Distribution and Composition of Photosynthetic Pigments in the South China Sea, Area II: Sabah, Sarawak and Brunei Darussalam Waters

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ABSTRACT

Depth integrated biomass of phytoplankton in the southern part of the South China Sea off Sarawak, Brunei Darussalam and Sabah in July 1996 and May 1997 was represented by in situ fluorescence. The total biomass in the study area was not much different between the 2 surveys. However, the spatial distribution of biomass clearly showed a unique pattern for each cruise. In overall, the local biomass per unit area did not correlate strongly with surface mixed layer thickness and sea surface temperature, two indicators of upwelling used in this study. Yet, anomalously high biomass of phytoplankton found in the vicinity of Stations 37 and 38 for both survey periods could be partially related by upwelling nearby.

Introduction

Photosynthetic pigments, especially chlorophylls, has been widely used as an important indicator of biomass of phytoplankton in the ocean and freshwater bodies. The main reason is that chemical approaches which are less subjected to human errors and bias than most other biological or physical approaches can determine these pigments quite conveniently.

The technique of using submersible fluorometer to measure profile of photosynthetic pigment in the water column was first introduced in this region by SEAFDEC in 1995 (Snidvongs 1998). Some advantages of this technique are ability of detect fine scale variability with depth which is due to the swarming of plankton, and ability of show real time data while measuring. Also since 1995, subsurface chlorophyll maxima were clearly verified at about 50-100 m in most Southeast Asian Waters deeper than ca. 50 m. For most offshore water in the region, despite the very low surface concentration of pigment comparable to that in oligotrophic open ocean, the concentration of pigment at the subsurface pigment maxima could be up to 10 times the surface concentration.

In this paper, dynamic of phytoplankton biomass in the South China Sea Area 2, Sabah, Sarawak and Brunei Darussalam, between 2 periods, July 1996 (Cruise 34) and May 1997 (Cruise 41), will be analyzed in relation to major physical characteristics of the region, e.g. vertical migration of thermocline and sea surface temperature, which are correlated to upwelling and downwelling processes.

Methods

The relative concentration of photosynthetic pigment was measured by a Sea Tech submersible fluorometer. The data was averaged at every 1 dbar interval. The fluorescence biomass above instrument baseline (taken at 0.5 and 0.4 volts for Cruises 34 and 41, respectively) was integrated from sea surface to 200 m, or to the bottom if depth was less than 200 m. This depth integrated fluorescence eliminates the problem due to vertical migration of plankton with time of the day, and therefore data from different time or sun phase are comparable.

To calibrate fluorescence data into pigment mass unit, water samples from 3-5 selected depths at each station were collected. Five to seven liter of sample was vacuum filtered through Whatman GF/F membranes on board in shaded environment. Pigment was extracted by acetone in dark glass or polypropylene centrifuge tubes in a freezer. After grinding and centrifuge, the supernatant in a 50 mm path-length cell was scanned by a spectrophotometer from 400 to 750 nm. Blanks were also centration using SCOR/Unesco (1966) equations (Strickland and Parsons, 1972). Concentration of chlorophyll a, b and c (in mg m-3) was linearly regressed against observed upcast fluorescence at each sampling depth. A correction factor was introduced to force the pigment concentration at the baseline, i.e. sub-photic zone, to be zero.

Results

Only chlorophyll a was found to be in significant concentrations in water samples collected (Table 1). The concentration was also well correlated linearly with in situ fluorescence (r2 = 0.93; Figure 1). The concentrations of the other two chlorophylls were low and poorly correlated with the in situ fluorescence and thus prohibited further analysis of those data.

Phytoplankton biomass per area in the study area as inferred from in situ fluorescence was especially high in the vicinity of St. 37 and 38 (Table 2), for both cruises. However, the plume of phytoplankton seemed to be from the northwest during Cruise 34 (Figure 2) and from the west during Cruise 41 (Figure 3). Phytoplankton biomass was concentrated more on the north side of the survey area during Cruise and more to the west during Cruise 41. However, despite this obvious difference in the spatial distribution of phytoplankton, the total biomass in the study area for both cruises was not much different from each other. The total biomass as chlorophyll a calculated using equation in Figure 1 would be 2,070 and 1,870 tons for the total survey area of 243,000 km2 for Cruises 34 and 41, respectively. The difference was less than 10%, which was surprisingly small.

