7. TEMPORAL AND SPATIAL VARIABILITY OF NUTRIENT SPECIES IN THE CAIRNS AND TULLY BOXES

One of the factors affecting our perception of nutrient levels and water quality in GBR waters, and the estimation of system fluxes, is the spatial and temporal variability in the components of interest. This variability can be partitioned between sampling and subsampling processes, analytical methodologies, spatial variations in concentration arising out of physical and biological processes affecting nutrient sources and sinks and temporal variations in those processes. As part of the ongoing program of oceanographic and geochemical studies being carried out in the central GBR, a number of hydrographic stations within each box were repeatedly occupied. This repeat sampling allows us to develop a quantitative understanding about spatial and temporal variability in dissolved and particulate nutrient concentrations.

Along the southern boundary of the Tully box, hydrographic stations were occupied at each of the sediment trap deployment sites when traps were deployed and recovered (**FAM** stations). This data set gives an indication of nutrient variability related to cross-shelf location (4 sites), seasonal changes (5 times), and day-to-day fluctuations (each station occupied once per day for 4 days per seasonal trip). Sampling along this transect was carried out during September, 1989; February, 1990; May, 1990; August, 1990 and November, 1991. For statistical analysis, the nutrient concentration data are dealt with as depth-weighted mean water column concentrations.

To specifically investigate levels of spatial and temporal variability in dissolved and particulate nutrient concentrations within coastal waters of the Cairns box, a transect of eleven stations between Cape Tribulation and Green Island (Figure 5; Table 17) were occupied ten times between February, 1989 and July, 1991. The transect will continue to be occupied, but only samples and data for the period indicated have been analysed to date. For brevity, the data are reported as depth weighted mean water column concentrations.

Table 17. Locations of longshore transect stations between Cape Tribulation and Green Island.

Station	Latitude	Longitude	Depth (m)	Site Name
1	16° 7.1'S	145° 28.9'E	17	Cape Tribulation
2	16° 14.3'	145° 30.8'	21	Snapper Island
3	16° 19.2'	145° 28.2'	12	Daintree River
4	16° 24.7'	145° 30.5'	16	Port Douglas
5	16° 39.9'	145° 42.1'	20	Double Island
6	16° 47.8'	145° 44.6'	9	Yorkey's Knob
7	16° 49.5'	145° 47.4'	9	Cairns Airport
8	16° 51.0'	145° 50.0'	8	Cairns Fairlead
9	16° 49.3'	145° 52.8'	14	Mission Bay
10	16° 47.8'	145° 55.1'	30	Shipping Channel
11	16° 46.6'	145° 57.1'	38	Green Island

On each cruise, all stations on the transect were occupied on a single day, proceeding from north to south. The transect consists of nine stations situated in close proximity to the coastline between Cape Tribulation and Cape Grafton. The two final stations of the transect were located in deeper waters of the shipping channel seaward of Cape Grafton (28-30 m depth) and near Green Island (34-36 m depth). The coastal stations generally lie outside of the nearshore zone of wave forced sediment resuspension, as suggested by water column turbidity. The northernmost three stations are situated downcurrent of the Daintree River as its outflow moves northward along the coast. Likewise, stations between Yorkey's Knob and Port Douglas are

directly affected by outflow from the Barron River. Distinct low salinity waters or plumes were not evident visually, though salinities tended to be slightly lower inshore.

Figures 27-32 summarize the temporal and spatial changes in depth-weighted mean water column nutrient and particulate concentrations measured at the Cairns box transect stations over a 30-month period. Overall means and standard deviations of the depth-weighted mean water column concentrations for the individual cruises are summarized in Table 18. The results of analyses of variance of the transect data (2-way fixed effect: Cruise, Station; Super Anova, Abacus Software) are summarized in Table 19.

Spatial (longshore) and temporal (cruise-to-cruise) variability varied considerably between individual nutrient and particulate species. Stocks of all species exhibited highly significant between-cruise variability. Significant between-station variability was observed for NO_3, DON, PN, PP, Si, Chl *a*, phaeophytin and suspended solids. However, spatial patterns of nutrient concentration changed considerably between individual cruises. With the exception of consistently lower water column nutrient concentrations in the mid-shelf waters near Cape Grafton and Green Island, no clear-cut recurrent patterns of nutrient concentration were evident for individual nutrient species. It should be noted that the chemical and statistical analysis of the samples and data from this exercise is incomplete and more interesting patterns or trends may emerge with more concentrated and sophisticated analysis.

Because of the often long intervals (up to 6 months) between cruises, it is not possible to attribute the observed temporal changes solely to seasonal factors. Rather, it is likely that the observed between-cruise differences reflect local responses to short-term events, such as wind mixing or resuspension in coastal waters. With the exception of DON and DOP, no distinct temporal trends in mean water column concentrations of any nutrient or particulate species were observed over the 30-month period examined to date (Figure 33). This is a rather short interval, so the absence of a distinct temporal trend in not surprising. DON and DOP concentrations (which were analysed simultaneously on the same samples) exhibited a simultaneous increase and decrease over time. If the initial and final mean concentrations are compared, little net change is apparent.

