CXXVIII. THE DIURNAL VARIATION OF THE GASEOUS CONSTITUENTS OF RIVER WATERS. PART III.

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THE work described in Parts I and II [Butcher, Pentelow and Woodley, 1927] has been continued and the present paper includes the following experiments over periods of 24 hours:

<i>R. Lark</i>	Series VI	September 7-8	Table XIII	Fig. 11
	Series VII	September 22-23	Table XIV	Fig. 12
	Series VIII	October 12-13	Table XV	Fig. 13
	Series IX	November 2	Table XVI	—
	Series X	November 17-18	Table XVII	Fig. 14
<i>R. Itchen</i>	Series V	August 23-24	Table XVIII	Fig. 15
	Series VI	September 30-Oct 1	Table XIX	Fig. 16
	Series VII	November 10-11	Table XX	Fig. 17
	Series VIII	December 14-15	Table XXI	Fig. 18

Variation in dissolved oxygen.

River Lark. September-November. The chief characteristic of the present series of observations on the River Lark is the markedly lower values obtained for the maximum and minimum values of oxygen saturation compared with those of the spring and summer. At this period of the year, the absence of diatoms, together with a heavy cutting of weeds in September and the death of most of the green plants in October, has resulted in a decreased production of oxygen; the consumption of oxygen by decomposing plants has continued, and consequently the maximum and minimum values of oxygen saturation for these months are lower than at any previous time.

It would appear that the main factors governing the oxygen content of a river of this character are:

- (1) the quantity and type of plant life present, these factors being governed by the season of the year;
- (2) the prevailing actinic conditions.

The relative effect of these factors is seen below.

(1) The combined effect of the quantity and type of plant life present together with that due to prevailing actinic conditions is seen from the values of the oxygen maxima and minima throughout the year.

Percentage saturation of dissolved oxygen.

	Maximum	Minimum
March 30-31	157	65
April 27-28	178	57
May 18-19	181	36
June 28-29	111	37
August 4-5	124	42
September 7-8	71	39
September 22-23	70	26
October 12-13	49	27
November 17-18	10	2

Abnormal results due to
pollution by beet-sugar
factory effluents

(2) Since the plants do not vary from day to day, a study of the oxygen values determined at the same hour on two successive days gives the effect of the day-to-day difference in actinic conditions.

	Date	Time	% saturation	Temp. ° C.	Remarks
R. Lark	March 30	7 p.m.	119	9.4	Fine
	31	7 "	116	9.25	Dull
R. Itchen	April 6	9 "	90.5	9.4	"
	7	9 "	81	7.0	Clear after dull day
R. Lark	" 27	6 "	137	11.0	Bright
	28	6 "	163	11.5	After bright day
R. Itchen	May 4	6 "	101	11.6	Dull
	5	6 "	115	13.6	Sunshine
R. Lark	" 18	6 "	165	15.0	Bright
	19	6 "	177	15.2	"
R. Itchen	" 31	10 a.m.	97	10.6	Dull
	June 1	10 "	104	11.9	"
R. Lark	" 28	10 "	57	12.6	"
	29	10 "	55	13.1	"
R. Itchen	July 5	9 "	99	12.6	"
	6	9 "	106	12.6	Some sunshine
R. Itchen	" 27	9 "	93	12.8	Dull
	28	9 "	113	13.4	"
R. Lark	Aug. 4	9 "	58	16.25	Sunshine
	5	9 "	53	16.1	"
R. Itchen	" 23	9 "	105.5	12.3	"
	24	9 "	107	11.0	"
R. Lark	Sept. 7	10 "	38	14.7	Dull
	8	10 "	55	14.0	Bright
R. Lark	" 22	8 "	26	14.9	Dull
	23	8 "	35	11.95	Bright
R. Itchen	" 30	7 "	76	6.2	"
	Oct. 1	7 "	80	9.0	Dull
R. Lark	" 12	10 "	36	10.5	"
	13	10 "	31	9.95	"
R. Itchen	Nov. 10	8 "	82	3.9	Bright sun
	11	8 "	81	4.1	"
R. Itchen	Dec. 14	10 "	88	6.0	Rain
	15	10 "	89	6.0	Dull. Fine

