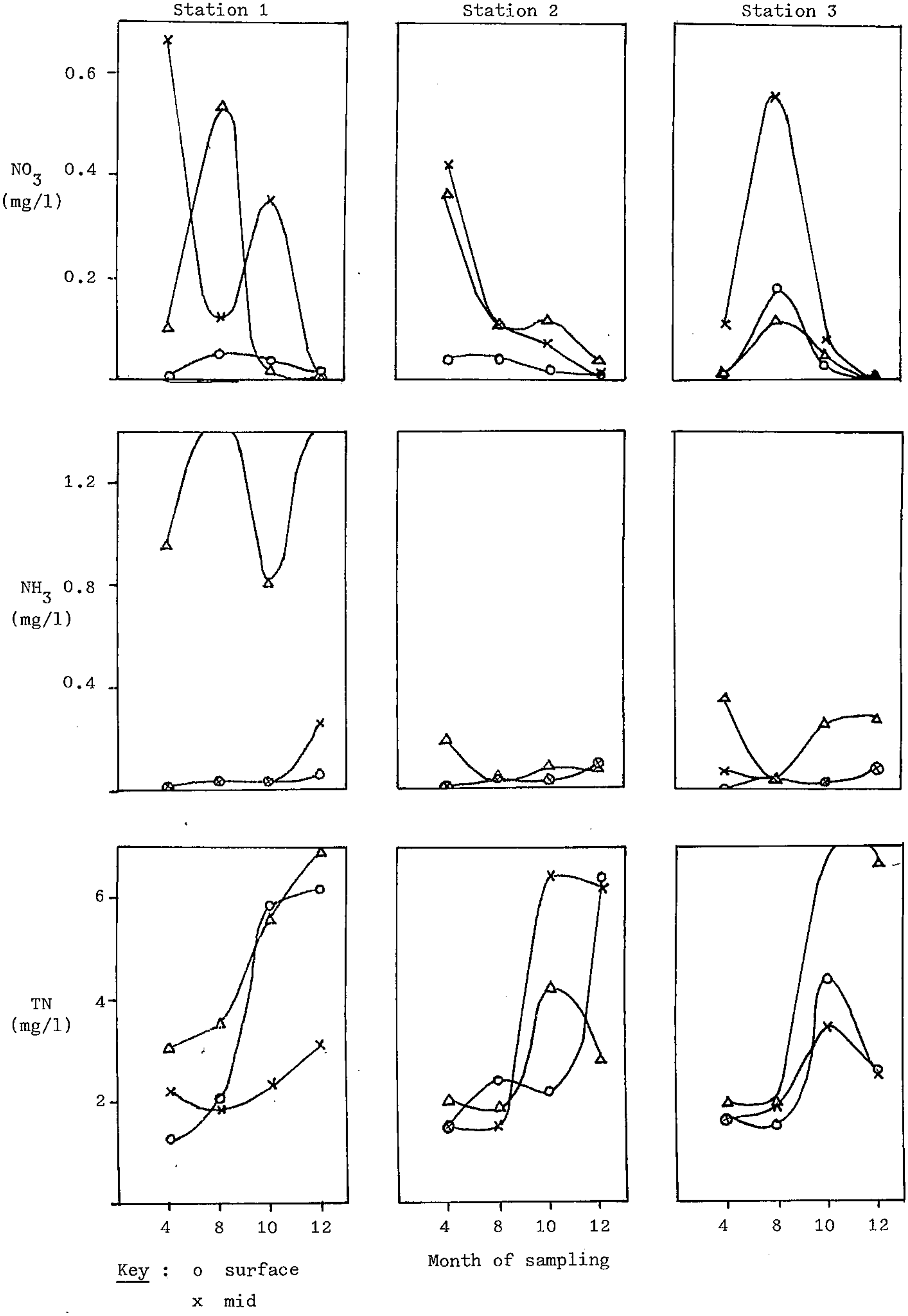
The photosynthetic utilization of carbon dioxide in excess of respiration in the trophogenic zone (upper layers) tends to reduce the carbon dioxide content and to increase pH which explains the relatively higher pH values of the surface waters. In the bottom layers of the reservoir there is degradation of organic matter, microbial methane fermentation, nitrification of ammonia and sulphide oxidation during aerobic periods. As the hypolimnion becomes anoxic decomposition becomes anaerobic together with dentrification and reduction of sulphate to sulphide. The combination of the decomposition processes results in a net increase in the carbon dioxide content of the hypolimnetic waters and a decrease in pH as observed in the summer months. Since the lethal effects of most acids begin to appear near pH 4.5 (Wetzel, 1975) the pH of the bottom waters of the Monasavu Reservoir which was never below 5.5 during 1985 is not a cause for concern. The difference in pH between the different layers is only slight (about 1 pH unit) indicating the strong buffering capacity of the system.