The limited set of results from this monitoring exercise clearly illustrate that the detection of trends in water quality parameters in coastal waters of the GBR region will require a long-term (>10 year) commitment to monitoring programs. It is unlikely that sampling programs of short duration, no matter how they are designed to resolve sampling and spatial variability, will be able to detect real temporal changes in water quality parameters.

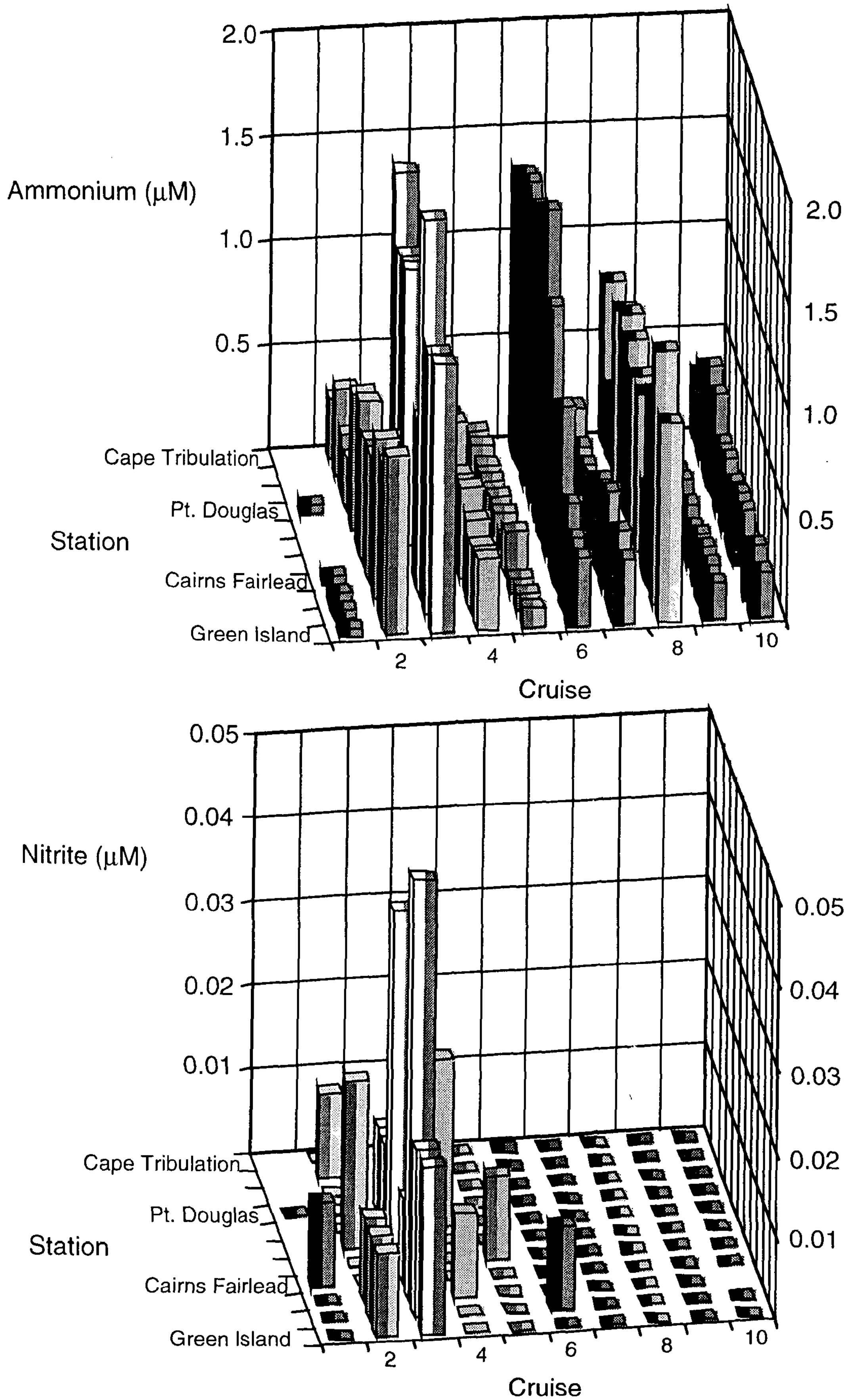

Figure 27. Depth-weighted mean water column concentrations of ammonium (Top) and nitrite (Bottom) along a transect between Cape Tribulation and Green Island, sampled ten times between February 1989 and July 1991.

