COMMONWEALTH OF AUSTRALIA

Commonwealth Scientific and Industrial Research Organization

Division of Fisheries and Oceanography

REPORT 40

20TH MARINE SCIENCE SCHOOL

MAY 22 - 27, 1966

Marine Laboratory
Cronulla, Sydney
1967

COMMONWEALTH OF AUSTRALIA

Commonwealth Scientific and Industrial Research Organization

Division of Fisheries and Oceanography

REPORT 40

20TH MARINE SCIENCE SCHOOL

MAY 22 - 27, 1966

Marine Laboratory
Cronulla, Sydney
1967

CONTENTS

When citing this report, abbreviate as follows:
CSIRO Aust. Div. Fish. Oceanogr. Rep. No. 40

INTRODUCTION

The 20th Marine Science School for university undergraduates was held from May 22 to 27, 1966 at the CSIRO Marine Laboratory, Cronulla, N.S.W. Before 1966, the course attracted mainly zoology and botany students and was known as the Marine Biology School. To bring in students from other departments, it was renamed the Marine Science School.

Up till 1966, the School consisted of a number of more or less unrelated half and full-day courses. In 1966, an integrated study of Port Hacking, on whose shores this Laboratory is located, was initiated: a study which will be continued by the students at future Schools.

The papers that follow are an account of the work of students under the guidance of members of the research staff of the Laboratory. They are based on material presented by students at a discussion session on the final day of the School. Students who attended, their universities, the groups they worked in, and the research staff who guided them, are given in the Appendix.

In 1967 the Marine Science School will be longer and students will have more time to prepare their own papers along the lines of those presented here.

The data in this report can be of use at future Schools.

HYDROLOGY

I. INTRODUCTION

Earlier hydrological investigations of the Port Hacking estuarine system had been mainly concerned with the seasonal and yearly changes at a number of stations (Rochford 1951). However during the 1966 Marine Sciences School, the opportunity was taken to study the daily changes in the freshwater, marine, and deep basin water components in the region upstream of Lilli Pilli.

II. METHODS

Chlorinity was determined both in the field and in the laboratory by chlorinity-temperature meter (Hamon 1956). Oxygen was determined by the Winkler method as used by CSIRO (CSIRO Aust. 1966).

III. RESULTS

The hydrological characteristics of the Port Hacking estuary were examined at selected station positions (Fig. 1) during 23-25/6/66. The positions of these were fixed on a preliminary survey by CSIRO on 12/5/66 (Table 1).

TABLE 1

TEMPERATURE-CHLORINITY PRELIMINARY SURVEY - 12.5.66

Station	Time	Depth (m)	Temp.*	Cl‰*	Time	Temp.+	Cl‰+	O_2
4	1230h	0	17.80	19.29				
		1	17.60	19.40				
		2	17.45	19.41				
		3	17.40	19.39				
5	1305h	0	17.90	19.33				
		1	17.90	19.32				
		2	17.90	19.33				
		3	17.90	19.33				
		4	17.90	19.33				
		5	17.80	19.32				
		6	17.80	19.32				
		7	17.80	19.32				
		8	17.70	19.32				
		9	17.70	19.32				
		10	17.70	19.32				
		11	17.70	19.32				
		12	17.70	19.32				
		13	17.60	19.34				
		14	17.60	19.35				
		15	17.60	19.35				
		16	17.60	19.35				
		17	17.60	19.34				
		18	17.60	19.34				
		19	17.60	19.34				
		20	17.60	19.35				
		21	17.60	19.35				
		22	17.60	19.35				
		23	17.60	19.35				

TABLE 1 (Cont'd...)

Station	Time	Depth (m)	Temp.*	Cl‰*	Time	Temp.+	Cl‰+	O_2
6	1314h	0	17.80	19.26				
		2	17.90	19.27				
		3	17.80	19.31				
		4	17.75	19.34				
		5	17.70	19.32				
		8	17.60	19.32				
		10	17.70	19.31				
		12	17.70	19.33				
		14	17.70	19.35				
		16	17.80	19.38				
		20	17.80	19.41				
		22	17.80	19.41				
7	1324h	0	17.85	19.31				
		1	17.80	19.37				
		2	17.90	19.33				
		4	17.80	19.33				
		7	17.85	19.35				
		11	17.85	19.36				
		13	18.00	19.37				
		14	18.10	19.42				
		16	18.00	19.42				
		17	17.90	19.41				
		18	17.85	19.41				
		19	17.70	19.41				
		20	17.70	19.41				
8	1418h	0	18.10	19.19	1545h	18.00	19.23	4.74
		1	18.10	19.19				
		3	18.10	19.19				
		4	18.30	19.25		18.22	19.30	4.30
		5	18.25	19.29				
		7	18.25	19.30				
		8	18.25	19.30		18.10	19.31	4.22
		10	18.25	19.29				
		11	18.25	19.31				
		12	18.25	19.31		18.04	19.30	4.24
		13	18.25	19.32				
		14	18.30	19.33				
		15	18.30	19.32				
		16	18.30	19.34		18.06	19.29	-
		17	18.20	19.33				
		18	18.20	19.33				
12	1450h	0	18.20	19.29	1500h	17.95	19.27	4.81
		1	18.20	19.29				
		2	18.20	19.29				
		3	18.20	19.29				
		4	18.20	19.31		18.02	19.28	4.71
		5	18.30	19.31				
		6	18.30	19.32				
		7	18.30	19.33				
		8	18.30	19.33		17.91	19.28	4.69
		9	18.30	19.34				
		10	18.20	19.33				
		11	18.20	19.34				
		12	18.20	19.34		17.88	19.28	4.65
		13	18.20	19.31				
		14	18.20	19.33				
		15	18.20	19.33				
		16	18.20	19.33		17.94	19.28	4.54
		17	18.30	19.34				
		18	18.40	19.38				

TABLE 1 (Cont'd...)

Station	Time	Depth (m)	Temp.*	Cl‰*	Time	Temp.+	Cl‰†	O_2
4		0			1522h	17.91	19.27	4.95
		5				17.91	19.27	4.96
		10				17.81	19.26	4.91
		15				17.74	19.27	4.93
		20				17.70	19.27	4.99
2		0			1545h	17.74	19.39	5.26
		4				17.66	19.38	5.24
		8				17.43	19.36	5.26
		12				17.44	19.37	5.17

* Chlorinity-temperature meter in field.

\+ Reversing thermometer in field.

† By meter in laboratory.

The bathymetry of the region (Fig. 2) prevented sampling from R.V. Saga in South West Arm, the Port Hacking River and the whole of the area east of Burraneer Bay. Supplementary stations were worked from a smaller launch on 24/5/66 at stations around the mouth of Port Hacking (Fig. 1), but large areas, notably Gunnamatta Bay, were not sampled.

At certain stations, detailed in situ profiles of temperature and chlorinity to the bottom were obtained using a chlorinity-temperature meter (Tables 2, 3 and 4).

TABLE 2

TEMPERATURE-CHLORINITY AT SELECTED STATIONS - 23.5.66

Station	Time	Depth* (m)	Temp.†	Cl‰†
1A	0930h	0	19.15	19.62
		1	19.15	19.63
		2	19.15	19.63
		3	18.10	19.68
		4	17.75	19.54
3	0950h	0	17.10	19.49
		1	17.10	19.48
		2	17.10	19.49
		3	17.10	19.49
		4	17.10	19.49
		5	17.10	19.49
		6	17.00	19.47
		7	17.00	19.49
4	1010h	0	17.30	19.27
		1	17.30	19.29
		2	17.30	19.29
		3	17.30	19.29
		4	17.30	19.29
		5	17.30	19.29
		6	17.30	19.29
		7	17.30	19.29
		8	17.30	19.29
		9	17.30	19.29
		10	17.30	19.29
		11	17.30	19.29

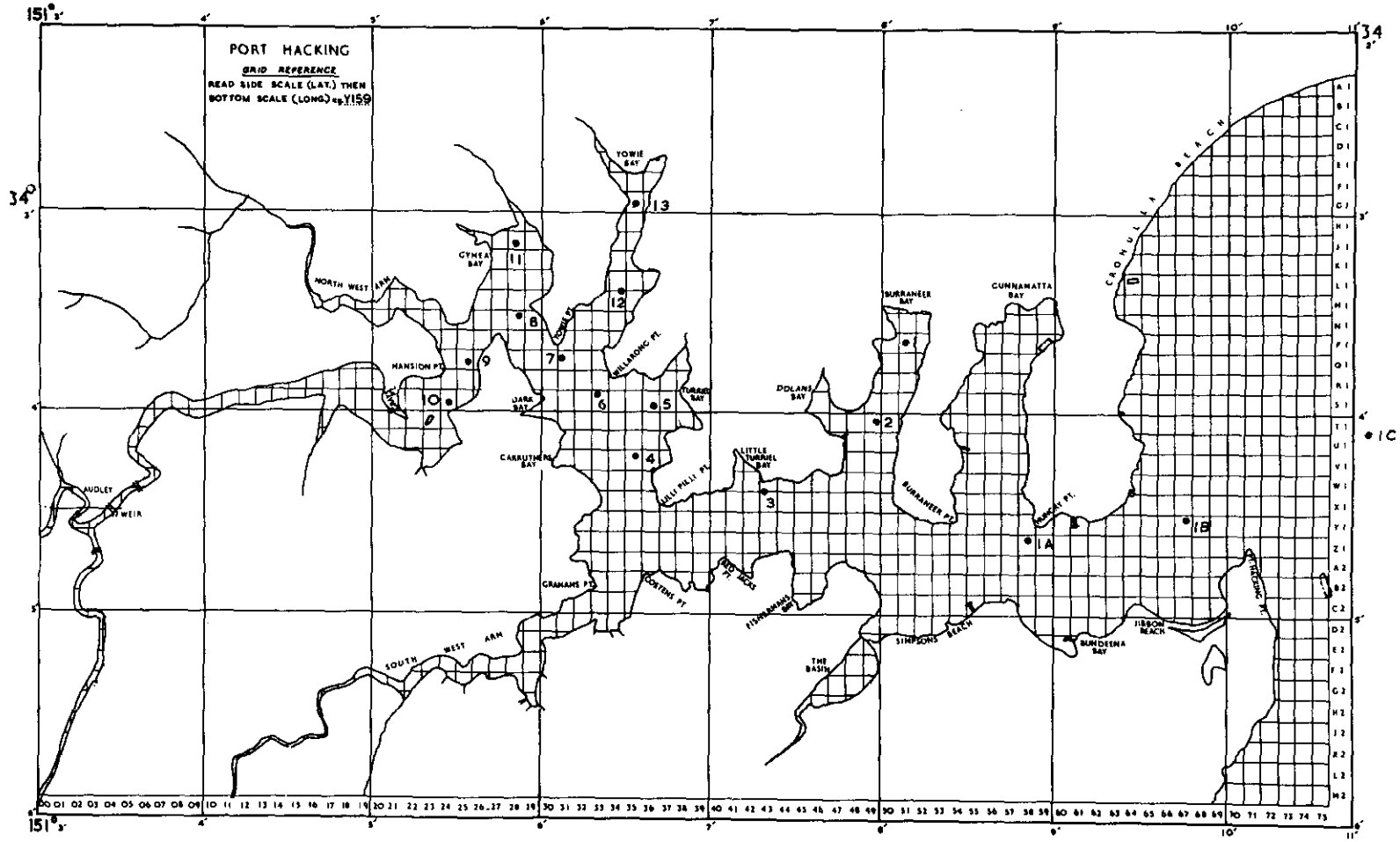


Fig. 1.- Hydrology station positions.

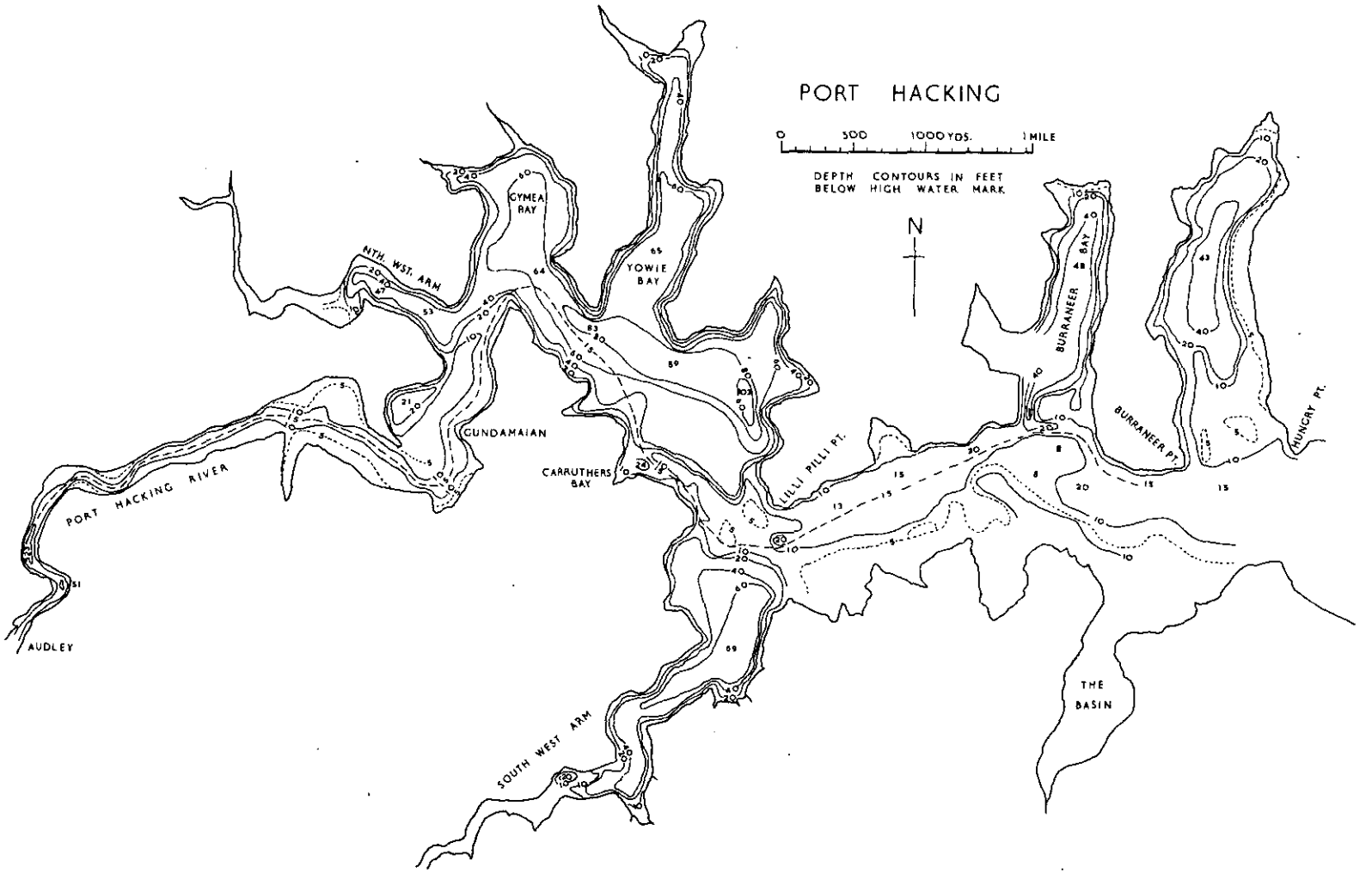


Fig. 2.- Port Hacking depth contours.

TABLE 2 (Cont'd...)

Station	Time	Depth* (m)	Temp.†	Cl‰†
		12	17.30	19.30
		13	17.30	19.30
		14	17.30	19.30
		15	17.30	19.30
		16	17.30	19.30
		17	17.40	19.32
		18	17.40	19.32
		19	17.40	19.32
		20	17.40	19.32
		21	17.40	19.32
		22	17.40	19.32
		23	17.40	19.32
		24	17.30	19.32
5	1020h	0	16.20	19.26
		1	16.20	19.25
		2	16.20	19.25
		3	16.20	19.25
		4	16.18	19.24
		5	16.18	19.24
		6	16.20	19.17
		7	16.21	19.21
		8	16.23	19.26
		9	16.22	19.25
		10	16.20	19.25
		11	16.20	19.32
		12	16.20	19.33
		13	16.20	19.33
		14	16.20	19.32
		15	16.19	19.34
		16	16.30	19.35
		17	16.30	19.34
		18	16.30	19.35
		19	16.30	19.35
		20	16.25	19.35
		21	16.25	19.38
		22	16.35	19.40
		23	16.50	19.41
6	1040h	0	17.00	19.20
		1	17.00	19.20
		2	17.00	19.20
		3	17.05	19.20
		4	17.05	19.20
		5	17.05	19.20
		6	17.10	19.21
		7	17.10	19.21
		8	16.40	19.30
		9	16.50	19.31
		10	16.50	19.34
		11	16.10	19.34
		12	16.50	19.36
		13	16.50	19.36
		14	16.50	19.35
		15	16.50	19.35
		16	16.40	19.37
		17	16.40	19.37
		18	16.40	19.37
		19	16.40	19.37
		20	16.40	19.39

TABLE 2 (Cont'd...)

Station	Time	Depth* (m)	Temp.†	Cl‰†
7	1100h	0	16.10	19.11
		1	16.10	19.11
		2	16.10	19.20
		3	16.10	19.20
		4	16.10	19.20
		5	16.20	19.20
		6	16.40	19.26
		7	16.60	19.30
		8	16.60	19.32
		9	16.50	19.30
		10	16.40	19.31
		11	16.40	19.31
		12	16.40	19.31
		13	16.40	19.31
		14	16.40	19.31
		15	16.50	19.36
		16	16.50	19.36
		17	16.50	19.36
		18	16.50	19.36
		19	16.60	19.40
		20	16.60	19.40
		21	16.40	19.39
8	1115h	0	16.05	19.06
		1	16.05	19.10
		2	16.42	19.08
		3	16.60	19.24
		4	16.80	19.30
		5	16.80	19.31
		6	16.70	19.31
		7	16.70	19.32
		8	16.70	19.32
		9	16.70	19.32
		10	16.70	19.34
		11	16.60	19.36
		12	16.60	19.32
		13	16.60	19.34
		14	16.60	19.34
		15	16.50	19.34
		16	16.50	19.34
10	1130h	0	15.70	18.82
		1	15.70	18.77
		2	15.70	18.79
		3	15.90	18.84
		4	15.90	18.96
		5	16.10	19.04
		6	16.10	19.08
		7	16.10	19.08
9	1145h	0	16.61	18.61
		1	16.10	18.89
		2	16.30	18.97
		3	16.40	19.11

* No correction for stray. Deepest sampling just above bottom.

† Chlorinity-temperature meter.

TABLE 3

TEMPERATURE-CHLORINITY AT SELECTED STATIONS - 24.5.66

Station	Time	Depth* (m)	Temp.†	Cl‰†
1	0930h	0	16.00	19.10
		1	16.00	19.10
		3	16.00	19.11
		4	16.00	19.11
		6	16.00	19.11
		8	16.00	19.11
		10	16.00	19.11
		12	16.00	19.11
2	0945h	0	16.00	19.29
		1	16.10	19.30
		2	16.10	19.33
		3	16.00	19.30
		4	16.10	19.29
		5	16.20	19.34
		6	16.20	19.34
		7	16.20	19.34
		8	16.25	19.32
		9	16.30	19.35
		10	16.35	19.38
		11	16.35	19.37
		12	16.30	19.37
		13	16.30	19.37
3	1000h	0	16.20	19.37
		1	16.20	19.37
		3	16.20	19.37
		5	16.20	19.37
		6	16.20	19.37
4	1015h	0	16.00	19.18
		1	16.00	19.19
		2	16.00	19.19
		3	16.00	19.19
		4	16.00	19.19
		5	16.10	19.19
		6	16.10	19.20
		7	16.10	19.20
		8	16.10	19.19
		9	16.10	19.19
		10	16.10	19.19
		11	16.10	19.19
		12	16.10	19.19
		13	16.10	19.20
		14	16.10	19.21
		15	16.00	19.21
		16	16.00	19.20
		17	16.00	19.20
		18	16.00	19.21
		19	16.00	19.21
		20	16.00	19.20
		21	16.00	19.21
		22	16.00	19.21
		23	16.00	19.21
		24	16.00	19.21
		25	16.00	19.21
		26	16.00	19.21

TABLE 3 (Cont'd...)

Station	Time	Depth* (m)	Temp.†	Cl‰†
5	1030h	0	16.02	19.21
		1	16.02	19.21
		2	16.02	19.23
		3	16.02	19.22
		4	16.02	19.22
		5	16.02	19.23
		6	16.02	19.23
		7	15.99	19.23
		8	16.02	19.24
		9	16.02	19.24
		10	16.02	19.25
		11	16.02	19.24
		12	16.02	19.24
		13	16.02	19.24
		14	16.02	19.27
		15	16.08	19.26
		16	16.08	19.26
		17	16.08	19.28
		18	16.18	19.27
		19	16.18	19.27
		20	16.18	19.27
		21	16.18	19.29
		22	16.22	19.28
		23	16.40	19.31
		24	16.50	19.35
6	1045h	0	15.80	19.13
		1	15.80	19.16
		2	15.81	19.15
		3	15.81	19.12
		4	15.81	19.16
		5	15.81	19.18
		6	15.81	19.18
		7	16.05	19.18
		8	16.25	19.20
		9	16.25	19.27
		10	16.25	19.27
		11	16.45	19.27
		12	16.45	19.32
		13	16.42	19.32
		14	16.42	19.32
		15	16.50	19.33
		16	16.40	19.33
		17	16.40	19.35
		18	16.40	19.35
		19	16.40	19.36
		20	16.40	19.35
7	1100h	0	15.80	19.08
		1	15.80	19.09
		2	16.01	19.15
		3	16.18	19.20
		4	16.00	19.22
		5	16.25	19.25
		6	16.45	19.25
		7	16.45	19.30
		8	16.45	19.30
		9	16.45	19.31
		10	16.60	19.31
		11	16.70	19.38
		12	16.70	19.38
		13	16.60	19.38

TABLE 3 (Cont'd...)

Station	Time	Depth* (m)	Temp.†	Cl‰†
7 (Continued)	1100h (Continued)	14	16.60	19.38
		15	16.60	19.38
		16	16.50	19.37
		17	16.50	19.37
		18	16.60	19.37
		19	16.60	19.37
		20	16.60	19.37
		21	16.60	19.38
8	1115h	0	15.65	19.02
		1	15.65	19.00
		2	15.65	19.00
		3	16.39	19.24
		4	16.45	19.26
		5	16.45	19.28
		6	16.40	19.27
		7	16.40	19.27
		8	16.40	19.27
		9	16.40	19.27
		10	16.40	19.30
		11	16.45	19.31
		12	16.45	19.31
		13	16.50	19.32
		14	16.50	19.32
		15	16.50	19.34
		16	16.50	19.35
		17	16.50	19.35
10	1130h	0	15.25	18.71
		1	15.40	18.74
		2	15.50	18.80
		3	15.60	18.87
		4	16.00	19.05
		5	16.05	19.09
		6	16.10	19.09

* † See TABLE 2

TABLE 4

TEMPERATURE-CHLORINITY AT SELECTED STATIONS -25.5.66

Station	Time	Depth* (m)	Temp.†	Cl‰†
1	1015h	0	16.15	19.35
		1	16.15	19.35
		2	16.10	19.35
		3	16.10	19.35
		4	16.10	19.35
		5	16.10	19.35
		6	16.10	19.35
		7	16.10	19.35
		8	16.10	19.35
		9	16.10	19.35
		10	16.10	19.35
		11	16.10	19.35
		12	16.10	19.35

TABLE 4 (Cont'd...)

Station	Time	Depth* (m)	Temp.†	Cl‰†
2	1030h	0	16.05	19.35
		1	16.05	19.35
		2	16.05	19.35
		4	16.05	19.34
		6	16.05	19.34
		8	16.00	19.35
		9	16.00	19.35
		11	16.00	19.35
		13	15.90	19.34
		15	15.90	19.34
3	1045h	0	17.00	19.50
		1	17.00	19.50
		2	17.00	19.50
		3	17.00	19.50
		4	17.00	19.50
4	1100h	0	16.10	19.24
		1	16.10	19.24
		2	16.10	19.24
		4	16.10	19.24
		6	16.10	19.24
		8	16.20	19.28
		9	16.20	19.28
		10	16.20	19.28
		12	16.20	19.29
		13	16.10	19.27
		14	16.10	19.27
		15	16.10	19.27
		16	16.20	19.30
		17	16.10	19.28
		18	16.10	19.28
		19	16.10	19.30
		20	16.20	19.30
		21	16.20	19.30
		22	16.20	19.30
		23	16.20	19.30
		24	16.20	19.31
5	1115h	0	16.10	19.20
		1	16.10	19.20
		2	16.00	19.20
		3	16.00	19.20
		4	16.10	19.20
		5	16.10	19.25
		6	16.10	19.25
		7	16.10	19.25
		8	16.10	19.25
		9	16.20	19.25
		10	16.20	19.30
		12	16.20	19.30
		14	16.20	19.30
		16	16.20	19.30
		18	16.20	19.30
		20	16.20	19.30
		22	16.50	19.35

TABLE 4 (Cont'd...)

Station	Time	Depth* (m)	Temp.†	Cl‰†
6	1130h	0	16.20	19.23
		2	16.20	19.23
		4	16.20	19.23
		6	16.20	19.25
		7	16.20	19.25
		9	16.20	19.30
		10	16.20	19.30
		12	16.20	19.30
		14	16.30	19.30
		15	16.30	19.32
		16	16.30	19.32
		18	16.40	19.33
		19	16.40	19.33
		20	16.40	19.37
		21	16.40	19.37
		22	16.40	19.37
		23	16.60	19.40
		24	16.60	19.40
		25	16.60	19.40
7	1145h	0	16.15	19.21
		1	16.15	19.21
		2	16.15	19.21
		3	16.15	19.21
		4	16.20	19.26
		5	16.30	19.27
		7	16.15	19.27
		8	16.20	19.29
		9	16.30	19.30
		10	16.30	19.30
		11	16.30	19.30
		12	16.30	19.30
		13	16.30	19.30
		14	16.30	19.30
		15	16.30	19.30
		16	16.30	19.32
		17	16.40	19.32
		18	16.40	19.35
		19	16.40	19.35
		20	16.40	19.35
		21	16.40	19.35
8	1205h	0	15.80	19.09
		1	15.80	19.09
		2	15.80	19.09
		3	15.90	19.17
		4	16.15	19.21
		5	16.40	19.25
		6	16.45	19.29
		7	16.45	19.31
		8	16.45	19.31
		9	16.40	19.31
		11	16.45	19.34
		12	16.45	19.33
		13	16.45	19.34
		15	16.40	19.35
		16	16.40	19.34
		17	16.40	19.34

TABLE 4 (Cont'd...)

Station	Time	Depth* (m)	Temp.†	Cl‰†
10	1230h	0	15.60	18.83
		1	15.90	19.00
		2	15.90	19.05
		3	16.00	19.07
		4	16.00	19.09
		5	16.10	19.12
		6	16.30	19.17
		7	16.30	19.20

* † See TABLE 2

At other stations Nansen bottles and reversing thermometers were used to collect samples for chlorinity and oxygen analysis and to record temperatures. Two groups of five students made separate collections of chlorinity and oxygen samples from each Nansen bottle, as well as reading and recording separate field log data. In the Laboratory these two groups made independent analyses for chlorinity and oxygen, and independently corrected temperatures given by reversing thermometers for expansion and index error. The results obtained by those two groups are given in Tables 5, 6, and 7.

TABLE 5

COMPARISON OF GROUP RESULTS - TEMPERATURE BY REVERSING THERMOMETER

Station	Date	Depth (m)	Temperature A	Temperature B	Date	Depth (m)	Temperature A	Temperature B	Date	Depth (m)	Temperatu A	
1	23/5/66	0	16.07	16.07	24/5/66	0	16.24	16.25	25/5/66	0	16.18	16.
		5	16.03	16.03		5	16.22	16.21		5	16.19	16.
		10	16.01	16.01		10	16.19	16.19		10	16.25	16.
2		0	16.40	16.42		0	16.32	16.32		0	16.26	16.
		4	16.43	16.43		4	16.35	16.35		3	16.30	16.
		8	16.39	16.40		8	16.32	16.32		6	16.21	16.
		12	16.38	16.36		12	16.40	16.43		9	16.17	16.
4		0	16.33	16.35		0	16.20	16.22		0	16.14	16.
		6	16.26	16.28		5	16.20	16.19		6	16.20	16.
		12	16.27	16.28		10	16.12	16.13		12	16.18	16.
		18	16.33	16.35		15	16.36	16.36		18	16.18	16.
5										0	16.14	16.
										6	16.16	16.
										12	16.24	16.
										18	16.27	16.
6						0	16.09	16.09		0	16.17	16.
						5	16.10	16.10		6	16.46	16.
						10	16.47	16.47		12	16.36	16.
						15	16.61	16.61		18	16.30	16.
7										0	16.22	16.
										5	16.20	16.
										10	16.48	16.
										15	16.38	16.

BLE 5 (Cont'd...)

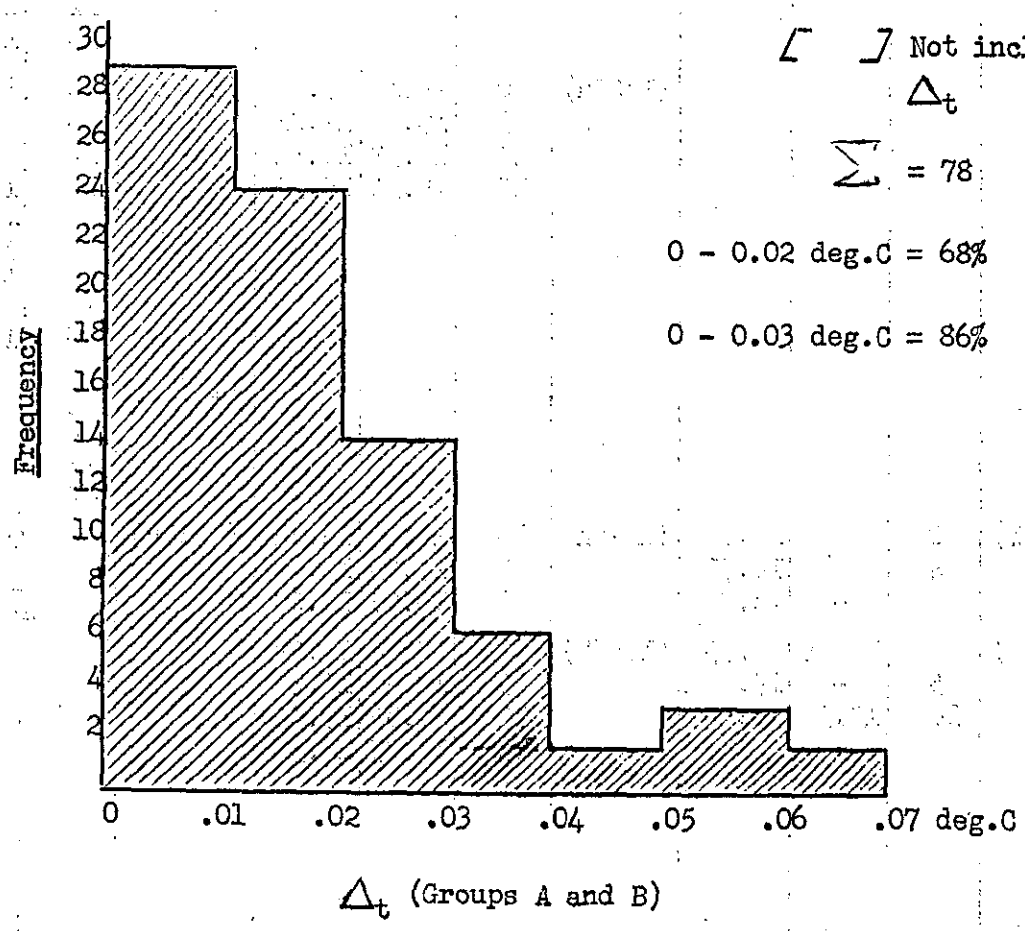
tation	Date	Depth (m)	Temperature A	Temperature B	Date	Depth (m)	Temperature A	Temperature B	Date	Depth (m)	Temperature A	Temperature B
8									25/5/66	0	15.92	15.94
										5	16.46	16.45
										10	16.50	16.51
										15	16.56	16.53
10	23/5/66	0	-	15.72	24/5/66	0	15.39	15.39		0	16.17	[16.76]
		4	-	16.05		3	16.19	16.19		3	16.31	16.18
		8	-	16.75		6	16.10	16.12		6	[15.74]	16.31
11		0	15.85	15.84		0	15.62	15.63				
		5	16.75	16.78		5	16.69	16.69				
		10	16.58	16.58		10	16.55	16.56				
		15	16.47	16.52		15	16.50	16.50				
12		0	16.18	16.19		0	16.09	16.09				
		6	16.14	16.14		6	16.32	16.32				
		12	16.55	16.56		12	16.52	16.52				
		18	16.47	16.48		18	16.69	16.69				
13		0	15.93	15.93		0	16.46	16.46				
		5	16.31	16.31		5	16.50	16.50				
		10	16.50	16.51		10	16.52	16.52				
		15	16.58	16.52		15	16.50	16.50				

[ ] Not included in Δ_t

$\sum$ = 78

0 - 0.02 deg.C = 68%

0 - 0.03 deg.C = 86%



Δ_t (Groups A and B)

TABLE 6

COMPARISON OF GROUP RESULTS - CHLORINITY BY REVERSING BOTTLES AND CHLORINITY-TEMPERATURE METER

Station	Date (Time)	Depth (m)	‰ A	‰ B	Date (Time)	Depth (m)	‰ A	‰ B	Date (Time)	Depth (m)	‰ A	
1	23/5/66	0	19.27	19.28	24/5/66	0	19.35	19.34	25/5/66	0	19.37	19
	(1433h)	5	19.28	19.28	(1439h)	5	19.34	19.33	(1519h)	5	19.37	19
	(H.W. 1030h)	10	19.31	19.29	(H.W. 1123h)	10	19.33	19.33	(H.W. 1220h)	10	19.38	19
2	(1420h)	0	19.35	19.34	(1423h)	0	19.34	19.35	(1507h)	0	19.37	19
		4	19.35	19.34		4	-	19.34		3	19.36	19
		8	19.35	19.35		8	19.35	19.34		6	19.35	19
		12	19.34	19.34		12	19.34	19.33		9	19.35	19
4	(1351h)	0	19.21	19.21	(1345h)	0	19.24	19.24	(1429h)	0	19.24	19
		6	19.24	19.23		5	19.25	19.25		6	19.25	19
		12	19.29	19.28		10	19.27	19.26		12	19.29	19
		18	19.30	19.29		15	19.31	19.31		18	19.31	19
5									(1419h)	0	19.23	19
										6	19.23	19
										12	19.29	19
										18	19.32	19
6					(1327h)	0	19.17	19.18	(1400h)	0	19.23	19
						5	19.20	19.21		6	19.31	19
						10	19.33	19.32		12	19.29	19
						15	19.35	19.35		18	19.31	19
7									(1330h)	0	19.10	19
										5	19.24	19
										10	19.32	19
										15	19.33	19
8									(1301h)	0	-	19
										5	-	19
										10	-	19
										15	-	19
10	(1138h)	0	-	18.78	(1128h)	0	18.72	18.72	(1237h)	0	18.81	19
		4	-	18.97		3	19.03	19.04		3	-	18
		8	-	18.93		6	19.07	19.08		6	19.19	19
11	(1211h)	0	18.95	18.95	(1158h)	0	18.98	18.99				
		5	-	19.26		5	19.23	19.22				
		10	19.32	19.31		10	19.32	19.33				
						15	19.35	19.34				