c) Nutrients

i) Nitrogen

Figure 11 gives the variation of the different forms of nitrogen in the water with time of the year for the three stations. The surface waters at all stations are characterised by lower levels of nitrate (NO_3^-) throughout the year because of higher photosynthetic activity and hence consumption of nitrate within it. Sufficient quantities of oxygen at the surface prevent the

FIGURE 11 : Variations of nitrate, ammonia and total nitrogen content of the Monasavu Reservoir with time of year in 1985

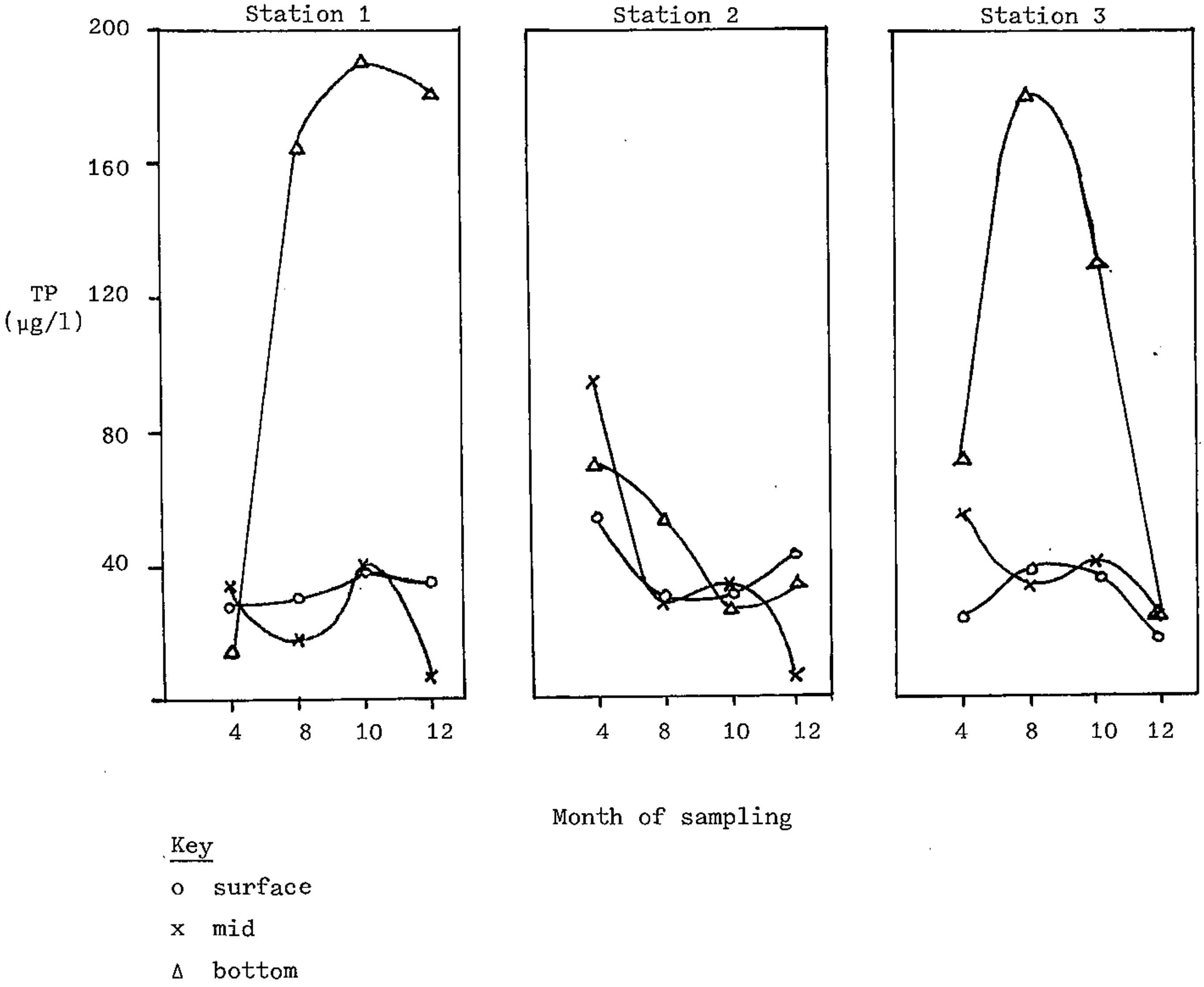


formation of ammonia (NH_3) as a decomposition product thereby explaining its observed low levels. In the winter months the higher levels of oxygen at depths allow the oxidation of settled and underlying organic matter and ammonia to nitrates which explains the general reduction in ammonia content and increases in the nitrate content at depths. As a result of higher levels of oxygen and nitrate at all depths the rate of production of organic forms of nitrogen could increase, to explain the observed increases in total nitrogen (TN) at all depths through the winter and into the summer months and the general reduction of nitrates due to consumption. The stable stratification in the summer months prevents reoxygenation at depths, explaining further reduction in the nitrate content and increases in the ammonia content due to heterotrophic bacterial decomposition of organic matter. The trends observed at Station 2 generally do not conform to the above descriptions possibly because the continuous outflow from this point to the power station does not allow sufficient time for patterns to develop at depths.

ii) Phosphorus