It will be seen that these day-to-day differences in oxygen saturation do not follow the water temperature, but are the result of the variation in actinic conditions. The variation in this respect, however, is small in comparison with the variation due to seasonal changes in plant life. Whereas the difference

between the highest and lowest maximum oxygen saturation throughout the year is 111 %, due to the combined effects of the variation in plant life and of the variation in actinic conditions, the greatest difference from day to day, due to actinic conditions only, is 26 % over this small collection of data.

The results given in Tables XV, XVI and XVII were obtained during the period of pollution of the River Lark by the effluents from the beet-sugar factory at Bury St Edmunds. In spite of this pollution the curves for October 12-13 and November 2-3 still indicate a small diurnal variation showing that there is still some photosynthetic activity.

Fig. 11.

River Itchen. August-December. On the River Itchen the oxygen saturation curves (Figs. 15-18) show a progressive lowering of the maximum value and a progressive increase in the minimum value; the range of variation decreases regularly from 48 % of saturation in August to 6 % in December.

During the winter the decrease in the number of water organisms and the retardation of the respiration of the remaining organisms due to the lower temperature result in a decreased oxygen absorption and a consequent increase in the minimum value of oxygen saturation.

Table XIII. *River Lark. Series VI. September 7-8, 1927.*

Time G.M.T.	Temp. ° C.	Dissolved oxygen		Ammoniacal nitrogen. Parts per 100,000	p_H	Remarks
		Parts per 100,000	% saturation			
10 a.m.	14.7	0.393	38	0.01-0.015	7.4-7.5	Dull
11 "	14.9	0.442	43	0.03	7.5-7.6	Sun
Midday	15.2	0.514	50	0.05-0.06	7.6	Sun and cloud
1 p.m.	15.55	0.572	56	0.09-0.1	7.7	"
2 "	16.0	0.653	65	0.14	7.8	Bright
3 "	15.9	0.688	68	0.14	7.8-7.9	Cloudy
4 "	16.0	0.710	70	0.15	7.9-8.0	Sunny
5 "	16.0	0.719	71	0.15	8.0	"
6 "	15.6	0.688	67	0.09	7.9-8.0	Sun going down
7 "	15.3	0.653	64	0.05-0.06	7.8-7.9	Dark
8 "	15.0	0.617	60	0.03	7.8-7.9	Moonlight
9 "	14.8	0.596	58	0.02	7.8	"
10 "	14.7	0.555	53	0.015	7.8	"
11 "	14.45	0.555	53	0.01-0.015	7.7	"
Midnight	14.35	0.555	53	0.01	7.6	"
1 a.m.	14.2	0.524	50	0.01	7.6	Moonset
2 "	13.95	0.504	48	0.01	7.5-7.6	"
3 "	13.8	0.473	45	0.01	7.5	"
4 "	13.8	0.458	44	<0.01	7.5	Sky just lightening
5 "	13.5	0.439	41	<0.01	7.5	Sunrise
6 "	13.3	0.429	40	<0.01	7.4-7.5	Misty bright
7 "	13.1	0.421	39	<0.01	7.5	Bright
8 "	13.2	0.432	40	<0.01	7.4-7.5	"
9 "	13.7	0.493	47	<0.01	7.5-7.6	"
10 "	14.0	0.575	55	<0.01	7.6-7.7	"

Sunrise 5.25 a.m.

Sunset 6.30 p.m.

It would appear that the progressive lowering of the maximum value of saturation is due to the decrease in temperature, since the oxygen expressed in parts per 100,000 is practically constant from June to December—November and December showing slight differences which are accounted for by prevailing actinic conditions, while the percentage saturation shows considerable variation. These results give some information on the relative effects upon the oxygen saturation of river waters of such factors as photosynthesis, respiration, temperature, absorption from air, which will be discussed further in Part IV when the completed data for a year will be presented.

