Biological Oceanographic Measurements in the Torres Strait and far northern Great Barrier Reef

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Abstract

Relatively little is known regarding the biological and chemical oceanography of the Torres Strait and far northern Great Barrier Reef. In addition to its traditional marine-based cultures, the Torres Strait now supports several commercial fisheries, is an international shipping route and serves as a political boundary between Australia and Papua New Guinea. To date, oceanographers from AIMS have conducted three chemical/biological surveys within the eastern Torres Strait and bordering zones of the far northern GBR and Gulf of Papua.

Waters of the eastern Torres Strait and far northern GBR are characterized by moderately, but not extremely low dissolved and particulate nutrient concentrations. Elevated concentrations of silicate and nitrate are associated with extensions of low salinity waters of the Fly River plume into the northeastern Torres Strait region. Extensive mixing caused by tidal currents through the reef matrix results in a well mixed water column for most biological/dissolved chemical parameters and enhanced suspended solids concentrations. No clear onshore-offshore or north-south gradients of water quality parameters were observed in the far northern GBR.

Because of their clarity and general shallowness, a significant proportion of light reaches the bottom, regardless of depth on the shelf. On a volume basis, shelf waters of the far northern GBR are highly productive, but water column primary production per unit area (0.6 - 1.65 g C $m^{-2}d^{-1}$ is low to moderate because of the shallowness of the water column. Biomass specific production rates indicate that water column populations of phytoplankton are growing at high rates.

Introduction

Traditional inhabitants and regional seafaring peoples have used the marine resources of the Torres Strait and far-northern Great Barrier Reef (hereafter FNGBR) over millenia. Increasingly, these resources are being utilized by modern commercial fishing interests. Despite the intensified recent interest in the commercial and traditional fisheries of the Torres Strait (e.g. Haines *et al.*, 1986; Mellors, 1990, Johannes and MacFarlane, in press), relatively little is known about the underlying biological and chemical oceanography of the Torres Strait and the adjoining far northern GBR and Fly River delta systems. To date, only three studies have been carried out which address these latter subjects in more than a cursory fashion.

Oceanographers from the Australian Institute of Marine Science (AIMS) first surveyed physical, chemical and biological characteristics of waters of the Gulf of Papua, eastern Torres Strait and far northern GBR (Figure 1) during late November, 1979 (Mitchell, 1982). Wolanski *et al.* (1984) presented and discussed aspects of this data set. AIMS oceanographers (Furnas *et al.*, 1990) have continued with a survey of biological and chemical characteristics of the far northern GBR shelf (11.5°-13° S) under mid-summer conditions (Figure 2). Robertson *et al.* (1990, this volume) carried out an extensive study of biological and geochemical processes in the Fly River delta and adjoining coastal waters. Providing a contextual backdrop for these data sets, Wolanski and his co-workers have provided useful discussions of the physical oceanography of the Torres Strait (Wolanski, 1986; Wolanski *et al.*, 1984, 1988). Harris (1988) addressed aspects of the dynamic sedimentology of the Torres Strait, proper, which ultimately bear upon the biology and geochemistry of the region.

Results and Discussion

Detailed descriptions of sampling and analytical methods for the individual studies are given in the pertinent data reports (Mitchell, 1982; Furnas *et al.*, 1990; Robertson *et al.*, 1990). Primary production measurements in the FNGBR were made according to Furnas and Mitchell (1987), with the exception that "metal-clean" sampling techniques (e.g. Chavez and Barber, 1987) were followed to a greater extent. Robertson *et al.* (1990) also measured surface productivity in the Fly River system using a similar approach.

The data presently available on distributions of dissolved nutrients and plankton biomass in the Torres Strait and FNGBR region are sufficiently limited as to preclude making more than basic generalizations regarding biological processes in the water column. In particular, time series data are lacking, which limits discussions regarding the dynamics of processes in the region.

Because of the shallowness of the Torres Strait region and the intensity of tidal mixing through the complex bathymetry, temperature variations in Torres Strait waters are relatively small (Figure 3). Some upwelling of cool water from the thermocline in the Coral Sea was noted at the shelfbreak on some cross-shelf transects in the FNGBR (SHL28; Figure 3). This cool water was dispersed through the water column within a few miles of the shelfbreak (SHL29; Figure 3) and did not penetrate far across the shelf as a recognizable water type (SHL30-33; Figure 3). Under calm, high insolation conditions, near-surface diurnal heating does occur (>1 C), producing temporary thermoclines in the surface layer.