Discussion and Conclusion

The hypothesis that biomass of phytoplankton in the survey area would be induced by upwelling had been tested using the mixed layer depth as indicated by the Brunt-Vaisala Stability Frequency. Generally, the surface mixed layer thickness during Cruise 34 was an average of 41 m while during Cruise 41, the thickness was only 28 m. The difference of 13 m indicated more intense upward movement of the pycnocline in May 1997 than in July 1996, especially at Stations 13, 20, 21, 25 and 26 where the surface mixed layer was less than 20 m (Figure 3).

Sea surface temperature taken from 5 m below surface was also used as another indicator of upwelling. However, unlike surface mixed layer depth, sea surface temperature was lowest at Stations 74 and 78 during Cruise 41. Sea surface temperature was much more evenly distributed in Cruise 34 than in Cruise 41.

Despite the upward migration of pycnocline, an indication of upwelling, neither the total biomass of chlorophyll in the area nor the horizontal distribution of pigment show any clear responses to this physical oceanographic feature (Figure 5). Yet this still does not completely rule out a linkage between the two, since time lagging between nutrient input and massive plankton proliferation could take a week or so, and that could be easily missed by the 2 survey, about a year apart. This is suggested by a weak correlation between elevated chlorophyll biomass at Stations 26, 37 and 38 in Cruise 41 while was near to the suspected upwelling area, even though they did not perfectly coincided geographically.

Table 1 Corrected chlorophyll a concentration in water samples

ST	Depth (m)	FLUR (V)	Chlorophyll *a* (mg m^{-3})	Chlorophyll *b* (mg m^{-3})	Chlorophyll *c* (mg m^{-3})
Cruise 41					
4	20	0.803	0.037	0.033	0.196
4	60	3.219	0.543	0.239	0.769
8	30	2.001	0.248	0.087	0.346
8	40	2.148	0.251	-0.046	0.402
12	60	3.896	0.204	-0.247	-0.697
13	50	0.746	0.014	0.069	0.297
13	90	1.427	0.12	0.13	0.434
14	30	0.675	0.064	0.091	0.467
15	10	0.623	-0.002	0.014	0.258
16	30	1.173	0.114	0.061	0.209
16	40	4.677	0.766	0.122	0.501
16	50	4.279	0.697	0.14	0.539
15	30	2.548	0.242	0.014	0.202
15	50	3.405	0.493	0.092	0.134
17	18	2.118	0.321	0.057	0.42
17	25	2.453	0.338	0.066	0.55
21	50	1.303	0.185	0.14	0.571
22	71	1.986	0.195	0.103	0.596
28	20	0.526	-0.018	-0.004	0.049
28	65	2.845	0.404	0.074	0.139
33	10	0.587	-0.054	-0.047	-0.097
34	60	3.452	0.508	0.13	0.3
35	80	2.242	0.249	0.063	0.16
36	80	1.056	0.156	0.232	0.585
42	70	2.612	0.336	0.103	0.208
43	90	1.302	0.081	0.077	0.085
44	60	2.424	0.347	0.066	0.026
45	20	0.561	0.088	0.044	0.062
45	50	2.093	0.424	0.319	0.652
46	10	1.274	0.185	-0.017	-0.09
46	19	4.433	0.81	0.061	0.569
47	20	1.041	0.116	-0.007	-0.019
48	40	1.821	0.162	-0.009	-0.087
49	90	1.206	0.062	0.043	0.012
51	30	0.613	0.035	-0.02	-0.003
60	40	1.013	0.204	0.069	0.109
76	20	0.519	0.027	-0.003	0.026
77	70	1.084	0.145	0.032	0.049

Table 2. Fluorescence peak height (V) and depth from sea surface at time of casting, and depth intergrated fluorescence