Unlike the many forms of nitrogen in lake systems, the only significant form of inorganic phosphorus is orthophosphate (PO_4^{3-}). However, a very large proportion (over 90%) of the phosphorus is usually bound organically in organic phosphates and cellular constituents in the living particulate matter. Total phosphorus (TP) which includes both

FIGURE 12 : Variation of total phosphorus with time of year for the Monasavu Reservoir



organic and inorganic phosphorus consists of the phosphorus in suspension in particulate matter and the phosphorus in dissolved form. The total phosphorus concentration of most uncontaminated surface waters is between 10 to 50 g/l (Wetzel, 1975) and it is noted that the surface concentrations in the Monasavu reservoir are generally within this range (Figure 12). TP builds at depths, particularly in the winter months because of greater decomposition of the underlying organic matter and the subsequent mobilization of the phosphorus into the surrounding water. The circulation of the entire water column in the winter months allow the movement of mobilized forms of phosphorus (possibly phosphates) into the upper layers where they are used up for metabolic processes. This action combined with the unavailability of more supplies of phosphorus in the bottom layers in the summer months because of anoxic conditions results in a net decrease in the phosphorus content of the bottom layers during the later phases of summer stratification. The behaviour of Station 2 is again uncharacteristic for reasons already discussed.

iii) Sulphur

The predominant form of sulphur in the oxidized state is sulphate. At the surface this is assimilated by biota in protein synthesis. Any decomposition of organic matter results in the release of hydrogen sulphide which under oxic conditions is quickly oxidised to sulphate and reused. This explains the low levels of total sulphur content of the surface waters.