Ammoniacal nitrogen curves.

River Lark. On the River Lark, the values of ammoniacal nitrogen for September, October and November vary roughly in a sense opposite to those of dissolved oxygen with the exception of those obtained on September 7-8; this set of observations, however, was made under abnormal conditions, since extensive weed cutting had taken place for one mile above the point of sampling, and large masses of dead and decaying weeds had been left in this stretch of the river.

Table XIV. *River Lark. Series VII. September 22-23, 1927.*

Time G.M.T.	Temp. ° C.	Dissolved oxygen		Ammoniacal nitrogen. Parts per 100,000	pH	Remarks
		Parts per 100,000	% saturation			
8 a.m.	14.9	0.269	26	0.05	7.5	Dull. Rain.
9 "	15.0	0.296	29	0.05-0.06	7.5-7.6	" " Windy
10 "	15.0	0.316	30.5	0.05-0.06	7.5-7.6	" " "
11 "	15.1	0.395	38	0.05-0.06	7.5-7.6	" Fine "
Midday	15.2	0.464	45	0.05-0.06	7.6	" Rain
1 p.m.	15.4	0.524	51	—	> 7.6	" "
2 "	15.3	0.573	55	0.05-0.06	7.6-7.7	" "
3 "	15.2	0.632	61	0.04	7.7	" "
4 "	15.05	0.652	63	0.03	> 7.7	" " Little sun
5 "	14.95	0.709	70	0.015	7.7-7.8	" Fine
6 "	14.7	0.700	68	0.01-0.015	7.8	" "
7 "	14.45	0.681	66	0.01	7.7-7.8	Fine. Dark
8 "	14.05	0.611	58	0.01	7.7	" " No moon
9 "	14.0	0.566	54	0.01	7.6-7.7	" "
10 "	13.45	0.504	48	0.01	7.6	" "
11 "	13.5	0.484	46	0.01	7.5-7.6	" "
Midnight	13.4	0.443	42	0.01	7.5-7.6	" "
1 a.m.	13.35	0.429	40	0.01	7.5-7.6	" "
2 "	13.1	0.425	40	0.01	7.5-7.6	" "
3 "	12.9	0.405	38	0.01	7.5-7.6	" "
4 "	12.7	0.395	37	0.01	7.5-7.6	" "
5 "	12.5	0.361	33	0.02	7.5-7.6	Dawn. Fine
6 "	12.3	0.362	33	0.03	7.5-7.6	Sunrise. Clear
7 "	12.2	0.375	34	0.03	7.5	Clear. Sunny
8 "	11.95	0.385	35	0.04-0.05	7.5	" "
9 "	12.0	0.449	41	0.05	7.5-7.6	" "

Sunrise 5.50 a.m.

Sunset 6.0 p.m.

Fig. 12.

Table XV. River Lark. Series VIII. October 12-13, 1927.