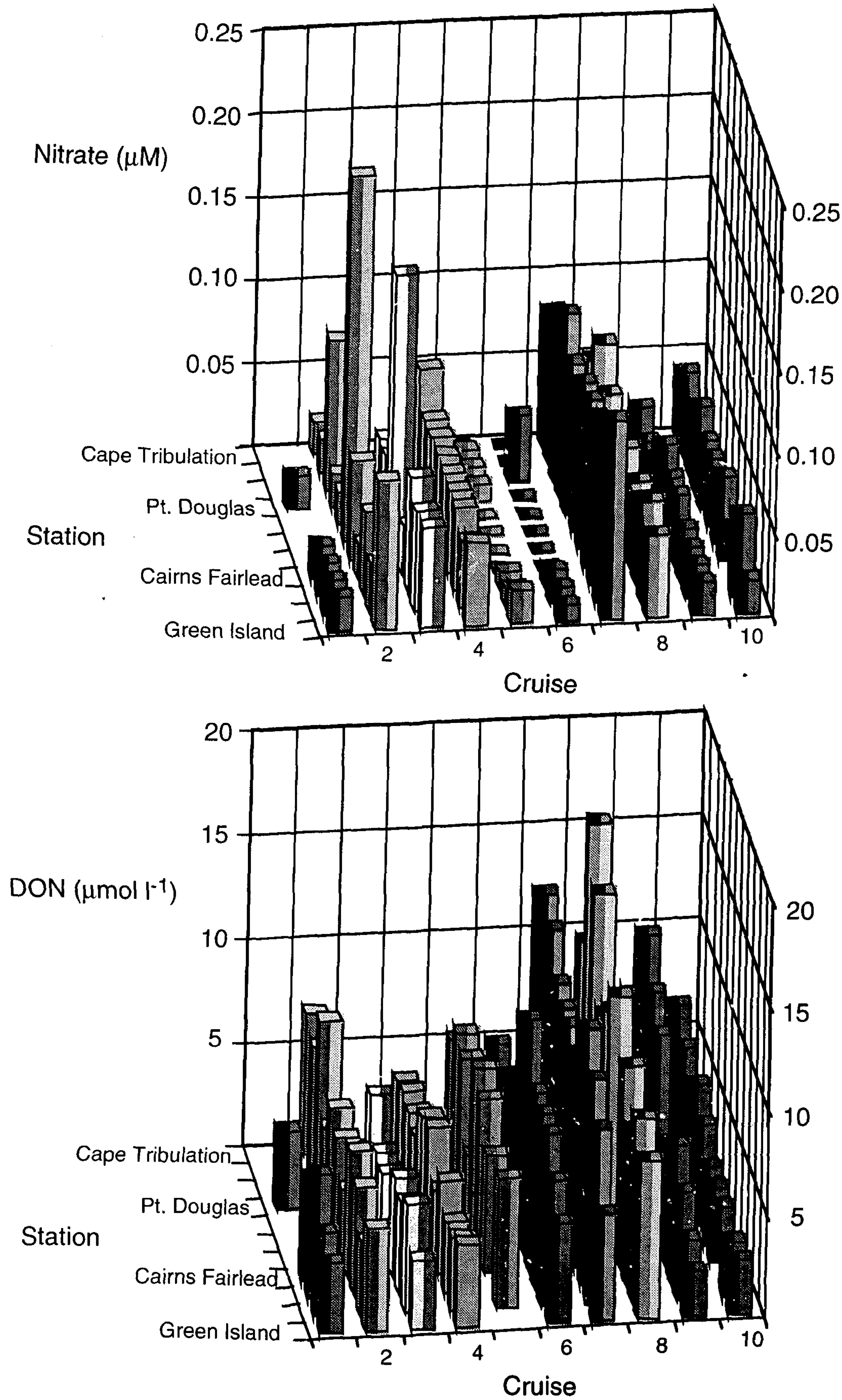

Figure 28. Depth-weighted mean water column concentrations of nitrate (Top) and dissolved organic nitrogen (Bottom) along a transect between Cape Tribulation and Green Island, sampled ten times between February 1989 and July 1991.