BLE 6 (Cont'd...)

tation	Date (Time)	Depth (m)	‰ A	‰ B	Date (Time)	Depth (m)	‰ A	‰ B	Date (Time)	Depth (m)	‰ A	‰ B
12	23/5/66 (1254h)	0	19.14	19.15	24/5/66 (1244h)	0	19.16	19.35				
		6	19.13	19.14		6	19.23	19.21				
		12	19.30	19.09		12	19.31	19.32				
		18	19.33	19.32		18	19.35	19.36				
13	(1326)	0	18.94	18.94	(1301)	0	19.18	19.15				
		5	19.13	19.14		5	19.24	19.22				
		10	19.20	19.19		10	19.32	19.32				
		15	19.29	19.28		15	19.34	19.34				

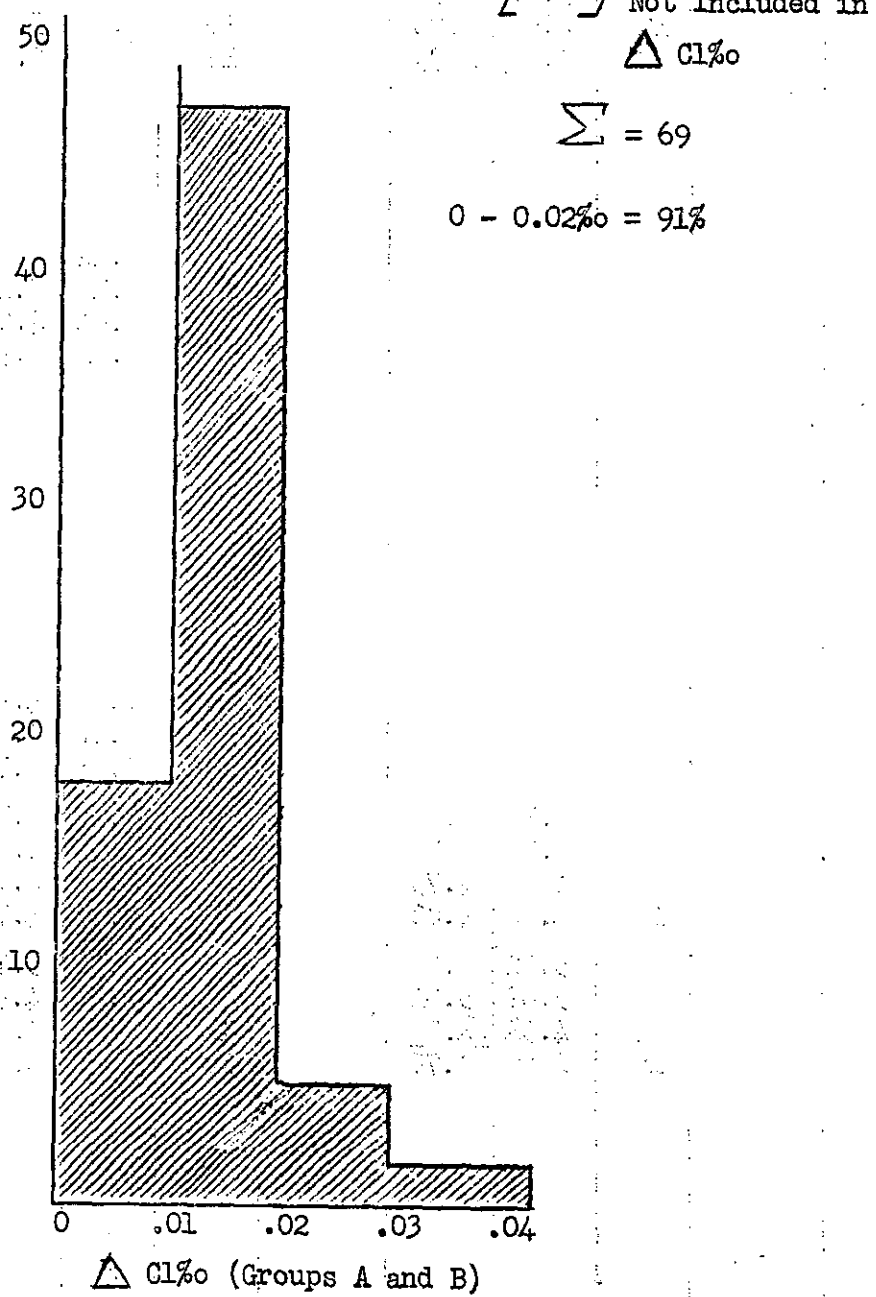


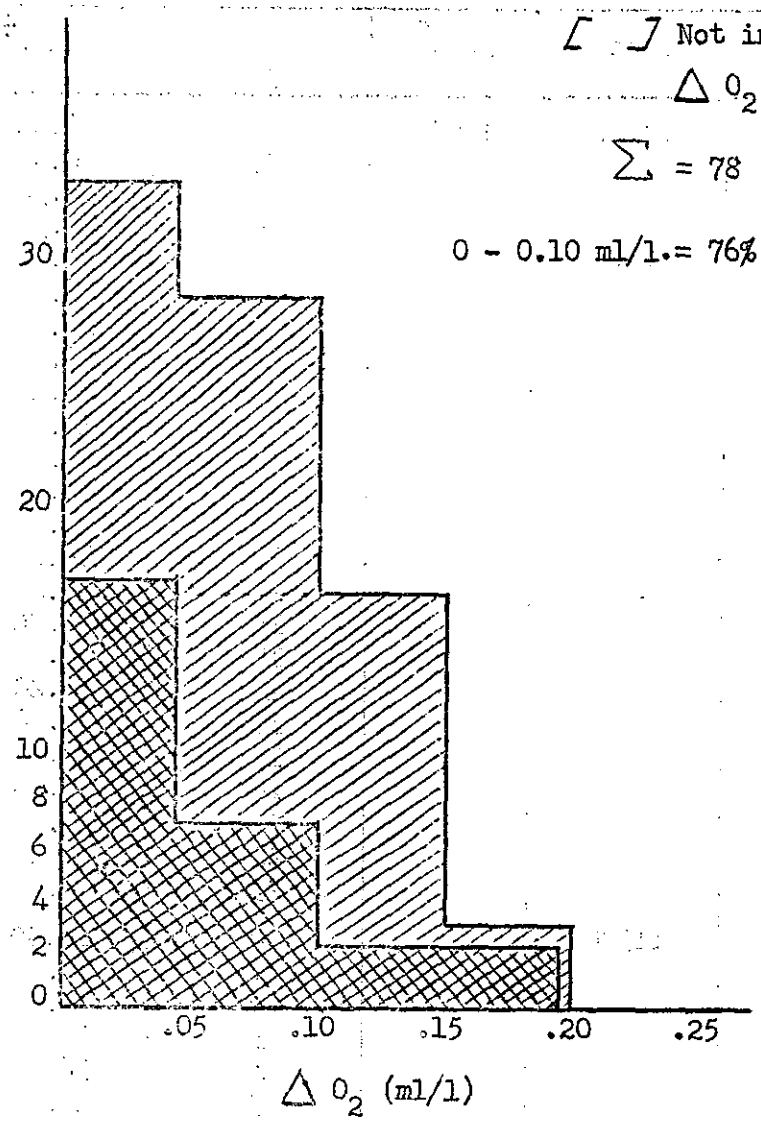
TABLE 7

COMPARISON OF GROUP RESULTS - OXYGEN BY WINKLER METHOD

Station	Date	Depth (m)	O_2 A	O_2 B	Date	Depth (m)	O_2 A	O_2 B	Date	Depth (m)	O_2 A	O_2 B
1	23/5/66	0	[1.98]	5.25	24/5/66	0	5.38	5.30	25/5/66	0	5.53	5.
		5	[2.99]	5.15		5	5.29	5.28		5	5.48	5.
		10	-	4.95		10	5.26	5.25		10	5.38	5.
2		0	5.22	5.12		0	5.35	5.29		0	5.50	5.
		4	5.26	5.13		4	5.30	5.29		3	5.42	5.
		8	5.26	5.21		8	5.33	5.26		6	5.39	5.
		12	5.18	5.12		12	5.23	5.16		9	5.37	5.
4		0	5.11	5.15		0	5.25	5.18		0	5.35	5.
		6	5.01	4.96		5	5.26	5.14		6	5.30	5.
		12	4.95	4.90		10	5.11	5.06		12	5.16	5.
		18	4.98	4.93		15	5.05	[5.97]		18	5.16	5.
5										0	5.39	5.
										6	5.34	5.
										12	5.09	5.
										18	5.20	5.
6						0	5.22	5.10		0	5.36	5.
						5	5.19	5.15		6	4.99	4.
						10	5.04	4.92		12	5.08	5.
						15	5.01	4.90		18	5.11	5.
7										0	5.18	5.
										5	5.18	5.
										10	4.92	4.
										15	[5.03]	4.
8										0	5.25	5.
										5	5.02	4.
										10	4.72	4.
										15	4.83	4.
10						0	4.93	4.92		0	5.01	5.
						3	4.82	4.86		3	5.06	4.
						6	4.83	4.78		6	4.83	4.
11		0	5.13	5.06		0	5.15	5.15				
		5	4.73	4.72		5	4.84	4.80				
		10	4.85	4.75		10	4.77	4.71				
		15	4.86	4.83		15	4.77	4.72				
12		0	5.12	5.02		0	5.02	5.18				
		6	5.09	5.01		6	5.06	4.92				
		12	4.94	[4.70]		12	4.96	4.92				
		18	4.87	4.78		18	5.04	5.09				

ABLE 7 (Cont'd...)

Station	Date	Depth (m)	O_2 A	O_2 B	Date	Depth (m)	O_2 A	O_2 B	Date	Depth (m)	O_2 A	O_2 B
13	23/5/66	0	5.29	5.23	24/5/66	0	5.12	5.18				
		5	5.11	4.97		5	5.02	5.06				
		10	4.96	4.86		10	4.76	4.79				
		15	4.81	4.71		15	4.62	4.71				



On 26/5/66 chlorinity-temperature profiles at Stations 4, 6 and 8 (Fig. 1) in the Lilli Pilli basin were determined at approximately hourly intervals from 1133 - 1420 h. Tide height and phase were measured. Results of this survey are given in Table 8. Supplementary stations were worked on 24/5/66 by CSIRO (Table 9).

TABLE 8

TEMPERATURE-CHLORINITY AT SELECTED STATIONS IN LILLI PILLI BASIN - 26.5.66

Station	Time	Tide*	Depth (m)	Temp.†	Cl‰†
4	1133h	1'0"	0	16.30	19.51
			1	16.30	19.52
			2	16.30	19.52
			3	16.30	19.47
			4	16.30	19.36
			5	16.20	19.34
			6	16.20	19.29
			7	16.20	19.28
			8	16.20	19.28
			9	16.20	19.28
			10	16.20	19.28
			11	16.20	19.28
			12	16.20	19.28
			13	16.21	19.28
			14	16.21	19.28
			15	16.20	19.28
			16	16.20	19.29
			17	16.20	19.29
			18	16.20	19.29
			19	16.20	19.29
			20	16.20	19.29
			21	16.20	19.29
			22	16.20	19.29
			23	16.20	19.31
6	1150h		0	16.30	19.24
			1	16.30	19.24
			2	16.30	19.25
			3	16.30	19.26
			4	16.20	19.28
			5	16.20	19.28
			6	16.20	19.26
			7	16.20	19.26
			8	16.20	19.27
			9	16.15	19.27
			10	16.15	19.27
			11	16.15	19.23
			12	16.25	19.23
			13	16.20	19.27
			14	16.20	19.27

TABLE 8 (Cont'd...)

Station	Time	Tide*	Depth (m)	Temp.†	Cl‰†
6 (Continued)	1150h	1'0"	15	16.20	19.29
			16	16.20	19.27
			17	16.30	19.25
			18	16.35	19.27
			19	16.35	19.29
			20	16.35	19.27
			21	16.40	19.32
			22	16.35	19.29
8	1214h		0	15.85	19.19
			1	15.85	19.18
			2	15.90	19.14
			3	15.90	19.11
			4	16.70	-
			5	16.70	19.10
			6	16.70	19.23
			7	16.70	19.27
			8	16.63	19.30
			9	16.60	19.31
			10	16.55	19.36
			11	16.55	19.33
			12	16.55	19.34
			13	16.50	19.34
			14	16.50	19.35
			15	16.40	19.35
4	1240h	1'9"	0	16.30	19.46
			1	16.30	19.35
			2	16.30	19.33
			3	16.30	19.28
			4	16.30	19.29
			5	16.30	19.29
			6	16.30	19.29
			7	16.30	19.29
			8	16.30	19.27
			9	16.30	19.27
			10	16.30	19.27
			11	16.22	19.29
			12	16.42	19.27
			13	16.42	19.28
			14	16.40	19.29
			15	16.40	19.29
			16	16.40	19.31
			17	16.40	19.30
			18	16.40	19.29
			19	16.40	19.32
			20	16.40	19.30
			21	16.41	19.32
			22	16.41	19.35

TABLE 8 (Cont'd...)

Station	Time	Tide*	Depth (m)	Temp.†	Cl‰†
6	1255h	1'9"	0	16.30	19.27
			1	16.30	19.26
			2	16.30	19.26
			3	16.25	19.28
			4	16.25	19.27
			5	16.25	19.26
			6	16.25	19.26
			7	16.25	19.26
			8	16.20	19.28
			9	16.20	19.27
			10	16.20	19.27
			11	16.20	19.27
			12	16.20	19.28
			13	16.20	19.29
			14	16.20	19.29
			15	16.25	19.29
			16	16.30	19.29
			17	16.45	19.31
			18	16.40	19.34
			19	16.50	19.34
			20	16.50	19.35
			21	16.50	19.35
			22	16.50	19.35
			23	16.55	19.35
8	1315h		0	16.00	19.24
			1	16.00	19.22
			2	15.95	19.14
			3	15.95	19.11
			4	16.70	19.11
			5	16.75	19.28
			6	16.70	19.31
			7	16.70	19.31
			8	16.70	19.31
			9	16.65	19.31
			10	16.65	19.31
			11	16.65	19.31
			12	16.65	19.31
4	1335h	2'3"	0	16.40	19.32
			1	16.40	19.28
			2	16.30	19.30
			3	16.30	19.27
			4	16.30	19.27
			5	16.30	19.26
			6	16.30	19.27
			7	16.30	19.26
			8	16.30	19.27
			9	16.30	19.27
			10	16.30	19.29
			11	16.30	19.28

TABLE 8 (Cont'd...)

Station	Time	Tide*	Depth (m)	Temp.†	Cl‰†
4 (Continued)	1335h	2'3"	12	16.30	19.29
			13	16.20	19.29
			14	16.20	19.29
			15	16.23	19.29
			16	16.23	19.29
			17	16.23	19.31
			18	16.23	19.31
			19	16.30	19.31
6	1355h		0	16.35	19.33
			1	16.35	19.28
			2	16.30	19.27
			3	16.25	19.21
			4	16.22	19.26
			5	16.22	19.26
			6	16.22	19.26
			7	16.22	19.28
			8	16.22	19.28
			9	16.22	19.28
			10	16.22	19.28
			11	16.38	19.30
			12	16.38	19.32
			13	16.38	19.32
			14	16.38	19.32
			15	16.45	19.32
			16	16.45	19.35
			17	16.45	19.39
			18	16.40	19.36
			19	16.40	19.36
			20	16.40	19.36
			21	16.62	19.36
			22	16.62	19.34
			23	16.62	19.34
8	1410h		0	16.00	19.18
			1	16.00	19.14
			2	16.50	19.11
			3	16.70	19.27
			4	16.70	19.31
			5	16.60	19.31
			6	16.60	19.31
			7	16.60	19.31
			8	16.50	19.31
			9	16.50	19.31
			10	16.50	19.31
			11	16.40	19.31
			12	16.40	19.31
			13	16.40	19.31
			14	16.40	19.31
			15	16.40	19.31
			16	16.40	19.31

TABLE 8 (Cont'd...)

Station	Time	Tide*	Depth (m)	Temp.†	Cl‰†
4	1420h	2'0"	0	16.40	19.30
			1	16.40	19.29
			2	16.40	19.29
			3	16.30	19.29
			4	16.20	19.29
			5	16.20	19.29
			6	16.20	19.28
			7	16.20	19.26
			8	16.20	19.26
			9	16.20	19.25
			10	16.20	19.28
			11	16.20	19.28
			12	16.20	19.28
			13	16.20	19.28
			14	16.20	19.30
			15	16.20	19.30
			16	16.20	19.31
			17	16.20	19.31
			18	16.20	19.32
			19	16.20	19.32
			20	16.20	19.32
			21	16.20	19.32
			22	16.20	19.32
6	1430h		0	16.35	19.39
			1	16.40	19.26
			2	16.40	19.26
			3	16.25	19.30
			4	16.20	19.28
			5	16.20	19.28
			6	16.20	19.28
			7	16.20	19.28
			8	16.20	19.27
			9	16.20	19.29
			10	16.20	19.27
			11	16.25	19.29
			12	16.25	19.28
			13	16.25	19.29
			14	16.25	19.28
			15	16.25	19.28
			16	16.25	19.29
			17	16.30	19.28
			18	16.30	19.31
			19	16.35	19.32
			20	16.40	19.33
			21	16.40	19.36
			22	16.40	19.36
8	1445h		0	16.20	19.16
			1	16.20	19.09
			2	16.20	19.16

TABLE 8 (Cont'd...)

Station	Time	Tide*	Depth (m)	Temp.†	Cl‰†
8 (Continued)	1445h	2'0"	3	16.45	19.26
			4	16.70	19.24
			5	16.70	19.31
			6	16.70	19.32
			7	16.60	19.32
			8	16.60	19.31
			9	16.60	19.32
			10	16.60	19.31
			11	16.60	19.32
			12	16.60	19.32
			13	16.50	19.32
			14	16.50	19.32

* Read off tide staff at Lilli Pilli.

† By chlorinity-temperature meter.

TABLE 9

TEMPERATURE-CHLORINITY AT SELECTED STATIONS IN LILLI PILLI BASIN - 24.5.66

Station	Time	Depth (m)	Temp.	Cl‰	O_2
1 B	0930h	0	18.74	19.69	5.26
		4	18.74	19.70	5.27
		9	18.67	19.69	5.23
1 C	1004h	0	19.12	19.70	5.13
		10	19.11	19.70	5.13
		20	18.73	19.69	5.16
5	1320h	0	16.08	19.20	5.24
		7	16.06	19.23	5.13
		14	16.32	19.30	5.01
		21	16.24	19.29	5.00

IV. DISCUSSION

(a) Comparison of group analyses

Temperatures by reversing thermometers agreed to within 0.02 deg.C in 68% of cases, and to within 0.03 deg.C in 86% of cases (Table 5). This is very similar to the agreement obtained with paired thermometers in the Laboratory's regular oceanographical programme. Chlorinities by two separate chlorinity-temperature meters agreed to within 0.02‰ in 91% of cases (Table 6) with little variation in this level of agreement

from day to day. Oxygen values by separate analysis of sub-samples from the one Nansen bottle did not agree to within 0.10 ml/l. in more than 76% of cases on the average, and by the third day only agreed to within 0.10 ml/l. in 59% of cases (Table 7). This is below the agreement of duplicate samples in the Laboratory's regular oceanographical programme. Moreover, on the first day, all of Group A values were higher than those of Group B, with 73% and 80% of values showing the same bias on the second and third day respectively. This bias effect could not be explained and was not investigated further.

(b) Hydrological features

Upstream gradiants of temperature and chlorinity on May 23, 24, and 25, 1966 are shown in Figures 3 and 4. Along the main channel, temperatures were generally lower during the ebb tidal phase. From day to day, however, the temperature difference between flood and ebb conditions of tide varied considerably (e.g. Station 4 (23/5/66) Fig. 3), whilst, despite near similarity of tidal phase, the temperature changed considerably from the 23-25/5/66 at Station 3 (Fig. 3). Temperatures in Yowie Bay, whilst comparable with channel temperatures on the 23rd, were much greater on the 24th (Fig. 3). Temperatures in Burraneer Bay were very constant throughout the period but were considerably lower than adjoining channel temperatures (Fig. 3). Chlorinity differences between flood and ebb tidal phase were small in relation to the upstream gradiant (c.p. Station 4 Fig. 4). Chlorinities in the head waters of Yowie Bay (Station 13) were lower than adjoining channel values on the 23rd (Fig. 4) but were quite normal again on the 24th. Chlorinities in Burraneer Bay were for the most part constant within a 0.10‰ range except for the 24th, when chlorinities of the head waters decreased considerably (Fig. 4). These day by day changes in chlorinity could be due to mixing, or tidal entrapment of upstream water, but in all probability they are caused by local discharge of fresh water effluent into the heads of these bays.

The degree of vertical stratification in both temperature and chlorinity was quite small (Figs. 5 and 6). In the Lilli Pilli basin, temperatures and chlorinities of the bottom waters were much more variable at the downstream (Station 4 Figs. 5 and 6), than the upstream end (Station 7 Figs. 5 and 6). Also, temperatures and chlorinities were generally less at the downstream than at the upstream end. This apparently anomolous condition is caused by greater vertical mixing at the downstream end. This problem was given special attention on the 26th and results will be discussed later.

The variation in oxygen content of the Lilli Pilli basin waters is shown in Figure 7. Within the downstream, better mixed region, oxygen values at all depths were much greater than upstream. However, the degree of undersaturation of these bottom waters was small, with a minimum of 87% of the oxygen saturation value at the upstream end of the basin. Surface waters were within 5% of the

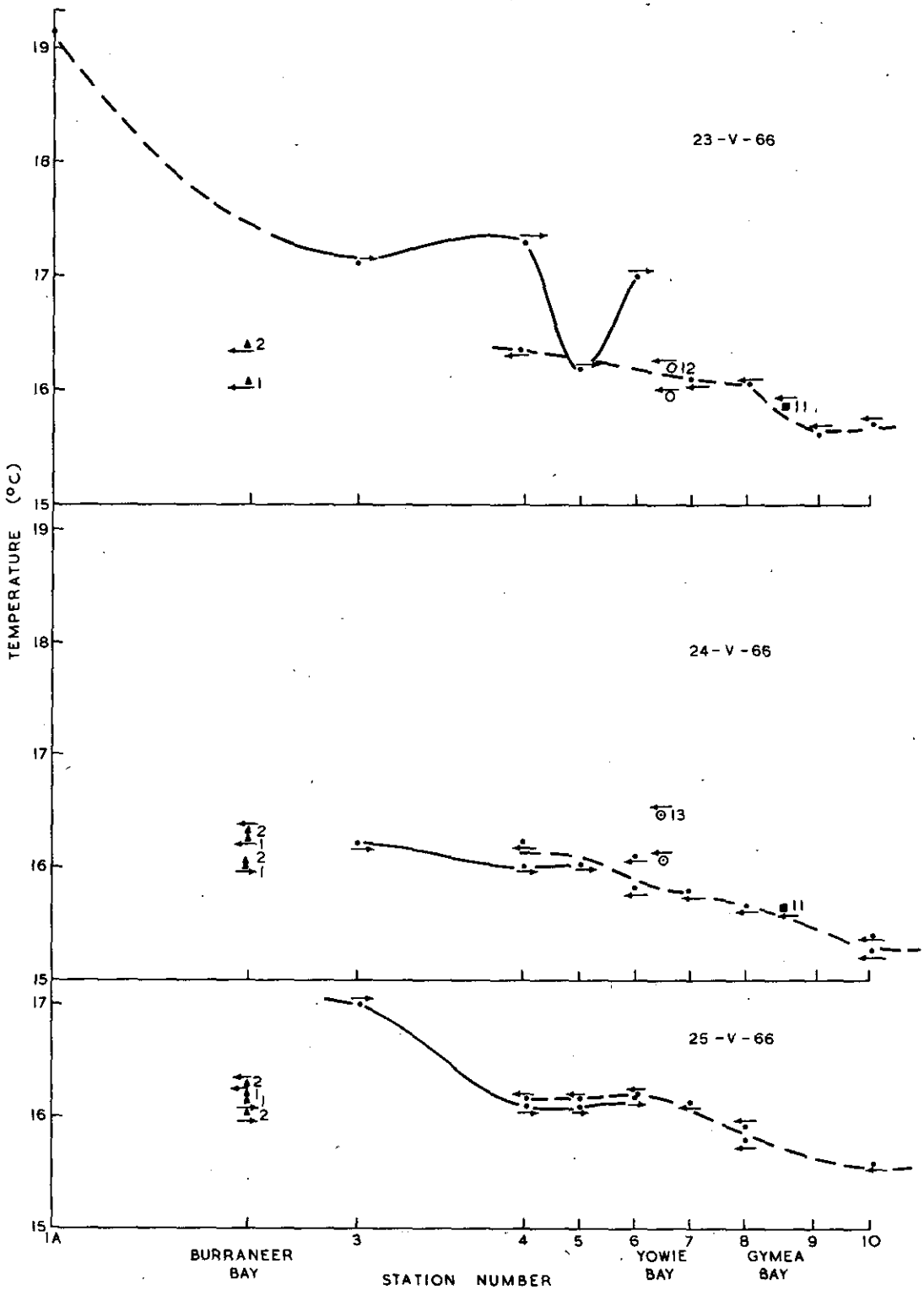


Fig. 3.- Changes in surface temp. (°C) along the main channel ——— Upstream surveys (Tables 2-4) - - - - - Downstream surveys (Table 5) ⟶ Flood tide ⟵ Ebb tide.

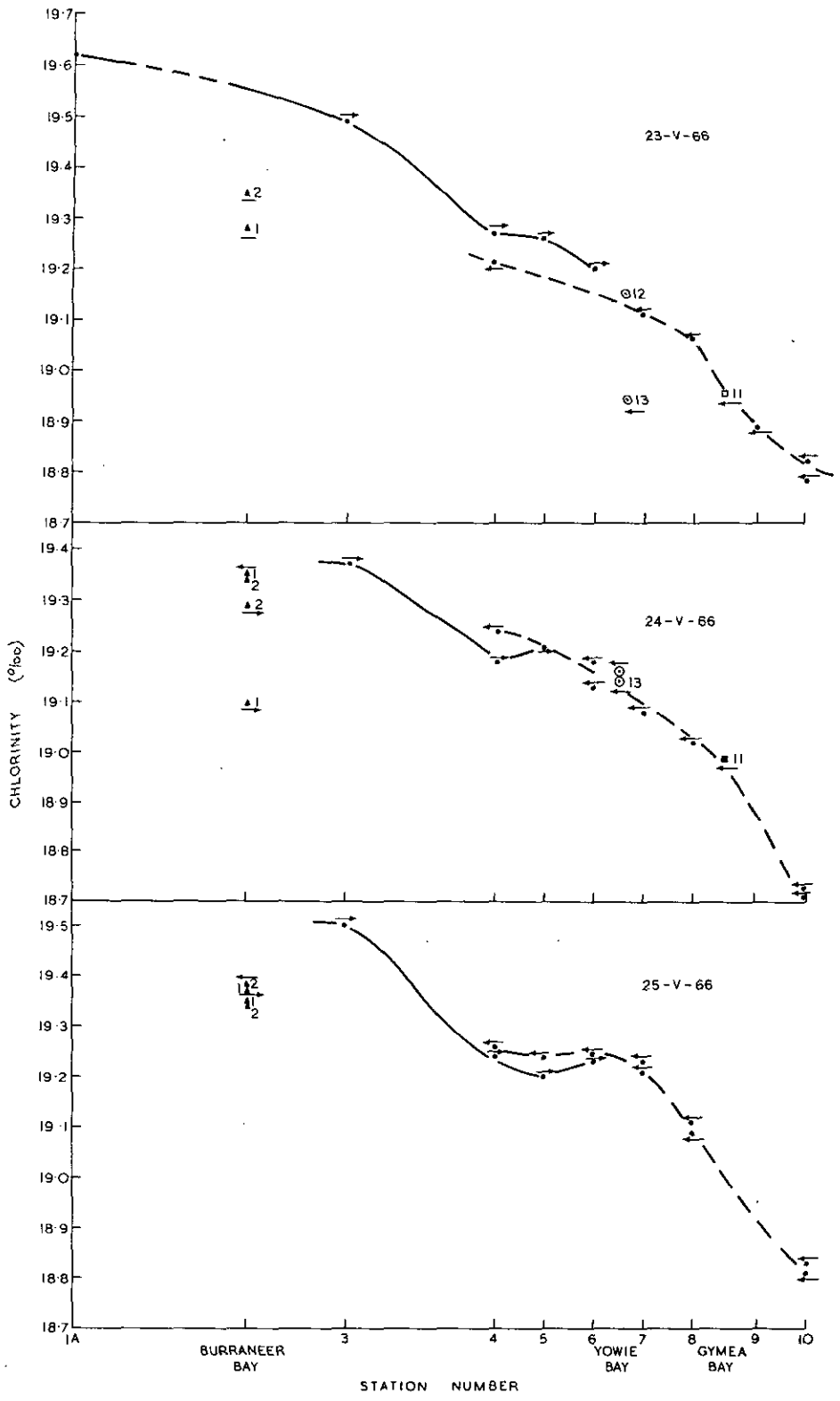


Fig. 4.- Changes in surface chlorinity (‰) along the main channel ——— Upstream surveys (Tables 2-4) ------- Downstream surveys (Table 6) ⟶ Flood tide ⟵ Ebb tide.

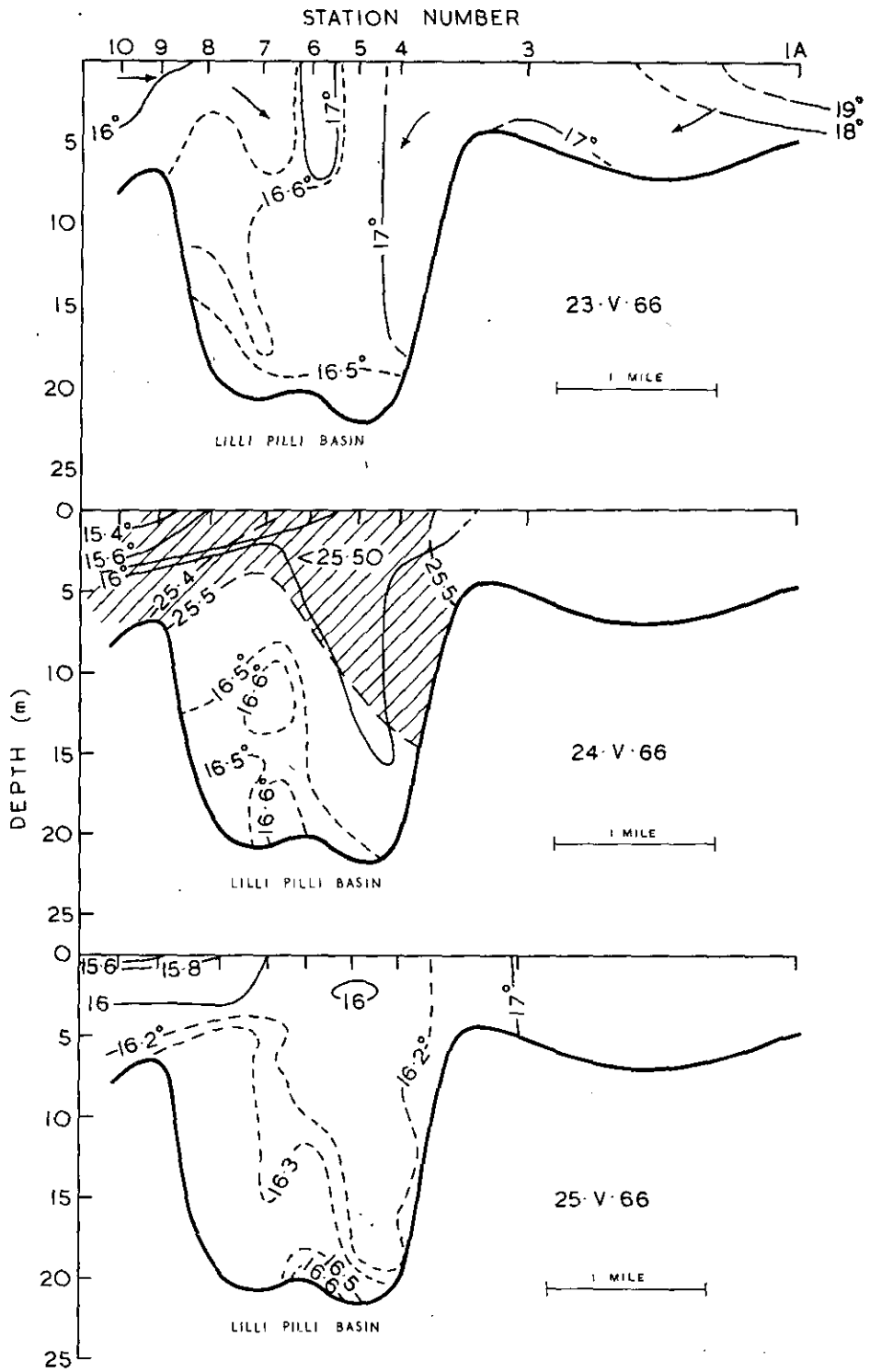


Fig. 5.- Temp. along a mid-channel section 23-25/5/66 (Table 5). On 24/5/66 the water layer with the lowest density ($\sigma_t < 25.50$) has been indicated ⟵ Flood tide Ebb tide ⟶ .