Time G.M.T.	Temp. ° C.	Dissolved oxygen		Ammoniacal nitrogen. Parts per 100,000	p _H	Remarks
		Parts per 100,000	% saturation			
10 a.m.	10.5	0.405	36	0.1	7.5	Dull. Fine. River clear
11 "	10.5	0.415	37	0.1	7.5-7.6	Dull. Drizzle
Midday	10.5	0.435	38.5	0.1	<7.6	" Fine
1 p.m.	10.6	0.461	41	0.1	7.7	" "
2 "	10.6	0.506	45	0.08	7.7-7.8	
3 "	10.6	0.555	49	0.08	7.7-7.8	
4 "	10.6	0.553	49	0.04-0.05	7.8	
5 "	10.6	0.523	46	0.03	7.7	Dull. Almost dark. Fine
6 "	10.6	0.405	36	0.015	7.7	Dark. Fine
7 "	10.6	0.456	40	0.01	7.6	" "
8 "	10.6	0.499	44	0.01	7.6	
9 "	10.6	0.497	44	<0.01	7.6	
10 "	10.6	0.496	44	<0.01	7.5	
11 "	10.6	0.475	44	<0.01	7.5	Drizzle
Midnight	10.5	0.464	41	<0.01	7.5	"
1 a.m.	10.5	0.443	39	<0.01	7.5	"
2 "	10.5	0.446	39	<0.01	<7.5	"
3 "	10.4	0.435	38	<0.01	<7.5	"
4 "	10.4	0.425	37	<0.01	<7.5	"
5 "	10.3	0.385	34	0.01	7.4-7.5	Daylight. Dull. Hazy
6 "	10.2	0.336	30	0.04	7.4-7.5	
7 "	10.15	0.309	27	0.09	7.4-7.5	Dull
8 "	10.1	0.324	28	0.11	7.5	"
9 "	9.9	0.324	28	0.1	7.5	"
10 "	9.95	0.359	31	0.1	7.5	"

Sunrise 6.20 a.m. Sunset 5.10 p.m.

Fig. 13.

Table XVI. *River Lark. Series IX. November 2, 1927.*

Time G.M.T.	Temp. ° C.	Dissolved oxygen		Ammoniacal nitrogen.	pH	Remarks
		Parts per 100,000	% saturation	Parts per 100,000		
10.30 a.m.	13.1	0.295	28	0.04	7.5-7.6	During pollution by the effluents from the beet-sugar fac- tory at Bury St Edmunds
11.45 "	13.2	0.338	31.5	0.03	7.5-7.6	
12.55 p.m.	13.35	0.359	34	0.02	7.6	
2.20 "	13.6	0.352	33	0.01	7.6	
3.30 "	13.7	0.327	31	0.01-0.015	7.6	
4.45 "	13.9	0.295	28	0.01-0.015	7.5-7.6	
6.40 "	13.8	0.264	25	0.01-0.015	7.5-7.6	
9.30 a.m. (Nov. 3rd)	13.1	0.137	12	0.03	7.5-7.6	

Sunrise 6.55 a.m.

Sunset 4.32 p.m.

Table XVII. *River Lark. Series X. November 17-18, 1927.*

Time G.M.T.	Temp. ° C.	Dissolved oxygen		Ammoniacal nitrogen.	pH	Remarks
		Parts per 100,000	% saturation	Parts per 100,000		
1 p.m.	8.2	0.083	7	0.16	7.5	Fine. Clear
2 "	8.1	0.124	10	0.08	7.5-7.6	
3 "	7.9	0.114	9.5	0.06	7.6	
4 "	7.7	0.072	6	0.05	7.5-7.6	Dusk
5 "	7.6	0.083	7	0.045	7.5-7.6	Dark
6 "	7.6	0.119	10	0.04	7.5-7.6	
7 "	7.5	0.089	7.5	0.03	7.5-7.6	
8 "	7.45	0.092	8	0.025-0.03	7.5-7.6	
9 "	7.4	0.093	8	0.025	7.5-7.6	
10 "	7.3	0.094	8	0.025	7.5-7.6	
11 "	7.2	0.074	6	0.03	7.5-7.6	
Midnight	—	—	—	—	—	
1 a.m.	7.3	0.042	3.5	0.08	7.5-7.6	
2 "	7.3	0.030	2.5	0.13	7.5-7.6	
3 "	7.3	0.035	3	0.14	7.5-7.6	
4 "	7.4	0.031	2.5	0.16	7.5	
5 "	7.4	0.031	2.5	0.16	7.4-7.5	
6 "	7.5	0.031	2.5	0.16	7.4-7.5	
7 "	7.5	0.027	2	0.16	7.4-7.5	
8 "	7.5	0.022	2	0.16	7.5	
9 "	7.5	0.031	2.5	0.16	7.5	
10 "	7.5	0.034	3	0.16	7.5	
11 "	7.6	0.021	2	0.16	7.5	
Midday	7.9	0.019	2	0.16	7.5	
1 p.m.	8.1	0.021	2	0.08	7.5	

Sunrise 6.30 a.m.