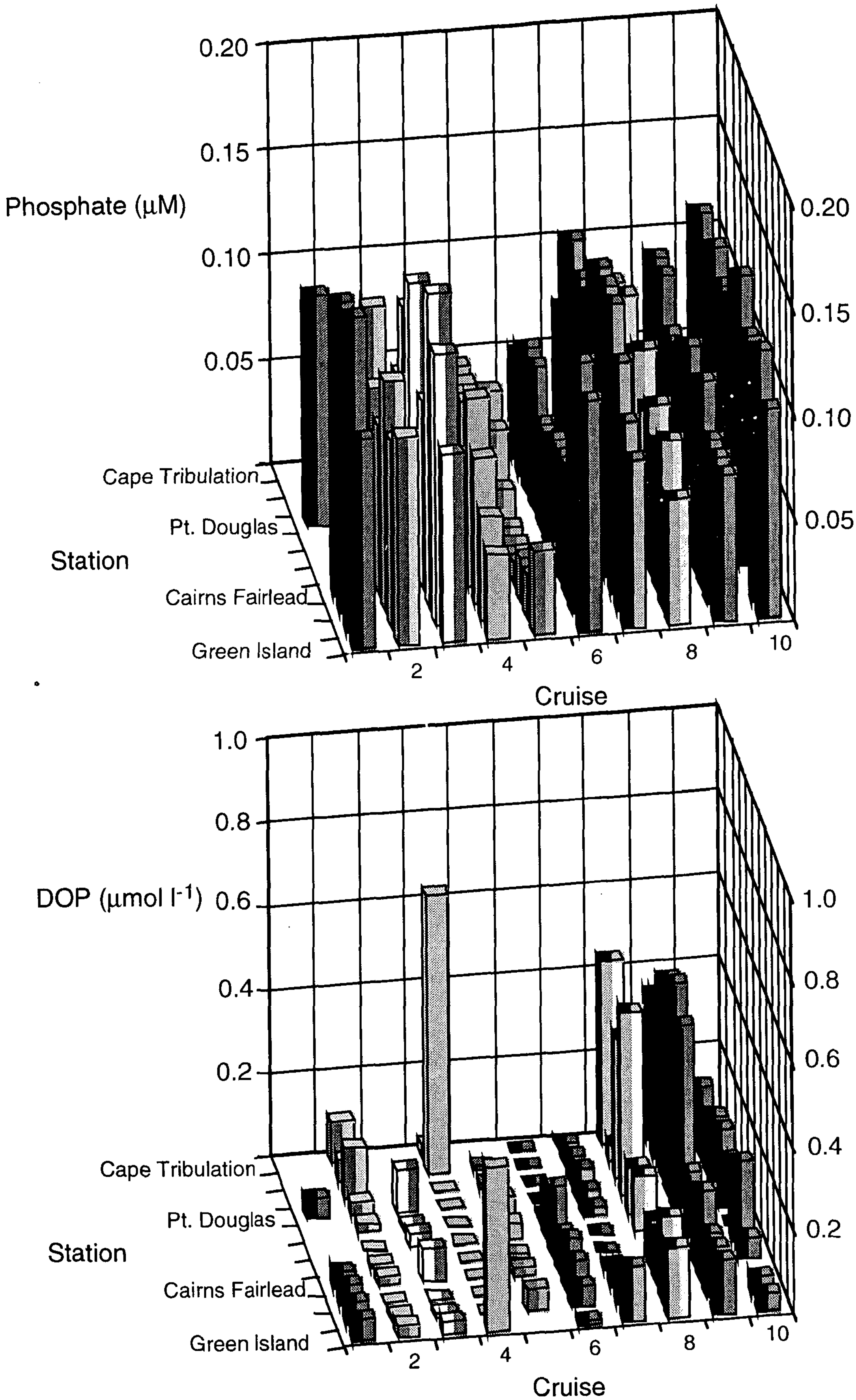

Figure 29. Depth-weighted mean water column concentrations of phosphate (Top) and dissolved organic phosphorus (Bottom) along a transect between Cape Tribulation and Green Island, sampled ten times between February 1989 and July 1991.