Cruise 34

St.	Fluorescence Max (V)	Fluorescence Max Depth (m)	Depth Integrated Fluorescence
1	1.923	36.3	11.92
2	4.326	53.2	22.52
3	4.834	66.1	81.53
4	3.685	61.2	37.17
5	3.942	54.2	89.59
6	3.572	40.3	19.43
7	3.319	26.4	48.96
8	0.912	30.3	6.03
9	3.05	63.1	45.28
10	2.818	76.1	49.98
11	2.662	67.1	63.84
12	2.511	78.1	77.99
13	2.656	73.1	73.16
14	2.93	70.1	64.76
15	4.948	54.2	68.88
16	3.807	40.3	99.1
17	2.365	26.4	22.24
18	5.141	44.3	41.85
19	4.038	56.2	69.86
20	3.095	68.1	81.73
21	2.911	76.1	91.7
22	2.254	62.1	74.88
23	3.016	58.2	90.9
24	2.718	56.2	105.36
25	2.192	66.1	56.39
26	2.972	69.1	84.67
27	4.527	63.1	95.26
28	3.521	67.1	71.53
29	3.823	52.2	43.23
30	2.555	29.3	22.4
31	4.607	18.4	18.53
32	2.88	31.3	16.32
33	3.747	46.2	34.29
34	5.614	63.1	54.85
35	3.076	70.1	68.71
36	2.82	64.1	69.85
37	3.574	70.1	113.55
38	3.728	66.1	140.14
39	3.103	51.2	106.59
40	2.744	63.1	97.95
41	2.664	67.1	89.99
42	3.787	68.1	87.55
43	3.018	67.1	65.82
44	2.926	63.1	57.16
45	4.675	58.2	40.97
46	1.353	18.4	4.77
47	3.812	28.3	15.91
48	2.682	57.2	44.9
49	3.49	70.1	74.75
50	4.561	65.1	111.55
51	2.051	68.1	54.15
52	3.05	74.1	83.45
53	3.074	79	92.47
54	2.62	74.1	95.75
55	3.051	65.1	104.9
56	3.731	78	105.72
57	3.365	75.1	87.92
58	2.811	86	87.05
59	2.172	59.2	78.7
60	2.613	53.2	88.97
61	2.426	71.1	100.34
62			
63	2.363	73.1	73.63
64	2.496	82.1	81.54
65	3.297	72.1	106.45
66	3.191	84.1	102.61
67	2.793	83.1	82.68
68	2.785	83.1	77.98
69	3.841	65.2	73.04
70	3.609	70.1	85.63
71	3.451	68.2	96.04
72	3.382	72.1	93.99
73	2.489	76.1	68.98
74	2.854	76.1	104.63
75	3.821	65.2	101.33
76	3.605	64.2	66.66
77	2.84	61.2	65.72
78	2.826	72.1	79.85
79	2.047	38.3	22.13

Cruise 41

St.	Fluorescence Max (V)	Fluorescence Max Depth (m)	Depth Integrated Fluorescence
1			
2			
3	5.261	34.3	143.176
4	4.098	61.2	80.706
5	2.748	47.2	74.28
6	3.842	33.3	59.192
7	3.216	25.4	55.181
8	2.062	40.3	23.236
9	2.786	62.1	52.564
10	3.148	70.1	84.299
11	2.956	63.1	84.903
12	4.58	60.2	135.712
13	2.534	81	74.679
14	2.433	63.1	72.773
15	3.913	45.2	93.785
16	4.876	51.2	101.443
17	2.277	26.4	19.794
18	2.856	46.2	24.477
19	2.815	67.1	87.547
20	2.409	71.1	66.424
21	2.397	64.1	88.854
22	1.828	76.1	64.925
23	2.212	72.1	75.089
24	3.583	73.1	107.355
25	2.01	63.1	60.285
26	2.585	60.2	115.737
27	2.978	67.1	76.184
28	4.399	65.1	80.121
29	2.945	54.2	26.19
30	1.912	33.3	13.248
31	2.95	19.4	13.347
32	2.204	31.3	16.726
33	2.494	50.2	17.246
34	2.602	71.1	49.722
35	2.14	79	69.137
36	1.895	71.1	63.241
37	2.154	68.1	101.741
38	3.148	74.1	140.798
39	2.429	82	77.189
40	2.139	85	69.546
41	2.421	67.1	92.186
42	2.86	70.1	98.637
43	2.278	61.2	87.654
44	2.165	75.1	57.67
45	1.949	64.1	39.928
46	3.612	19.4	17.944
47	2.057	26.4	13.422
48	2.076	63.1	51.621
49	2.021	73.1	65.49
50	2.144	65.1	69.181
51	1.933	70.1	71.897
52	2.466	58.2	85.581
53	2.554	63.1	82.115
54	2.051	52.2	70.654
55	1.885	70.1	57.948
56	2.257	56.2	77.982
57	1.791	54.2	84.283
58	1.925	70.1	87.369
59	1.367	50.2	46.09
60	1.447	52.2	66.22
61	1.433	81	70.442
62	1.979	66.1	57.235
63	1.854	55.2	50.772
64	1.86	56.2	53.421
65	2.195	66.1	58.629
66	2.047	62.1	53.229
67	1.435	62.1	37.653
68	1.184	73.1	40.166
69	1.444	41.3	52.767
70	0.857	51.2	35.842
71	0.985	55.2	33.734
72	1.476	53.2	48.569
73	1.442	69.1	47.775
74	1.235	47.2	40.046
75	1.486	50.2	54.243
76	2.011	62.1	50.627
77	1.293	64.1	31.035
78	1.566	66.1	48.643
79	2.283	50.2	30.905