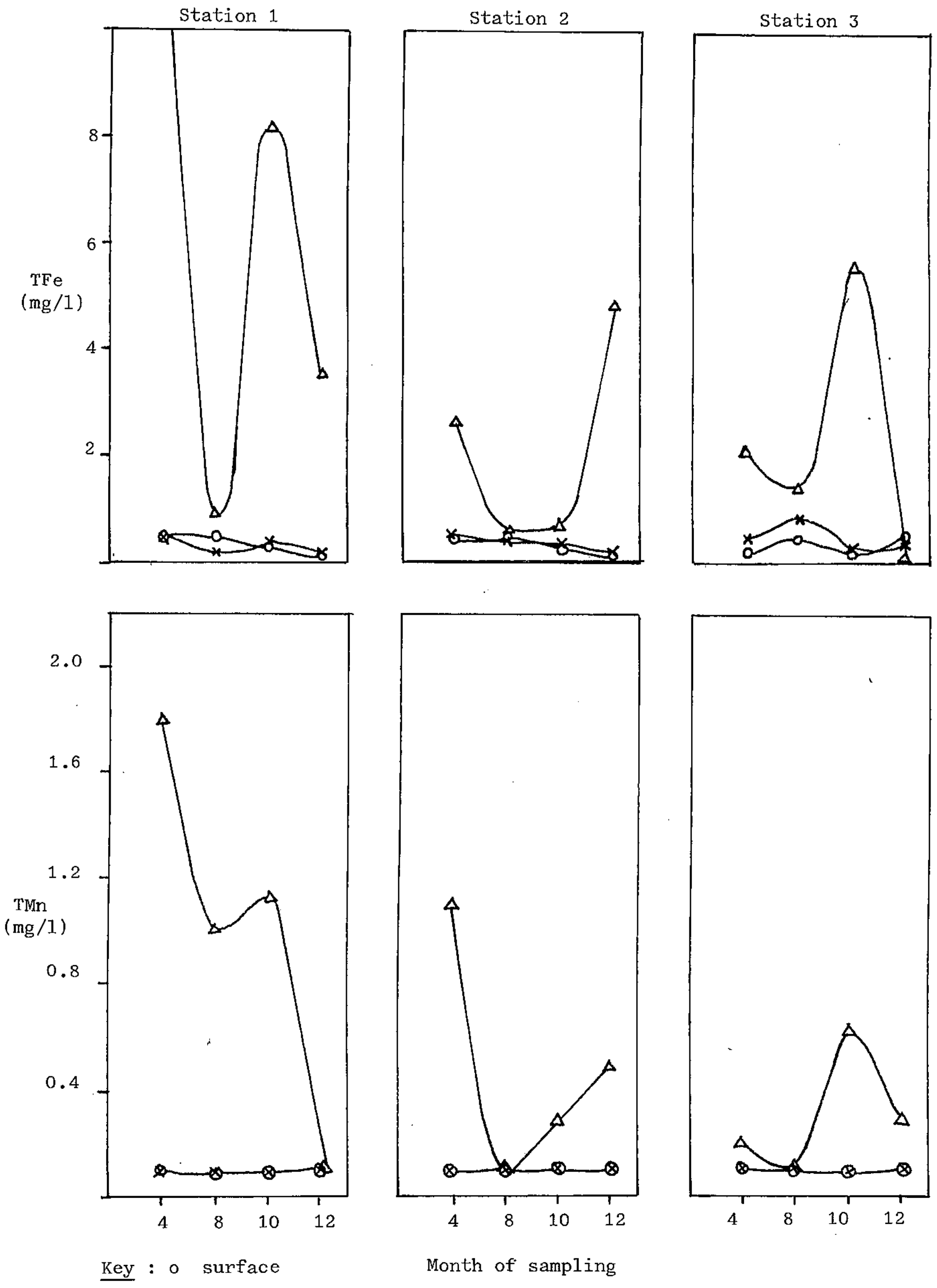
However sedimentation of particulate organic matter to depths and its subsequent decomposition as well as the decomposition of the underlying organic matter releases hydrogen sulphide which is not oxidised to sulphate under the predominant anoxic conditions. Iron (II) ions which are also released under anoxic conditions react with sulphides to form insoluble metallic sulphides under neutral or alkaline pH conditions and which are then lost to sediments. This explanation accounts for the low levels in total sulphur observed at depths.

d) Iron and Manganese

Dissolved iron and manganese is that fraction of these metals which passes through a 0.5 m size filter and is assumed to be in solution. Total iron and manganese includes both the dissolved and particulate fractions and by definition should always be greater than or equal to the dissolved fraction which is the case with the Monasavu data. The trends observed in the total concentrations of these metals are looked at in Figure 13.

The cycling of iron and manganese is regulated to a large extent by the seasonal variations in dissolved oxygen content of the water. Ionic forms of iron and manganese in oxygenated water are exceedingly low. They unusually exist as insoluble forms in particulate matter which settle to the deeper parts of the reservoir, thus explaining the relatively low levels of these metals from the surface to the middle of the reservoir. Normally iron and manganese form strong complexes with many organic molecules and an enrichment

FIGURE 13 : Variations in total iron and manganese with time of year in the Monasavu Reservoir



Key : o surface

x mid

of these elements is commonly found in surface waters with a high content of dissolved organic matter (Wetzel, 1975). However, since the levels of iron and manganese in the surface and middle layers of the reservoir are very close to their respective detection limits explaining any differences would not be truly justified.