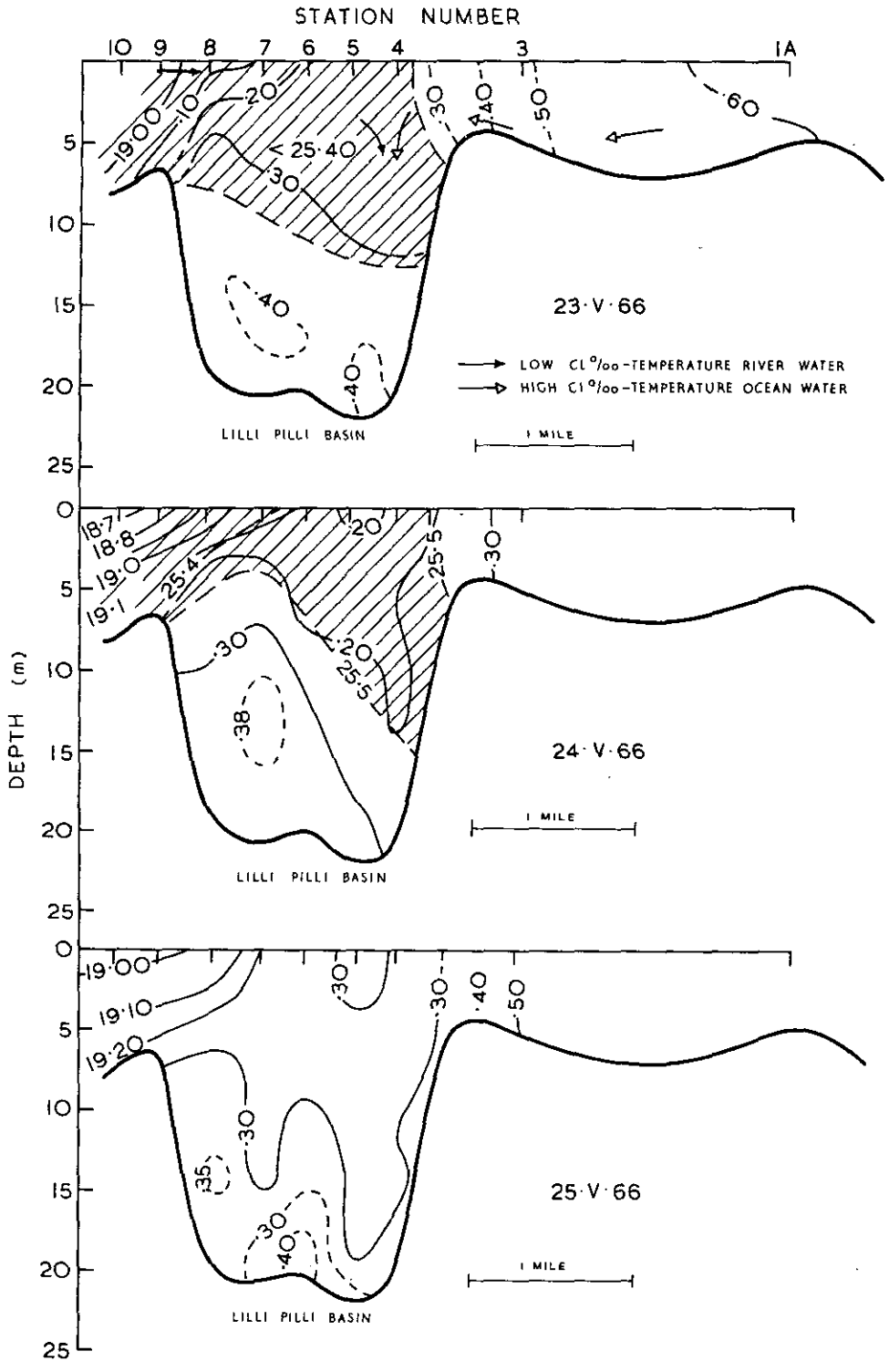


Fig. 6.- Chlorinity along a mid-channel section 23-25/5/66 (Table 6). Cross hatching indicates the extent of waters of $\sigma_t < 25.40$ on 23/5/66, and $\sigma_t < 25.50$ on 24/5/66.

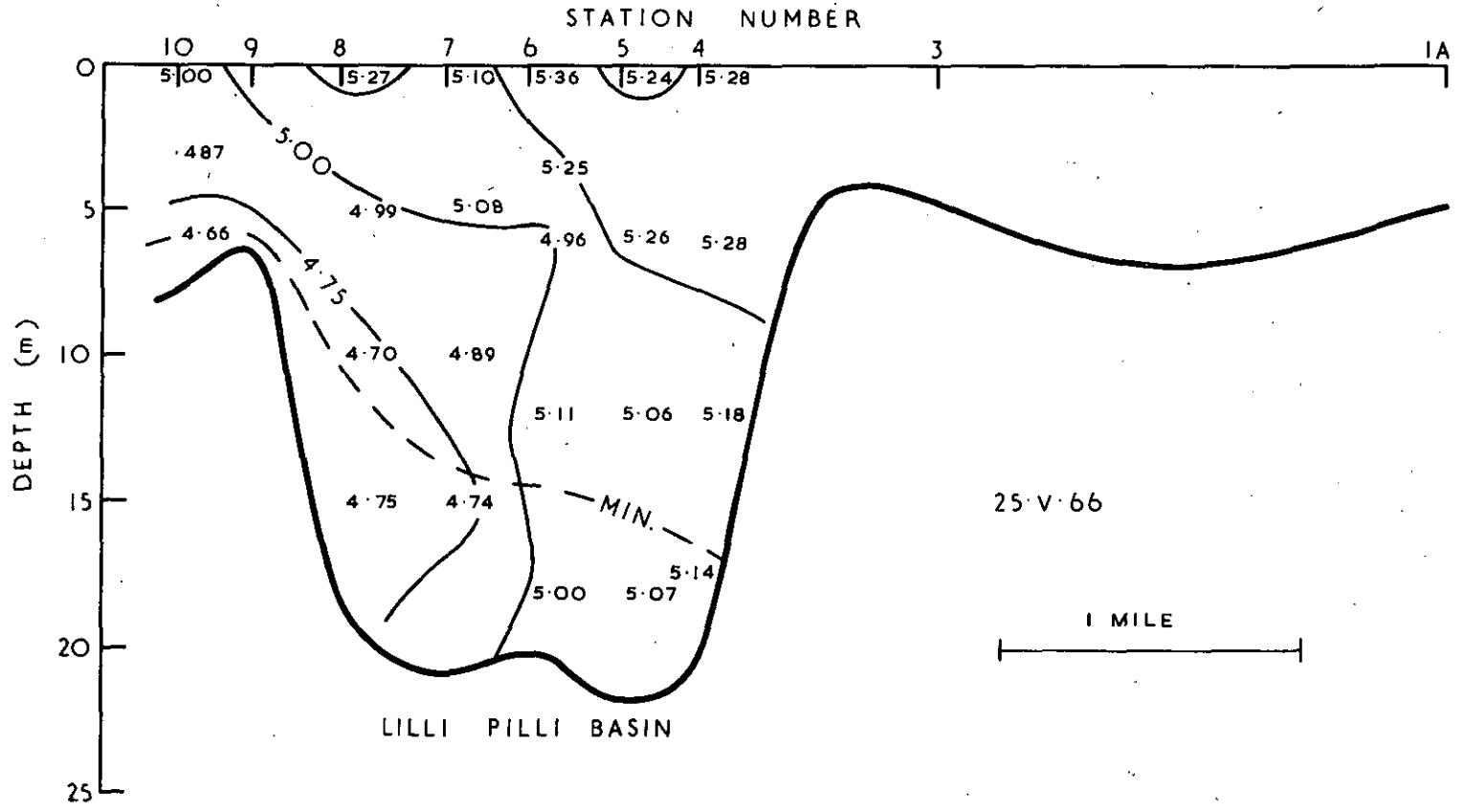


Fig. 7.- Oxygen (ml/l) along a mid-channel section 25/5/66.

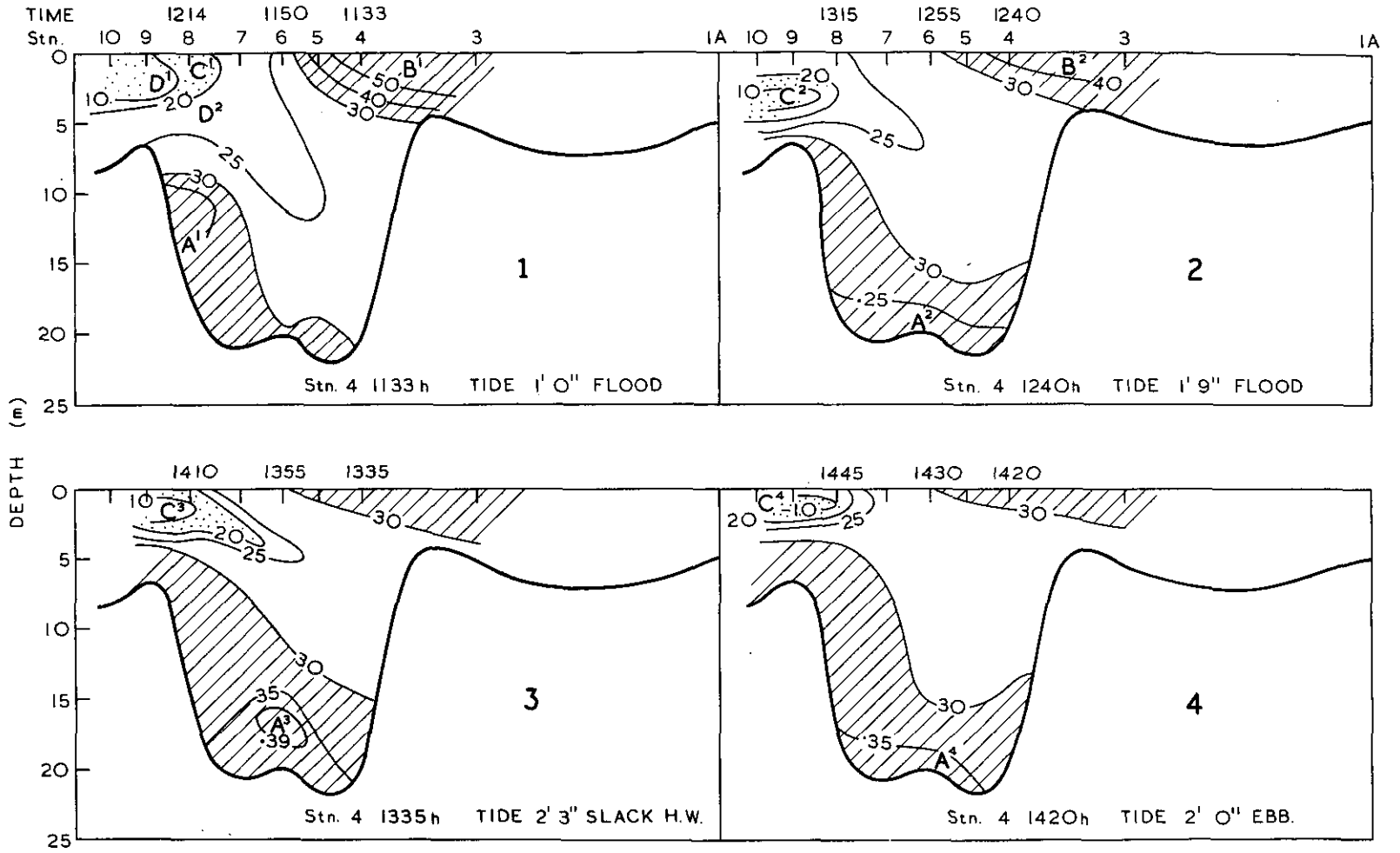


Fig. 8.- Chlorinity changes in Lilli Pilli Basin during 3 hr on 26/5/66. $A^1B^1C^1D^1$ - $A^4B^4C^4D^4$ show the extent of the various water masses derived from Figure 9.

saturation value of oxygen throughout the region examined, except at Station 10 in the Audley River where oxygen values were around 90% of the saturation value.

(c) Changes in basin bottom water

On May 26, profiles of Cl‰ and temperature were obtained at approximately hourly intervals at Stations 4, 6, and 8 along the Lilli Pilli Basin. From these profiles, Figure 8 showing the chlorinity in relation to tide height and phase, and Figure 9 the chlorinity-temperature relations of these basin waters, have been constructed.

Deep basin water remained nearly constant in temperature-chlorinity during the period from 1133h to 1445h (A^1, A^2, A^3, and A^4 Fig. 9), but the 19.30‰ isochlor forming their upper boundary oscillated considerably in depth and position along the basin (Fig. 8). In the early flood phase, the surface water entering the basin from the seaward end was colder and more saline than at any other time (B^1, B^2 Figs. 8 and 9). This water is thought to be formed by cooling of oceanic type water as it spreads across the large expanse of tidal flats which have been uncovered in the early morning ebb tide. Subsequently, however, the surface waters at the seaward end of the basin were always mixtures of river water (C^1-C^3 Figs. 8 and 9), and deep basin water (A^1-A^4 Figs. 8 and 9). During the period 1214h-1445h the temperature of this river water increased some 0.4°C (C^1-C^4 Fig. 9). During the early flood phase and to a limited extent throughout the period, a warmed low chlorinity water below the surface occurred at Station 8 (D^1-D^2 Figs. 8 and 9).

These secondary effects of heating and cooling complicate the interpretation of the changes in temperature and chlorinity of these basin waters in terms of tidal displacement and mixing. However, considering only the deep basin water of temperatures between 16.4 and 16.6°C and chlorinity greater than 19.30‰, it is thought that some form of tidal energized displacement of these waters out of the main basin into the adjoining bays (e.g. Yowie Bay) occurs during the period of maximum flood tidal velocity and a return movement into the basin some time after the diminution of this flood velocity maximum (c.p. A^1 and A^3 Fig. 8).

(d) Water type components

From the chlorinity-temperature relations of Port Hacking estuarine waters (Fig. 10) at least three water types were present during 23-25/5/66. These were - an oceanic water type of chlorinity around 19.70‰ and temperature around 19°C (3 Fig. 10), a deep basin water type of chlorinity around 19.40‰ and temperature around 16.5°C (2 Fig. 10), and a river water type of chlorinity around 18.80‰ and a temperature around 15.75°C (1 Fig. 10).

On the 23rd and during a preliminary survey on the 12/5/66 (Table 1) there was apparent evidence of direct mixing between oceanic and river water, but considering the effects of diurnal

heating and cooling (Fig. 9), it is more likely that the mixing was predominantly between water types 1 and 2, upstream of Lilli Pilli Point, and between 2 and 3 downstream of this point. On this basis Figure 11 has been constructed to show the average (23-25/5/66) high water composition of the Port Hacking estuarine waters. It is noteworthy that the Burraneer Bay waters from surface to bottom are the same as the deep water of the Lilli Pilli basin. The oceanic intrusion into this Bay must therefore be quite small. Within the Lilli Pilli basin the deep water type was confined to the upstream end (Fig. 12) and mixing of the type investigated on the 26th (Fig. 8) was continually diminishing its extent.

In bays such as Yowie and Burraneer, however, this deep basin water type probably mixes only very slowly with the main tidal circulated channel waters.

V. CONCLUSIONS

In future schools, particular attention should be given to the type of circulation and mixing (e.g. wind, tidal, seiche) that occurs in bays such as Burraneer and Gunnamatta.

The use of a number of boats of small enough draught to navigate all parts of the estuary at mid-tide level would be desirable. Continuous observations at fixed positions in deep water (e.g. Lilli Pilli jetty) over 24 - 36 hr would also add greatly to the hydrological value of such a semi-synoptic survey.

VI. REFERENCES

CSIRO AUST. (1966).- Oceanographical observations in the Indian and Pacific Oceans in 1961. H.M.A.S. Gascoyne Cruise G2/61. CSIRO Aust. Oceanogr. Cruise Rep. No. 10.

HAMON, B.V. (1956).- A portable temperature-chlorinity bridge for estuarine investigations and seawater analysis. J. scient. Instrum. 33: 329-33.

ROCHFORD, D.J. (1951).- Studies in Australian estuarine hydrology. I. Introductory and comparative features. Aust. J. mar. Freshwat. Res. 2: 1-116.

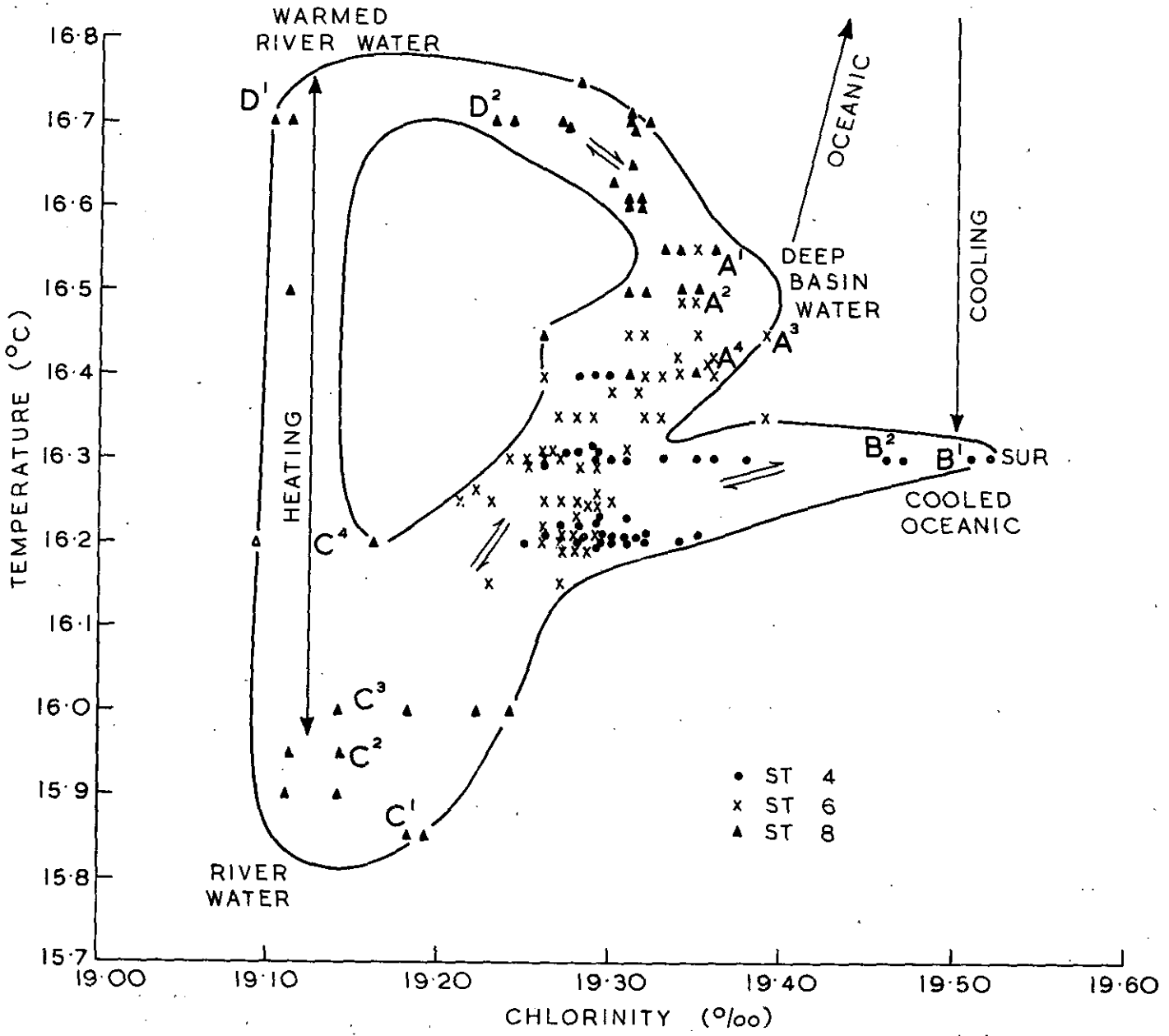
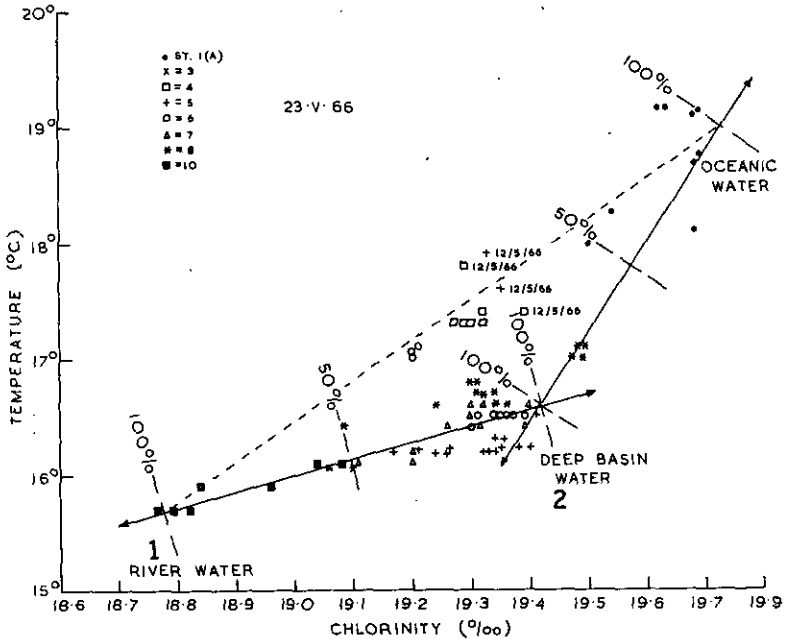
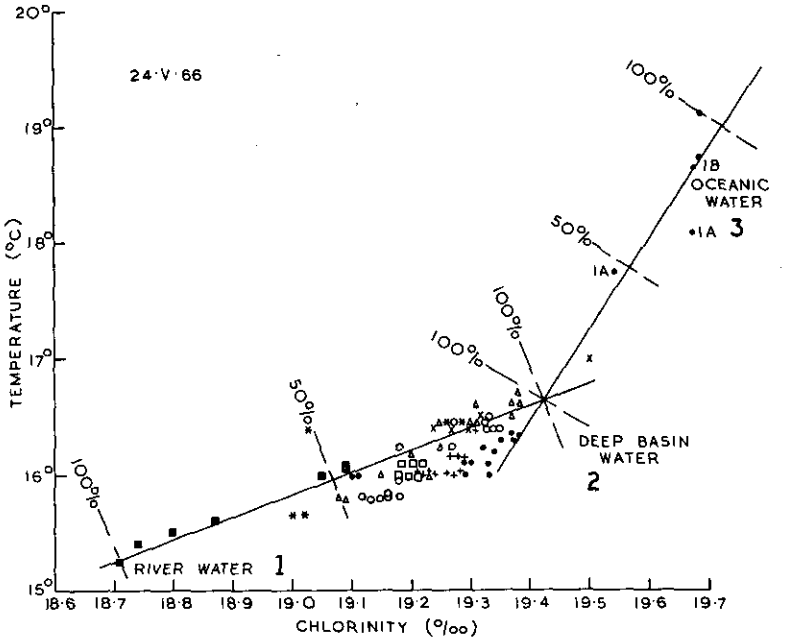


Fig. 9.- Chlorinity-temp. relations in Lilli Pilli Basin 26/5/66. $A^1B^1C^1D^1$ - $A^4B^4C^4D^4$ water masses of Figure 8.





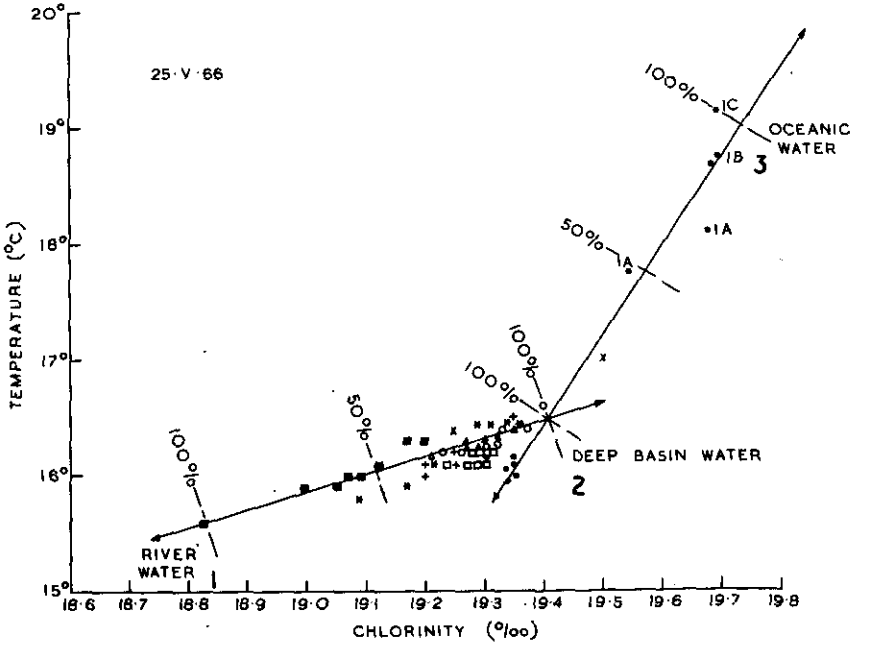


Fig. 10.- Chlorinity-temp. relations in Port Hacking. The % values show the extent of mixing between the three main water masses.

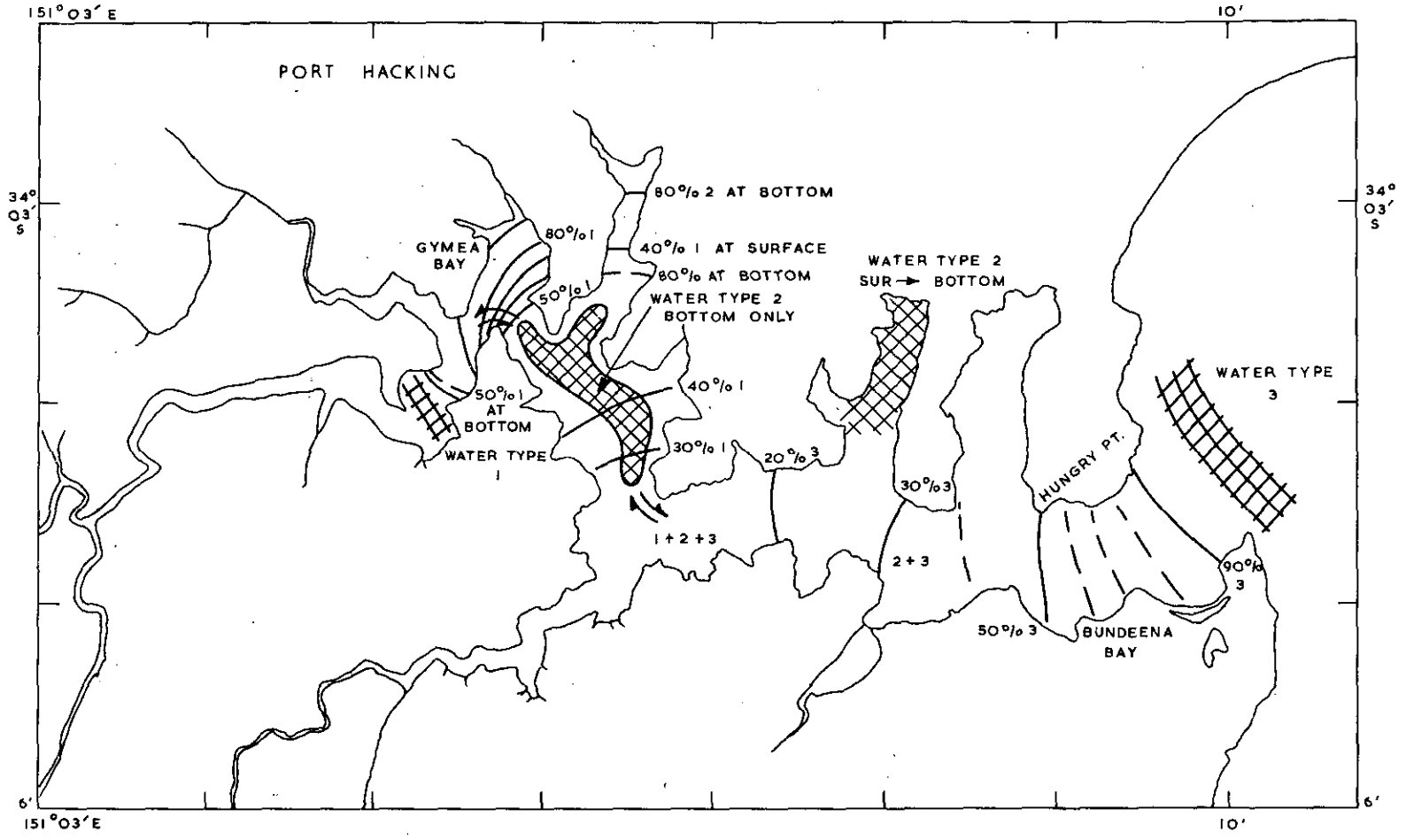


Fig. 11.- Percentages of the three main water masses in Port Hacking 23-25/5/66.

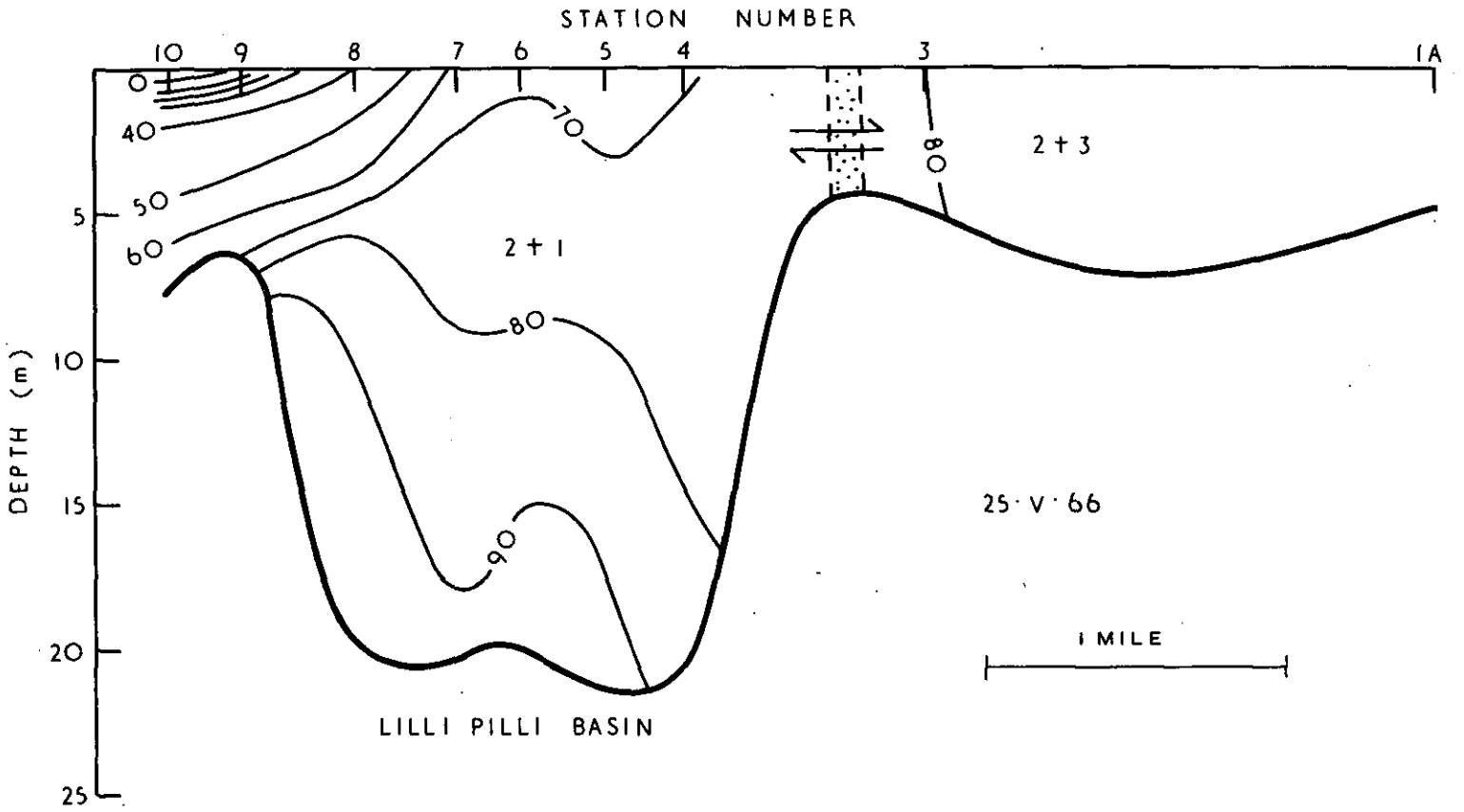


Fig. 12.- Percentages of the three main water masses in Lilli Pilli Basin 25/5/66.

PHYSICAL CHEMISTRY

I. INTRODUCTION

All chemical reactions involve a re-shuffling of electrons in the reacting molecules. The availability of electrons within a chemical system will dictate the compounds that are formed from the elements present. In aqueous solutions the hydrogen ion (H^+) is always present. The effective concentration of H^+ exerts a control over the stability of compounds within a chemical system. Hydrogen ions and electrons are therefore constituents that are universally present in natural systems and together they control the courses of chemical reactions. Electrochemical methods can be used to measure the effective concentrations of these constituents. The quantities measured are the Eh and the pH. The pH gives a direct estimate of the availability of hydrogen ions. The Eh is related to the pH and to the electron availability by the equation,

$$Eh = E_{redox} - \text{const. pH}$$

E_{redox} is a measure of the electron availability and the constant depends on the temperature and the nature of the reactions occurring in the system.

In stagnant conditions, Eh/pH measurements may be used to define regions of different chemical activity in a complex environment. The regions delineated in this way will differ in the energy sources they provide for micro-organisms. The method should therefore be useful in studying the ecology of organisms living in the sediment.

In this case, the chemical environment on a sand flat was studied by measuring the Eh and pH of sand samples taken with a hand-corer. The field data were supplemented by chemical analysis of selected samples and by preparing bacterial cultures from the interstitial water. Models were set up in the laboratory to test the hypotheses suggested by the raw field data.

II. METHOD

A Cambridge portable nul-balance pH meter was used to measure the emf's of cells made up of platinum or glass electrodes inserted in the sand, with a saturated calomel electrode as a reference standard. The calomel electrode was connected to the sample by a porous pot liquid junction. The platinum/calomel cell was used to measure the oxidation-reduction potential (Eh) of the sample and this electrode pair was calibrated in a ZoBell ferro-ferricyanide buffer at the end of each day's readings. The pH was measured with a glass electrode/calomel pair which was standardised against a seawater buffer (pH 8.2) between each set of readings. A second calibration using standard phthalate buffer (pH 4.01) was carried out at the end of each day's work to ensure that the glass electrode

was maintaining its theoretical pH response. The electrodes were washed in seawater between each set of readings and the platinum electrode was frequently cleaned with fine crocus cloth.