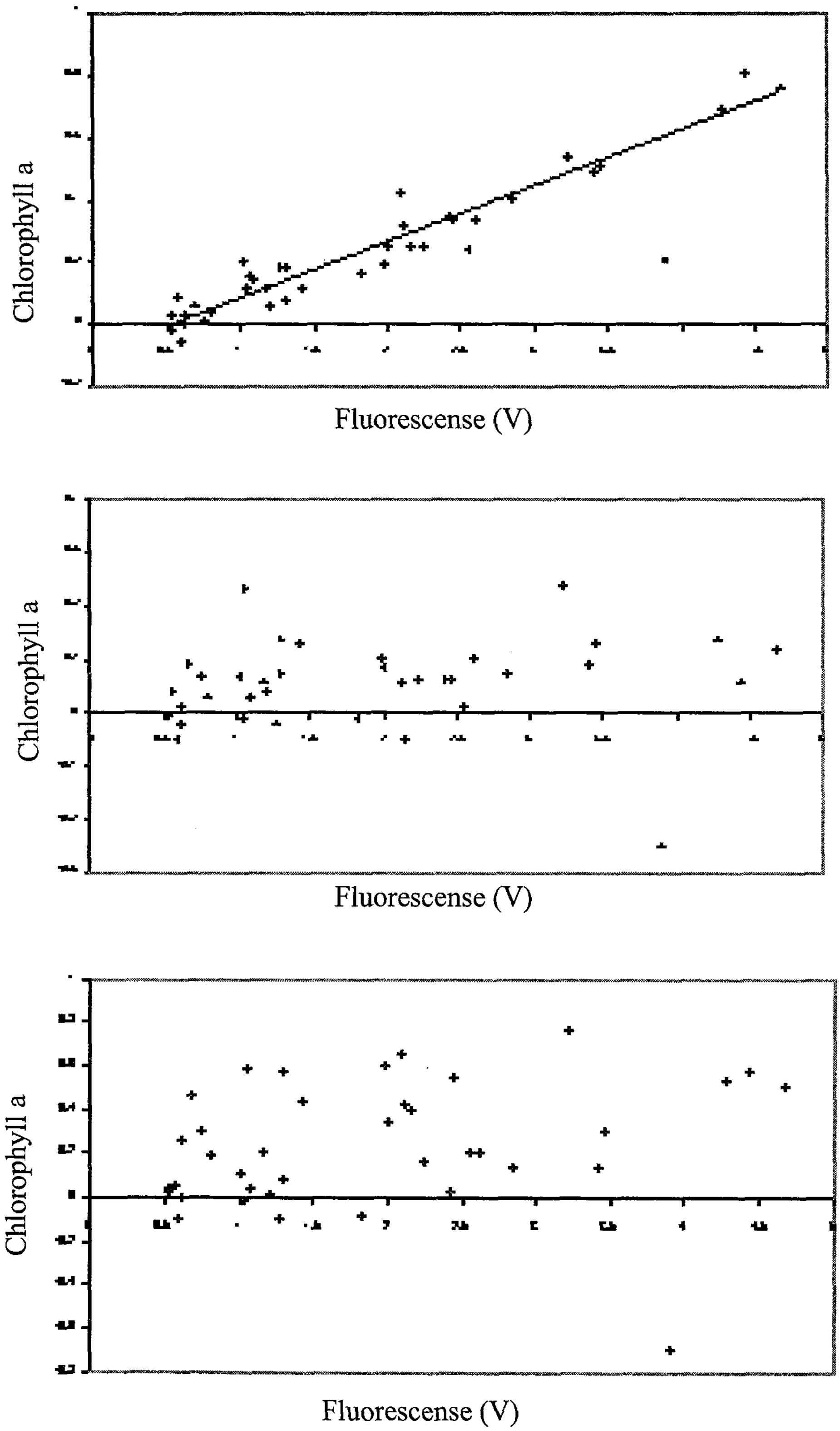


Fig. 1 Concentration of chlorophyll a, b and c in water samples collected during the Cruise 41 (top, Center, and bottom panels)