The seasonal variations in iron and manganese are most pronounced in the bottom of the reservoir. In the deoxygenated waters of the hypolimnium iron (II) manganese (II) ions diffuse readily from the sediments and accumulate in the bottom waters. During the turnover of the winter months when oxygen is present at these depths the iron (II) and manganese (II) ions are oxidised, subsequently precipitated and returned to the sediments in form of particulate matter. Figure 13 shows this effect quite clearly. The reintroduction of the summer stratification reestablishes the migration of these ions into solution and an increase is observed. As the decomposition in the hypolimnion continues throughout the period of stratification and the water is further deoxygenated, hydrogen sulphide is released by bacterial decomposition of sulphur containing organic compounds. Iron (II) and other metallic ions which are present in solution in significant quantities at this stage reacts with sulphide to form metallic sulphides which are very insoluble under normal lake conditions. A depletion of these metals in the later phases of summer stratification for stations 1 and 3 is thus explained. Station 2 does not exhibit such a behaviour because of complications set in by the outflow to the power station.

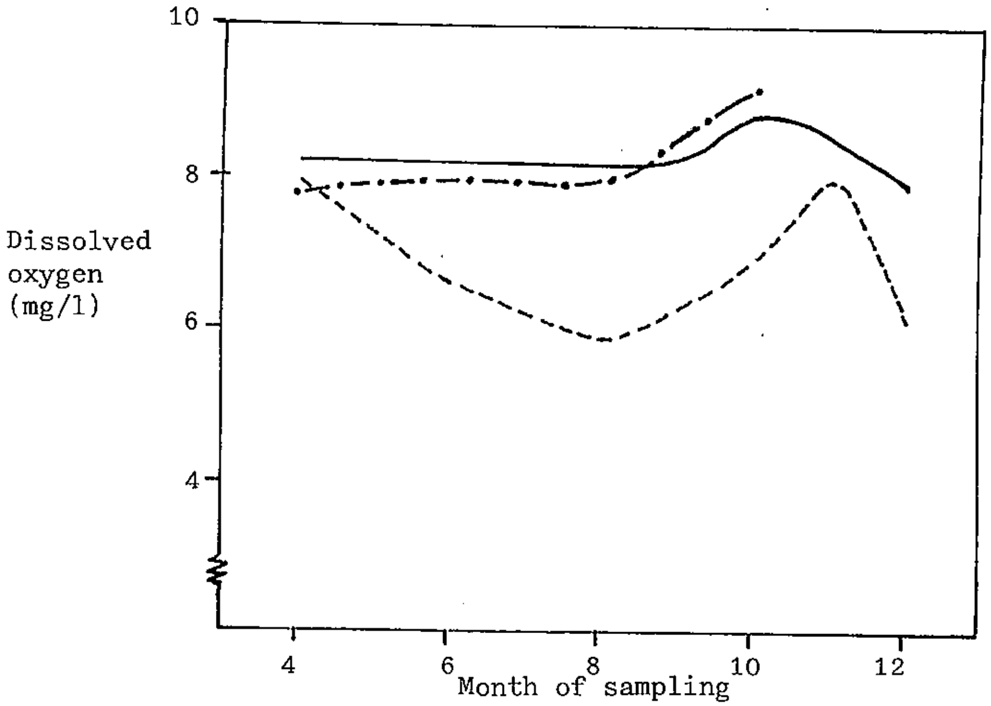
Comparison of the 1985 data with that for 1984 shows little change in the surface composition of reservoir. Differences are more prominent for the bottom sections of the reservoir, especially where nutrients are concerned. Although the total nitrogen values do not show any marked variations from last year, the nitrate content at depths is seen to increase, particularly during the winter months. The amounts of ammonia and total phosphorus on the other hand, decreased in 1985. This could be indicative of the decreasing amounts of organic matter left to be decomposed at the bottom of the reservoir.

4.2 The Wailoa River

The point from which water is drawn to the Wailoa power station is located at the bottom of Station 2 and according to the conditions prevalent in the reservoir the power station would normally be receiving water of very low dissolved oxygen content throughout the year and especially during the summer months. Together with this low dissolved oxygen condition the water would contain other constitutents characteristic of the anoxic deeper waters of the reservoir; for example relatively high concentrations of iron and manganese, ammonia and possibly hydrogen sulphide.