The samples were taken from specified positions on the sand flat using a hand-corer. The length of core, positions for electrode readings, time of coring, and temperature, were noted, and a brief description of significant features of the core was recorded. The core was then carried on a plastic sheet to the measuring station and the electrodes were inserted immediately. Readings were usually completed within ten minutes of sampling. The fragility of the galvanometer in the pH meter made it impossible to make the measurements at the sampling site.

Limitations of the method.- The sample was exposed to air-oxidation from the time the core was extruded onto the plastic sheet; this was accentuated by introducing air into the centre of the core as the electrodes were inserted. Although oxidation was minimised by rapid handling of the sample and careful use of the electrodes there was no way of estimating its effect on Eh and pH with the equipment available. The complexity of the chemical systems maintaining the Eh and pH balance made it difficult to determine the equilibrium values of electrode potentials, a slow drift in potential being observed for several hours after the insertion of the electrodes. Laboratory tests using a potentiometric recorder indicated that results consistent and reproducible to ± 30 mV could be obtained under the field conditions if the emf's were measured three minutes after the insertion of the electrodes.

The maximum core length obtainable was 8 or 9 inches.

III. RESULTS

(a) Field data

Transects A, B, & C (Fig. 1) were sampled at 30 ft intervals on the first day (Table 1). No gradation in pH was observed. Transect A showed a slow decrease in Eh down the beach but transects B & C showed a marked decrease in Eh in the vicinity of the Zostera bed (or creek). This was the most significant feature in the Eh profile; only a slow downward drift in Eh being noted further up the beach (see Figs. 2-4).

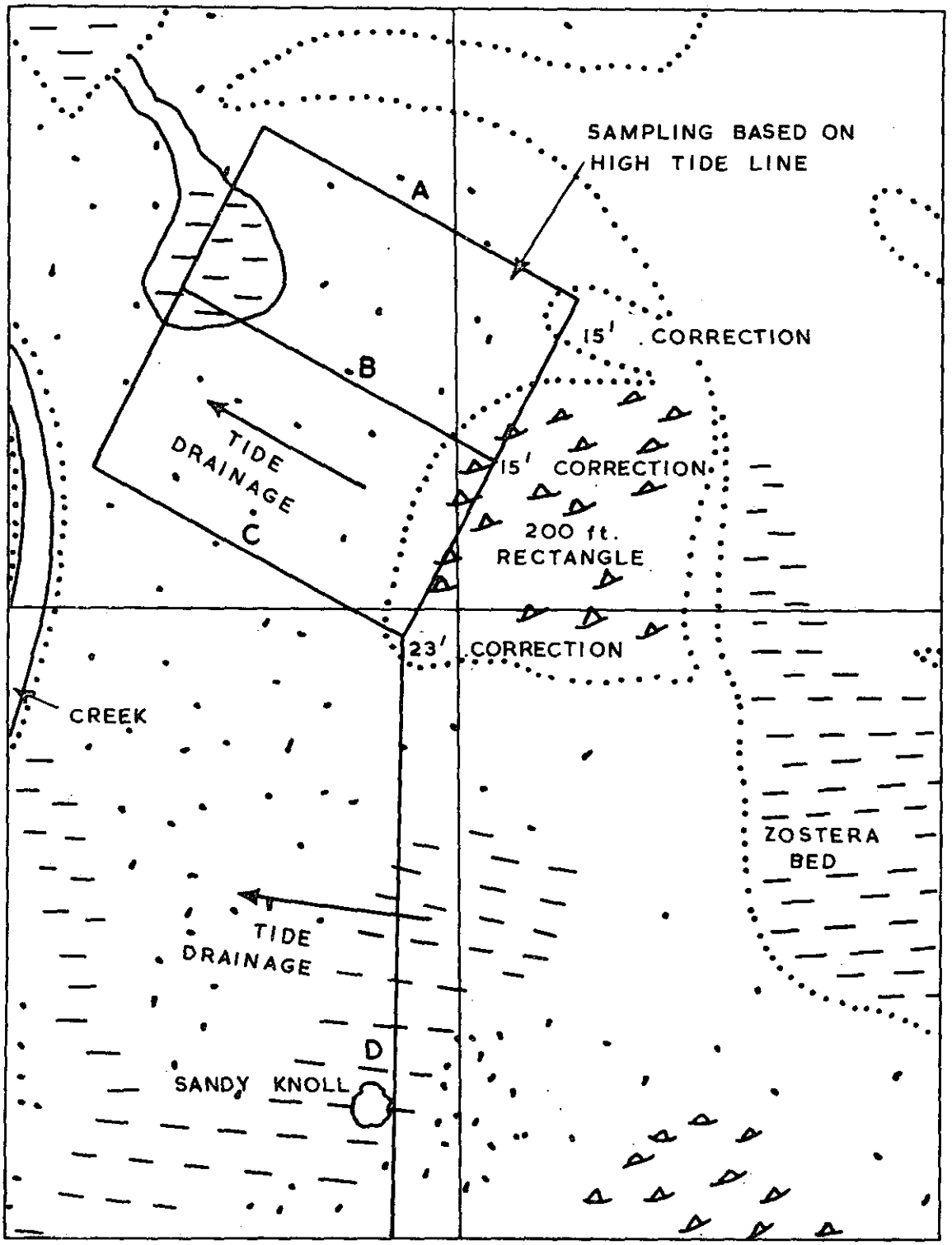


Fig. 1.—Sampling area.

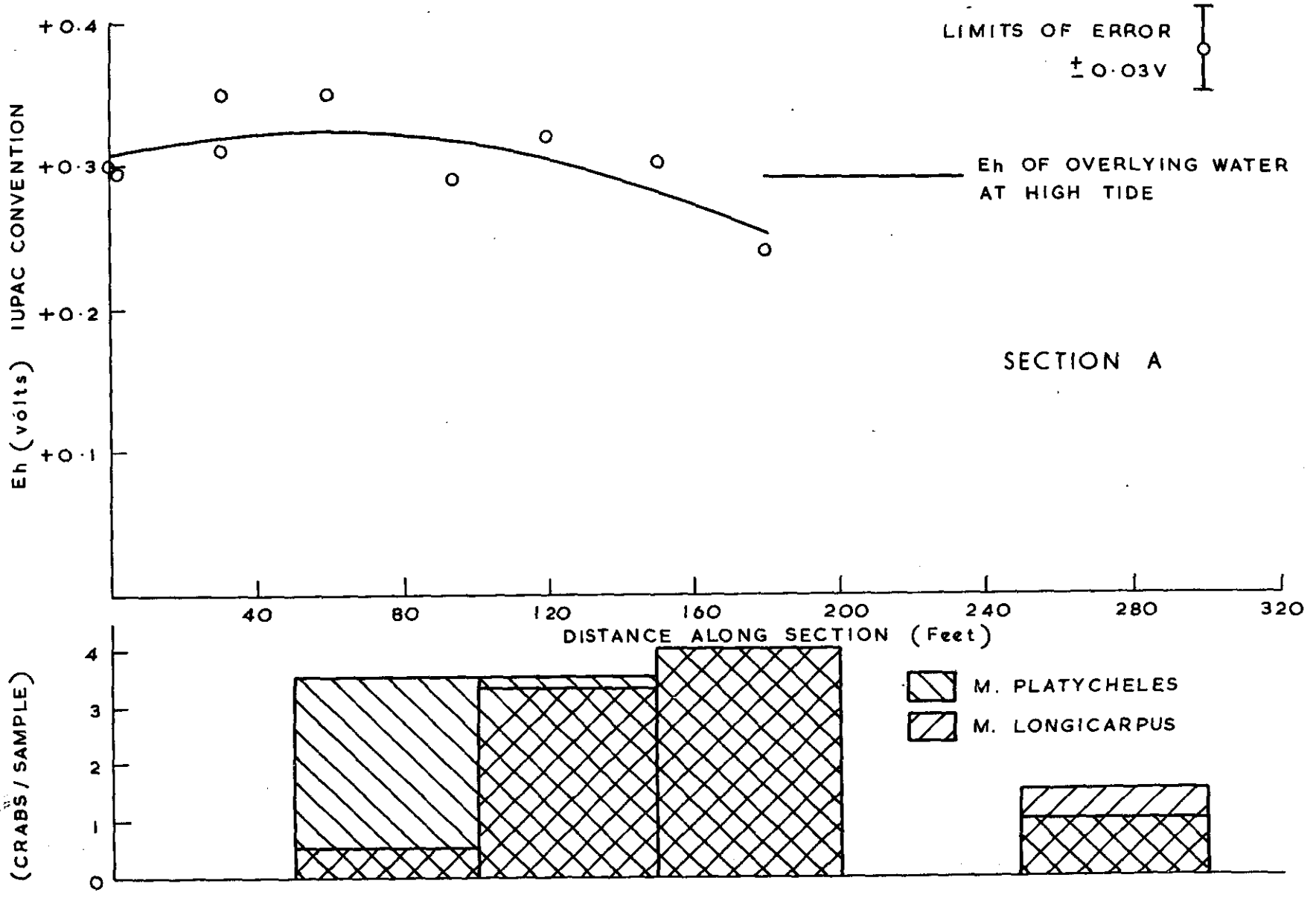


Fig. 2.—Section A.

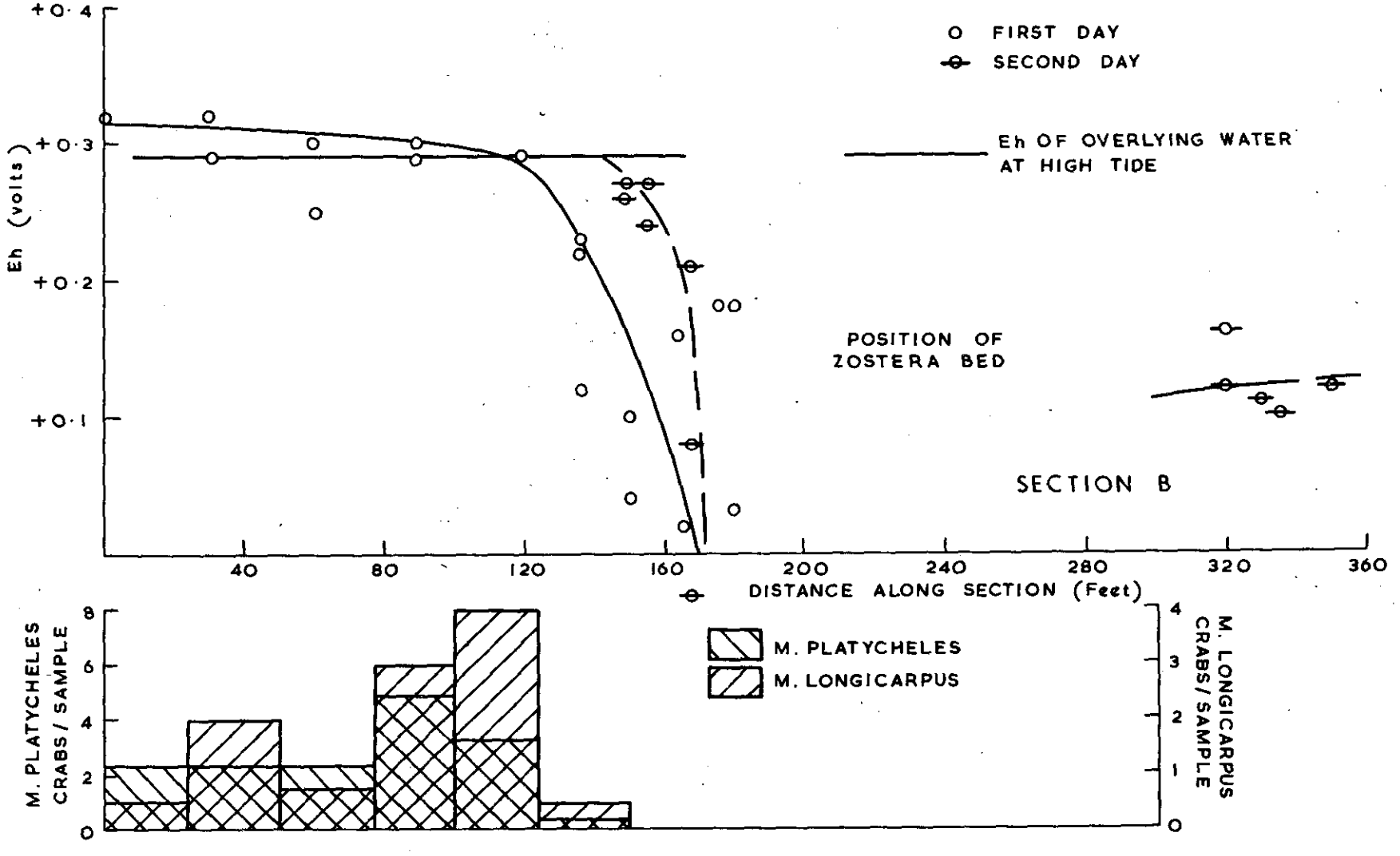


Fig. 3.—Section B.

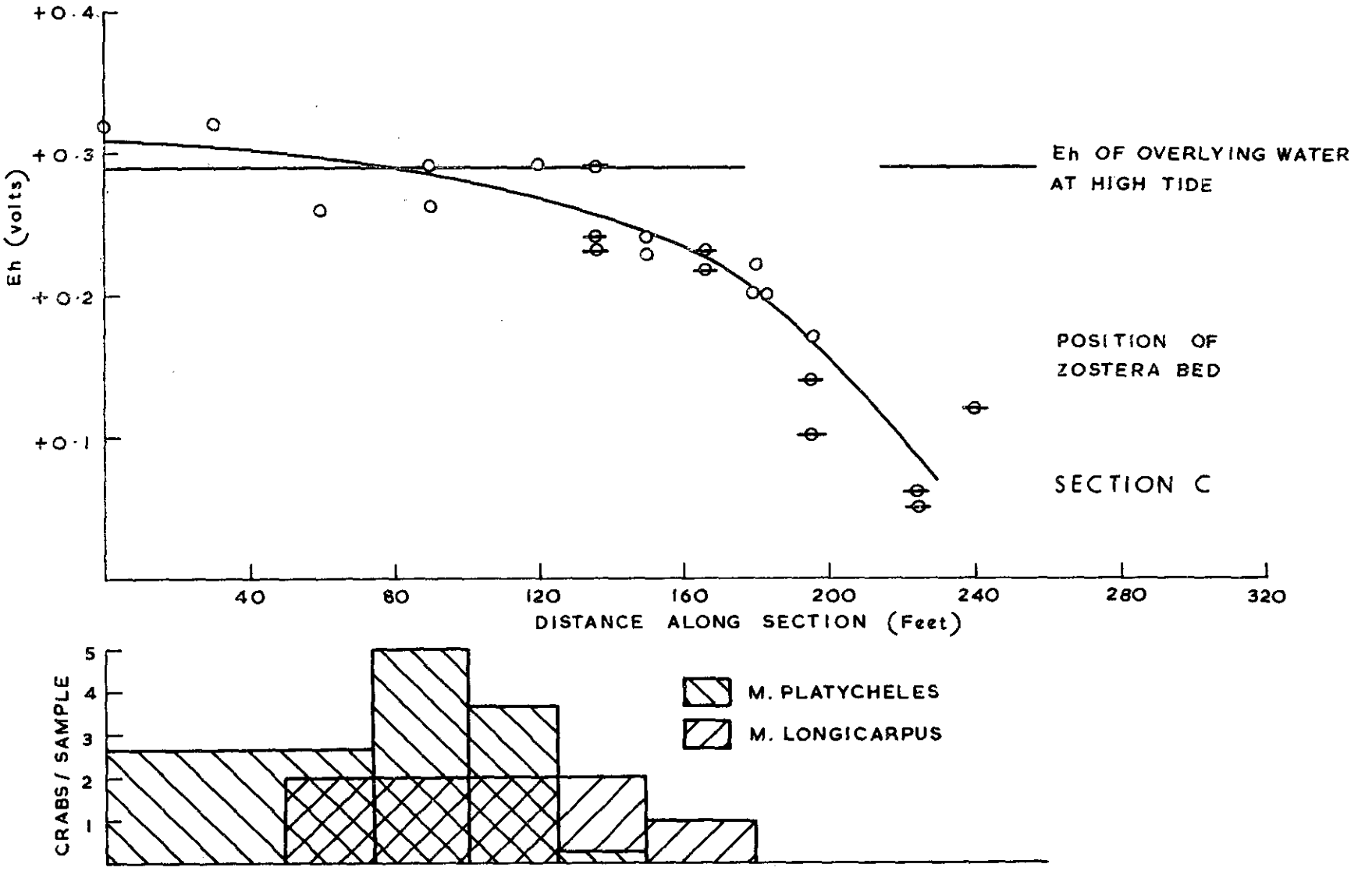


Fig. 4.—Section C (omitting beaker samples).

TABLE 1

FIELD DATA

Transect	Distance* down beach (ft)	Depth of Sample (in.)	Length of core (in.)	Eh (volts)	pH	Temp. °C	Time core taken
A 23/5/66	0	1.5 3.5	6	0.30 0.30	8.1 8.2	15	12.14
	30	1.5 4	5.5	0.31 0.35	8.0 8.0	15	1.50
	60	3	6	0.35	8.1	15	2.00
	90	3	5.75	0.29	8.1	15	2.06
	120	3	6	0.32	8.1	16	3.02
	150	2.5	5.5	0.30	8.1	15	3.08
	180	4	7.5	0.24	8.1	16	4.20
B 23/5/66	0	2	4.75	0.32	8.1	16	12.30
	30	1 3	5	0.32 0.28	8.1 8.0	16 16	1.45
	60	2.5 7.25	7.5	0.29 0.25	8.0 8.1	16	2.15
	90	2 6	8	0.29 0.28	8.1 8.0	16	2.20
	120	3.5	7	0.28	8.1	16	2.58
	135	1 4 7	7.5	0.23 0.22 0.12	8.0 8.0 8.1	16	3.22
	150	1.5 7	7.5	0.10 0.03	7.9 8.0	16	3.15
	165	0.5 5 8	9	0.16 0.02 0.05	8.0 8.0 8.0	16	4.05
	180	0.5 3 6	7	0.03 0.18 0.18	8.0 8.0 8.0	16	4.11
C 23/5/66	0	2.25	5.75	0.32	8.3	16	12.52
	30	3	7.5	0.32	8.1	15	12.58
	60	3	6.5	0.25	8.0	16	2.35
	90	1 4	7.5	0.25 0.28	8.0 8.1	16	2.42
	120	3	7.5	0.28	8.0	16	2.47
	150	1 6	7	0.23 0.24	8.0 8.0	16	3.52
	180	1.25 4 8	9	0.20 0.22 0.04	8.0 8.0 8.0	16	3.55

TABLE 1 (Cont'd...)

Transect	Distance* down beach (ft)	Depth of Sample (in.)	Length of core (in.)	Eh (volts)	pH	Temp. °C	Time core taken
B 24/5/66	150	3	6	0.26	8.0	15	3.07
	156	2	6	0.27			3.13
		5		0.23			
	168	1	8	0.22			3.15
		4		0.08			
		6		-0.03			
	320	1	8	0.12			4.13
		7		0.16			
	335	0.5	7	0.10			3.56
		6		0.11			
	350	3	6	0.12			3.53
C 24/5/66	120	3	8	(0.16)		15	3.18
		6		(0.09)			
	135	0.5	7	0.24		15	3.23
		3		0.24			
		6		0.28			
	165	1	8	0.22			3.31
		6		0.23			
	195	1	9	0.10			3.40
		6		0.17			
		8		0.14			
	225	1	8	0.06			4.17
		5		0.05			
Beaker samples	240	1	8	0.12			4.20
		4		0.08			
		8		0.16			
	255	1	6	0.19			4.34
		6		0.22			
	315	1	6	0.20			4.41
Seawater				0.29	8.2		11.23
Zostera bed water				0.28	8.2		12.7
Surface mud of *Zostera* bed				0.14	8.1		12.19

TABLE 1 (Cont'd...)

Transect	Distance* down beach (ft)	Depth of Sample (in.)	Length of core (in.)	Eh (volts)	pH	Temp. °C	Time core taken
D 25/5/66	0	3	6	0.32			3.40
	60	3	4	0.30			3.43
		4	8	0.18			3.46
		7		-0.03			
	120	1	8	0.01			3.50
		7		0.09			
	165	1	7	0.09			3.55
		6		0.13			
	180	1	9	0.08			4.11
		4		0.10			
		8		0.20			
	180	1	7	0.08			4.15
		6		0.10			
	180	1	8	0.17			4.23
		7		0.10			
	240	1	7	0.13			4.29
		6		0.16			
	300	1	7	0.40			4.38
		6		0.40			
	360	1	9	0.15			4.46
		5		0.27			
		8		0.42			

* From high tide line.

Samples of sand were taken at 0, 140, and 160 ft down the beach from transect B, and interstitial water was taken from 140 and 160 ft for the preparation of bacterial cultures. All distances down the beach are measured from the high water mark.

In order to study the effects of vertical drainage on the beach, two open ended perspex cylinders 6 in. in diameter and 1 ft long were sunk vertically into the sand until their rims were just visible on the surface. One (α) was sited at 140 ft and the second (β) at 160 ft on transect B. The cylinders cut off a section of the sand from horizontal contact with surrounding material but allowed vertical drainage through the sand column.

On the second day the sharp Eh drop in transects B & C was re-investigated and wherever possible the transect was continued beyond the Zostera bed. Because of the late tide, only a few samples could be taken but these confirmed the Eh drop and

indicated that the Eh profile was asymmetrical about the Zostera bed in section B. The Eh 'front' had moved some 20 ft down the beach in this section (see Fig. 3).

Samples of surface material were taken from transect B for moisture content analysis (Fig. 8).

The sharp front on the landward side of the bed and the gradual Eh tail-off on the seaward side could be explained by considering the tidal drainage down the beach as the major oxidising influence and the seepage of organic material from the Zostera bed as the major reducing influence. The tide drains across the bed so that on the landward side these effects are in opposition causing a sharp differentiation between oxidised and reduced regions and on the seaward side they work together to produce a more diffuse less highly reduced deposit.

To check this hypothesis, measurements were made in a region of reduced mud produced by intermittent run off from another Zostera bed (transect D, Fig. 1). In this case the tide drained in the same direction as the run-off and so a more symmetrical Eh profile would be expected. A symmetrical pattern was observed in the top 5" of sand (Fig. 5) but an irregular pattern was found at greater depths. This irregularity was caused by the shallowness of the reduced layer (Fig. 6) and by the presence of a deeper layer of highly reduced material isolated from the surface bed.

The perspex cylinders buried on the first day were uncovered and their contents compared with the surrounding mud. The contents of the α - cylinder at 140 ft were almost completely oxidised whereas the surrounding sand was in the same condition as was observed on the first day (Table 1). In the case of the second cylinder, the bulk of the material was unchanged although the thin oxidised surface layer was slightly deeper inside the cylinder ($\frac{3}{4}$ in. deep cf. $\frac{1}{2}$ in. outside). On the second day the 'reduced front' in this region had moved some 20 ft down the beach and during this change the material in the first cylinder would be oxidised whereas that in the second cylinder would be unaffected. On the third day when the front had apparently moved back up the beach the material in the first cylinder was cut off from the supply of reduced material and therefore remained oxidised. This indicates that the transport of reduced material is mainly by horizontal movements in the sand whereas oxidation occurs largely as the result of vertical drainage down through the sand column.

(b) Model data

Laboratory models were set up to supplement the field observations. A model beach was made by dividing a plastic tray (14 in. x 28 in. x 3 in. deep) into five segments $5\frac{1}{2}$ in. x 14 in.

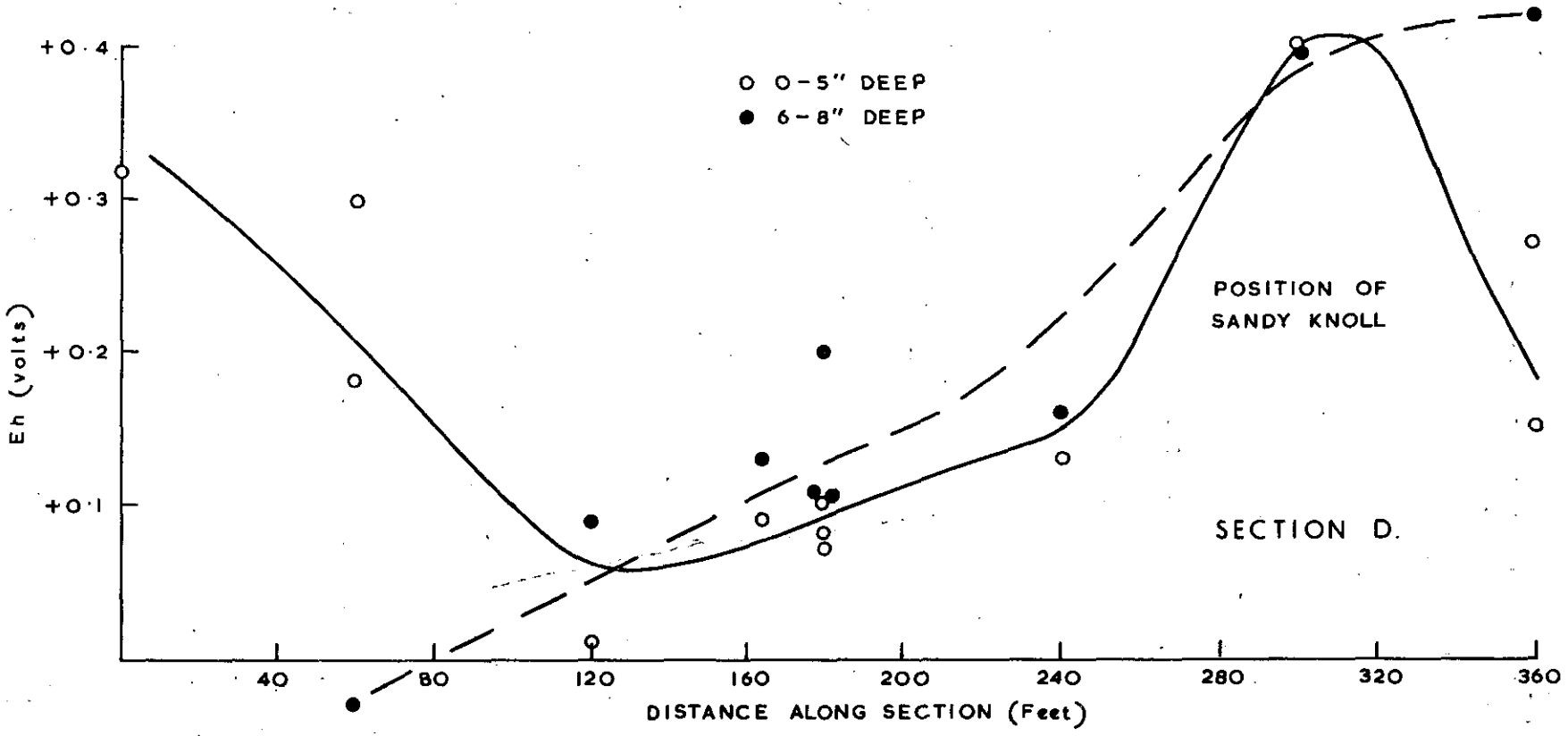


Fig. 5.—Section D. Variation in Eh with depth.

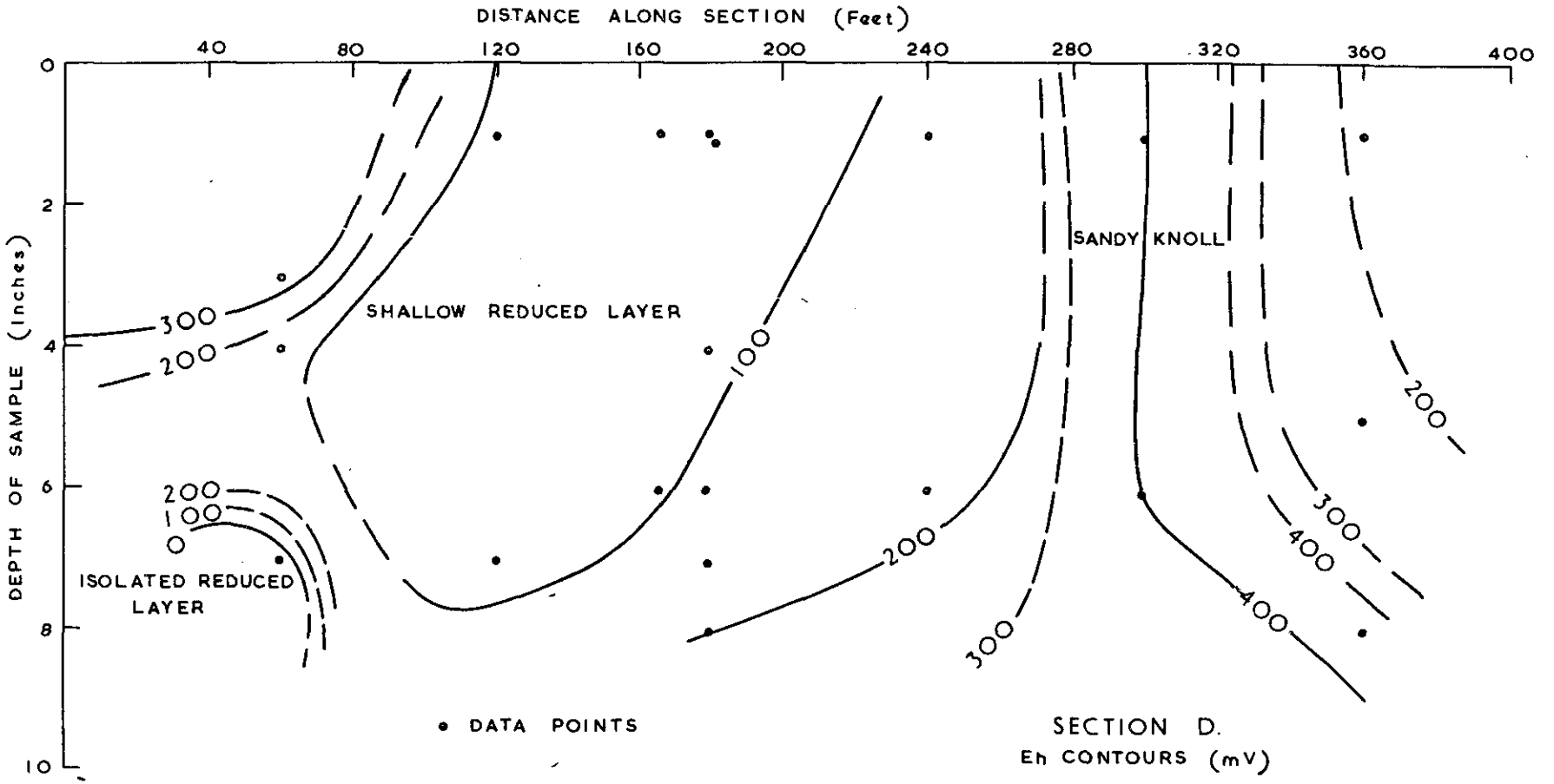


Fig. 6.—Section D. Eh contours.

long using perspex partitions 1½ in. high. Each segment was filled with sand and the tray was tilted so that the segments formed sand strips running up and down the slope. A water inlet and siphon outlet were adjusted so that a regular 'tide' washed up and down the sand strips. Mechanical difficulties limited the tidal period to 3 to 5 hours and the unit was allowed to run continuously for two days. Two strips each of 140 and 160 ft sand were used with one central strip of sand from the high tide level. Horizontal contact between the different regions was prevented by the perspex partitions but all strips were interconnected by seawater at high tide. This model was designed to indicate the kind of Eh profile that would be encountered on a beach that was not under the influence of a source of decaying organic material (e.g. the Zostera bed).

The Eh of the beach was measured at various points using the field electrodes and the pH meter. The model yielded uniform Eh profiles in all five segments after two days operation. The profile showed a gradual increase in the extent of oxidation as the beach was traversed from the high tide line to the low water level. The gradient was therefore in the opposite sense to that found in transect A on the sand flat and no sharp Eh discontinuities were observed. This result gave further weight to the hypothesis that the Zostera bed was exerting a considerable influence on the Eh balance of the sand flat.

Two columns were made of the low Eh material from 160 ft to study the significance of vertical drainage and photosensitive oxidation. The sand was packed into glass tubes about 1 inch in diameter and 30 inches long. The bottom of each tube was plugged with cotton wool and was provided with a tap to control the rate of water flow. Half of the circumference of each column was covered with black tape for about 3 inches down from the mud/water interface to cut out the light and the uncovered portion was turned towards the window. The columns were clamped vertically and left to develop for two days; one with freshwater and the other with seawater flowing through at the rate of 1 l. per hr.

The seawater column showed preferential oxidation on the surface exposed to the light. No such photosensitive oxidation was observed in the freshwater column. The Eh at various points in the column was measured with a fine platinum probe: the calomel reference electrode being dipped into the water layer above the sand column. The emf of the cell was amplified by an electrometer and the amplified signal fed to a potentiometric recorder. Using this combination of a fine probe and a sensitive recorder it was possible to measure the difference in Eh between the light and dark sides of the seawater column (20 - 25 mV).

(c) Chemical analysis and bacterial culture experiments

Mr Dal Pont kindly provided us with analytical data for sand samples taken at the surface at 10, 135, and 160 ft on transect B (Table 2).

TABLE 2

CHEMICAL ANALYSIS OF SAND SAMPLES - SECTION B

Distance down beach (ft)	Salt	Carbonate	Organic matter	Ash	Fe	Mn	S
0	0.78	29.0	0.20	20.3	0.10	Trace[+]	0.08
135	1.81	50.6	0.97	46.8	0.12	"	-
160	3.26	64.7	2.72	29.2	0.20	"	0.50

[+] about 1/100 of concn. of Fe.

All values in weight % of ovendried sample.

The material at 160 ft showed a marked increase in the amount of organic matter, iron, and sulphur compared with the other two samples. Iron and sulphur metabolising bacteria might be expected in this region although the trace quantities of manganese make the appearance of manganese utilising bacteria unlikely. The large proportion of carbonate even in the reducing material probably contributes to the uniformity of the pH in the interstitial water. Bacterial culture plates were made from inoculations of interstitial water taken at 180 ft and repeat cultures were made from interstitial water taken at 140 and 160 ft. The incubation was carried out for three days under a variety of pH, oxygen access, and light conditions using a sulphur based medium with some enrichment of iron or manganese (see Tables 3 and 4).