Sunset 5.0 p.m.

This experiment was made after the River Lark had been seriously polluted for a period of 6 weeks by the effluents from the beet-sugar factory.

In general, the commencement of the period of maximum of ammoniacal nitrogen follows just after the commencement of the period of minimum of oxygenation, and *vice versa*.

In the bacterial nitrification of ammonia, the effects of such factors as concentration of dissolved oxygen, mechanical aeration, presence of suspended particles and of dissolved salts, temperature, etc., are considerable, and the data obtained during these experiments are insufficient to give a complete explanation of these abnormal ammoniacal nitrogen figures.

There can be little doubt, however, that the accumulation of organic matter at the point of sampling during the pollution of the river bed has led to this abnormal production of ammonia and amino-compounds; it was noted during the estimations of ammoniacal nitrogen that the greenish tinge indicative of amino-compounds was usually obtained on addition of Nessler's reagent.

Fig. 14.

The condition of the river bed at the point of sampling may be due to the pollution during the winter months by the effluents from the beet-sugar factory, or in part to the sewage effluent which enters the river two miles above Icklingham.

River Itchen. As in the spring and summer no diurnal variation of ammoniacal nitrogen was observed. The ammonia content was usually 0.005

Table XVIII. *River Itchen. Series V. August 23-24, 1927.*

Time G.M.T.	Temp. ° C.	Dissolved oxygen		Am- moniacal nitrogen. Parts per 100,000	pH	Remarks
		Parts per 100,000	% saturation			
9 a.m.	12.3	1.149	105.5	0.005	7.9	Fine. Sunny. Occasional cloud
10 "	12.6	1.192	110	0.005	8.0	" "
11 "	13.2	1.200	112	0.005	8.1	" "
Midday	14.4	1.213	117	0.005	8.2	Fine. Cloudy. Occasional sun
1 p.m.	14.4	1.190	114	0.005	8.2	Raining slightly
2 "	14.3	1.129	108	0.005	8.2	Dull. Fine. Thundery
3 "	14.9	1.216	118	0.005	8.2	Fine. Occasional sun
4 "	14.8	1.186	115	0.005	8.2	Raining slightly
5 "	14.2	1.150	110	0.005	8.0	"
6 "	13.9	1.099	105	0.005	8.0	Sunshine
7 "	13.1	0.971	91	0.005	7.8	"
8 "	12.9	0.880	82	0.005	7.7	Cloudy, almost dark
9 "	12.2	0.823	75.5	0.005	7.6	Dark, some cloud
10 "	11.9	0.838	76	0.005	7.6	Clear and stormy
11 "	11.1	0.822	73	0.005	<7.6	Ground mist
Midnight	10.9	0.809	72	0.005	7.5	"
1 a.m.	10.4	0.803	70	0.005	7.5	"
2 "	10.0	0.801	70	0.005	7.4-7.5	"
3 "	9.9	0.827	72	0.005	7.4-7.5	" Moon shining
4 "	9.8	0.817	71	0.005	7.4	" Dawn
5 "	9.6	0.825	71	0.005	7.4-7.5	" Daylight
6 "	9.3	0.873	75	0.005	7.5	Sun shining through mist
7 "	9.3	0.971	86	0.005	7.5-7.6	Sunshine. Mist clearing
8 "	10.0	1.093	95	0.005	7.8	"
9 "	11.0	1.195	107	0.005	7.9	" Some cloud

Sunrise August 23, 4.57 a.m.

Sunset " 23, 7.7 p.m.

Sunrise " 24, 4.59 a.m.

Fig. 15.