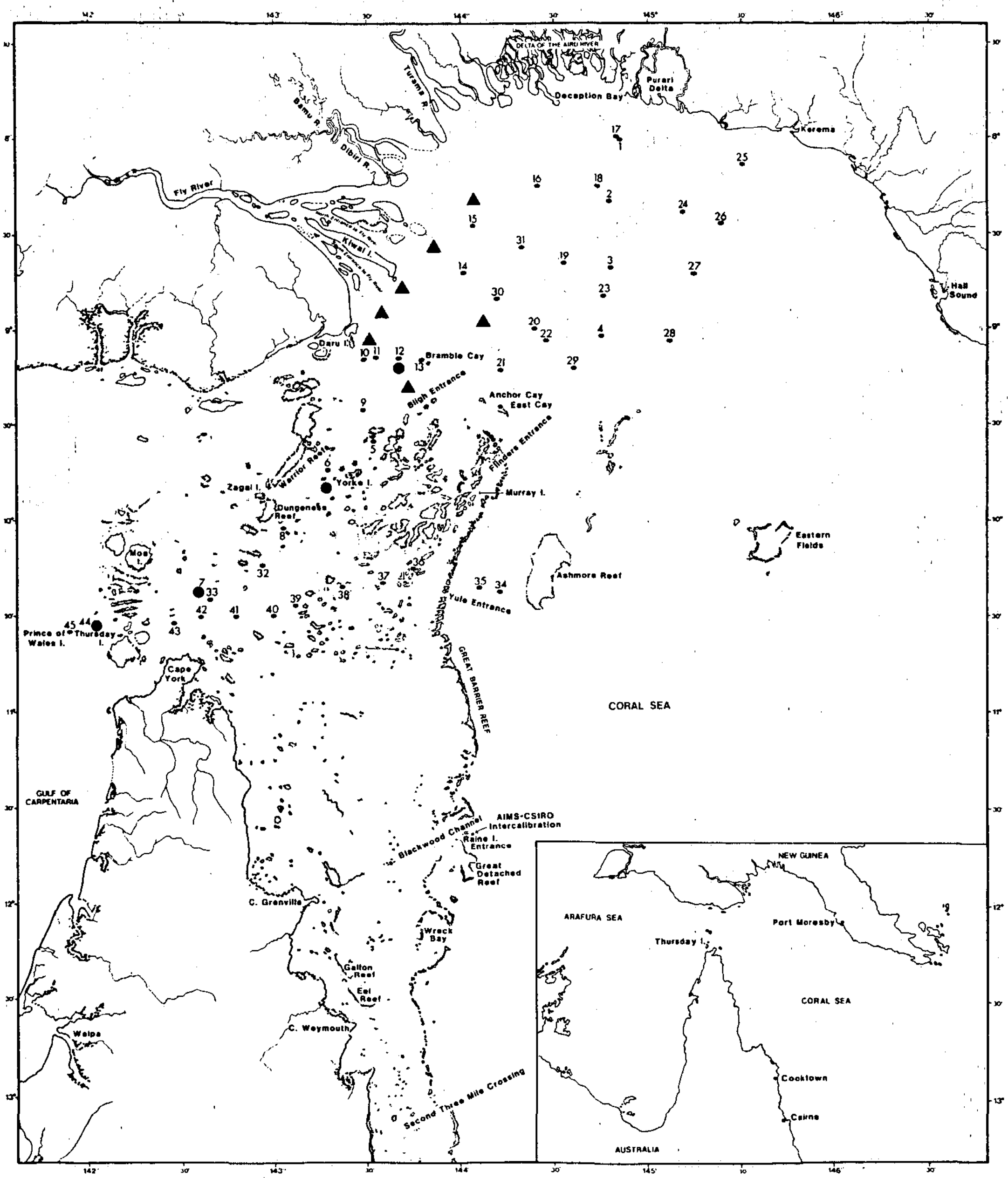

Figure 1. (▲) indicates stations occupied in the Torres Strait and NW Gulf of Papua during December 1989. Large filled symbols (●) identify stations shown in later figures. Stations occupied during November-December 1979 are shown by smaller dots. The base map and station locations for 1979 stations were taken from Mitchell (1982).