TABLE 3

MEDIA USED IN BACTERIAL CULTURE EXPERIMENTS

9K Basal Medium

$(NH_4)_2SO_4$	3.0 g
KCl	0.1 g
K_2HPO_4	0.5 g
$MgSO_4.7H_2O$	0.5 g
$Ca(NO_3)_2$	0.01 g
Distilled water	to 200 ml

Set with Agar

Energy source : $FeSO_4.7H_2O$ (300 ml of 14.7% w/v solution) or equivalent quantity of $MnSO_4$

Basal medium enriched with thiosulphate for sulphur metabolising bacteria.

TABLE 4

RESULTS OF BACTERIAL CULTURE EXPERIMENTS - SECTION B

Position of sample	$MnSO_4$		$S_2O_3^{2-}$		$FeSO_4$		Conditions
	pH 7.0	pH 8.5	pH 7.0	pH 8.5	pH 7.0	pH 8.5	
140'			*	*	/	/	Aerobic, Dark
			*	*	/	/	Aerobic, Light
			*	*	/	/	Aerobic, Dark
160'			*	*			Aerobic, Dark
			*	*			Aerobic, Light
			*	*			Aerobic, Dark

* Indicates bacterial cultures observed.

/ No plating experiments.

The iron enriched culture plates had oxidised before the repeat cultures were made. Sulphur metabolising bacteria were found under all conditions but there was no evidence for the growth of iron or manganese utilising bacteria.

Eh field data are shown in Figure 7 on an Eh/pH plot. The boundaries representing the limits so far observed in the natural environment are drawn together with the boundaries for marginal marine sediments, sulphate reducing and iron utilising bacteria. The absence of iron utilising bacteria in the samples plated out may be due to the deterioration of the enriched media; the region for prolific growth of iron bacteria is however outside the range of Eh and pH measured here (Fig. 7).

(d) Miscellaneous data

Samples of surface sand taken at 160 and 130 ft on transect B were analysed for photosensitive pigments. Breakdown products of some pigments were observed but no residues from the decay of Chlorophyll b were found. This indicates that the mud contains no material from the recent breakdown of the higher plants.

The moisture content of surface samples taken along transect B is shown in Figure 8; no sharp boundary was found in the region of the Eh front. The sharp drop in Eh appeared to coincide with a change in the nature of the material found below the water table. The common yabby (Callianassa australiensis) was being taken from below the water table at distances up to 130 ft down the beach on the first day and the sand-water slurry brought up by the pump used was yellow to yellow-grey. Slightly further down the beach where the yabbies occurred in fewer numbers the material below the water table was grey to grey-black. This indicates that the reducing material in the vicinity of the Zostera bed is not bounded by the water table.

IV. DISCUSSION

The data indicate that in the region studied the presence of the Zostera bed has a major influence on the chemical environment. This effect is balanced by the oxidising influence of air-equilibrated water brought in by each tide and the system is in a state of dynamic equilibrium. The sharpness of the Eh boundary is confirmed by all data and its position coincides with maxima in the distribution of burrowing soldier crabs (M. longicarpus and M. platycheles) in sections B & C (Figs. 3 and 4). In section A where no sharp boundary is observed no marked maximum is found in the distribution of crabs (Fig. 2). The relationship between these two factors may be causal or it may be coincidental; further work is needed to clarify this point.

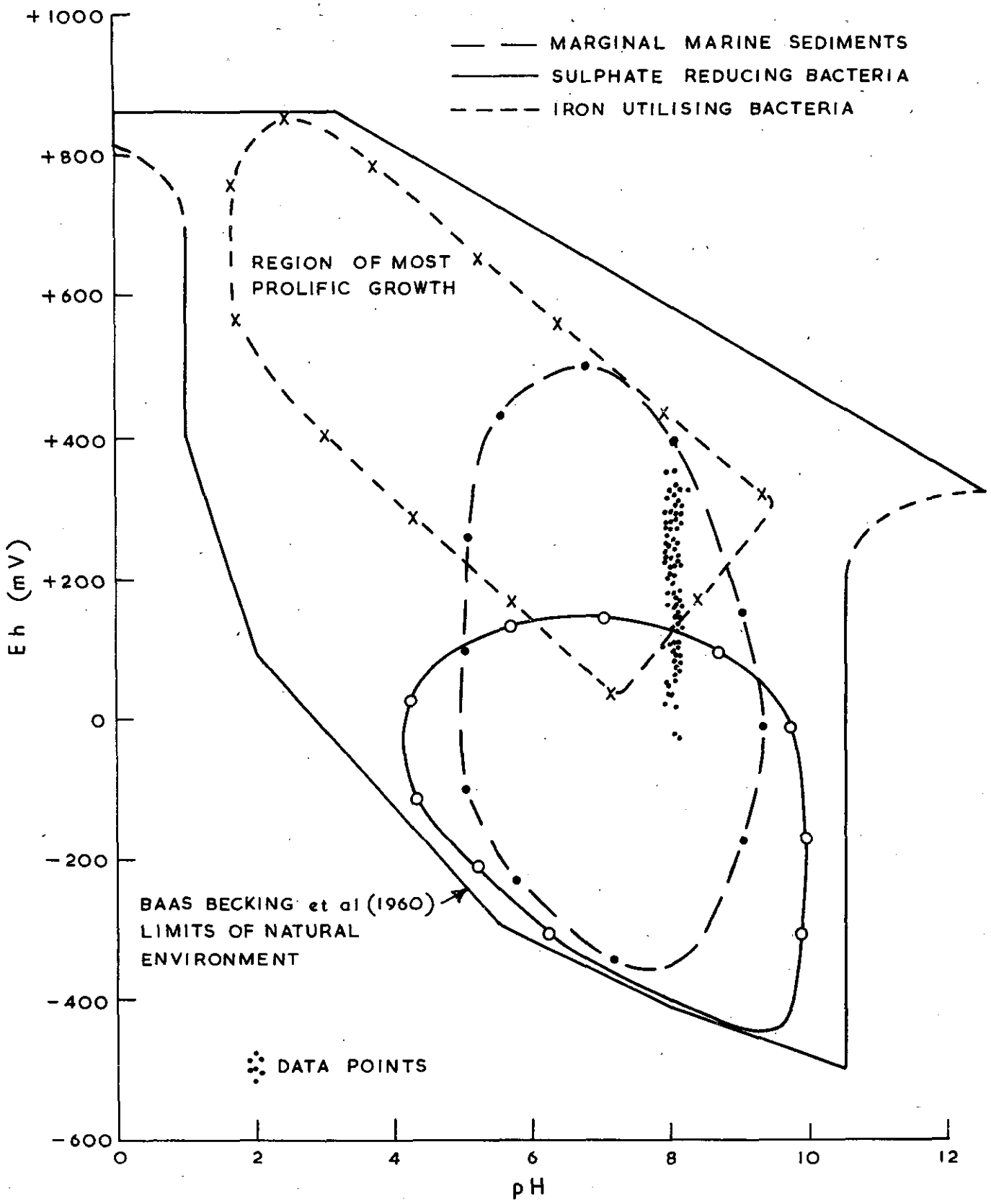


Fig. 7.—Eh-pH limits of data (from Table 1).

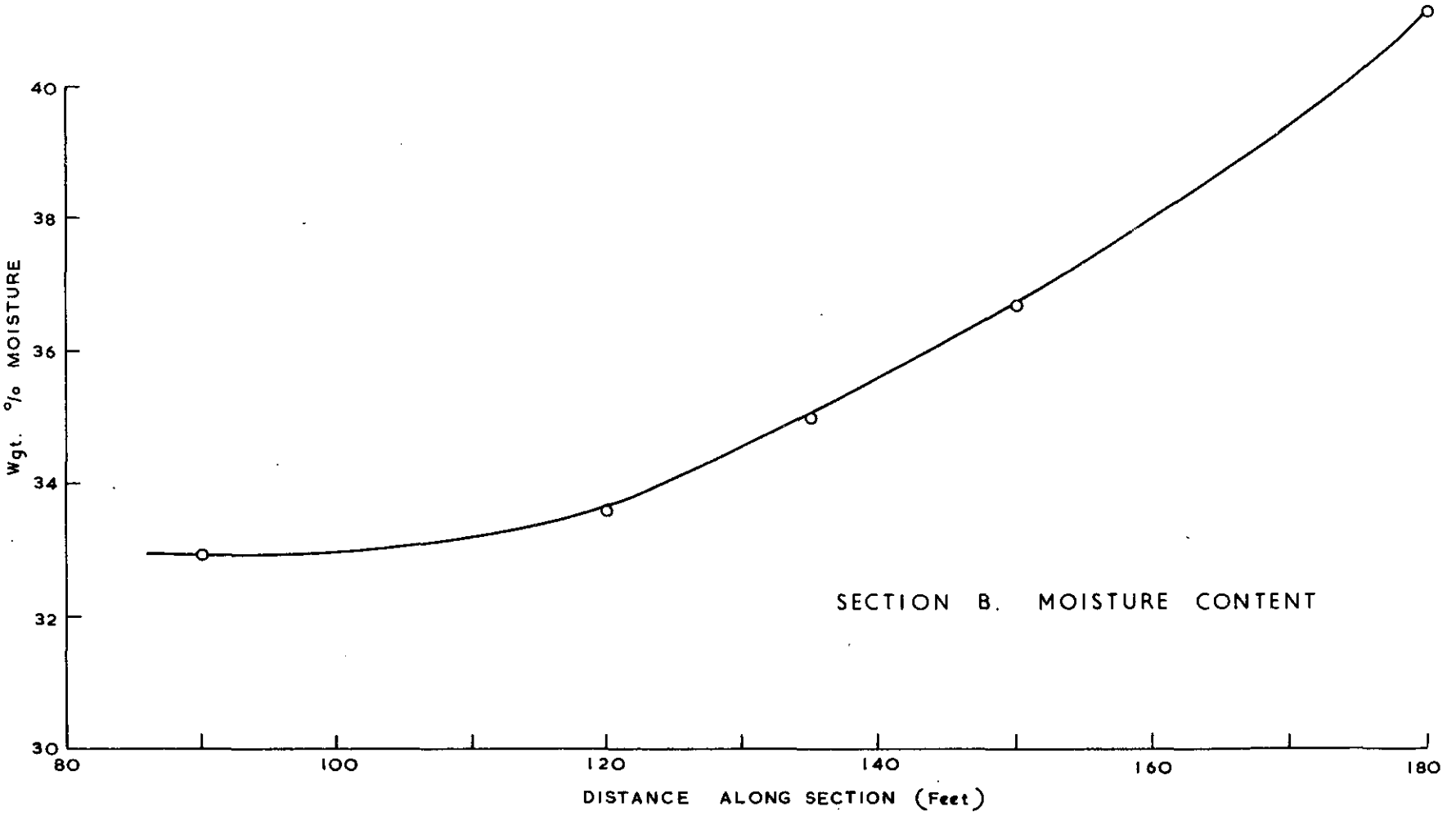


Fig. 8.—Section B. Moisture content.

B A C T E R I O L O G Y

I. INTRODUCTION

A brief survey of the heterotrophic bacteria of the Port Hacking estuary was carried out. The program consisted of two parts. The first was to observe the numerical distribution of bacteria at different depths, both in the estuary and adjacent coastal waters, and subsequently to isolate two strains of bacteria for the following comparative experiments - a) plotting of growth curves, b) salinity tolerance tests, and c) antibiotic sensitivity tests. The second part of the program was to test for polluting organisms of the coliform group in the water samples collected. The presence of Escherichia coli is generally considered to be an indication of faecal pollution.

II. METHODS AND MATERIALS

(a) Sampling

To give a wider range of distribution of bacteria, samples were taken at six stations. Four of these were within the estuary, and two were in adjacent coastal waters. Samples were collected at different times on two consecutive days (May 23 and 24). Consequently, the tide level was not the same for all samples. Station positions, which were the same for both sampling days, are noted in Table 1 (see RESULTS), which also gives the tide state at sampling.

Samples were collected in Nansen bottles, and immediately transferred to sterile salinity bottles for transport to the laboratory.

(b) Viable counts

Viable counts were carried out using the surface inoculation method, where an aliquot (0.1 ml) of seawater was spread over the surface of each of the following plates (in duplicate):-

Brown (1964)

1) Seawater (millipore filtered) + 1% peptone (W/v) (SWP agar)
2) SWP + 0.5% glucose (W/v)
3) Difco nutrient agar

Plates were incubated at 30°C for 48 hr. Counts were made of the number of bacterial colonies per ml seawater.

(c) Methods for the comparative work on the two strains of bacteria A and B

(i) Plotting of growth curves

The organisms were inoculated into seawater and freshwater media. The seawater medium used was SWP. The freshwater medium used was 1% peptone-0.5% dextrose-1% yeast extract broth made with distilled water. Growth was measured turbidimetrically, using an EE colorimeter (red filter).

(ii) Salinity tolerance tests

The organisms were inoculated into a series of media, both solid and liquid, of increasing salinity. The media used were peptone-dextrose-yeast extract broth, prepared with distilled water, and also nutrient agar. To both media NaCl was added to give W/v NaCl concentrations of 0%, 1%, 2%, 3.5%, 7%, 15%, and 30%.

(iii) Antibiotic sensitivity tests

The entire surfaces of SWP, SWP + glucose, and nutrient agar (N/A) plates were inoculated with A and B. Antibiotic discs (Difco Unidisks and Biolab Polydiscs) were then introduced onto the surfaces of the plates.

(d) Polluting organisms

The samples collected for Part 1 of the program were also tested for the presence of polluting bacteria of the coliform group (Escherichia - Aerobacter). A presumptive test was carried out by inoculating seawater samples into lactose broth, and the positive results of this method were verified using Levine E.M.B. agar for positive identification.

Lactose broth was prepared as follows:-

Beef extract	3.0 g
Bacto-peptone	5.0 g
Lactose	5.0 g
1 l. distilled water	
pH	6.7

The medium was distributed in 10 ml aliquots into test tubes with fermentation vials, sterilized at 121°C for 15 minutes, cooled, and then inoculated.

Levine E.M.B. agar was prepared as follows:-

Peptone	10 g
Lactose	10 g
Dipotassium phosphate	2 g
Agar	15 g
Eosin-Y	0.4 g
Methylene blue	0.065 g
1 l. distilled water	
pH	7.1

III. RESULTS

Table 1 shows the relationship between number of colonies and sampling position. Colonies per ml ranged from 10, in water collected from the surface at the 20 m station, to 2,000 in water collected from 21 m in Yowie Bay.

TABLE 1

DISTRIBUTION OF BACTERIA IN PORT HACKING

Station	Depth (m)	Media and Counts (colonies/ml seawater)					
		SWP		SWP + Glucose		N/A	
		23.5.66	24.5.66	23.5.66	24.5.66	23.5.66	24.5.66
20 m	0	5	180	35	285	0	640
	10	15	435	40	310	0	415
	20	15	90	10	185	5	15
	TIDE	2ft (inward)	3ft6in. (inward)				
Port Hacking Entrance	0	30	300	35	160	25	5
	4	55	60	55	85	70	0
	9	50	70	45	45	70	0
	TIDE	1ft7in. (low)	4ft (inward)				
Little Turriel Bay (Hydrology Station 3)	0	100	5	125	10	5	10
	4	120	65	85	30	10	30
	TIDE	4ft4in. (high)	3ft (out)				
Lilli Pilli (Hydrology Station 5)	0	70	165	50	140	15	40
	7	-	55	-	85	-	190
	8	45	-	30	-	Contam.	-
	14	-	45	-	85	-	40
	16	100	-	75	-	Contam.	-
	21	-	65	-	105	-	30
	24	250	-	120	-	10	-
	TIDE	4ft (out)	3ft (out)				

TABLE 1 (Cont'd...)

Station	Depth (m)	Media and Counts (colonies/ml seawater)					
		SWP		SWP + Glucose		N/A	
		23.5.66	24.5.66	23.5.66	24.5.66	23.5.66	24.5.66
Yowie Bay (Hydrology Station 12)	0	70	55	40	55	10	65
	6	-	175	-	100	-	20
	7	45	-	30	-	35	-
	12	-	75	-	55	-	30
	14	65	-	85	-	0	-
	18	-	115	-	90	-	30
	21 (muddy)	1675	-	1705	-	50	-
Gundamain (Hydrology Station 12)	0	45	70	100	45	Contam.	40
	4	170	75	170	70	135	25
	7	60	-	70	-	40	-
	8.5	-	880	-	1130	-	320

Where possible, the organisms cultured were identified. The two strains A and B isolated for further experiments came from water sampled at 20 m depth at the 20 m station, and from surface water at Gundamain, thought to be a freshwater layer, respectively.

A and B were both found to be gram negative rods. The appearance of their colonies on SWP agar was as follows:-

A - dark yellow, translucent colonies, with well defined edges;

B - light yellow, translucent colonies, with diffuse edges.

Tables 2 and 3 give the results of growth rates of A and B and Figures 1 and 2 the plotted growth curves.

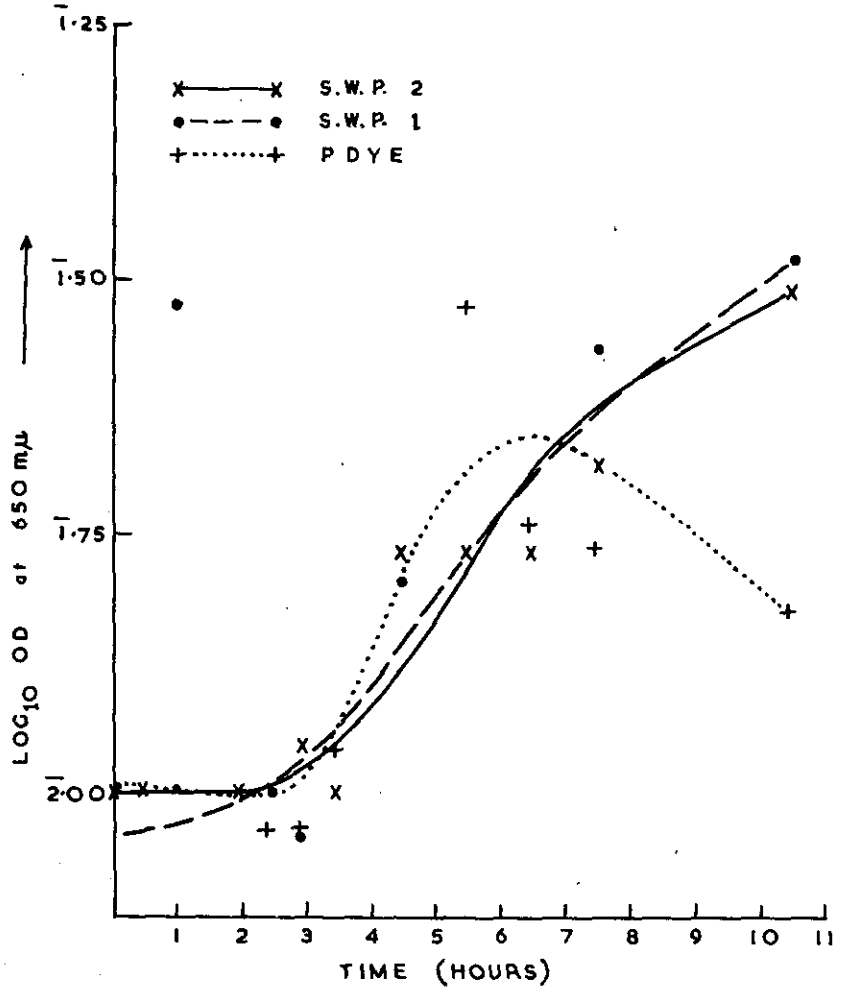


Fig. 1—Growth curves of organism A in two different media.

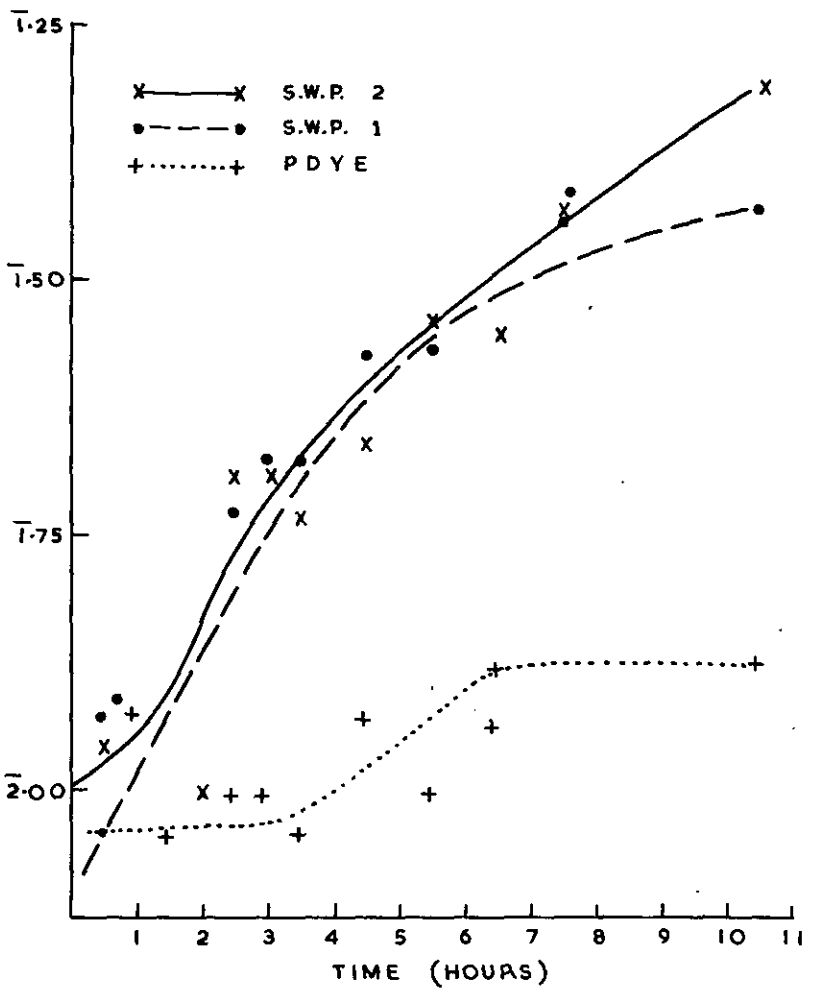


Fig.—2. Growth curves of organism B in two different media.

TABLE 2

MEASUREMENT OF GROWTH OF ORGANISMS A AND B

Time (Hours)	OD 650 mμ					
	A			B		
	SWP1	SWP2	*PDYE	SWP1	SWP2	*PDYE
0	0.009	0.010	0.010	0.000	0.010	0.010
½	0.010	0.010	0.010	0.012	0.011	0.009
1	0.020	0.020	0.010	0.021	0.020	0.012
1½	0.019	0.020	0.012	0.022	0.020	0.009
2	0.010	0.010	0.010	0.010	0.010	0.010
2½	0.010	0.010	0.009	0.019	0.020	0.010
3	0.009	0.011	0.009	0.021	0.020	0.010
3½	0.010	0.010	0.011	0.021	0.019	0.009
4½	0.016	0.017	0.017	0.026	0.022	0.012
5½	0.017	0.017	0.020	0.028	0.029	0.010
6½	0.017	0.017	0.018	0.028	0.028	0.011
7½	0.026	0.021	0.017	0.037	0.038	0.011
10½	0.033	0.031	0.015	0.048	0.049	0.011

* Peptone-dextrose-yeast extract broth.

TABLE 3

MEASUREMENT OF GROWTH OF ORGANISMS A AND B

Time (Hours)	LOG_{10} OD at 650 mμ of A and B					
	A			B		
	SWP1	SWP2	*PDYE	SWP1	SWP2	*PDYE
0	$-\bar{2}.0458$	$\bar{2}.0000$	$\bar{2}.0000$	0	$\bar{2}.0000$	$\bar{2}.0000$
½	$-\bar{2}.0000$	$\bar{2}.0000$	$\bar{2}.0000$	$\bar{1}.9208$	$\bar{1}.9586$	$\bar{2}.0458$
1	$-\bar{1}.6990$	$\bar{1}.6990$	$\bar{2}.0000$	$\bar{1}.6778$	$\bar{1}.6990$	$\bar{1}.9208$
1½	$-\bar{1}.7212$	$\bar{1}.6990$	$\bar{1}.9208$	$\bar{1}.6576$	$\bar{1}.6990$	$\bar{2}.0458$
2	$-\bar{2}.0000$	$\bar{2}.0000$	$\bar{2}.0000$	$\bar{2}.0000$	$\bar{2}.0000$	$\bar{2}.0000$
2½	$\bar{2}.0000$	$\bar{2}.0000$	$\bar{2}.0458$	$\bar{1}.7212$	$\bar{1}.6900$	$\bar{2}.0000$
3	$\bar{2}.0458$	$\bar{1}.9586$	$\bar{2}.0458$	$\bar{1}.6778$	$\bar{1}.6900$	$\bar{2}.0000$
3½	$\bar{2}.0000$	$\bar{2}.0000$	$\bar{1}.9586$	$\bar{1}.6778$	$\bar{1}.7212$	$\bar{2}.0458$
4½	$\bar{1}.7959$	$\bar{1}.7696$	$\bar{1}.7696$	$\bar{1}.5850$	$\bar{1}.6576$	$\bar{1}.9208$
5½	$\bar{1}.7696$	$\bar{1}.7696$	$\bar{1}.6990$	$\bar{1}.5528$	$\bar{1}.5376$	$\bar{2}.0000$
6½	$\bar{1}.7696$	$\bar{1}.7696$	$\bar{1}.7427$	$\bar{1}.5528$	$\bar{1}.5528$	$\bar{1}.9586$
7½	$\bar{1}.5850$	$\bar{1}.6778$	$\bar{1}.7696$	$\bar{1}.4318$	$\bar{1}.4202$	$\bar{1}.9586$
10½	$\bar{1}.4815$	$\bar{1}.5086$	$\bar{1}.8239$	$\bar{1}.3188$	$\bar{1}.3098$	$\bar{1}.9586$

* Peptone-dextrose-yeast extract broth.

The experiment to observe the salinity tolerance of organisms A and B was unsuccessful, insofar as no growth at all occurred, this perhaps indicating that the media lacked some essential nutrient.

Table 4 gives the results of the sensitivity of A and B to various antibiotics. There was no growth of either A or B on N/A plates, and growing organisms on the other media showed differences in sensitivity to the various antibiotics used.

TABLE 4

SENSITIVITY OF ORGANISMS A AND B TO ANTIBIOTICS

Antibiotic	Concentration	Media					
		SWP		SWP + G		N/A	
		A	B	A	B	A	B
Penicillin	5 units	0	0	x	1	-	-
	10 units	3	1	2	0	-	-
Streptomycin	5 µg	1	0	0	0	-	-
	25 µg	0	0	0	0	-	-
Chloramphenicol	10 µg	3	2	x	0	-	-
	30 µg	5	5	3	4	-	-
Erythromycin	5 µg	2	3	0	5	-	-
	15 µg	3	5	3	4	-	-
Tetracycline	10 µg	3	1	2	2	-	-
	30 µg	4	4	1	2	-	-
Kanamycin	10 µg	0	0	0	0	-	-
Novobiocin	10 µg	4	0	2	0	-	-
Sulphafurazole	250 µg	4	2	3	2	-	-
Polymixin-B-Sulphate	300 units	0	0	0	0	-	-
Bacitracin	10 units	0	0	0	0	-	-

\- Indicates no growth of the organism.
0 - 5 Indicates the degree of effect of the antibiotic on the bacterial growth.
x Indicates no result.

Polluting organisms, i.e. E. coli, were found in abundance at 4 m, and to a lesser extent at 8.5 m at Gundamain, in surface water at Yowie Bay, and at 8.5 m at Lilli Pilli (Table 5).

TABLE 5

THE DISTRIBUTION OF POLLUTING ORGANISMS (COLIFORMS) (3rd May, 1966)

Station	Presumptive test Lactose broth Depth (m)	Presumptive test Lactose broth Description of Growth (30°C)	Verification Eosin Methylene blue agar Description of Growth (30°C)
20 m	0	Growth, but no gas production	(Only sample which fermented lactose used as inocula)
	10	Slight growth, but no gas production	
	20	Slight growth, but no gas production	
Port Hacking Entrance	0	Growth, no gas production	
	4	Growth, no gas production	
	9	Growth, no gas production	
Little Turriel Bay	0	Growth, no gas production	
	4	Growth, no gas production	
Lilli Pilli	0	Growth, no gas production	
	8	Growth, gas production	Colonies with green, metallic sheen *E. coli*, also purple colonies, dark centres, *Aerobacter*
	16	Growth, no gas production	
	24	Growth, no gas production	
Yowie Bay	0	Growth, gas production	Green, metallic sheen, *E. coli*, also purple, dark centred *Aerobacter*
	7	Growth, no gas production	
	14	Growth, no gas production	
	21	Growth, gas production	Several, unidentified pink colonies
Gundamain	0	Growth, no gas production	
	4	Growth, gas production	Green, metallic sheen, *E. coli*, also purple, diffuse *Aerobacter*
	8.5	Growth, gas production	Purple, diffuse, with dark centres, *Aerobacter*, also few colonies, e green, metallic sheen, *E. coli*

The only organisms positively identified were Bacillus mycoides, Escherichia coli, and Aerobacter aerogenes. An unidentified actinomycete was present also.

IV. REFERENCES

BROWN, A.D. (1964).- Seasonal variations in heterotrophic bacterial populations in waters off Sydney. Aust. J. mar. Freshwat. Res. 15: 73-6.

DIFCO (1953).- "The Difco Manual". (Difco Laboratories: Michigan).

ZOOPLANKTON

I. INTRODUCTION

The distribution of zooplankton groups in Port Hacking was investigated. Areas such as shallow channels, deep bays, and areas of freshwater influence, which were thought likely to have different populations, were sampled separately. Because soldier crab populations were being studied during the School, particular attention was given to the distribution of zoea larvae. Day and night hauls were made to see if there was evidence for vertical migration of zooplankton in the estuary.

II. METHODS

The zooplankton of Port Hacking was sampled at a number of stations (Fig. 1) during the period May 23-25. The sampling programme was designed to include shallow channels, deep bays, and shallow areas of freshwater influence. The programme was most intensive in Burraneer Bay where samples were taken at various positions, times, and tide states.

The sampler was a conical townet with a mouth area of $\frac{1}{4}$ m^2 and a mesh aperture of 0.5 mm, towed from a 2 m leader and a 3-leg bridle. The net was towed horizontally just beneath the surface, the leader being attached to the warp 1 m above a 25 lb weight. Towing speed was 1.5-2 kt. Towing duration was of the order of 1 min. A flowmeter (TSK) was suspended within the net mouth at a point approximately 5" from the ring. The net was washed down with a hose after each haul.

III. RESULTS

Tables 1 and 2 show the groups of zooplankton in the day samples, and their frequency per sample.

TABLE 1

ZOOPLANKTON CATCH (NO. OF ORGANISMS) AT PORT HACKING STATIONS
MAY 23, 1966

(High tide 1030h, low 1600h)

	Time and Station									Seaward →
GROUP	S1/24	K1/29	P1/31	H1/35	M1/34	R1/34	X1/40	V1/48	Q1/51	Z1/58
	1144	1221	1239	1312	1332	1340	1404	1410	1427	0940 h
Total copepods	138	262	39	27	410	204	212	104	760	4240
Cladocera	0	7	0	11	85	20	375	28	748	0
Ctenophores	2	6	6	12	4	4	0	0	0	0
Decapod larvae	15	107	8	48	296	95	21	64	381	25
Fish eggs/larvae	0	3	13	1	10	0	0	3	14	382
Chaetognaths	1	2	0	0	0	0	12	2	49	1715
Salps	0	0	0	0	0	0	0	0	0	1
Doliolids	0	0	0	0	0	0	0	0	2	9

TABLE 1 (Cont'd...)