Table XIX. *River Itchen. Series VI. September 30–October 1, 1927.*

Time G.M.T.	Temp. ° C.	Dissolved oxygen		Am- moniacal nitrogen. Parts per 100,000	p _H	Remarks
		Parts per 100,000	% saturation			
7 a.m.	6.2	0.956	76	0.005	7.5	River high but clear. Sunshine. Ground frost
8 "	6.1	1.057	84	0.005	7.5–7.6	Sunshine
9 "	6.8	1.124	91	0.005	7.6	"
10 "	7.8	1.184	98	0.005	7.6	Some cloud. Weed-cutting
11 "	8.5	1.188	100	0.005	7.7	Water turbid due to weed- cutting
Midday	9.3	1.202	104	0.005	7.8	Sunshine. Weed-cutting stop- ped. Water clear
1 p.m.	10.0	1.181	103	0.005	7.9	Sunshine
2 "	10.5	1.181	104	0.005	7.9	"
3 "	11.0	1.186	106	0.005	8.0	"
4 "	10.8	1.126	99	0.005	7.9	Dull
5 "	10.3	1.080	95	0.005	7.9–7.8	"
6 "	10.1	1.013	90	0.005	7.8	" Sunset
7 "	9.8	0.954	83	0.005	>7.7	Cloudy. Dark
8 "	9.7	0.908	78	0.005	7.7	"
9 "	9.6	0.904	78	0.005	<7.7	"
10 "	9.5	0.893	77	0.005	>7.6	"
11 "	9.4	0.872	75	0.005	7.6	"
Midnight	9.4	0.872	75	0.005	<7.6	"
1 a.m.	9.3	0.903	78	0.005	<7.6	Sky clear
2 "	9.1	0.886	76	0.005	<7.6	"
3 "	9.0	0.873	76	0.005	<7.6	Some cloud
4 "	9.0	0.897	77	0.005	<7.6	Storm at 4.30
5 "	9.0	0.899	78	0.005	<7.6	Dull. Sky just lightening
6 "	9.0	0.886	76	0.005	<7.6	Daylight. Raining slightly
7 "	9.0	0.932	80	0.005	7.5	Raining

Sunrise September 30, 5.58 a.m.
Sunset " 30, 5.41 p.m.
Sunrise October 1, 6.0 a.m.

Fig. 16.

Table XX. *River Itchen. Series VII. November 10-11, 1927.*

Time G.M.T.	Temp. ° C.	Dissolved oxygen		Am- moniacal nitrogen. Parts per 100,000	pH	Remarks
		Parts per 100,000	% saturation			
8 a.m.	3.9	1.080	82	0.005	7.8	Bright sun. Frost
9 "	4.0	1.148	89	0.005	7.8	Sunshine
10 "	4.6	1.194	92	0.005	7.8-7.9	"
11 "	5.4	1.250	98	0.005	7.9	Cloudy. Occasional sun. Cold wind
Midday	6.0	1.260	100	0.005	7.9	Sunshine. Cold wind
1 p.m.	6.2	1.250	100	0.005	7.9	Sunshine. Some cloud. Cold wind
2 "	6.2	1.238	100	0.005	7.9	Sunshine. Some cloud. Cold wind
3 "	6.2	1.217	97	0.005	7.9	Sunshine
4 "	6.0	1.179	94	0.005	7.9	" Sun setting
5 "	5.7	1.105	87	0.005	7.9-7.8	Dusk. Fine
6 "	5.5	1.077	84	0.005	7.9-7.8	Dark. Cloudy
7 "	5.5	1.070	84	0.005	7.8	" "
8 "	5.4	1.066	83	0.005	7.8	" "
9 "	5.3	1.047	82	0.005	7.8	" "
10 "	5.1	1.056	82	0.005	7.8	Moonlight. Clear
11 "	4.9	1.051	81	0.005	7.8	" "
Midnight	4.7	1.056	81	0.005	7.8-7.7	" "
1 a.m.	4.5	1.038	80	0.005	7.8-7.7	" "
2 "	4.5	1.052	81	0.005	7.8-7.7	" "
3 "	4.5	1.054	81	0.005	7.8-7.7	" "
4 "	4.4	1.053	81	0.005	7.8-7.7	" "
5 "	4.3	1.053	81	0.005	7.8-7.7	" "
6 "	4.2	1.056	80	0.005	7.8-7.7	Moonlight. Sky just lightening
7 "	4.2	1.077	82	0.005	7.8-7.7	Daylight. Clear
8 "	4.1	1.072	81	0.005	7.8-7.7	Sunshine