Examination of Figure 14 which illustrates the dissloved oxygen content of the tailrace water with respect to its content in other parts of the river shows that although the dissolved oxygen content of the tailrace water is lower than that of the river water around it, it is not as low as the dissolved oxygen content of the deeper waters at Station 2. Obviously the water is significantly oxygenated at the power

FIGURE 14 : Dissolved oxygen in the Wailoa River during 1985



Key (to Figs. 14 and 15)

____ Site 100 m above Power Station

---- At tailrace

•—•- 150 m below Power Station

.... At Laselevu

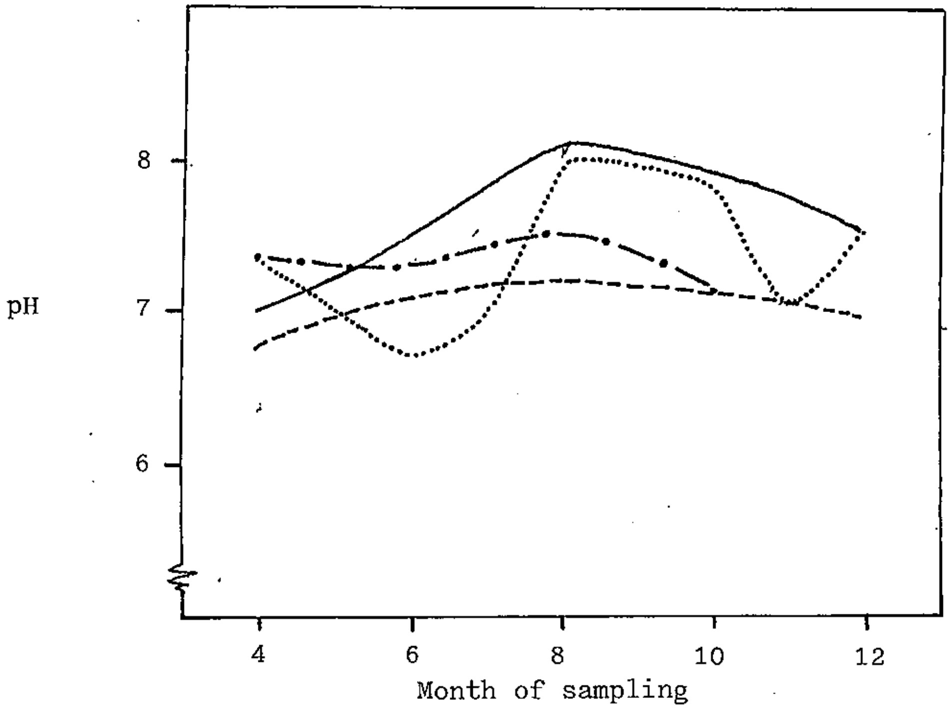


FIGURE 15 : Variation in pH in the Wailoa River during 1985

station and therefore does not impose any major effect on the dissolved oxygen content of the river. About 150 m below the tailrace, the dissolved oxygen content of the water returns to levels present in the water before contact with the tailrace is made.