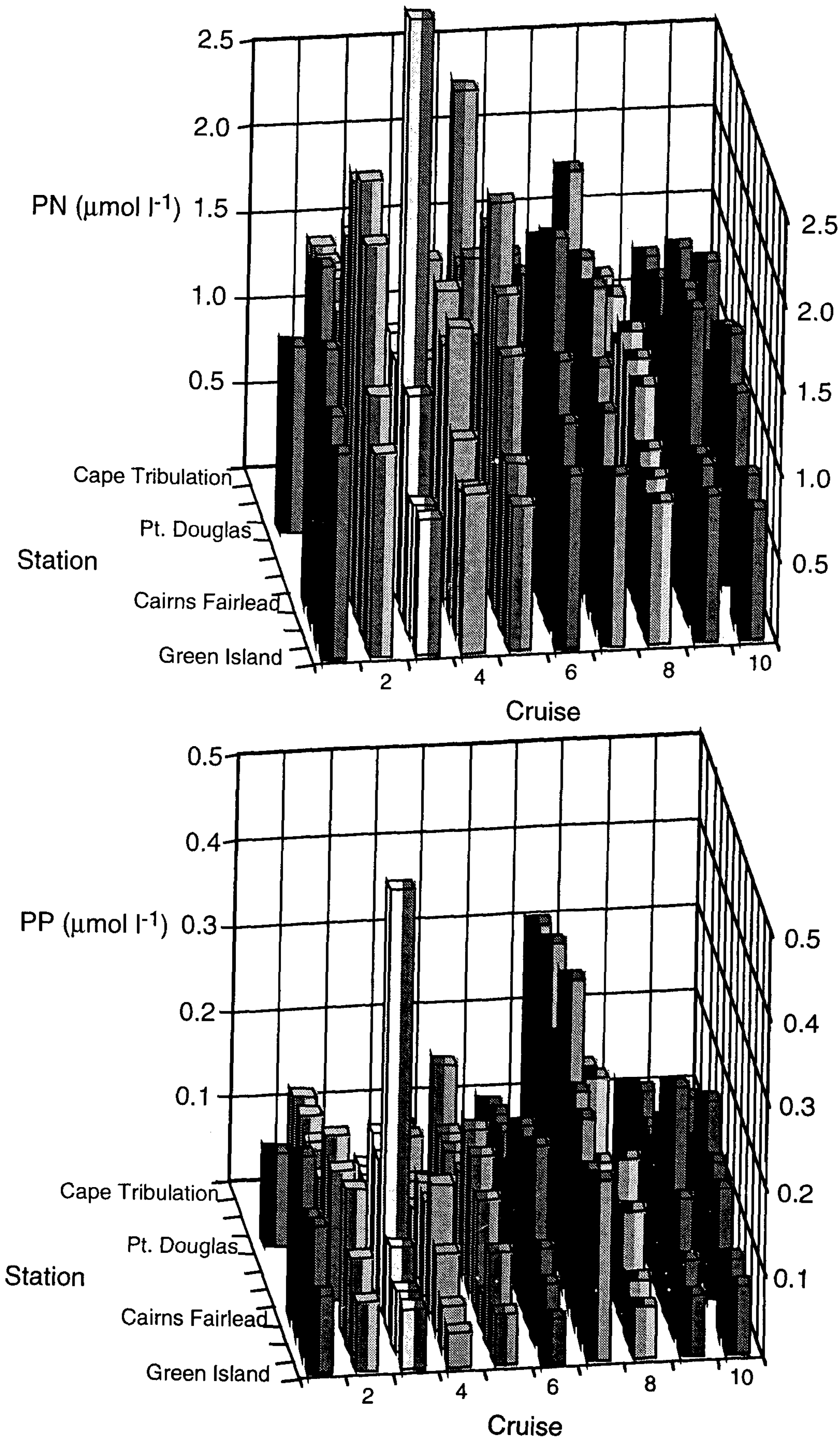

Figure 30. Depth-weighted mean water column concentrations of particulate nitrogen (Top) and particulate phosphorus (Bottom) along a transect between Cape Tribulation and Green Island, sampled ten times between February 1989 and July 1991.