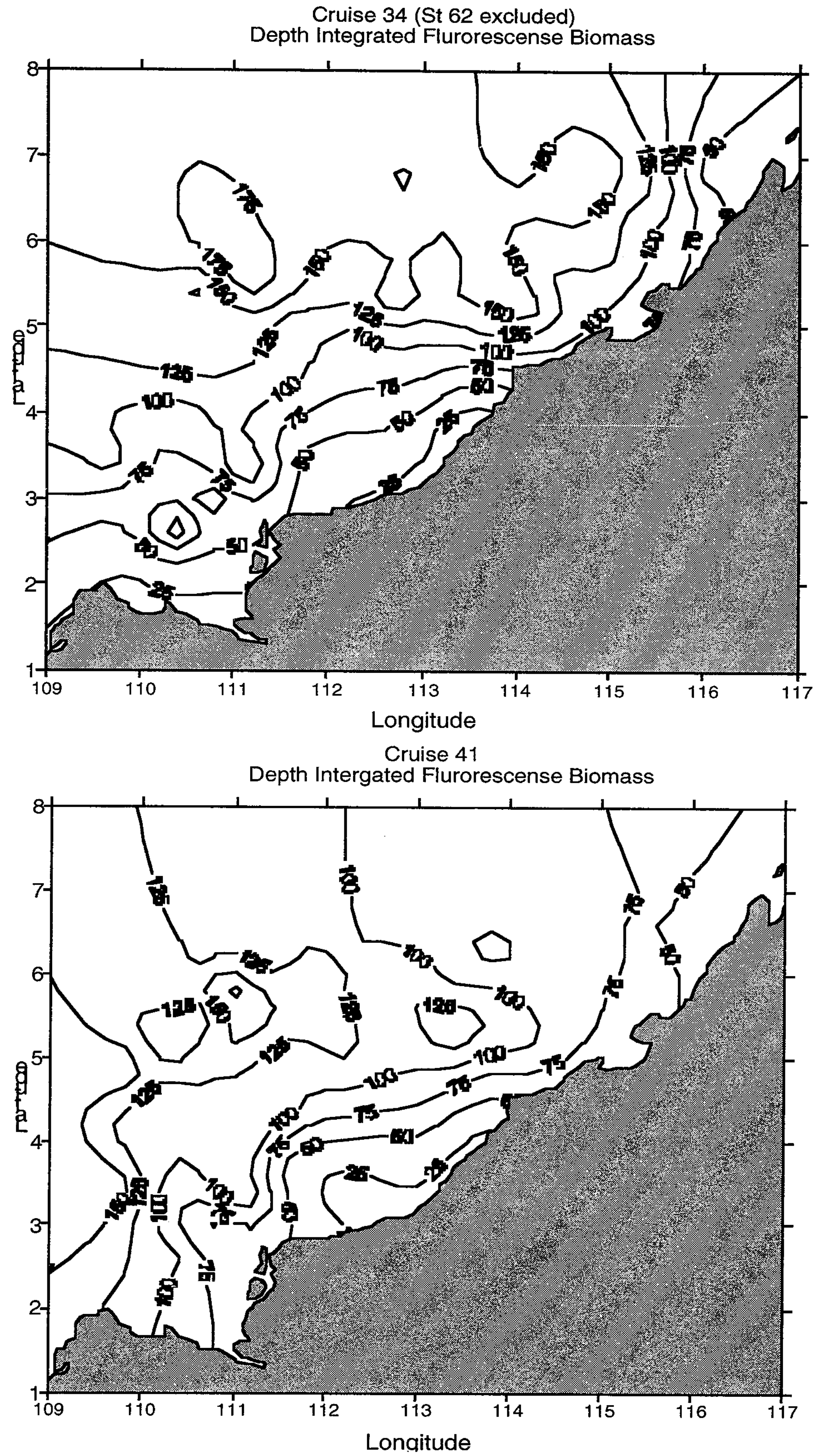


Fig. 2 Depth integrated fluorescense biomass (V)