Sunrise November 10, 7.8 a.m.
 Sunset " 10, 4.19 p.m.
 Sunrise " 11, 7.10 a.m.

Fig. 17.

Table XXI. *River Itchen. Series VIII. December 14-15, 1927.*

Time G.M.T.	Temp. ° C.	Dissolved oxygen		Am- moniacal nitrogen. Parts per 100,000	pH	Remarks
		Parts per 100,000	% saturation			
10 a.m.	6.0	1.104	88	0.015	7.8	Rain. Water turbid
11 "	6.0	1.101	87	0.015-0.01	7.8	
Midday	6.0	1.101	87	0.015-0.01	7.8	Dull. "Fine. "Water turbid
1 p.m.	6.0	1.109	88	0.015-0.01	7.8	
2 "	6.0	1.105	88	0.015-0.01	7.8	Slight rain. "Water turbid
3 "	6.1	1.089	86	0.015-0.01	7.8	
4 "	6.1	1.085	86	0.01-0.005	7.8	" "
5 "	6.2	1.075	86	0.01-0.005	7.8	" " Dark
6 "	6.3	1.064	85	0.01-0.005	7.8	" " "
7 "	6.4	1.070	86	0.01-0.005	7.8	Dull. "Fine. Dark "
8 "	6.4	1.059	85	0.01-0.005	7.8	" " "
9 "	6.4	1.055	84	0.01-0.005	7.8	Rain. Dark "
10 "	6.4	1.055	84	0.01-0.005	7.8	Dull. "Fine. Dark
11 "	6.3	1.055	84	0.01-0.005	7.8	" " "
Midnight	6.2	1.055	84	0.01-0.005	7.8	" " "
1 a.m.	6.1	1.043	83	0.01-0.005	7.8	" " "
2 "	6.2	1.055	84	0.01-0.005	7.8	" " "
3 "	6.3	1.055	84	0.01-0.005	7.8	" " "
4 "	6.3	1.055	84	0.01-0.005	7.8	" " "
5 "	6.2	1.055	84	0.01-0.005	7.8	Drizzle. "Dark
6 "	6.1	1.059	84	0.01-0.005	7.8	
7 "	6.0	1.071	85	0.01-0.005	7.8	Drizzle. "Sky just lightening
8 "	6.0	1.075	85	0.01-0.005	7.8	Dull. "Fine. Daylight
9 "	6.0	1.095	87	0.01-0.005	> 7.8	" " Water clearer
10 "	6.0	1.116	89	0.01-0.005	> 7.8	" " "

Sunrise December 14, 7.58 a.m.
Sunset " 14, 3.51 p.m.
Sunrise " 15, 7.59 a.m.

Fig. 18.

parts per 100,000, although occasional higher values 0.01 and 0.015 were obtained, and were probably due to contamination of the river by soil drainage during rainy periods.

p_H curves. The *p_H* curves are again similar in structure and in general follow the oxygen curves, the range in the winter being less than that in the spring and summer. This decrease in the range of *p_H* variation is accounted for by the decrease in photosynthesis and the lessened respiration mentioned in the discussion of the oxygen curves.

Water temperature curves. The temperature curves show the expected diurnal similarity but over different ranges according to the month of the year and the prevailing weather conditions.

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REFERENCE.

Butcher, Pentelow and Woodley (1927). *Biochem. J.* **21**, 945, 1423.