GROUP	Time and Station → Seaward									
	S1/24	K1/29	P1/31	H1/35	M1/34	R1/34	X1/40	V1/48	Q1/51	Z1/58
	1144	1221	1239	1312	1332	1340	1404	1410	1427	0940 h
Medusae	10	0	1	0	0	1	4	0	0	5
Siphonophores	0	0	0	0	0	0	2	2	0	25
Amphipods	0	0	2	0	1	4	0	0	4	4
Isopods	0	0	0	0	0	0	2	0	0	17
Ostracods	0	2	0	0	0	0	2	1	0	0
Larvaceae	0	2	1	0	0	1	3	1	12	42
Gastropod larvae	0	0	0	0	0	0	8	0	13	58
Euphausiids	0	0	0	0	0	0	0	0	0	5
Polychaetes	0	0	0	0	0	0	1	0	0	0
Stomatopod larvae	0	0	0	0	0	0	0	3	0	0
Cephalopods	0	0	0	0	0	0	0	0	0	0
Total	166	391	70	99	806	329	642	208	1983	6528
No./m^3	3.6	6.94	1.8	3.27	2.34	8.90	16.75	5.66	56.4	182.0

TABLE 2

ZOOPLANKTON CATCH (NO. OF ORGANISMS) AT PORT HACKING STATIONS
MAY 24, 1966

(High tide 1123h, low 1649)

GROUP	Time and Station → Seaward									
	S1/24	K1/29	P1/31	H1/35	M1/34	R1/34	X1/40	V1/48	Q1/51	
	1140	1210	1220	1305	1245	1330	1355	1410	0930	h
Total copepods	36	102	72	334	10	99	80	597	2038	
Cladocera	4	2	52	412	10	35	4	124	22	
Ctenophores	2	12	1	69	56	7	8	6	10	
Decapod larvae	5	41	39	128	7	69	105	147	450	
Fish eggs/larvae	2	17	11	2	0	0	14	278	0	
Chaetognaths	1	3	0	1	0	0	5	6	37	
Salps	0	0	0	0	0	1	0	1	0	
Doliolids	1	0	0	0	0	0	0	0	4	
Medusae	8	0	0	1	0	0	0	2	2	
Siphonophores	0	0	0	0	0	0	1	4	0	
Amphipods	1	1	0	1	0	0	0	4	9	
Isopods	0	0	0	0	0	0	0	2	0	
Ostracods	0	0	0	0	0	0	5	1	0	
Larvaceae	2	0	4	0	0	0	0	1	7	
Gastropods	0	0	1	1	0	0	0	0	10	
Euphausiids	0	0	0	0	0	0	0	4	0	
Polychaetes	0	0	0	1	0	0	0	0	12	
Stomatopods	0	0	0	0	0	0	0	2	0	
Cephalopods	0	0	0	0	0	0	1	0	0	
Total	62	178	180	950	83	211	223	1179	2601	
No./m^3	1.56	5.40	5.14	24.50	1.64	5.54	7.45	13.78	72.6	

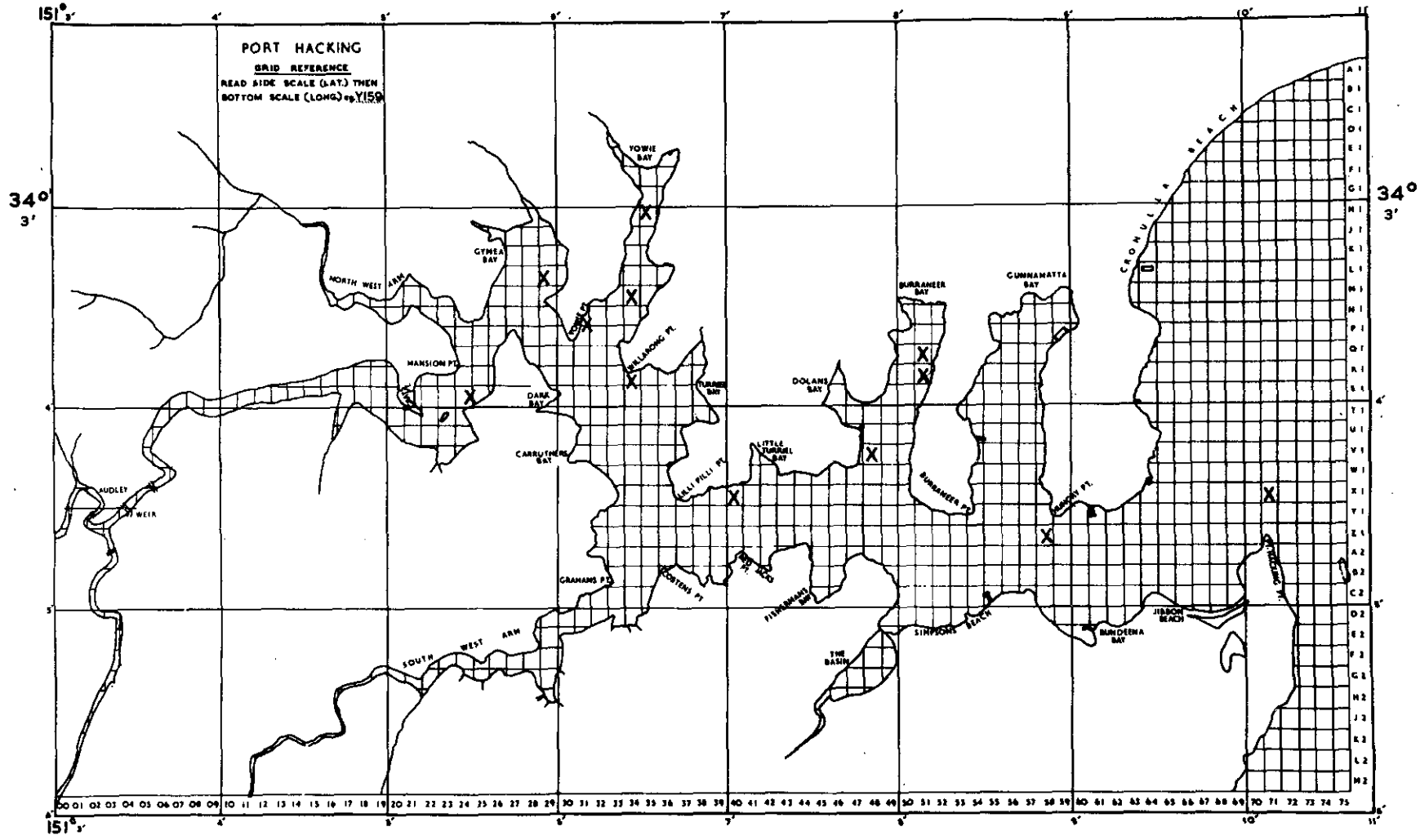


Fig. 1.- Zooplankton stations

The general distribution on May 24th agreed with that on May 23rd. The catches consisted mainly of copepods, cladocerans, decapod larvae, fish eggs and larvae, and chaetognaths. Medusae, siphonophores, larvaceae, and gastropod larvae were less common. Salps, doliolids, amphipods, isopods, ostracods, euphausiids, polychaetes, stomatopod larvae, and cephalopods were rare.

The catches were approximately 10 times greater near the entrance to Port Hacking than inside the estuary. This was due to the greater concentration, on the seaward side, of copepods, chaetognaths, fish eggs and larvae, and, to a lesser extent, of siphonophores and larvaceae. Chaetognaths occurred almost exclusively seaward of Lilli Pilli Point. By contrast, cladocerans, ctenophores, and decapod larvae tended to be more abundant within the estuary.

The most striking feature of the zooplankton concentration toward the mouth of the estuary was the large number of species represented. This was particularly noticeable among the copepods (Table 3) where at least 13 species failed to penetrate significantly into the estuary. The only species represented in significant numbers both at the entrance to the estuary and within the estuary was Temora turbinata.

TABLE 3

SPECIES COMPOSITION (%) OF COPEPOD CATCHES AT VARIOUS STATIONS IN PORT HACKING MAY 1966

SPECIES	Station and Location								
	X1/71 Outside Heads	Z1/58 Hungry Point	V1/48 Entrance to Burraneer Bay	X1/40 Lilli Pilli Point	P1/31 Yowie Point	K1/29 Gymea Bay	R1/34 Entrance to Yowie Bay	H1/35 Upper Yowie Bay	S1/24 Gray's Point
Temora turbinata	60-80	85-90	20	25	50	30	20	0.5	4
Acartia spp.	0.01	0.01	60-70	70	50	60	80	80	80
Oncaea sp.									
Corycaeus sp.									
Labidocera acutum									
Undinula vulgaris									
Euchaeta marina									
Eucalanus sp.	6-15%	6-15%	Either absent or in very low frequencies						
Centropages furcatus									
Macrosetella gracilis									
Calocalanus sp.									
Clausocalanus sp.									
Candacia sp.									
Small calanids									
Sapphirina sp.									

The dominant estuarine copepods were species of Acartia which comprised up to 80% of the total zooplankton population (Table 3). There were two species, Acartia erythraea and Acartia spinicauda (Mori 1937) the former being by far the more abundant (Table 4). Females were more numerous than males.

TABLE 4

DISTRIBUTION OF ACARTIA SPP. IN PORT HACKING
MAY 1966

Station and Location	May 23 A. erythraea: A. spinicauda	♀ : ♂	May 24 A. erythraea: A. spinicauda	♀ : ♂
Z1/58 Hungry Point	0.5 : 1			
X1/40 Lilli Pilli Point	2.5 : 1		3 : 1	
M1/40 Entrance to Yowie Bay	100% A. erythraea	34 : 1		
H1/34 Upper Yowie Bay	2 : 1	3 : 1	100% A. erythraea	5 : 1

The decapod larvae taken in the samples were very varied. There were at least two types of crab larva, represented at both the megalopa and zoea stages. Some early zoeas correspond fairly closely to the description of the first zoea of the soldier crab (Cameron 1965). At least six types of non-brachyuran zoeae and megalopae were present. The more common types were photographed for future reference. The general distribution of decapod larvae in Port Hacking, as indicated by the sampling programme, is given in Table 5.

TABLE 5

DISTRIBUTION OF DECAPOD LARVAE IN PORT HACKING
1100-1400h MAY 23, 1966

Station and Location	Frequency (No./m^3)			% of Total No. of Organisms		
	Brachyuran Zoea	Brachyuran Megalopa	Others	Brachyuran Zoea	Brachyuran Megalopa	Other
S1/24 (Gray's Point)	0.03	0	0.34	0.7	0	8.3
K1/29 (Gymea Bay)	0.35	0	1.34	3.7	0	13.9
P1/31 (Yowie Point)	0.10	0	0.10	5.6	0	5.6
H1/35 (Upper Yowie Bay)	0.36	0	0.77	14.4	0	31.1
M1/34 (Entrance Yowie Bay)	0.64	0.02	3.30	3.3	0.2	17.0
X1/40 (Mid Stream)	1.80	0.10	3.30	8.9	0.5	16.4
Q1/51 (Upper Burraneer Bay)	2.60	0.06	3.60	4.9	0.1	7.3

One of the most interesting discoveries of the School was a night-time swarm of luminescent ostracods in Burraneer Bay (Table 6). Whereas hauls at 1600h, both at the surface and at 36 ft, indicated an ostracod density $< 1/m^3$, by 2100h the density had risen to $> 50/m^3$.

TABLE 6

DENSITY OF CLADOCERA AND OSTRACODA IN BURRANEER BAY
MAY 1966

Date	Station	Time	Depth (m)	No./m^3		% Total No. of Organisms	
				Cladocera	Ostracoda	Cladocera	Ostracoda
23/5/66	Q1/51	1430	0	19	0	38	0
24/5/66	Q1/51	0930	0	0.5	0	0.9	0
	Q1/51	1430	0	4	0	28	0
25/5/66	Q1/51	1000	0	9	0	47	0
	Q1/51	1555	0	24	.6	43	1.2
	R1/51	2110	0	3	103	2	69
	R1/50	2134	0	2.5	40	0.3	65
	Q1/51	1015	12	24	0.1	45	0.1
	Q1/51	1615	12	15	0	23	0
	R1/51	2124	12	5	112	4	91

Ostracods were rare throughout the estuary by day (Tables 1 and 2). This suggests that these organisms might live on or near the bottom by day and rise into the upper layers by night.

Tests with a finer net (mesh aperture 200 μ) suggested that the estuarine plankton was inadequately sampled with the net used during the School (500 μ). The finer net would sample the cladocera, small copepods, and larval stages more representatively.

IV. CONCLUSIONS

The fauna of the estuary differed between areas of different hydrological conditions. There were indications that shelf fauna penetrated partially into the outer bay. The vertical migration in one bay over one day was very marked.

On the basis of these observations, an intense study, in co-operation with other groups, of one of the outer bays is contemplated for the next School.

V. REFERENCES

CAMERON, A.M. (1965).- The first zoea of the soldier crab, Mictyris longicarpus (Grapsoidea; Mictyridae). Proc. Linn. Soc. N.S.W. 90 (2): 222-4.

MORI, T. (1937).- The pelagic copepoda from the neighbouring waters of Japan. (Published privately).

PIGMENTS IN MARINE ALGAE

I. INTRODUCTION

The assay of photosynthetic pigments in seawater is often used as a measure of plant biomass, and as a means of assessing productivity rates of phytoplankton. Simple spectroscopic methods for chlorophyll determinations were used formerly, but chromatographic methods have now been developed which separate all the major pigments of each class of marine algae, as well as the major chlorophyll decomposition products. The present project was centred around a study of the photosynthetic pigments of all the main classes of marine algae, using two-dimensional paper chromatography, and then applying knowledge gained with cultures of algae, to a variety of field situations.

Cultures of the following marine organisms were studied -

i) the green flagellate Dunaliella tertiolecta,
ii) the diatom Phaeodactylum tricornutum,
iii) the brown flagellate Isochrysis galbana,
iv) the dinoflagellate Amphidinium sp.,
v) the blue-green alga Anabaena sp.,
and vi) the red alga Porphyridium sp.

A higher plant (spinach), and a brown seaweed (Eklonia sp.) were studied also. Pigments were identified by R_f values, and by absorption spectra of eluted fractions.

Chromatographic separation of pheophytins, pheophorbides, and chlorophyllides of chlorophylls a, b, and c were also studied by two-dimensional paper chromatography.

In several field situations seawater samples, and sand or mud samples were analysed for photosynthetic pigments. Information gained helped to establish the nature of the marine algae present in the sample, and the presence or absence of decomposition products. The latter indicated the physiological state of the organisms, and their immediate previous history.

II. MATERIALS AND METHODS

Cultures of algae were grown in the Laboratory prior to the School. Cells were harvested by centrifuging at 2,000 r.p.m. for 5 min. Larger volumes of cultures, or seawater samples of 10 l. or more, were centrifuged in a continuous plankton centrifuge. Sand samples were prepared for extraction by filtering off excess seawater on a Buchner funnel, until the mud or sand sample was "damp-dry". It was essential that no water remain in the sample during acetone extraction. When acetone concentration falls below 90% chlorophyllase present in the algae will retain sufficient activity to degrade chlorophylls.

Preparation of pigment extracts. Packed cells were extracted with 90% acetone for several minutes until the residue was colourless. The samples were centrifuged to remove tissue debris, and the acetone extract containing the pigments mixed with an equal vol. of diethyl ether, and shaken with 5-10 vol. of 10% NaCl. The pigments migrated to the ether layer. The ether extract was concentrated for chromatography by evaporation under a stream of nitrogen. Sand or mud samples were extracted with 100% acetone for about 30 min., the acetone extract filtered off, and pigments transferred to ether as above.

Chromatography. Pigments were chromatographed on squares of Whatman No. 3MM paper (22 cm x 22 cm). The solvent systems were 4% n-propanol in petroleum ether (60-80), and 30% chloroform in petroleum ether. Chromatograms were run in the dark to prevent photo-oxidation of the pigments.

Absorption spectra. These were determined in a Unicam SP500 spectrophotometer after eluting the pigment zones in an appropriate solvent. Special samples were determined in a Unicam SP700 recording spectrophotometer.

III. RESULTS AND DISCUSSION

(a) Laboratory studies

Pigments present in the different algae were characterised by their R_f values, and the pigment distribution in the main classes of marine algae was mapped. This distribution (Table 1) can be put to a number of uses.

TABLE 1

PIGMENTS FOUND IN THE VARIOUS CLASSES OF ALGAE, AND IN A HIGHER PLANT

Pigment	Organism							
	Blue-green algae	Red algae	Diatom	Brown flagellate	Dinoflagellate	Brown seaweed	Green flagellate	Spinach
Chlorophyll a	+	+	+	+	+	+	+	+
Chlorophyll b							+	+
Chlorophyll c			+	+	+	+		
Chlorophyll d								
Carotene	+	+	+	+	+	+	+	+
Fucoxanthin			+	+		+		
Dinoxanthin					+			
Diadinoxanthin			+	+	+	+		
Diatoxanthin			+	+	+			
Peridinin					+			
Zeaxanthin		+						
Biliprotein	+	+						
Myxoxanthophyll	+							
Lutein			+				+	+
Neoxanthin							+	+
Violoxanthin							+	+

It highlights phylogenetic relationships and can be of use as a "diagnostic" tool in determining the presence or absence of certain organisms in field samples. For example, the presence of peridinin in a sample can be taken as conclusive evidence of the presence of dinoflagellates, as this is the only group of marine algae possessing this pigment.

The absorption spectra of all algal extracts were determined, and on these curves peaks and inflections corresponding to the various pigments could be seen. Figure 1 shows the absorption spectrum of the extract of the brown flagellate Isochrysis galbana.

Some of the major pigment zones were eluted for absorption spectra measurements. The spectra obtained were in good agreement with previously published work. Figure 2 shows the absorption spectra of chlorophylls a and c.

Chlorophylls were incubated with a chlorophyllase from the diatom Phaeodactylum tricornutum. Breakdown products were separated chromatographically. Figure 3 shows the decomposition products of chlorophylls a and b separated by two-dimensional chromatography.

(b) Field studies

(i) Invertebrate ecology

Soldier-crabs, when feeding, leave behind small sand pellets. It was unknown whether these were faecal or buccal pellets.

A sand sample, taken before crab feeding had commenced, revealed the presence in the feeding area of dense populations of diatoms together with a few dinoflagellates. Chromatograms were run on the pigments extracted and these showed pigment distributions characteristic of a healthy diatom population. The presence of peridinin, characteristic of dinoflagellates, was also noted.

The pellet material occurring after feeding was collected. Microscopic examination revealed that the pellets contained mainly macerated material and a few small diatoms. The chromatogram of the extract of this material showed that the following pigments were present: carotene, chlorophyll a, diadinoxanthin, fucoxanthin, chlorophyllide a, and chlorophyll c. Thus there was only a limited breakdown of the pigments originally present. Only one breakdown product of chlorophyll a was found.

It was concluded that the pellets were ejected from the mouth after maceration. There were no indications of acid breakdown such as would occur in the gut of the crab.

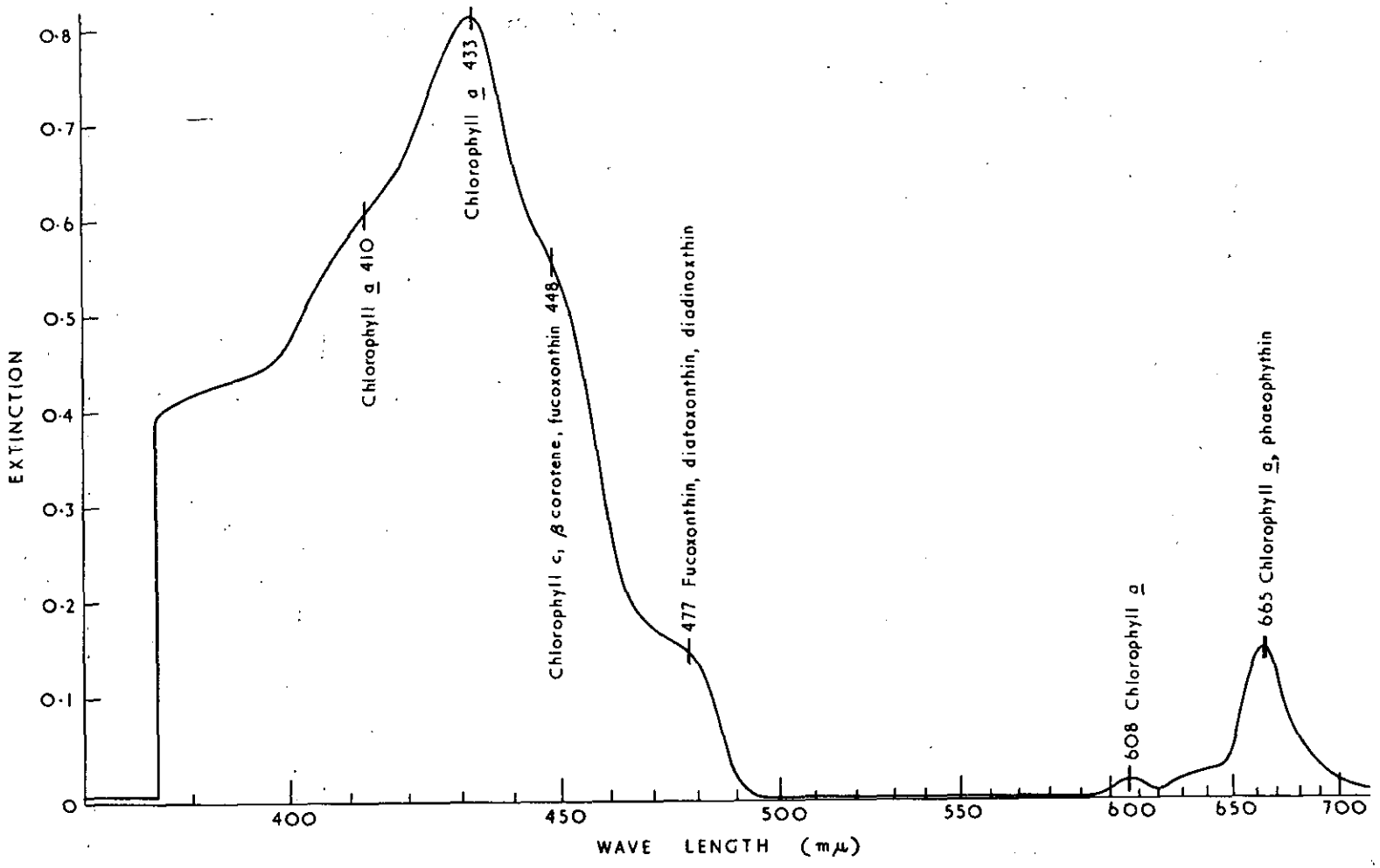


Fig. 1.- Absorption spectrum of the brown flagellate Isochrysis galbana. (Recorder pen off scale 495-595 mμ.)

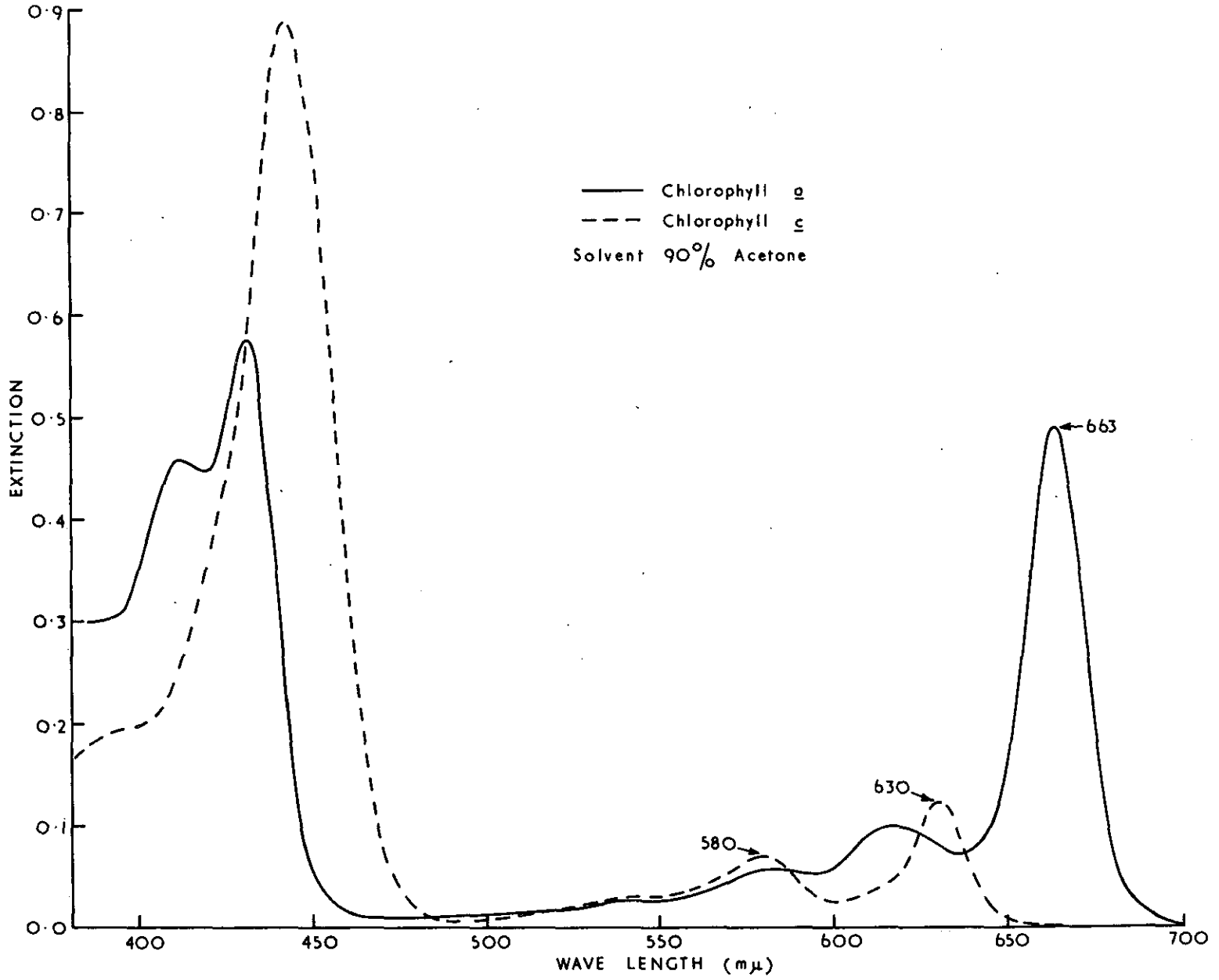


Fig. 2.- Absorption spectra of chlorophylls a and c.

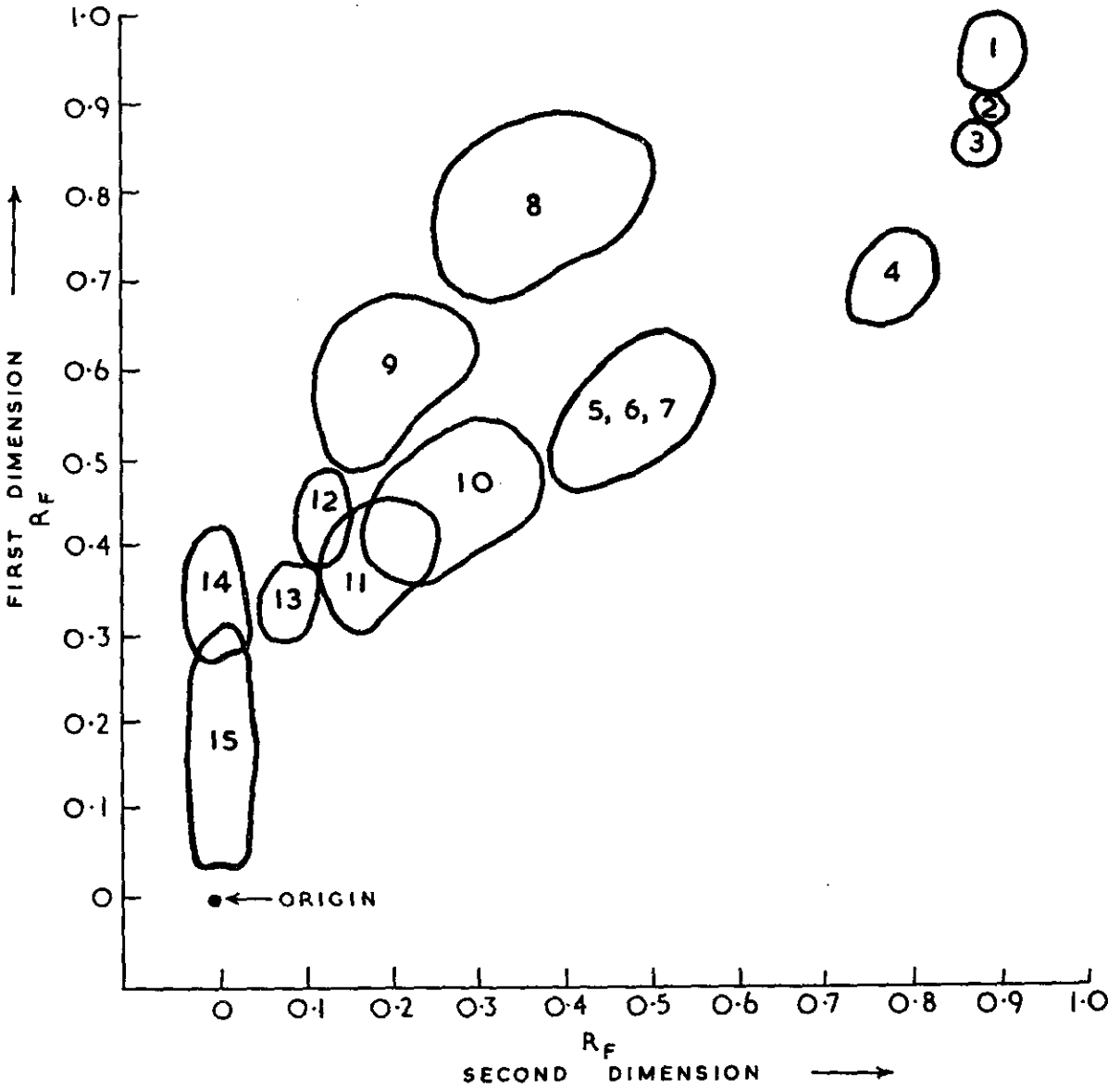


Fig. 3.- Two-dimensional chromatogram of pigments found in marine algae. 1 Carotenes (orange): 2 Esterified astaxanthin (pink): 3 Pheophytin a (grey-green): 4 Lutein (yellow): 5 Diatoxanthin (yellow): 6 Diadinoxanthin (yellow): 7 Violaxanthin (yellow): 8 Chlorophyll a (blue-green): 9 Chlorophyll b (olive green): 10 Fucoxanthin (deep orange): 11 Peridinin (brick-red): 12 Neofucoxanthin A and B (orange): 13 Neoxanthin (yellow): 14 Chlorophyllide a (blue-green): 15 Chlorophyll c (light-green).

(ii) Pigments in aerobic and anaerobic mud

The physical chemistry group supplied samples of aerobic and anaerobic mud. The aim was to note any differences in the phytoplankton populations of the two environments.

No differences were detected in the pigments of the two types of mud, but significant amounts of chlorophyll a and c breakdown products were present in both the aerobic and anaerobic specimens. No chlorophyll b was detected in either type of mud.

The conclusion drawn from this work was that the sediment material examined was all of marine origin. If material from the higher plants had been contributing to the system then chlorophyll b and/or its breakdown products would have been present. This result was somewhat anomalous in that the sediments examined were close to an area of freshwater run-off.

(iii) Zooplankton pigments

The zooplankton group supplied samples taken from areas of Port Hacking which showed a vertical stratification of the populations of zooplankton. In the top few mm of the water, there appeared only one species of small crustacean, while lower down in the water column there were mixed populations. Pigments were extracted from the different regions of the sample and identified chromatographically. Only one astaxanthin-like pigment was found in the top sample, whereas in the mixed populations from deeper waters a number of chromatographically different esterified astaxanthins were found. In addition, in the second sample significant amounts of phytoplankton breakdown products were found. It was concluded that the second zooplankton sample contained a number of different organisms which were feeding on phyto-plankton containing chlorophyll c. It was suggested that crustaceans containing astaxanthin would have a mechanism for absorbing UV radiation. This would have adaptive significance in organisms living at the sea surface.

(iv) Pigments in seawater samples

Samples taken at hydrology stations were examined for pigments (Table 2).

TABLE 2

PIGMENTS IN SEAWATER SAMPLES

Station	Pigments present	Phytoplankton organisms
A	Chlorophylls a and c Carotene Fucoxanthin Dinoxanthin Diadinoxanthin Zooplankton pigments	Diatoms and flagellates present and in healthy condition.
B	Chlorophylls a and c Carotene Fucoxanthin Diadinoxanthin Zooplankton pigments	As above.
C	Chlorophylls a and c Carotene Fucoxanthin Diadinoxanthin Dinoxanthin Peridinin	Diatoms and dinoflagellates present in significant numbers.

Station B was in a fast flowing region, and dinoflagellates and diatoms were not numerous. They contributed to a much smaller microfauna than they did at Stations A and C.

IV. CONCLUSIONS

Chromatographic and spectrophotometric studies of phytoplankton pigments are a tool in field studies to determine the organisms present. The methods may be used to supplement microscopical investigations. In addition, on the basis of breakdown products present, inferences can be made about the 'state of health' of the organisms present.

It is possible to do a quantitative estimation of the chlorophyll levels of an area, such as one of the sampling stations. This would be a preliminary step to doing any C^{14} fixation studies on the productivity of an area. However, the techniques used by this group were of a qualitative nature, and lack of time prevented an examination of quantitative techniques.

STATISTICAL ECOLOGY

I. INTRODUCTION

Populations of soldier crabs (Mictyris spp.) were found on a sand flat near the Laboratory. Since these populations were mobile, abundant, and changeable in behaviour, we decided to make exploratory observations on their distribution and density through the intertidal range; size, sex and age composition studies; behaviour, movements, and feeding; and relationships with associated fauna.

II. MATERIAL AND METHODS

The soldier crabs were identified as Mictyris longicarpus Latreille and Mictyris platycheles H. Milne-Edwards from McNeill's (1926) descriptions. Crab samples for the studies were taken from the large flat in front of Fisherman's Bay township. The sampling area is shown in Figure 1, which is a map prepared from an aerial photograph showing the distribution of the Zostera (marine angiosperm plants) beds, sand, scrub, creeks, and waterholes over the sand flat. The slope selected for sampling contained a graded series of these environmental variables; it lay on the north-west side of the scrubby knoll shown in the sampling area (Fig. 1) and extended from clean white sand at high water to black mud and Zostera at low water. This area was gridded and samples of the substratum obtained with a cylindrical corer that took a sample 9" wide and about 15" deep. The crabs in the samples were recovered by washing and sieving, and preserved in plastic bags.

III. RESULTS

Figures 2 and 3 show our interpretation of the distribution of the crabs over the slope on May 23. Both species were virtually absent from the Zostera ("seaweed") zone and tended to be most concentrated about half-way up the slope. Their density decreased further up the slope. Both species coincided broadly in their distribution but M. platycheles, the smaller species, tended to extend slightly further up the slope.

On the following day, May 24, a more detailed study was made in the areas where the two species were most dense. The results are shown in Figure 4. The two species had separated as shown and the most dense areas of each species did not overlap. M. platycheles, the smaller species, was at its maximum density further up the slope than M. longicarpus. In addition the most dense areas for each species had moved along the beach a few feet.

Further analysis of the samples showed that the total population of M. platycheles in the sample area was about 270,000 (c. 8 per sq. ft.). M. longicarpus was less abundant (120,000; c. 4.8 per sq. ft.). In some areas, high densities of 30 crabs per sq. ft. were recorded.

Figures 5 and 6 show the size distributions of the samples of both species. For the small and medium sized crabs the females appear to be slightly larger than males of the same age. Small age groups dominated in M. platycheles; large males dominated in M. longicarpus. In both species there was a residue of large old males, but not females.

Morphometric measurements (Figs 7-10) suggest that width is approximately proportional to length in both species but that M. platycheles is slightly wider than M. longicarpus for a given length.

The distribution of males and females in the samples was approximately the same. Four female M. platycheles carrying egg masses were found in the samples.

Observations on behaviour and movements could not be made because the crabs did not emerge from the sand to any great extent during the daylight hours of the study period. It was noted, however, that a population of M. platycheles emerged and fed on the north side of the sample area for a short period in the late afternoons of the 23rd and 24th. M. longicarpus emerged on the eastern side of the sample area at dusk (1700-1800 h) on the nights of the 24th, 25th, and 26th in very large numbers. Unfortunately, it was too dark by then to make proper observations.

There are indications that both species are herbivorous and probably feed on diatoms and other minute algae living in the surface few millimetres of the sand flat. Both on the flat and in the laboratory crabs were seen scraping this surface sand into large balls which they masticated and then ejected from the mouth. M. platycheles was often noticed carrying sand stacked on its claws like a front end loader; apparently munching this as it scuttled along. The structure and movements of the mouth parts of both species are very similar to those described for some fiddler crabs. Perhaps Mictyris uses the "filter press" method of feeding described by Miller (1961). Attempts to feed starved Mictyris in the laboratory during (and for several weeks after the school) with pieces of fish and shellfish were not successful, thus strengthening the view that Mictyris is not carnivorous and is probably herbivorous.