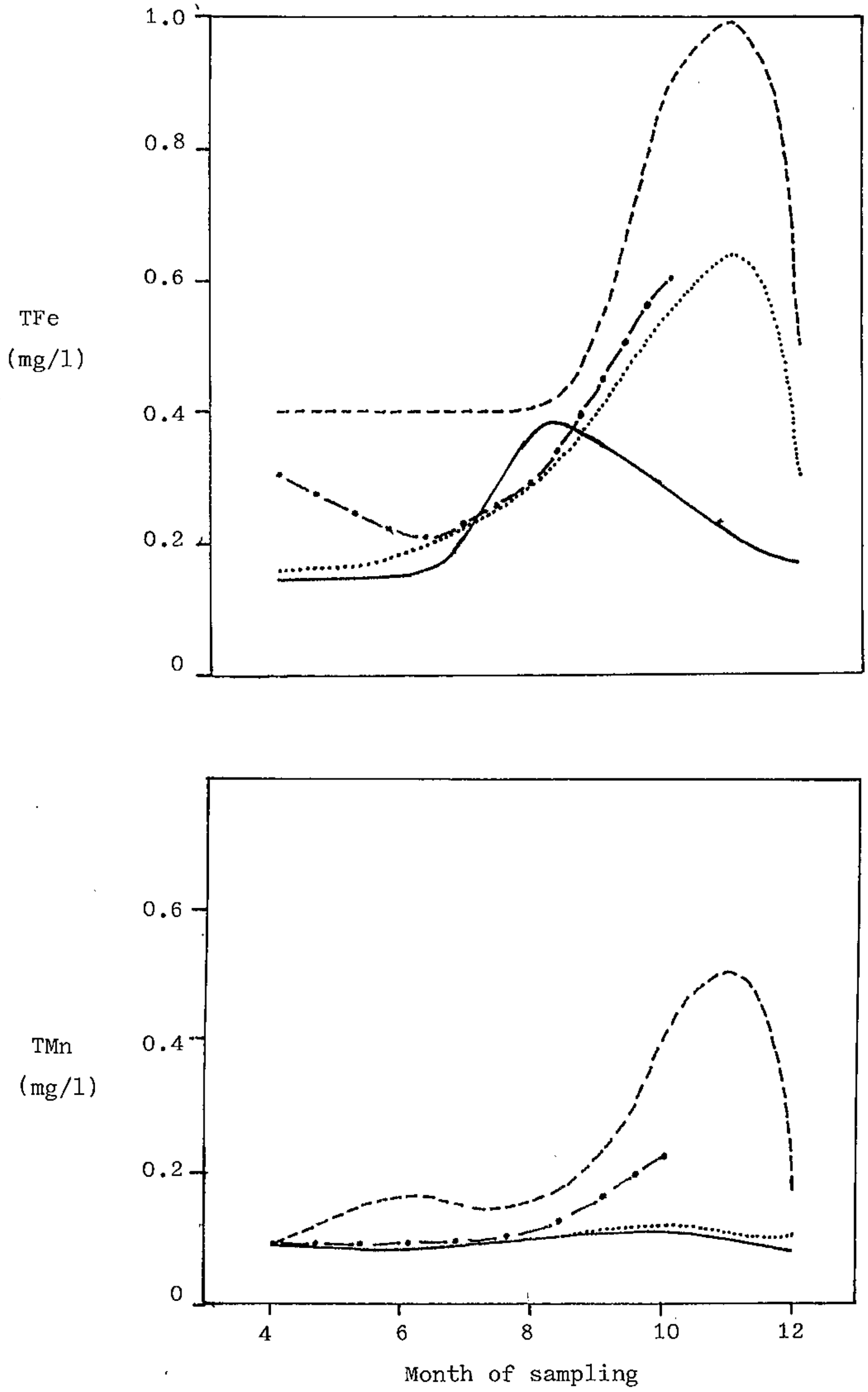
The effect of the pH of the tailrace water on the rest of the river illustrated in Figure 15 shows that although the pH of the tailrace has always been slightly lower than the pH of the water 100 m above it, it does not have any significant effect on the pH of the water at the sites further down. The oxygenation of the water at the power station would also oxidise the ammonia, the hydrogen sulphide and the reduced forms of iron and manganese. There has been a notable lack of any distinct smell of hydrogen sulphide at the power station which is not due entirely to oxygenation of the water but rather to the decreasing levels of organic matter left in the reservoir to be decomposed. Examination of the data available shows that the ammonia content of the tailrace water is very much lower than that of the Station 2 bottom waters and is not significantly higher than or different from the ammonia content of the water at the site 100 m above tailrace. The tailrace total nitrogen content is consistently higher than and the total phosphorus content generally lower than those in the water 100 m upstream (Table 10). The net effect is a slight build up of total nitrogen and a slight reduction in total phosphorus levels at the two sites below the tailrace.

TABLE 10 : Total nitrogen and phosphorus level in the Wailoa River

	Total Nitrogen (mg/l)				Total Phosphorus (g/l)			
Sampling Date	100 m Above	Tail-Race	150 m Below	Lase-levu	100 m Above	Tail-Race	150 m Below	Lase-levu
24/4/85	1.3	1.5	1.4	1.2	84	56	55	56
24/6/85	1.6	2.0	2.1	2.5	160	130	150	140
19/8/85	1.4	1.8	1.6	1.4	60	63	43	43
23/10/85	5.8	6.5	5.6	5.5	58	32	46	56
14/11/85	2.7	2.8		3.3	60	44		50
18/12/85	3.2	4.2		5.3	50	43		50

A close inspection of the figures given in Table 11 shows that the total iron and manganese content of the tailrace is generally lower than that of the bottom waters of Station 2. The loss occurs possibly at the power station. When the water gets oxygenated, the reduced forms of these metals get oxidised and precipitate out as insoluble particulates. This should be a cause for concern for FEA as deposition of such material could impose mechanical problems at the power station. It appears that such a problem arose once in 1984 when INR was called on to analyse the material depositing on the cooling fins in the tailrace.