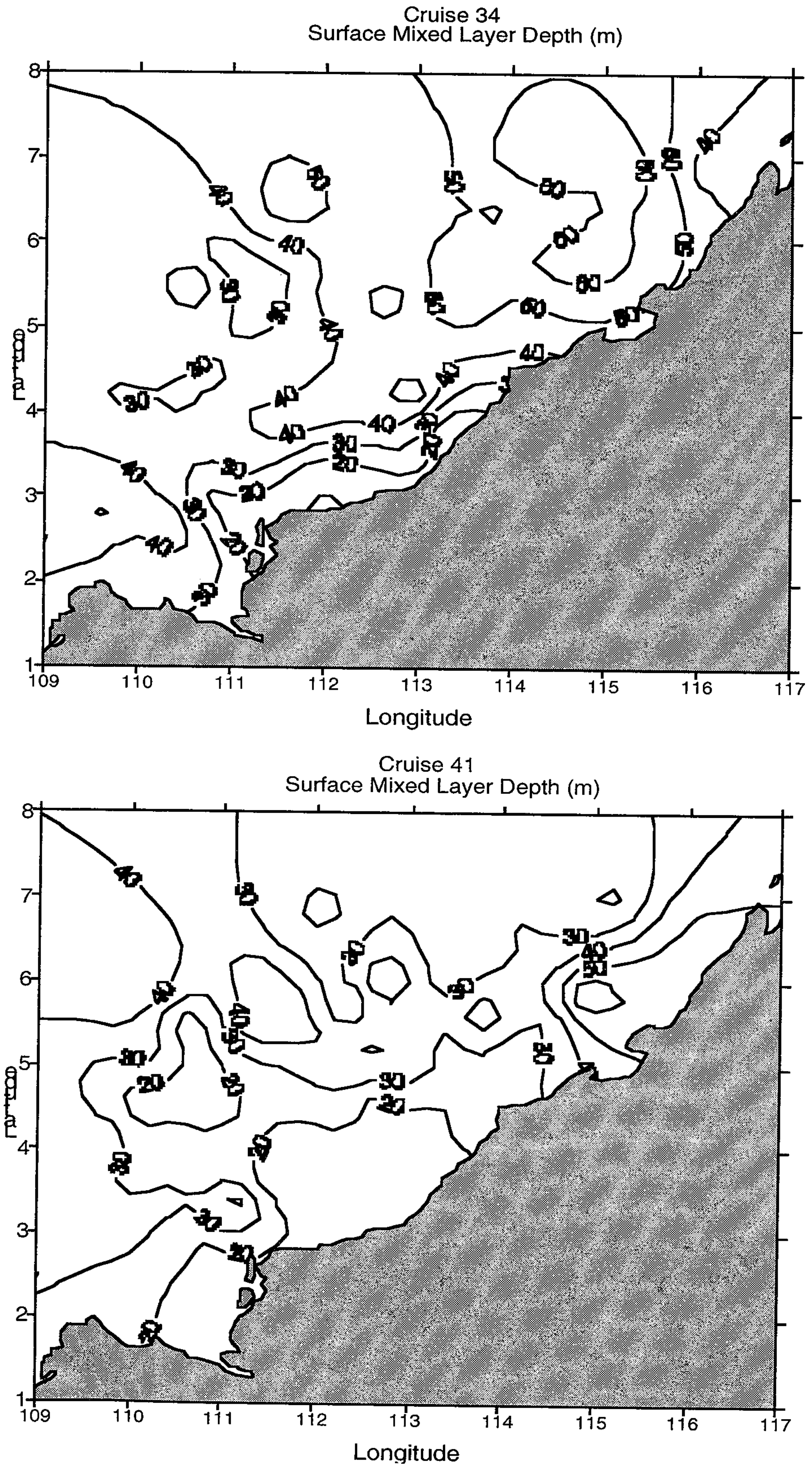
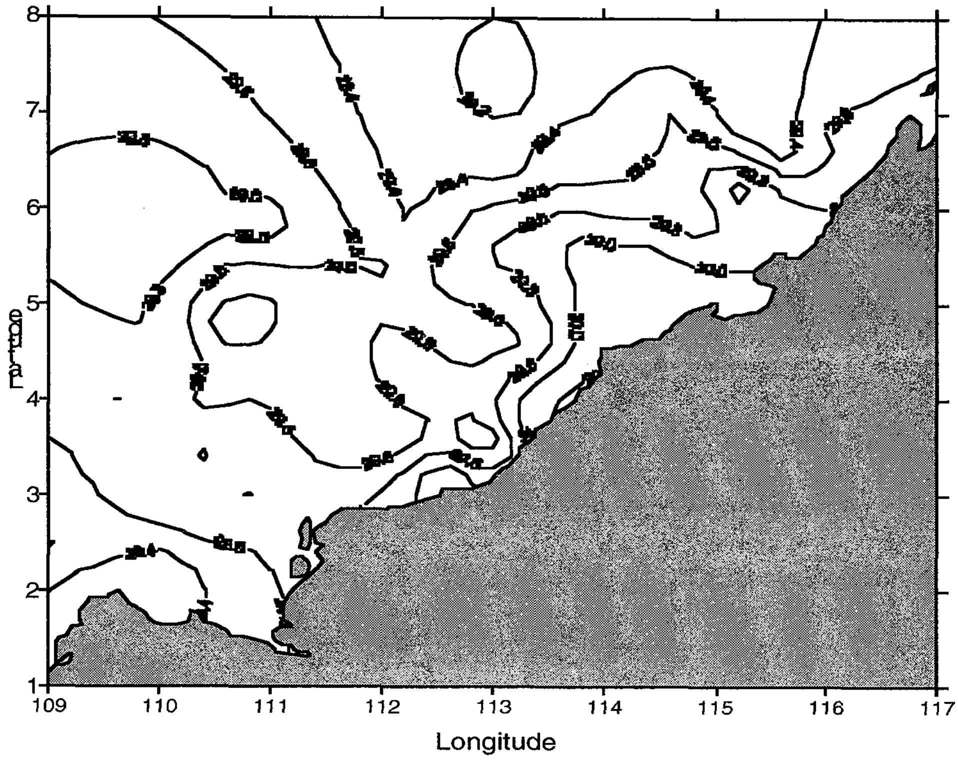