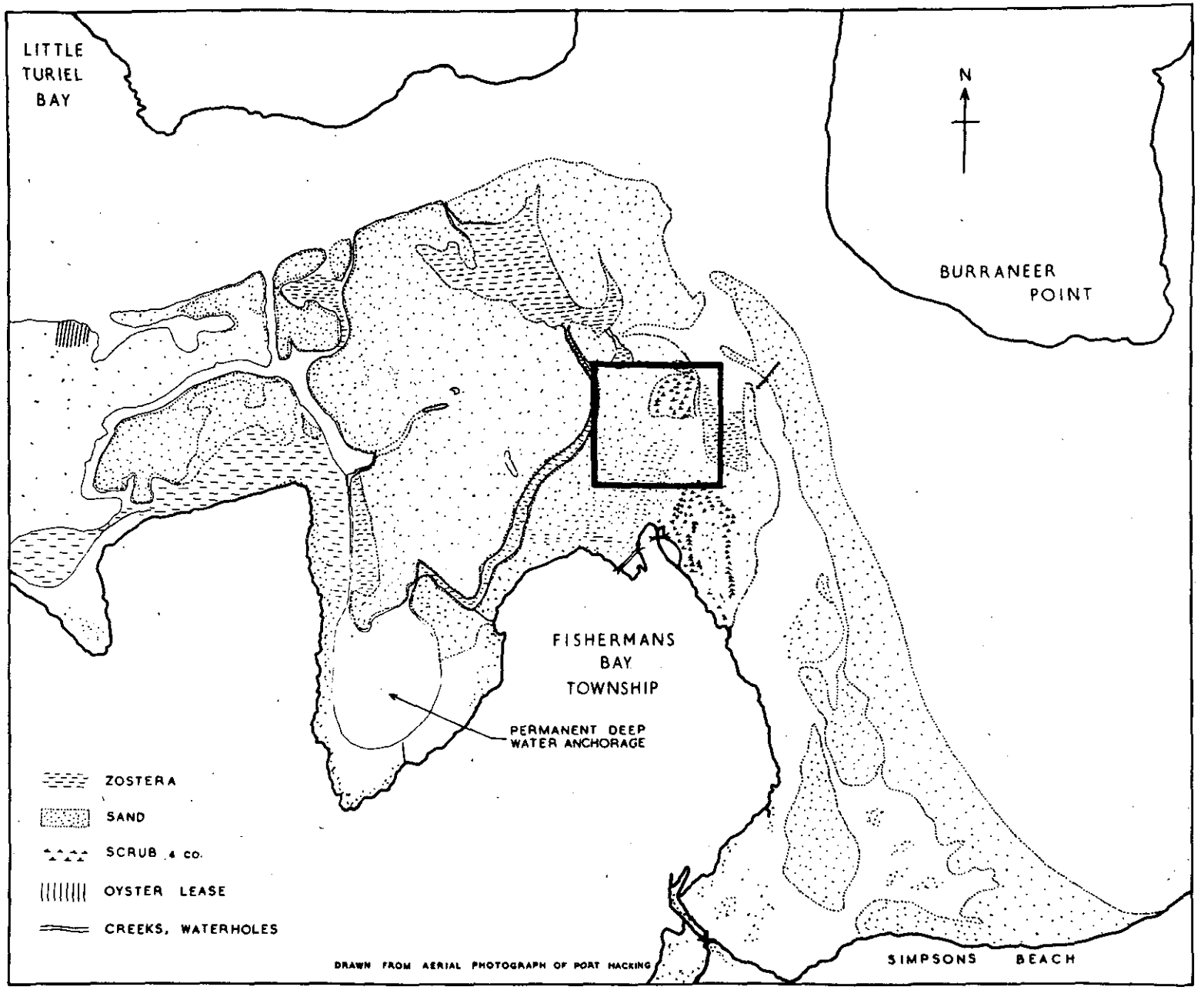


Fig. 1.-Location of sampling area

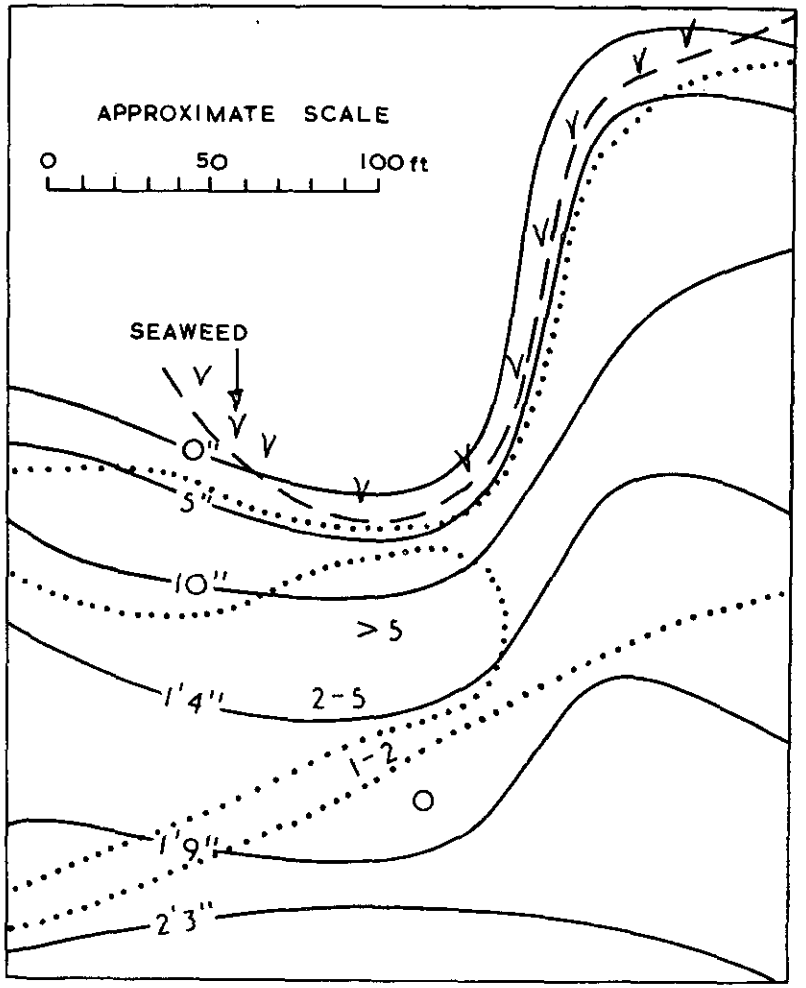


Fig. 2.–Distribution of Mictyris longicarpus.

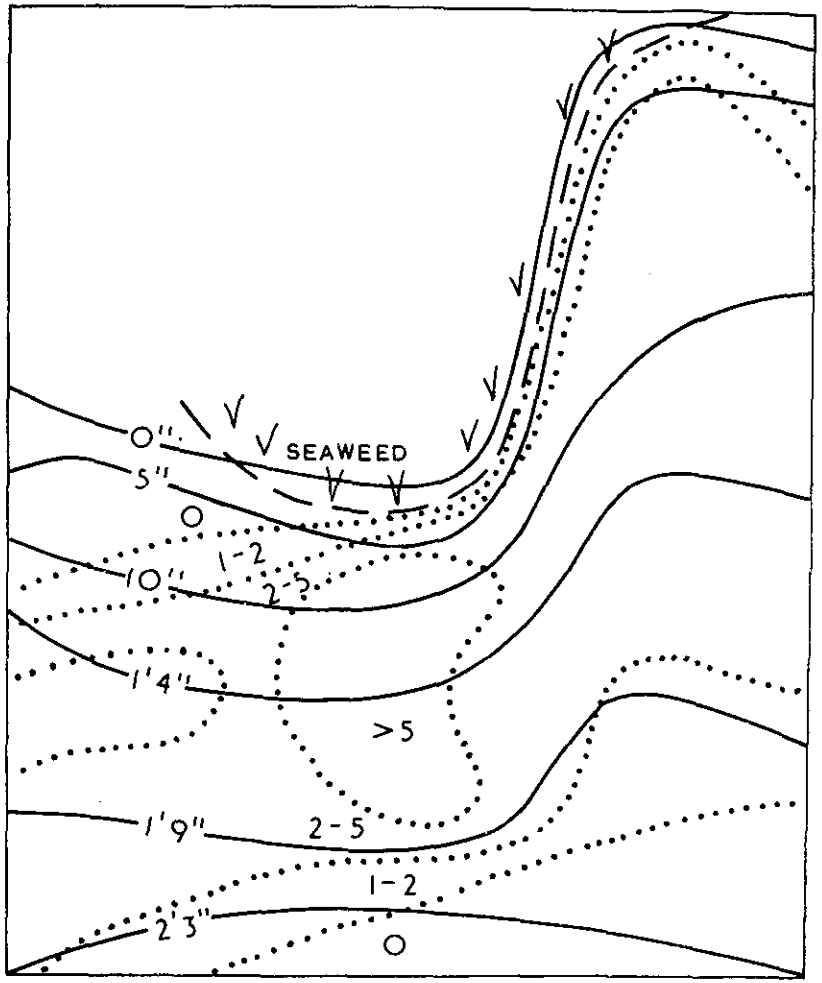


Fig. 3.–Distribution of Mictyris platycheles.

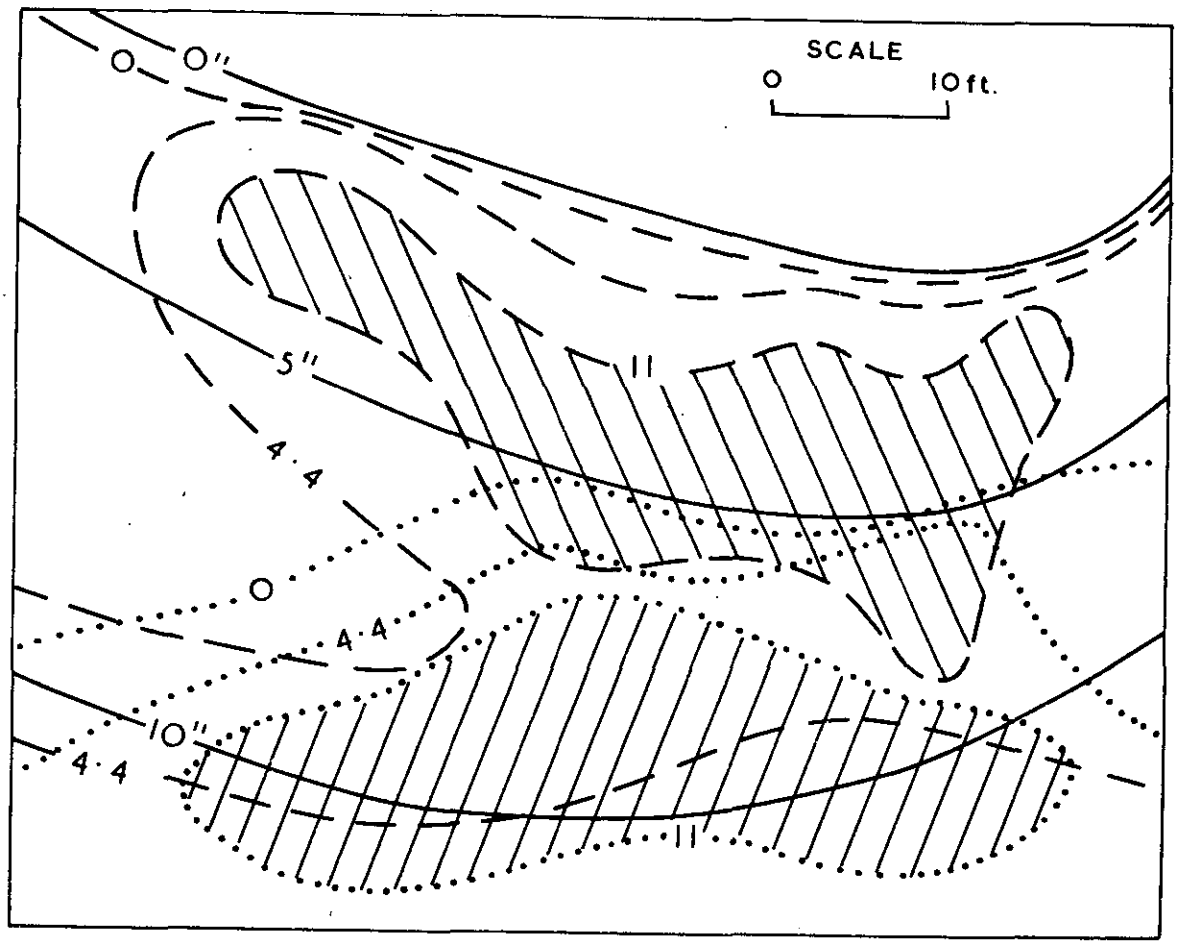


Fig. 4.—Distribution of Mictyris longicarpus and M. platycheles.
Topographical contours ———
Contours of equal density (in crabs/sq. ft) of M. longicarpus ----
Contours of equal density (in crabs/sq. ft) of M. platycheles .....
Cross hatching shows density greater than 11 crabs/sq. ft for each species.

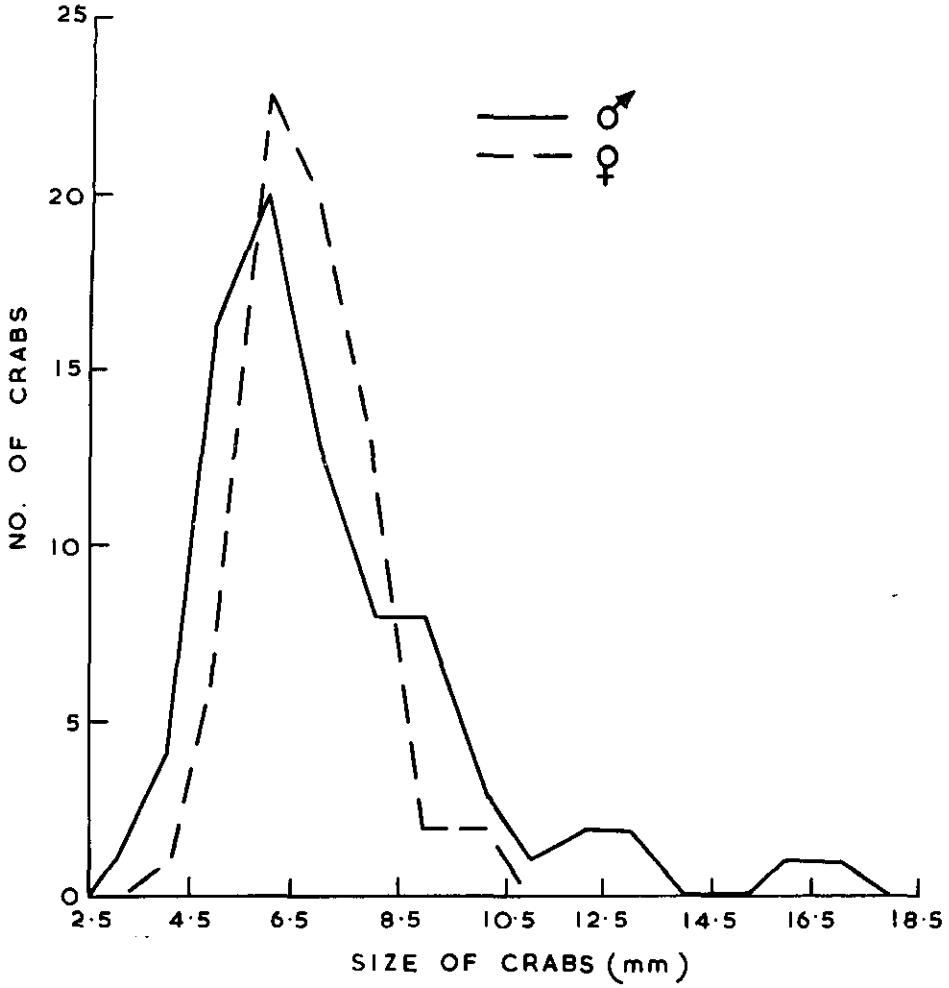


Fig. 5.–Size distribution of Mictyris platycheles.

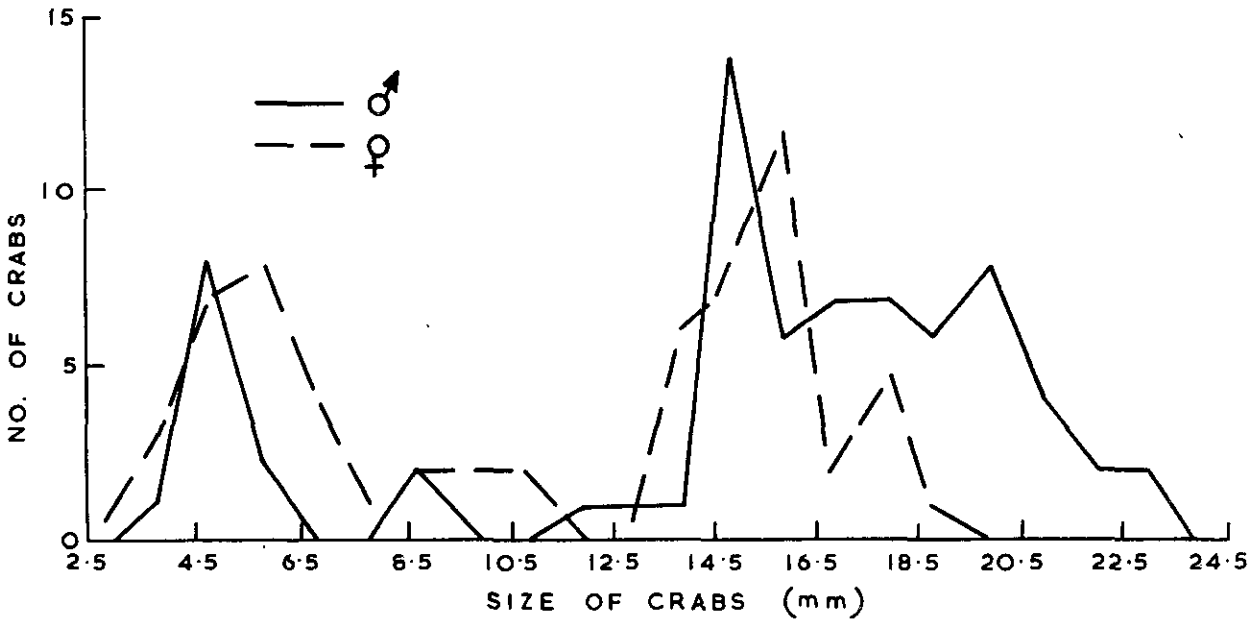


Fig. 6.–Size distribution of Mictyris longicarpus.

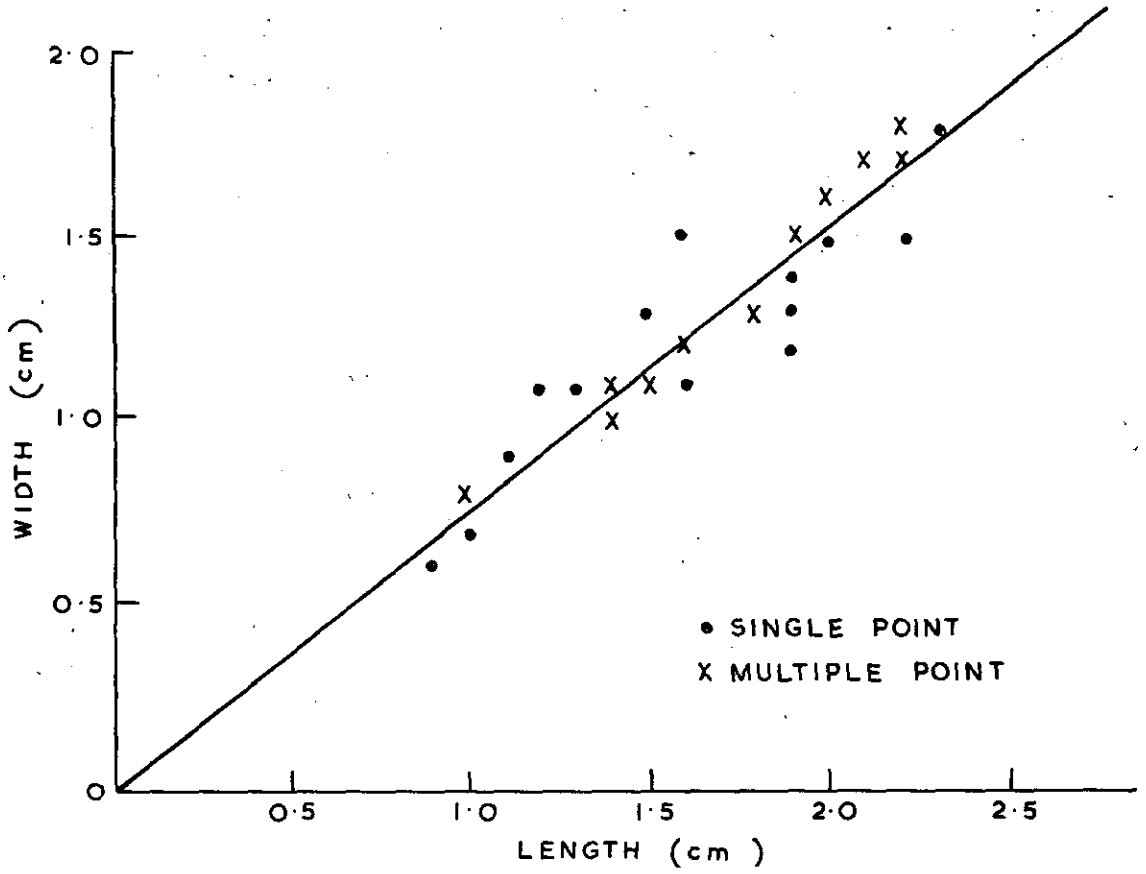


Fig. 7.-Morphometricsof Mictyris longicarpus (male).

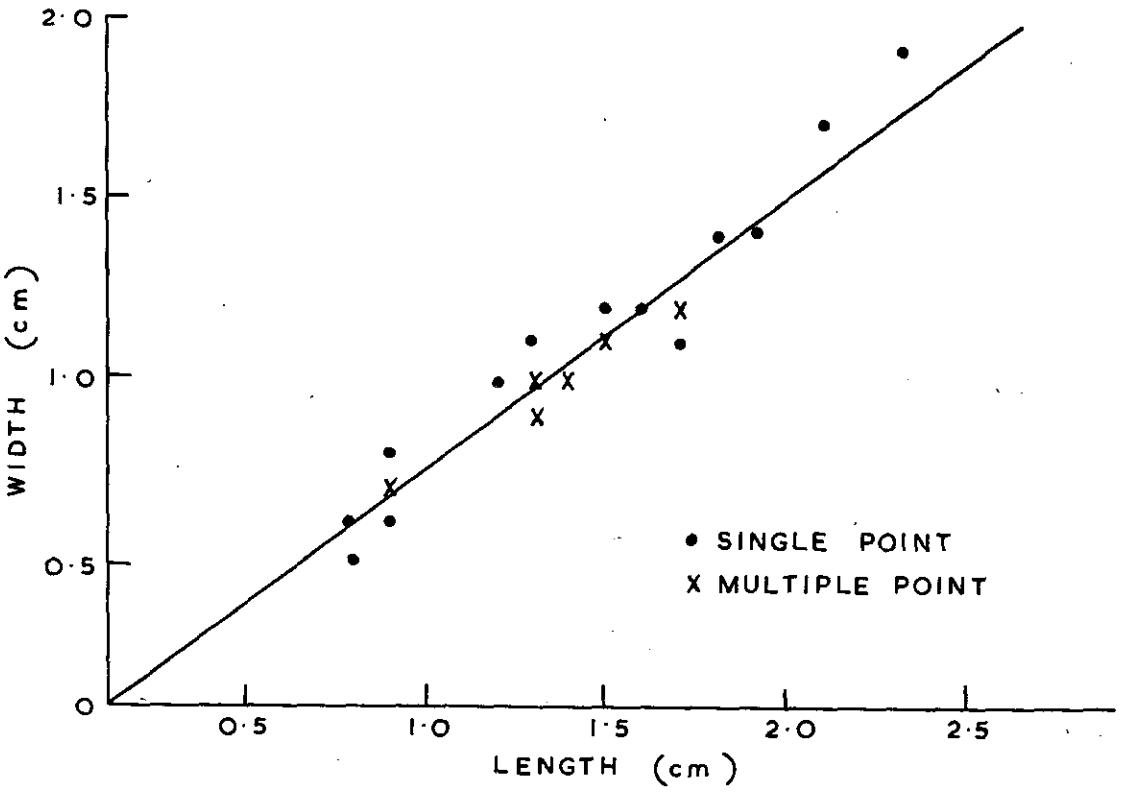


Fig. 8.-Morphometricsof Mictyris longicarpus (female).

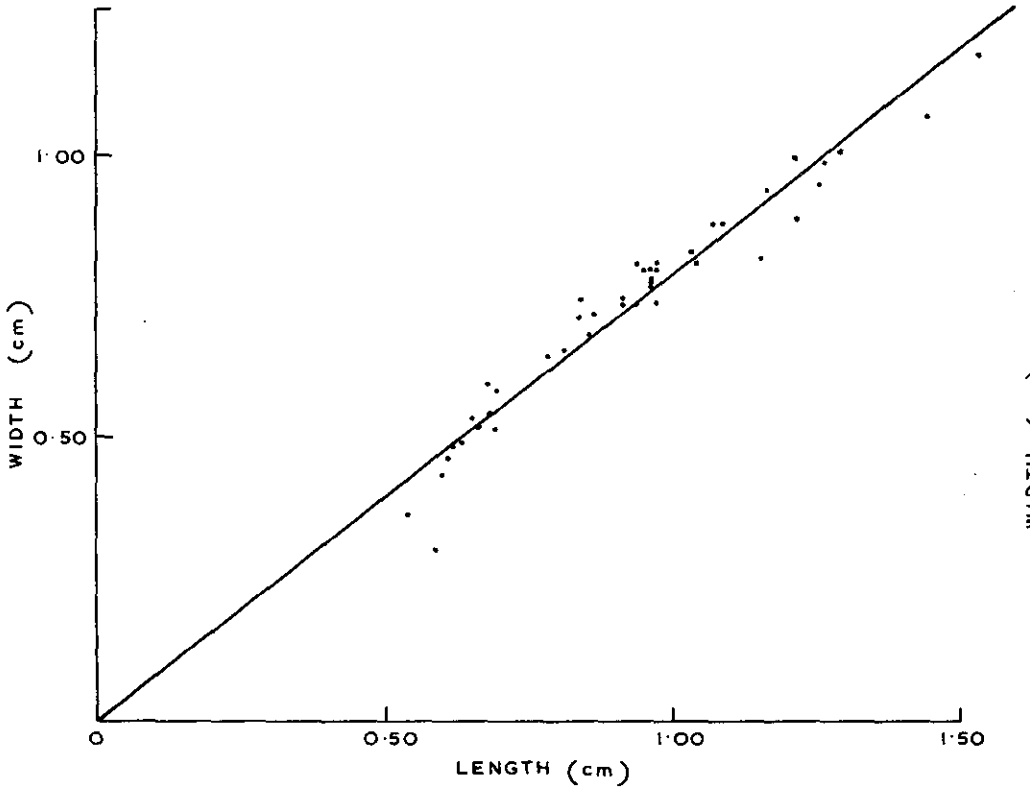


Fig. 9.- Morphometrics of Mictyris platycheles (male). (with regression through origin)

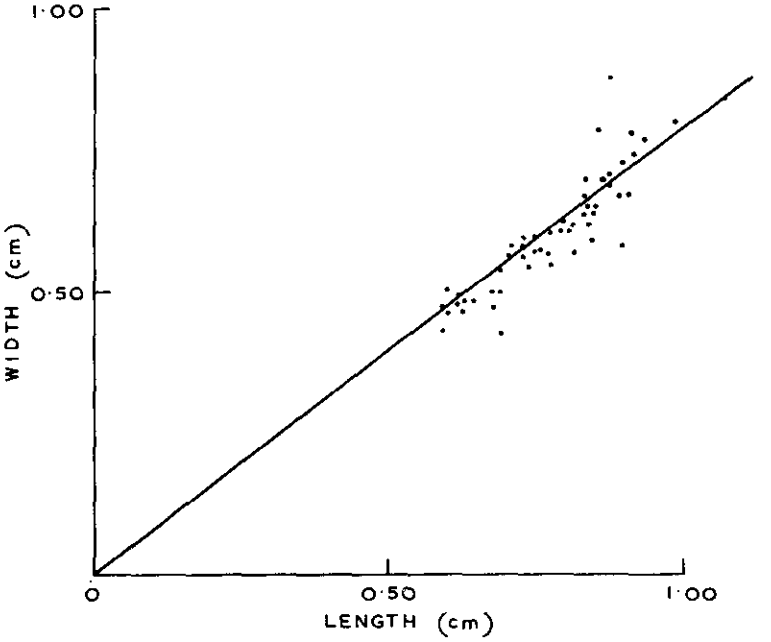


Fig. 10.- Morphometrics of Mictyris platycheles (female) (with regression through origin).

IV. REFERENCES

McNEILL, A.F. (1926).- Studies on Australian carcinology. Rec. Aust. Mus. 15: 100-31.

MILLER, D.C. (1961).- The feeding mechanism of fiddler crabs with ecological considerations of feeding adaptations. Zoologica, N.Y. 46: 89-100.

FISH ECOLOGY

I. INTRODUCTION

The objective of this programme was to make assessments of the population sizes of sand-whiting (Sillago ciliata), sea-mullet (Mugil cephalus), sand-mullet (Myxus elongatus), and luderick (Girella tricuspidata) in Port Hacking, and to determine aspects of population structure, such as size composition, age composition, and sex ratio.

II. METHODS

One method of estimating population size is to carry out a capture - recapture experiment. This consists of taking a set of one or more samples from a population, returning them to the population after marking them in a distinctive manner (tagging), and recording the number of marked individuals recaptured in a second set of one or more samples.

If N = total population size,
M = number taken in first sample, marked and returned to the population,
n = number taken in second sample,
and m = number of marked individuals recaptured in second sample,
then $\frac{m}{n} = \frac{M}{N}$, or $N = M\frac{n}{m}$.

An alternative method, that is particularly applicable to a net fishery, is to determine the catch taken from the area swept by the net and then to relate this to the total area of the fishing ground.

The fishing method used in Port Hacking was that of beach seining. With one end of the net held fast ashore the remainder of the net was set from a dinghy which was rowed on a semi-circular course to a point farther along the shore. The two ends of the net were then hauled so that the fish enclosed between the net and shore were brought into shallow water where they were captured and held in a cauf prior to being tagged.

The net used was 240 yd long and 12 ft deep with a 15 yd length of rope at each end. The bunt of the net had a mesh size of $1\frac{1}{8}$ in. and the wings were of $2\frac{1}{2}$ in. mesh.

Two weeks prior to the School (9.5.66) four net hauls were made in Port Hacking and the small numbers of fish captured were tagged with opercular strap tags and released into the population.

A further ten hauls were made during the first three days of the School. Most of the fish from these hauls were tagged and scale samples taken from the first 25 or so for age determination.

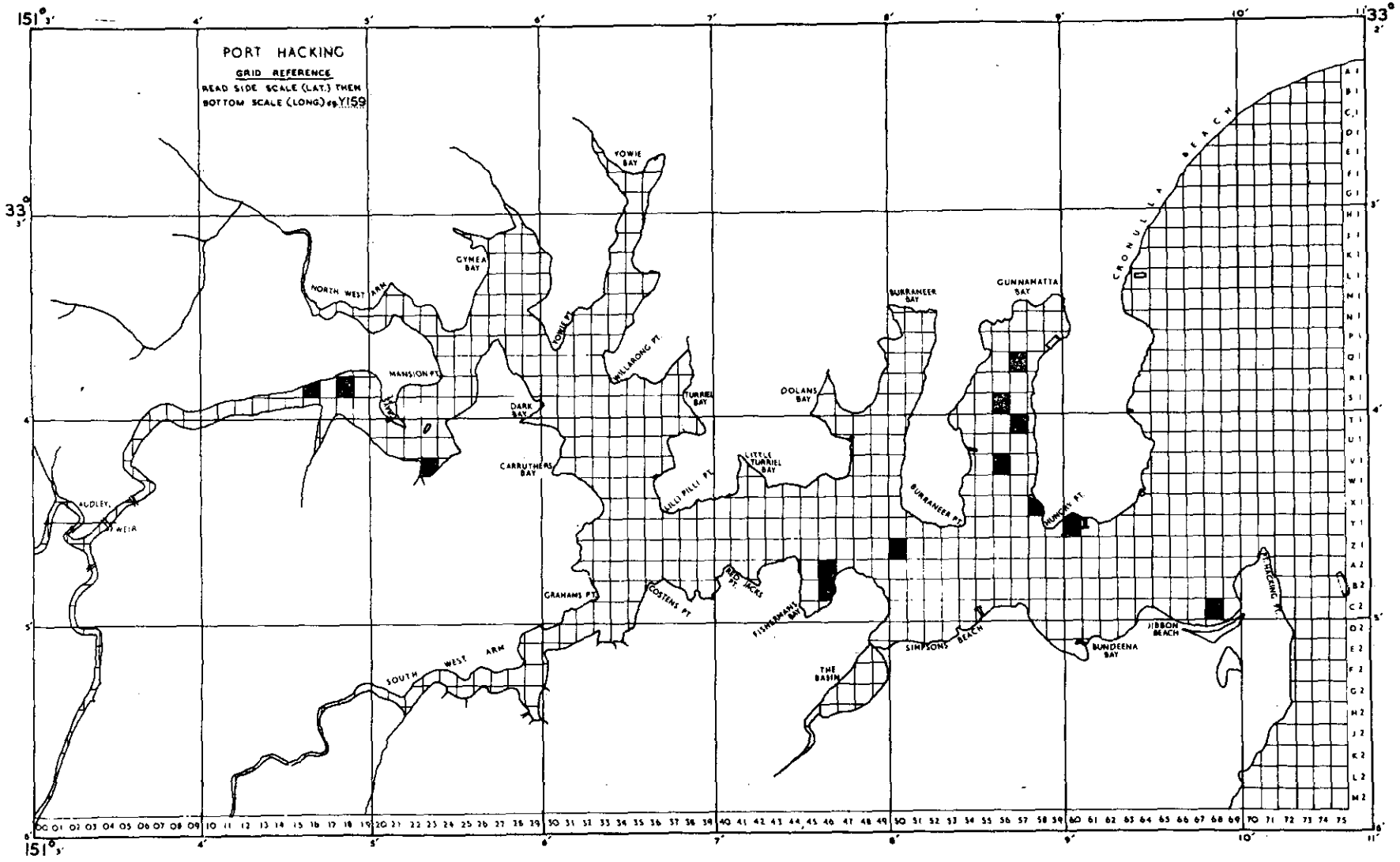


Fig. 1.- Netting and tagging localities.