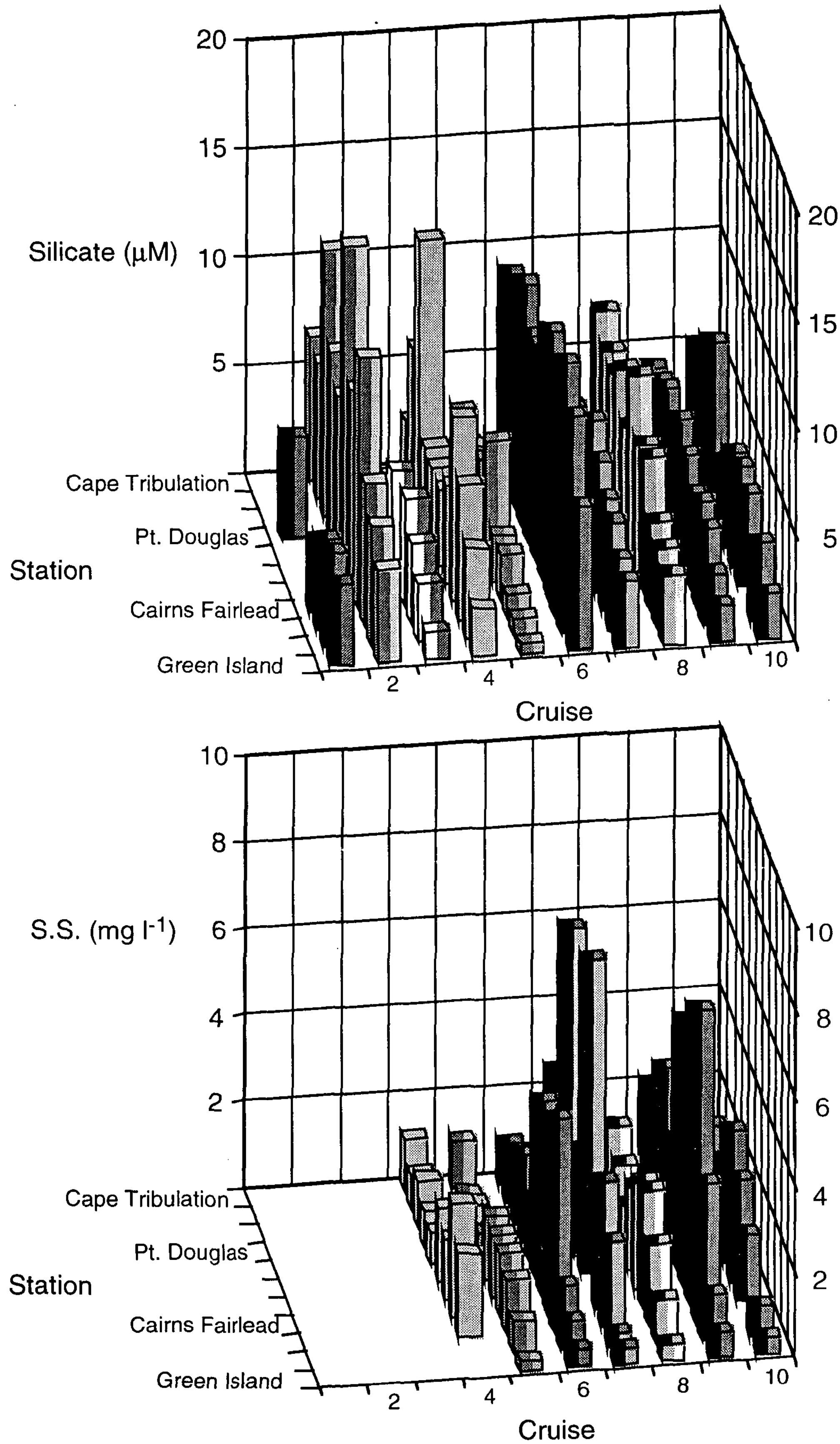

Figure 31. Depth-weighted mean water column concentrations of silicate (Top) and suspended solids (Bottom) along a transect between Cape Tribulation and Green Island, sampled ten times between February 1989 and July 1991.