Fig. 3 Surface mixed layer depth (m) for Cruise 34 and 41

Cruise 34
Sea Surface Temperature (5 m)



Cruise 41
Sea Surface Temperature (5 m)

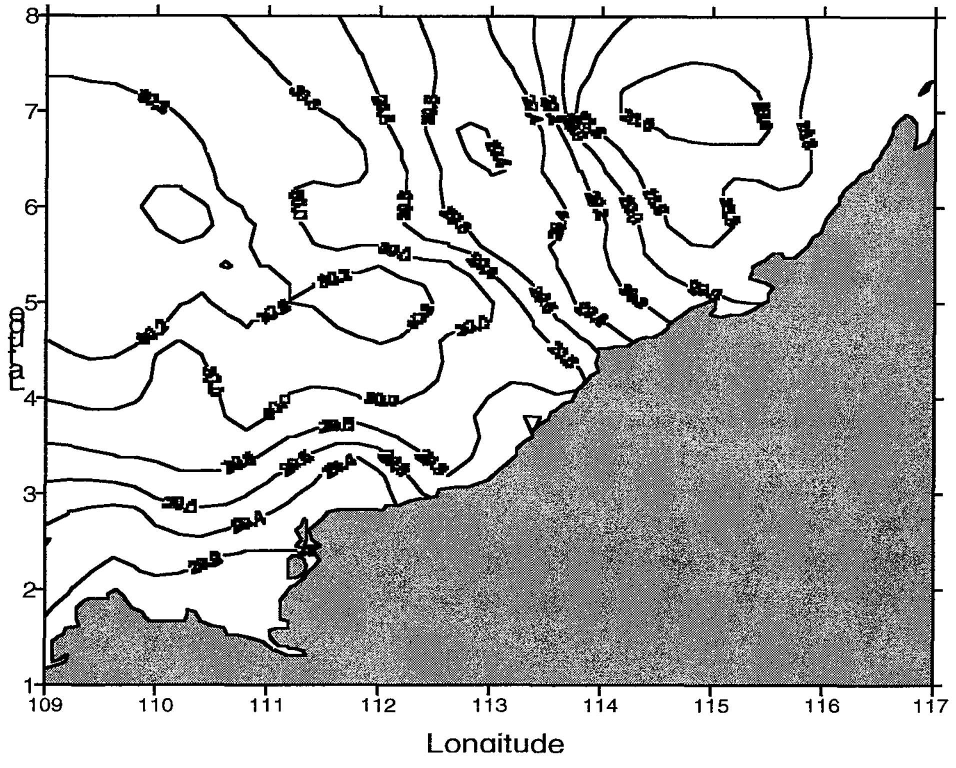


Fig. 4 Sea surface (5m) temperature for the Cruise 34 and 41