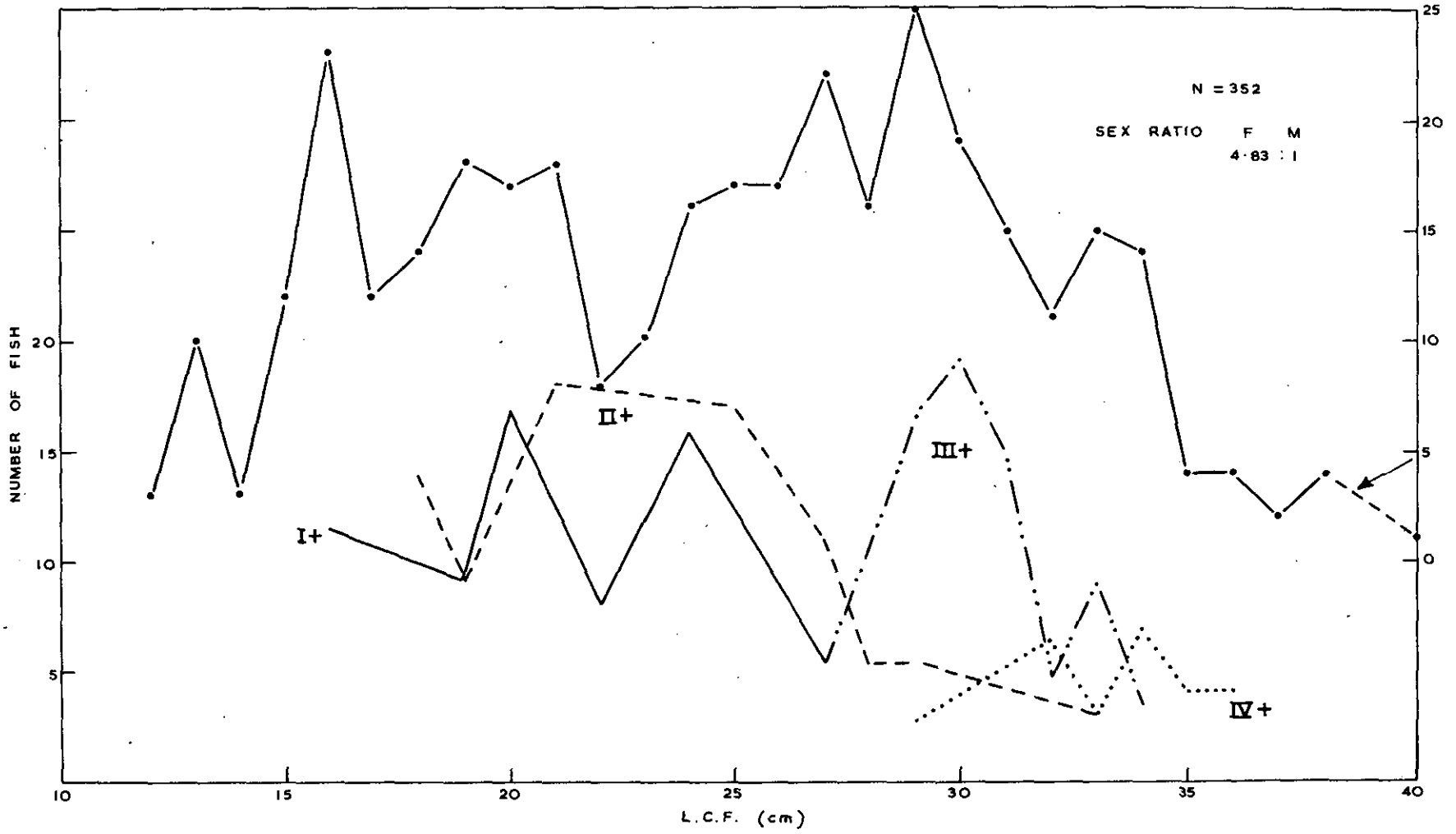


Fig. 2.- Size and age composition of whiting (Sillago ciliata).
Total no. of fish - 352. (Female/male = 4.83.)

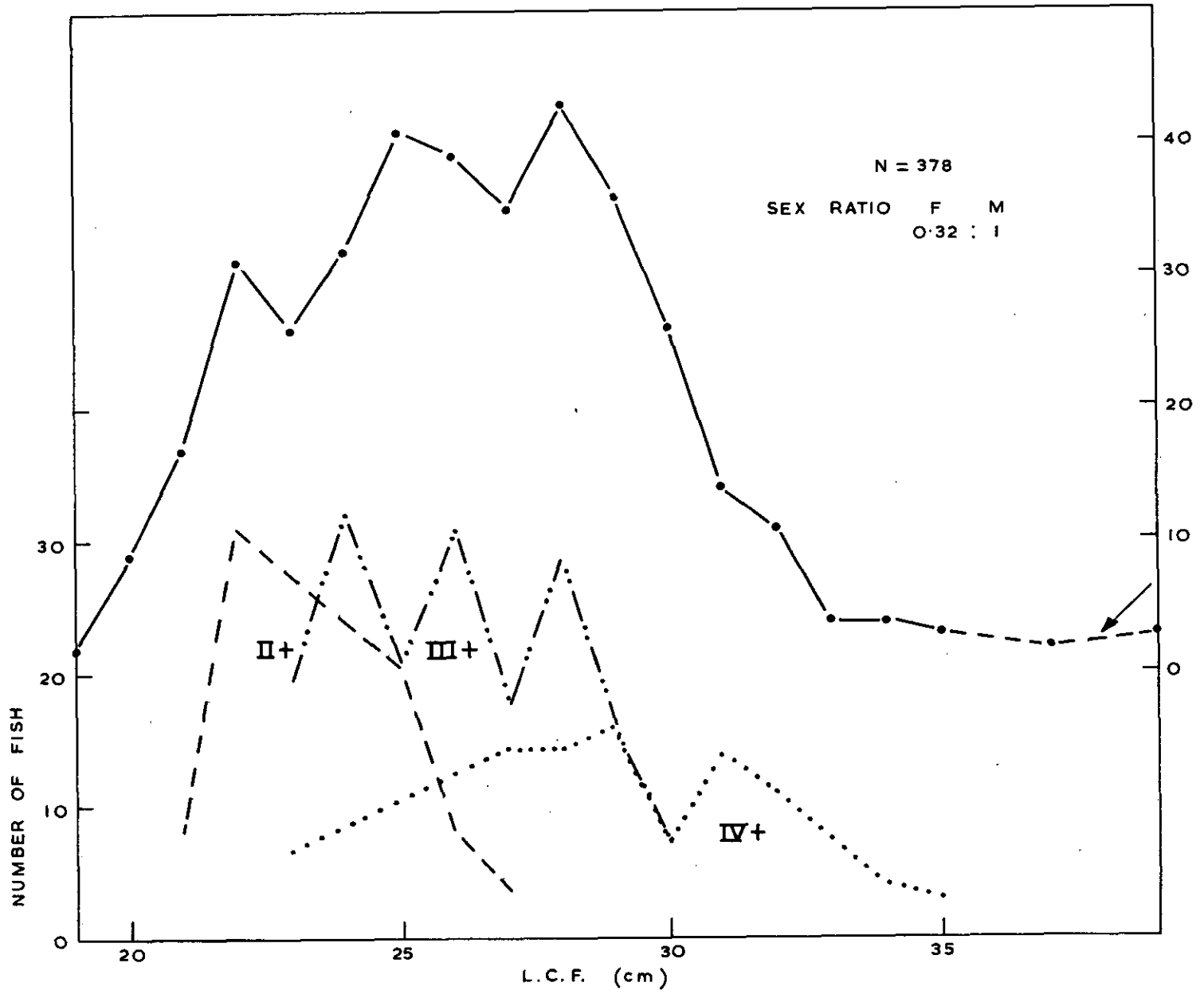


Fig. 3.- Size and age composition of sea mullet (Mugil cephalus). Total no. of fish - 378. (Female/male = 0.32)

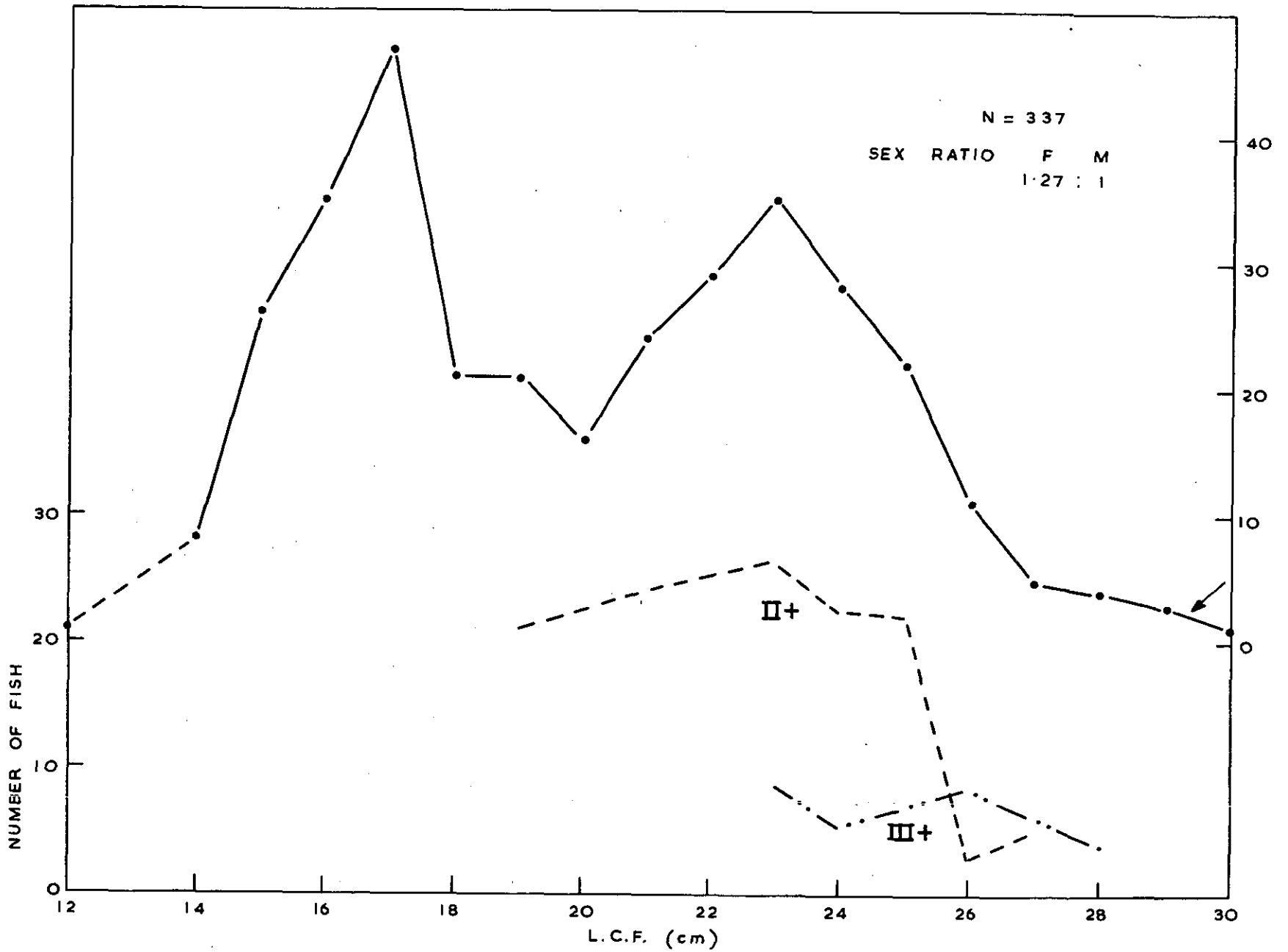


Fig. 4.- Size and age composition of sand mullet (Myxus elongatus). Total no. of fish - 337. (Female/male = 1.27)

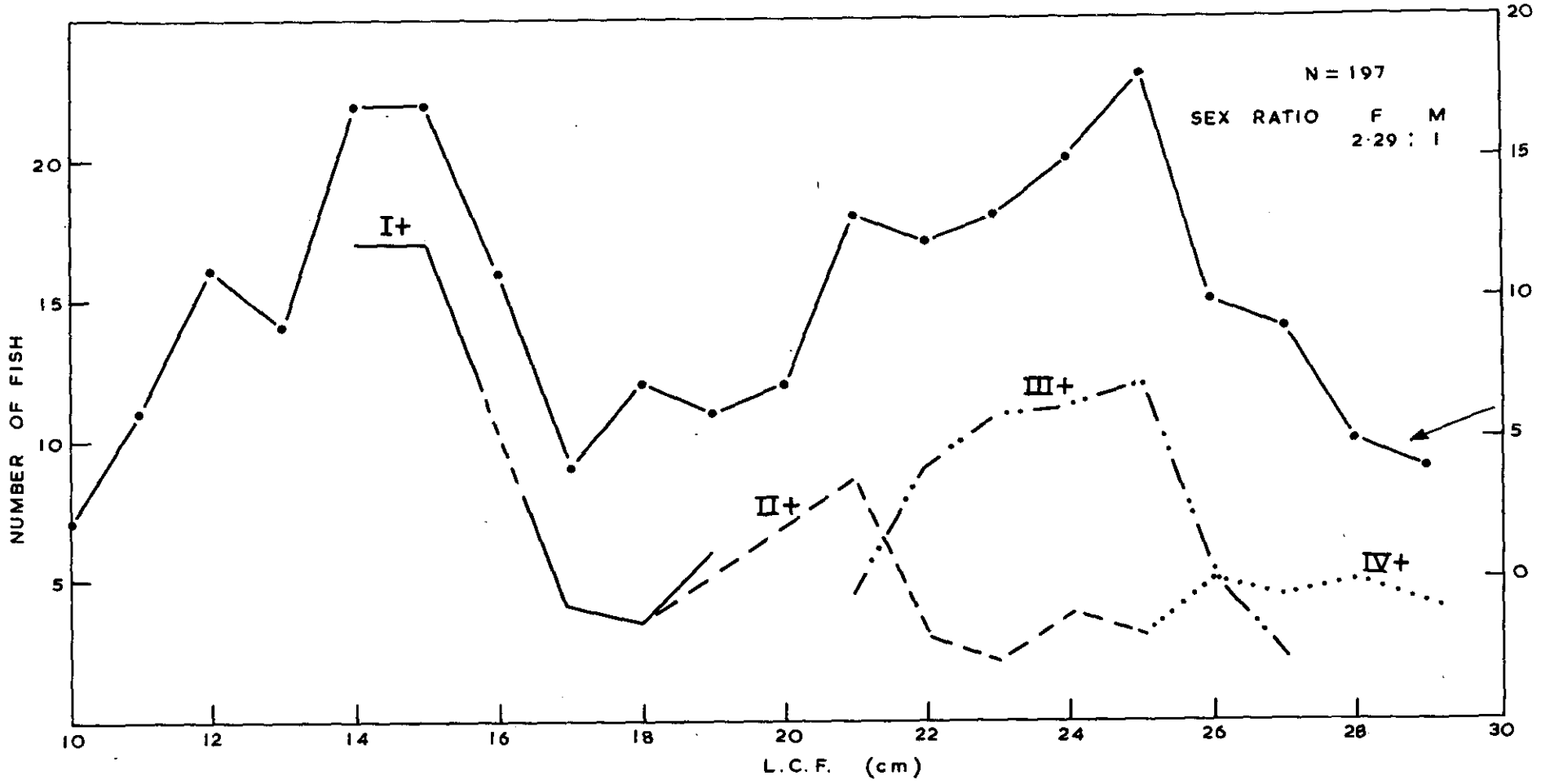


Fig. 5.- Size and age composition of luderick (Girella tricuspidata). Total no. of fish - 197. (Female/male = 2.29)

Samples of those not tagged were returned to the Laboratory for sex determination.

III. RESULTS

Netting and tagging localities are shown in Figure 1. The results of operations are summarised in Table 1.

The hauls made during the School failed to capture any of the fish tagged prior to the School.

Nine fish released and recaptured during the School were taken from closely adjoining areas and within an hour of being released. This interval of time was not of sufficient length to allow adequate mixing of the tagged and untagged members of the population, so that these recaptures could not be used in a capture - recapture experiment.

The results of calculations based on the swept area method, given that the area of Port Hacking is 1101 times that of the area swept by the net, are shown in Table 2.

Results of scale readings for the four species are given in Tables 5, 8, 11, and 14. Age-length keys were derived from these data (Tables 3, 6, 9, and 12). These were then used to determine the age composition of the catches (Tables 4, 7, 10, and 13).

The size composition of the catches of the four species are shown in Figures 2, 3, 4, and 5 together with their component age groups and sex ratio.

TABLE 1

SUMMARY OF NETTING OPERATIONS IN PORT HACKING
9-25.5.66

Date	Haul No.	Area	Sea-Mullet		Sand-Mullet		Sand-Whiting		Luderick	
			Tagged	Untagged	Tagged	Untagged	Tagged	Untagged	Tagged	Untagge
9.5.66	1/66	V1 56								
	2/66	X1 58					7			
	3/66	T1 57	31				35		4	
	4/66	Y1 60					11			
23.5.66	5/66	S1 56								
	6/66	Q1 57								
	7/66	C2 68								
	8/66	X1 58	7		94	243	9	26		
24.5.66	9/66	A2 46	48	4			52	25	10	
	10/66	B2 46	9+	2			51*	12	3	
	11/66	Z1 50	6				72	10		
25.5.66	12/66	V1 23	214	26					61	24
	13/66	R1 18	60				42	47	27	40
	14/66	R1 16	2[x]					6	9	24
	Total		377	32	94	243	279	126	114	88

* Plus 4 Recaptures from previous haul (re-released)

\+ Plus 2 " " " " (")

[x] Plus 3 " " " " (")

TABLE 2

POPULATION NUMBERS CALCULATED FROM NETTING OPERATIONS OF 23-25.5.66

Species	Total Catch	No.of Hauls	Mean Catch per Haul (A)	Area Port Hacking Area of Net (B)	Total Population (AxB)	S.D.	95% Limits
Sand-Whiting	352	10	35.2	1101	38,755	38.6	35.2 ± 77.2
Sea-Mullet	378	10	37.8	1101	41,618	74.4	37.8 ± 148.8
Sand-Mullet	337	10	33.7	1101	37,104	106.6	33.7 ± 213.2
Luderick	198	10	19.8	1101	21,800	31.6	19.8 ± 63.2

TABLE 3

SAND-WHITING - AGE/LENGTH KEY

LCF cm	Numbers						Percentages					
	Age Group						Age Group					
	0+	1+	2+	3+	4+	5+	0+	1+	2+	3+	4+	5+
16	1	1					50	50				
18			1						100			
19		1	1					50	50			
20		4						100				
21			1						100			
22		1						100				
24		1						100				
25			1						100			
27		1	2	1				25	50	25		
28			2	4					33	66		
29			2	6	1				22	66	11	
30				5						100		
31				6						100		
32				3	4					43	57	
33			1	3	1				20	60	20	
34				1	2	1				25	50	25
35					2						100	
36					2						100	
38						1						100
40						1						100

2516

TABLE 4

SAND-WHITING - AGE COMPOSITION OF CATCH

LCF cm	Nos.	Age Group					
		0+	1+	2+	3+	4+	5+
12	3						
13	10						
14	3						
15	12						
16	23	11.5	11.5				
17	12						
18	14			14			
19	18		9	9			
20	17		17				
21	18			18			
22	8		8				
23	10						
24	16		16				
25	17			17			
26	17						
27	22		5.5	11.0	5.5		
28	16			5.3	10.6		
29	25			5.5	16.5	2.7	
30	19				19		
31	15				15		
32	11				4.7	6.3	
33	15			3	9	3	
34	14				3.5	7.0	3.5
35	4					4	
36	4					4	
37	2						
38	4						4
39							
40	1						1
41	1						

TABLE 5

SAND-WHITING - SCALE READINGS

LCF cm	LO cm	L1 cm	L2 cm	L3 cm	L4 cm	L5 cm
32.0		14.9	19.9	23.8	29.1	
20.0	8.1	14.7				
25.0		10.8	19.2			
21.0		14.2	19.8			
29.0		14.5	19.3	22.9	26.0	
31.0		16.8	22.5	28.3		
18.0		10.9	16.5			
19.0		11.5	14.4			
35.0		17.0	25.3	30.3	34.6	
34.0		12.5	20.9	27.4	31.0	33.4
28.0		12.6	21.0			
31.0		12.5	22.9	28.0		
28.0		14.0	21.0	24.1		
29.0		11.2	22.3	26.3		
32.0		10.5	22.6	28.6	31.2	
35.0		17.5	24.8	29.7	33.9	
33.0		14.8	21.5	27.6	31.0	
30.0		11.1	22.2	28.6		
38.0		15.6	24.6	32.2	34.0	37.1
34.0		13.5	23.1	29.0	33.0	
36.0	7.5	18.7	25.5	31.5	34.5	
27.0		11.9	20.9	25.9		
29.0		12.5	21.1	26.1		
36.0	8.2	13.7	21.6	27.4	32.9	
31.0		14.7	20.1	27.9		
29.0		14.5	20.2	25.2		
32.0		11.3	20.2	27.5	30.4	
27.0		13.0	21.4			
28.0		10.2	19.5	25.6		
29.0		14.7	20.9	26.8		
29.0		14.3	24.4			
32.0	6.3	16.2	25.7	30.2		

TABLE 5 (Cont'd...)

LCF cm	L0 cm	L1 cm	L2 cm	L3 cm	L4 cm	L5 cm
34.0		18.5	25.9	31.4		
16.0	9.1					
19.0	10.4	18.6				
20.0	10.2	18.9				
16.0	4.9	15.4				
20.0	10.4	18.5				
20.0		18.9				
28.0		12.6	19.4	25.1		
28.0		11.8	19.4	25.3		
33.0		16.3	26.0	31.4		
30.0		14.4	22.0	28.0		
32.0		13.4	20.9	28.4	31.6	
34.0		17.4	24.4	28.8	32.7	
31.0	12.1	15.1	23.4	28.7		
30.0		14.6	23.2	29.3		
31.0		12.6	23.0	29.1		
32.0		14.0	23.2	29.4		
30.0	8.9	14.4	22.2	27.8		
27.0	6.2	20.8				
33.0		13.4	22.6	29.2		
24.0		16.3				
29.0		12.7	22.8	27.2		
27.0		14.9	24.1			
33.0	7.6	21.4	29.9			
33.0		16.9	25.5	29.9		
31.0		15.1	23.7	25.7		
29.0		10.4	21.6	27.7		
30.0		17.0	24.9	28.8		
22.0		13.0				
32.0		15.4	20.5	29.9		
28.0		15.6	23.6			
29.0		14.1	23.5			

TABLE 6

SEA-MULLET - AGE/LENGTH KEY

LCF cm	Numbers						Percentages					
	Age Group						Age Group					
	0+	1+	2+	3+	4+	5+	0+	1+	2+	3+	4+	5+
21		1	1					50	50			
22			2						100			
23				3	1					75	25	
24				2						100		
25			1	1					50	50		
26			1	4					20	80		
27			1	5	4				10	50	40	
28				4	2					66	33	
29				4	4	1				44	44	11
30				2	2	3				28	28	43
31					4						100	
32					2						100	
33												
34					1						100	
35					1						100	

TABLE 7

SEA-MULLET - AGE COMPOSITION OF CATCH

LCF cm	Nos.	Age Group					
		0+	1+	2+	3+	4+	5+
19	2						
20	9						
21	17		8.5	8.5			
22	31			31.0			
23	26				19.5	6.5	
24	32				32.0		
25	41			20.5	20.5		
26	39			8.0	31.0		
27	35			3.5	17.5	14.0	
28	43				28.6	14.3	
29	36				16.0	16.0	4.0
30	26				7.3	7.3	11.2
31	14					14.0	
32	11					11.0	
33	4						
34	4					4	
35	3					3	
36							
37	2						
38							
39	3						

TABLE 8

SEA-MULLET - SCALE READINGS

LCF cm	L0 cm	L1 cm	L2 cm	L3 cm	L4 cm	L5 cm
35.0	8.3	11.5	19.3	28.1	33.1	
34.0		13.5	23.4	29.9	33.7	
28.0		12.9	18.7	22.9	27.1	
32.0		11.0	20.1	22.9	26.2	
30.0		14.5	18.6	23.8		
29.0	10.5	13.5	18.7	22.3		
31.0		9.3	21.3	25.0	30.0	
27.0		10.2	14.9	19.6	22.2	
27.0		10.8	14.9	19.7	23.2	
26.0		12.1	15.9	22.5		
27.0		10.5	15.7	19.0		
29.0		9.3	12.6	20.0	25.3	
28.0		9.9	16.0	20.0		
30.0		9.1	13.7	19.4	24.9	
27.0		14.1	17.8	20.2		
29.0		10.1	15.1	19.5		
23.0		9.6	15.1	18.2	21.3	
28.0		12.5	17.3	21.4		
22.0		10.1	12.7			
27.0		10.8	14.2	19.0		
27.0		11.3	14.4			
26.0		12.5	18.5			
29.0		9.0	12.9	18.3	23.1	
25.0		11.2	16.2	23.7		
26.0		10.4	15.3	22.0		
30.0		9.0	14.7	21.3	25.0	28.3
30.0		9.7	17.4	23.0		
31.0		9.9	15.5	20.5	24.0	
28.0		8.1	15.6	20.2	24.2	
30.0		7.8	14.4	20.4	24.6	28.5
24.0		12.2	15.8	23.0		

TABLE 8 (Cont'd...)

LCF cm	L0 cm	L1 cm	L2 cm	L3 cm	L4 cm	L5 cm
29.0		10.5	18.2	22.5		
29.0		10.1	18.3	22.5	26.5	
21.0		10.7	14.7			
26.0		11.1	18.0	22.1		
31.0		10.8	17.0	21.6	25.6	
28.0		7.1	15.1	20.7		
30.0		10.2	13.6	17.3	21.0	
27.0		8.9	14.0	19.7	22.2	
23.0		10.9	15.3	18.9		
27.0		10.5	14.4	18.3	21.6	
22.0	8.2	11.6	16.3			
23.0		10.1	13.2	19.0		
31.0		10.3	16.5	24.8	30.1	
30.0		11.4	15.8	20.8	24.7	28.5
27.0		10.2	14.1	18.0		
29.0		9.3	14.8	18.9	24.9	
27.0	6.1	11.0	16.3	22.7		
21.0	8.7	12.9				
32.0	10.2	16.2	23.0	26.7		
23.0		8.4	13.5	19.1		
29.0	6.7	10.6	15.6	19.5		
29.0		10.5	12.5	18.6	21.5	24.9
25.0		10.7	15.6			
28.0		7.4	14.7	20.6		
24.0		9.2	13.8	16.6		
26.0		11.1	15.8	22.2		

TABLE 9

SAND-MULLET - AGE/LENGTH KEY

LCF cm	Numbers				Percentages			
	Age Group				Age Group			
	0+	1+	2+	3+	0+	1+	2+	3+
19			1				100	
20		1				100		
21			2				100	
22								
23			3	1			75	25
24			4	1			80	20
25			5				100	
26			1	3			25	75
27			1				100	
28				1				100

TABLE 10

SAND-MULLET - AGE COMPOSITION OF CATCH

LCF cm	Nos.	Age Group.			
		0+	1+	2+	3+
10					
11					
12	1				
13					
14	8				
15	26				
16	35				
17	47				
18	21				
19	21			21	
20	16		16		
21	24			24	
22	29				
23	35			26.25	8.75
24	28			22.4	5.6
25	22			22	
26	11			2.75	8.25
27	5			5	
28	4				4
29	3				
30	1				

2516

TABLE 11

SAND-MULLET - SCALE READINGS

LCF cm	LO cm	L1 cm	L2 cm	L3 cm	L4 cm
23.0		10.7	18.5		
25.0	7.8	14.7	20.3		
23.0		13.4	17.0		
26.0		13.6	17.1	20.0	
26.0		10.6	15.7	20.7	
25.0		14.3	20.8	20.5	
25.0		11.7	21.3		
20.0	7.5	12.5			
24.0		15.6	19.8		
26.0		11.4	20.5		
21.0		13.5	18.2		
23.0		14.4	20.7		
19.0	4.1	12.5	16.8		
24.0		11.7	20.2		
23.0		11.7	17.6		
25.0	7.8	13.9	20.4		
21.0		12.8	18.4		
24.0	9.6	13.8	19.2	22.5	
24.0		16.0	21.3		
25.0	8.2	16.1	22.7		
27.0		16.2	24.3		
28.0	7.73	13.5	21.2	25.1	
26.0		10.2	19.5	23.8	
24.0		10.8	18.4		

TABLE 12

LUDERICK - AGE/LENGTH KEY (From Scale Samples)

LCF cm	Numbers						Percentages					
	Age Group						Age Group					
	0+	1+	2+	3+	4+	5+	0+	1+	2+	3+	4+	5+
10	1						100					
14		2						100				
15		2						100				
17		1						100				
18		1	1					50	50			
19		2						100				
21			2	1					66	33		
22			1	3					25	75		
23			1	5					17	83		
24			1	3					25	75		
25			1	4	1				17	66	17	
26				2	2					50	50	
27				1	2	1				25	50	25
28					1						100	
29					1						100	

TABLE 13

LUDERICK - AGE COMPOSITION OF CATCH

LCF cm	Nos.	Age Group					
		0+	1+	2+	3+	4+	5+
8	1						
9							
10	2	2					
11	6						
12	11						
13	9						
14	17		17				
15	17		17				
16	11						
17	4		4				
18	7		3.5	3.5			
19	6		6				
20	7						
21	13			8.6	4.3		
22	12			3.0	9.0		
23	13			2.2	10.8		
24	15			3.7	11.2		
25	18			3.0	11.9	3.0	
26	10				5.0	5.0	
27	9				2.2	4.5	2.2
28	5					5.0	
29	4					4.0	
30							

TABLE 14

LUDERICK - SCALE READINGS

LCF cm	L0 cm	L1 cm	L2 cm	L3 cm	L4 cm	L5 cm
27.0		6.4	11.5	17.1	20.4	25.0
26.0		9.0	13.9	19.1		
28.0		6.5	11.3	19.4	23.4	
26.0		7.6	13.5	16.2	22.2	
24.0		10.4	16.4	19.6		
26.0		6.9	12.5	16.3	20.8	
25.0		10.5	14.8	18.7		
23.0		10.4	13.6	16.8		
21.0		9.3	15.7			
24.0		8.9	14.5	19.4		
25.0		8.9	15.5	19.8		
22.0		9.3	15.1	21.2		
25.0		9.5	14.0	18.7	21.7	
27.0	9.5	13.6	19.5	24.2		
24.0		9.1	16.1	19.7		
25.0		12.5	17.5	20.3		
25.0	9.1	13.1	18.7			
23.0		10.5	16.3	18.9		
23.0		7.7	16.1			
23.0		10.1	15.5	18.4		
21.0		9.8	16.0	17.3		
25.0	7.0	13.5	16.9	21.9		
29.0		11.3	15.1	19.4	25.0	
23.0		10.0	13.6	18.2		
19.0	9.2	13.5				
22.0		11.0	15.4	18.5		
19.0	6.2	12.7				
23.0		10.7	15.9	18.4		
22.0	8.3	15.5	21.6			
17.0	7.6	13.3				

TABLE 14 (Cont'd...)

LCF cm	LO cm	L1 cm	L2 cm	L3 cm	L4 cm	L5 cm
27.0		9.8	16.37	21.82	23.46	
21.0	7.6	13.1	17.2			
18.0	8.0	14.0				
22.0	11.0	15.9	19.2			
24.0	8.8	14.3	19.9			
27.0		9.9	16.5	19.3	22.9	
18.0		10.1	13.9			
10.0	4.0					
15.0	6.6	11.4				
26.0		13.4	17.7	20.6		
15.0		9.9				
14.0		10.0				
14.0	9.3	12.1				

Appendix

Hydrology Mr D. Rochford

L. Allen (N.S.W.)
A. Butler (S.A.)
J. Griffiths (N.S.W.)
P. Harmata (Syd.)
J. Kraegen (Syd.)
N. Malajczuk (W.A.)
J. Marwood (Syd.)
A. Scott (N.S.W.)
P. Walsh (Melb.)

Zooplankton Mr D. Tranter
Mr A. Heron

S. Ong (Tas.)
Margaret Gare (Adel.)
T. Helbig (Qld.)
Angela Frecker (Syd.)
T. Moulton (Syd.)
Br G.R. Rossiter (Syd.)
Anne Russell (Syd.)
P. Smith (Syd.)

Fish Ecology Mr R. Cowper

K. Chiu (Tas.)
M. Denny (N.S.W.)
Sandra Donaldson (Syd.)
Janice Edwards (Adel.)
D. Hamilton (Tas.)
R. Mahon (W.A.)
C. Page (Syd.)
K. Anderson (Syd.)
Judith Sykes (Adel.)

Physical Chemistry Dr M. Whitfield

J. Bennett (Syd.)
Mary Campbell (Syd.)
Anne Kenny (Syd.)

Bacteriology Dr B. Grant
Miss I. Turner

M. Hill (Syd.)
Pamela Kelly (Syd.)
D. Oswald (Syd.)
K. Rainsford (A.N.U.)
Pat Smart (Syd.)
D. Tracey (Syd.)

Pigments in Marine Algae Dr S. Jeffrey

G. Sylvester (N.S.W.)
Elizabeth Ross (A.N.U.)
J. Hambley (Adel.)
Alison Seagrim (A.N.U.)

Statistical Ecology Dr B. Wisely,
Mr A. Stark
Mr J. Kerr

R. Bradbury (Qld.)
Barbara Brown (W.A.)
Alison Jessup (Syd.)
Roslyn Jones (W.A.)
C. Leong (A.N.U.)
J. Mott (W.A.)
Frances Owen (Melb.)
I. Reid (Melb.)
M. Reynolds (A.N.U.)
Clare Schroder (Adel.)
I. Skinner (N.S.W.)
Anthea Wellington (Monash)

Benthos Dr A. Albani (University of N.S.W.) - no report available

Jane Berwick (Tas.)
Dianne Cooney (Syd.)
Madeleine Haremaker (Syd.)
Roslyn Hill (N.S.W.)
Marietta Grubb (Tas.)
Pamela Hooke (Syd.)
Lesley Mulligan (N.S.W.)
Malle Rebase (Syd.)
G. Taylor (N.S.W.)