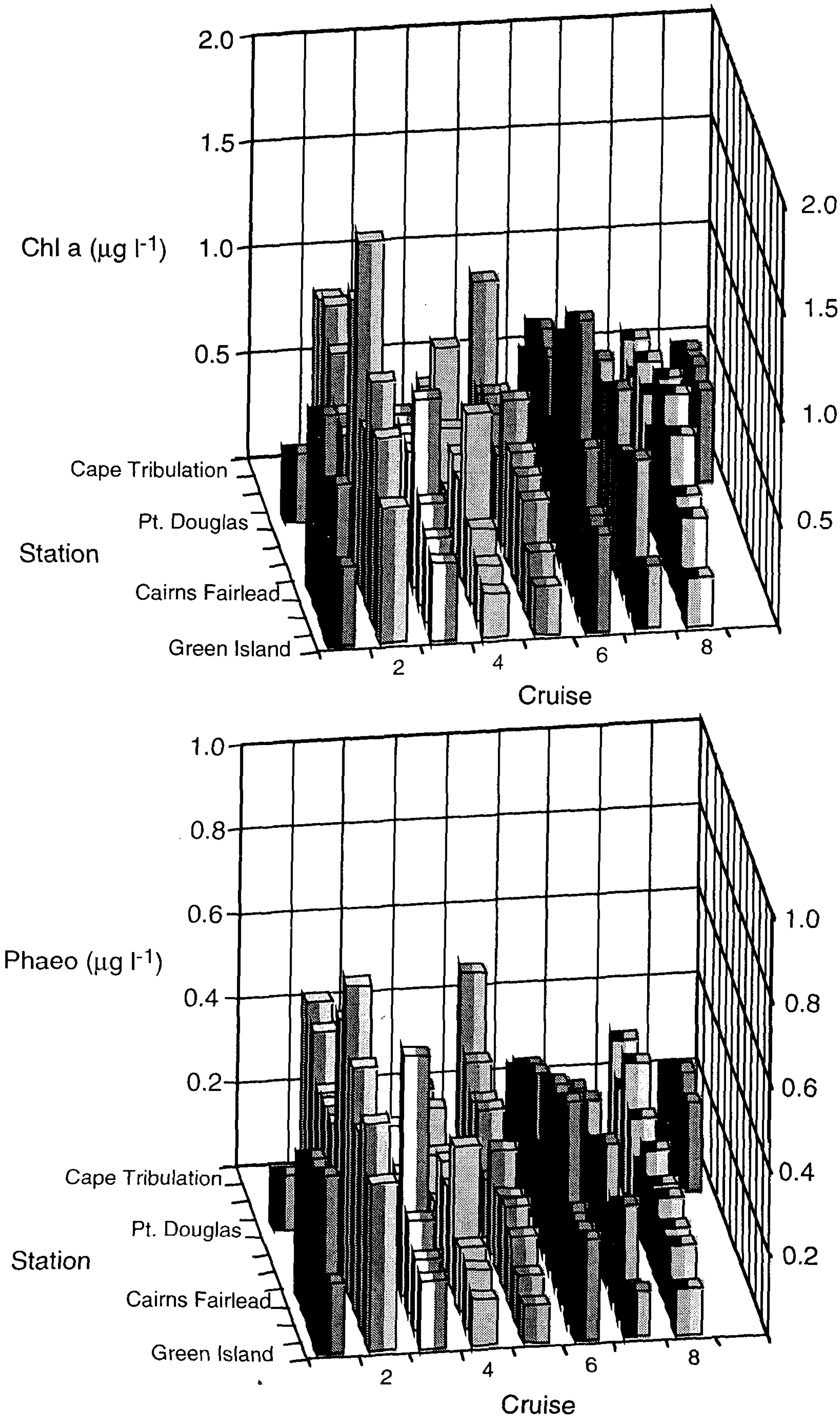

Figure 32. Depth-weighted mean water column concentrations of chlorophyll (Top) and phaeophytin (Bottom) along a transect between Cape Tribulation and Green Island, sampled ten times between February 1989 and July 1991.

Table 18. Overall station means and standard errors for water column variables measured at transect stations between Cape Tribulation and Cape Grafton. *** = significant difference at $p < 0.001$. * = significant difference at $0.01 < p < 0.05$

	NH_4		NO_2		NO_3		DON		PN		PO_4		DOP		POP		SiO		Chl		Phaeo		S.S.	
									µmol l^{-1}										µg l^{-1}		µg l^{-1}		mg l^{-1}	
Sta.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.	mean	s.e.
1	0.42	0.15	0.001	0.001	0.03	0.01	7.17	1.09	1.25	0.15	0.064	0.011	0.15	0.07	0.13	0.03	5.0	0.8	0.54	0.07	0.28	0.04	1.47	0.23
2	0.45	0.14	0.001	0.001	0.03	0.01	7.45	1.49	1.02	0.10	0.074	0.008	0.16	0.09	0.12	0.02	5.1	0.8	0.50	0.07	0.24	0.03	1.08	0.16
3	0.46	0.15	0.000	0.000	0.05	0.01	7.66	1.36	1.42	0.08	0.075	0.008	0.14	0.06	0.14	0.03	7.5	1.3	0.59	0.04	0.26	0.02	2.42	0.78
4	0.47	0.16	0.001	0.001	0.03	0.01	6.09	0.74	1.08	0.08	0.071	0.008	0.13	0.06	0.11	0.02	4.6	0.8	0.44	0.02	0.20	0.02	1.46	0.21
5	0.60	0.17	0.003	0.002	0.03	0.01	6.12	0.84	1.06	0.12	0.076	0.010	0.09	0.05	0.11	0.02	4.8	0.6	0.38	0.04	0.16	0.03	1.08	0.17
6	0.54	0.15	0.007	0.005	0.07	0.03	6.53	1.04	1.63	0.09	0.090	0.013	0.05	0.02	0.17	0.03	6.8	1.2	0.76	0.10	0.32	0.05	3.56	0.83
7	0.34	0.08	0.001	0.001	0.04	0.01	5.12	0.98	1.68	0.14	0.080	0.014	0.05	0.03	0.15	0.02	5.8	1.1	0.75	0.15	0.29	0.07	2.50	0.43
8	0.40	0.08	0.002	0.001	0.03	0.01	6.24	0.82	1.86	0.22	0.086	0.012	0.06	0.02	0.21	0.04	5.9	1.0	0.76	0.09	0.35	0.06	3.19	0.70
9	0.53	0.19	0.008	0.005	0.04	0.01	5.97	0.76	1.35	0.14	0.086	0.013	0.05	0.02	0.12	0.02	5.0	1.0	0.59	0.08	0.23	0.03	1.85	0.30
10	0.48	0.14	0.004	0.002	0.04	0.01	5.06	0.70	0.96	0.10	0.092	0.012	0.06	0.02	0.09	0.01	4.0	0.8	0.45	0.08	0.22	0.05	0.72	0.11
11	0.46	0.13	0.003	0.002	0.05	0.01	4.18	0.55	0.94	0.50	0.079	0.008	0.11	0.04	0.08	0.02	2.9	0.6	0.35	0.05	0.17	0.04	0.38	0.04
Cruise	***		***		***		***		***		***		***		***		***		***		***		***	
Station					*		*		***						***		***		***		***		***	

Table 19. Summary of ANOVAs for significance of variability related to cruises and stations on the transect between Cape Tribulation and Green Island. The comparison was run as a 2-way analysis with Cruise and Station as fixed factors. The data was not transformed.