FIGURE 16 : Distribution of total iron and manganese in the Wailoa River in 1985



Key

- ——— Site 100 m above Power Station
- - - - - At tailrace
- •—•— 150 m below Power Station

5. VECTOR-BORNE DISEASE SURVEY

Dr Alison Haynes, a biologist from the School of Pure and Applied Sciences, USP and Ms Usha Prasad, a medical anthropologist attached to the Institute of Natural Resources carried out a survey on 19/20 September and 23 October respectively of the Monasavu area for possible disease hosts. Each of their reports is included in this section.

5.1 Gastropods in Lake Monasavu in September, 1985

by Dr Alison Haynes

Lake Monasavu was visited on 19 and 20 September, 1985 in order to find if any gastropod snail populations were living in the lake, and if so, to discover if they were hosts to any trematode warms.

Rocks, stones and vegetation near the shore were searched for gastropods (water snails). Other animals present were also noted. A search was made where the shore could be reached by boat and where the water was reasonably shallow. Most freshwater snails feed on the film of microscopic algae and fungi which covers rocks and rotting vegetation. This film of microorganisms is not present in the deep parts of the lake where light can not penetrate.

Two species of Gastropods (Mollusca) were found
(1) a small pulmonate limpet called _Ferrissia noumeensis_ which is less than 4 mm long.
(2) a larger left handed pulmonate snail called _Physastra nasuta_. All specimens found were less than 6 mm high, although they do reach 20 mm.

Neither species was abundant. Two other benthic invertebrate species were observed. A predatory leech of the family Erpobdellidae, possibly of the genus _Vivabdella_. These were quite abundant as 2 to 3 were found under most rocks.

The other invertebrate species was an encrusting Bryozoa. This formed a mat on the underside of many rocks especially those on the edge of the dam. Shoals of small _Tilapia_ were observed.

In July and December, 1982 when the lake was filling, the water snail _Physastra_ _nasuta_ was the most abundant invertebrate in the lake. Since then their numbers have declined drastically, probably because they are being eaten by _Tilapia_ and leeches.

The snail _Physastra_ _nasuta_ is closely related to _Bulinus_ _globosus_ which is host to the blood fluke, _Schistosoma_ _mansoni_. This trematode warm causes Schistosomiasis (Bilharzia). During the visit to Lake Monasavu all _Physastra_ _nasuta_ were collected and taken to the laboratory at the School of Pure and Applied Sciences where they were dissected and examined for trematode worms. No trematodes of any kind were found.

The common prosobranch snail _Melanoides_ _tuberculata_, which is found in ditches, ponds, streams and rivers throughout Viti Levu and which is present in the streams of the Nadrau plateau was absent from Lake Monasavu. This may have been due to insufficient dissolved oxygen in the lake. This snail is known to be host to the lungfluke, _Paramonostomium_ _aegyptiacum_ in Egypt although it is not known to carry any disease in Fiji.

5.2 Mosquitoes in the Monasavu Lake area

by Ms Usha Prasad

The purpose of the visit to Monasavu Reservoir was to locate and identify the species of mosquitos found in the area. Over the 36 hour period, only one species of mosquito – Tripteroides (tripteroides) Purpuratus Edwards – was found (also the sample size consisted of only one mosquito). The species was identified according to Belkin's, The Mosquotos of the South Pacific. It also appears that this mosquito species is not anthroprophilic (blood sucking) but is rather a nectar feeder.

None of the Aedes stegomyia species common to Fiji inland areas, were found in or around the bass camp. An attempt to monitor "known" peak biting hours (early morning and evening) also proved with negative results.

6. CONCLUSIONS

The trends observed in the water quality of the Monasavu Reservoir and Wailoa River in 1985 were similar to those of 1984. The operation of an aerator near Station 2 in the reservoir did not seem to have any marked effect on the dissolved oxygen content of deeper waters during summer. However, indications are that the water at the bottom of the reservoir is improving in quality as evidenced by the notable lack of smell of hydrogen sulphide at the power station.

The oxygenation of the water at the power station helps in restoring conditions characteristic of oxic waters so that its effect on the Wailoa River is minimal. The deposition of particulate iron and manganese at the power station as a result of oxygenation could present problems in the future if left unchecked.

With the improved water quality and the results on the vector-borne disease survey apparently negative it is suggested that only very limited monitoring be continued

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