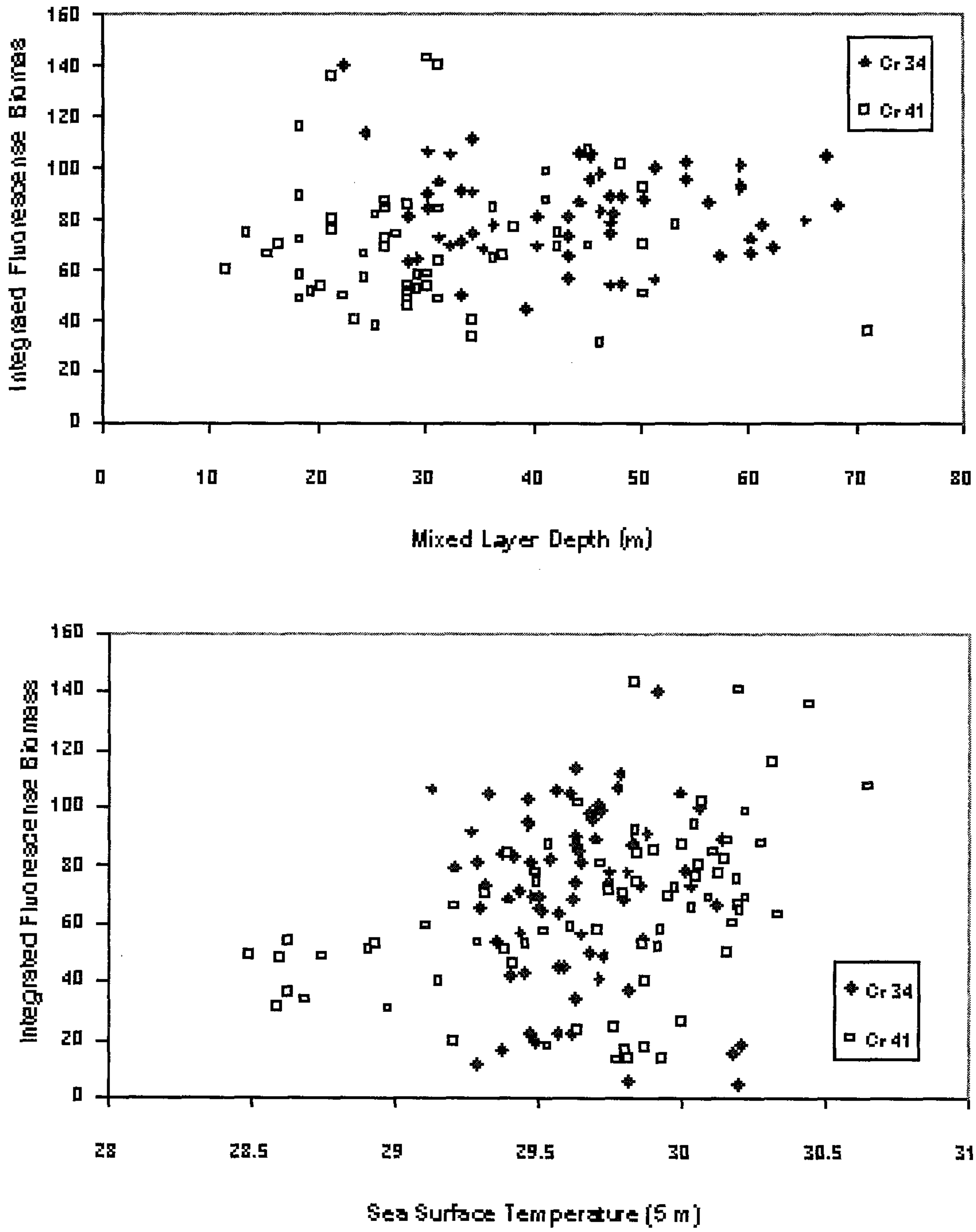


Fig. 5 Relationships between integrated fluorescense biomass with surface mixed layer depth (upper panel) and with sea surface temperature (lower panel)