	Cruise		Station	
Variable	F	p	F	p
Ammonia	**27.39 (9,79)**	<.001	0.39 (10,79)	0.945
Nitrite	**11.32 (9,79)**	<.001	1.05 (10,79)	0.407
Nitrate	**13.11 (9,79)**	<.001	**2.35 (10,79)**	<.001
DON	**15.28 (9,75)**	<.001	**2.28 (10,75)**	0.021
PN	**4.80 (9,79)**	<.001	**9.52 (10,79)**	<.001
Phosphate	**19.45 (9,79)**	<.001	1.394 (10,79)	0.199
DOP	**5.66 (9,75)**	<.001	1.05 (10,75)	0.410
PP	**9.15 (9,78)**	<.001	**5.83 (10,78)**	<.001
Silicate	**22.52 (9,79)**	<.001	**5.63 (10,79)**	<.001
Chlorophyll	**8.11 (8,63)**	<.001	**6.70 (10,63)**	<.001
Phaeophytin	**11.76 (8,63)**	<.001	**4.306 (10,63)**	<.001
Suspended Solids	**5.76 (6,55)**	<.001	**7.37 (10,55)**	<.001

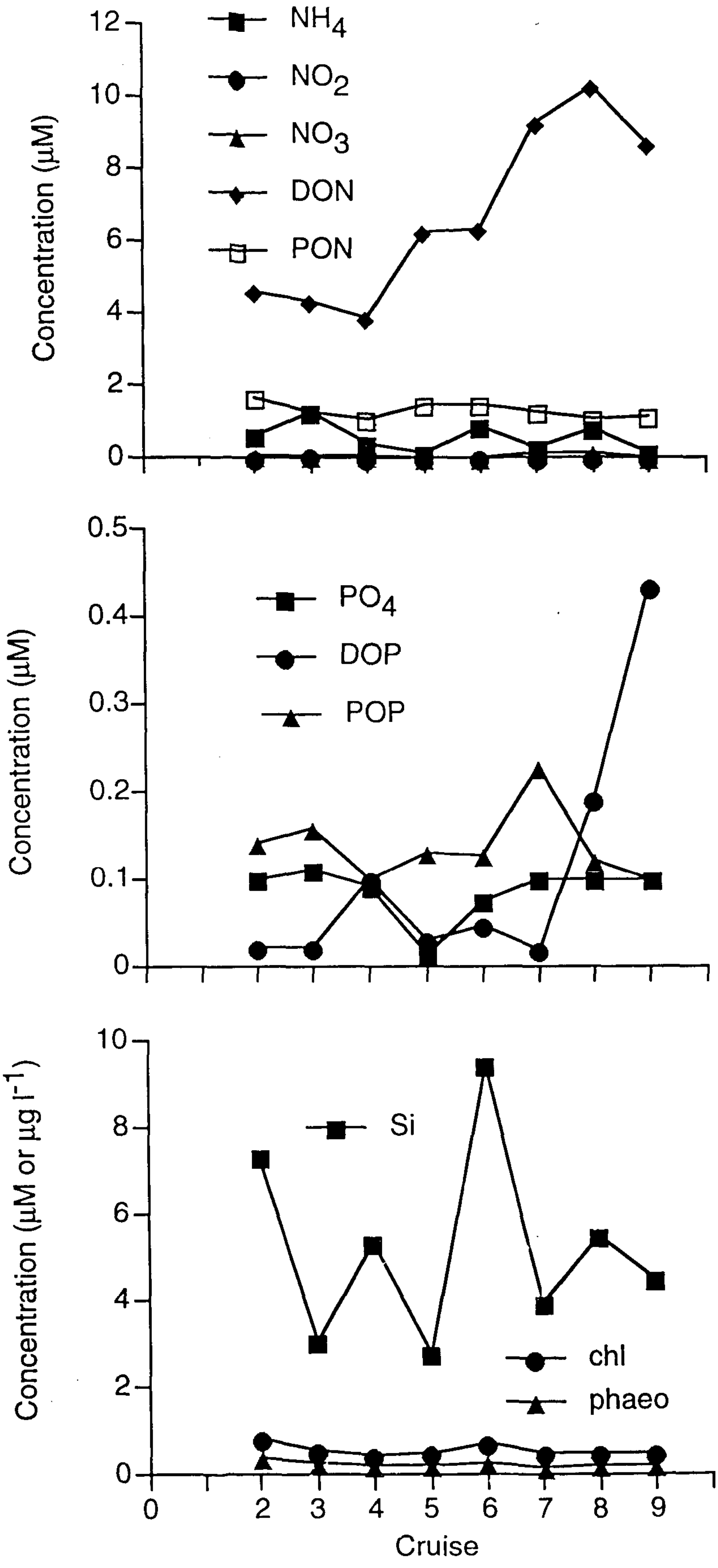

Figure 33. Cruise means for depth-weighted mean water column concentration of (Top) nitrogen species, (Middle) phosphorus species and (Bottom) silicate and pigments on the 11 station Cairns box transect.