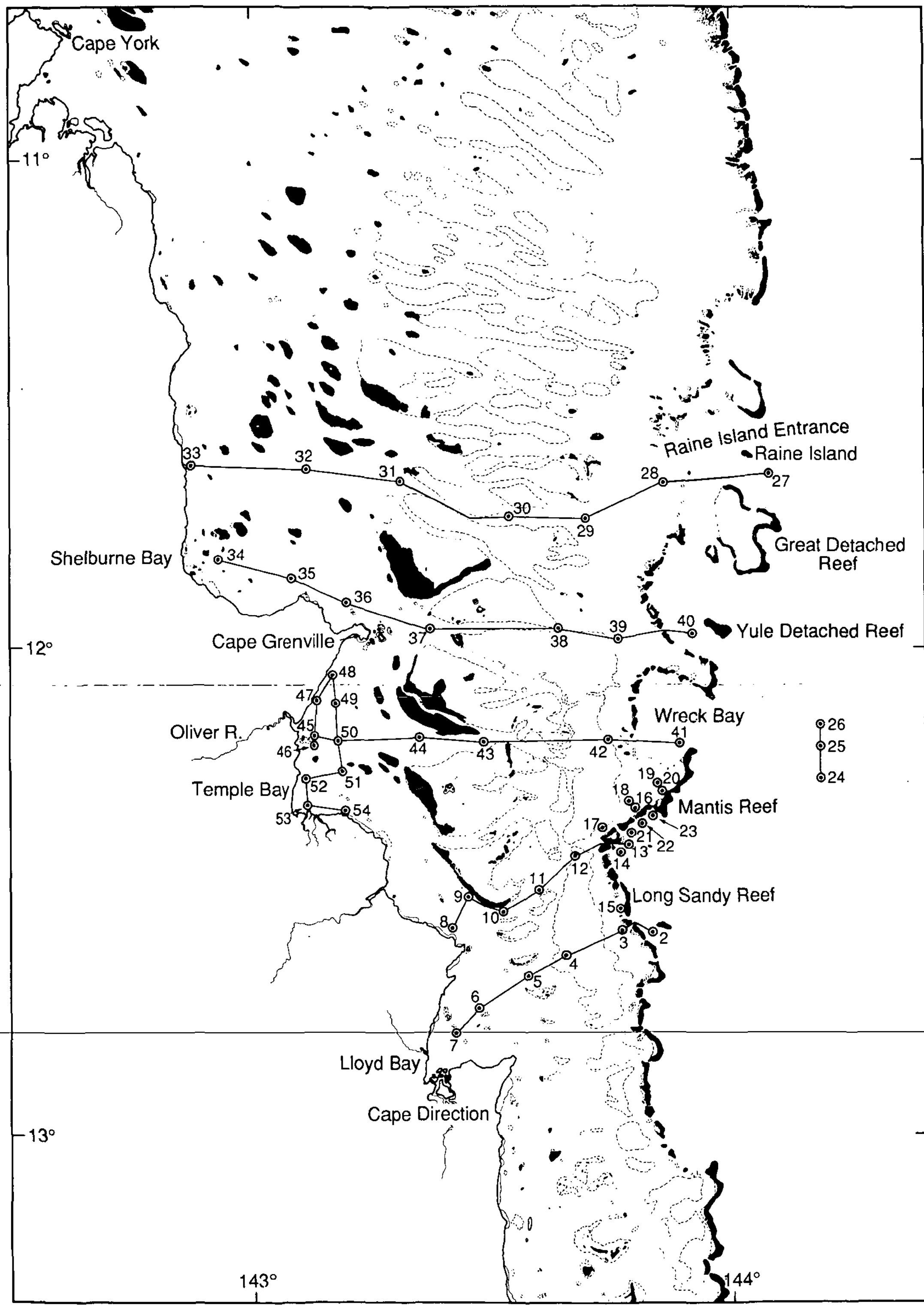

Figure 2. Stations occupied in the far northern GBR during February, 1990 (from Furnas *et al.*, 1990). Large filled symbols identify stations used for comparative figures.

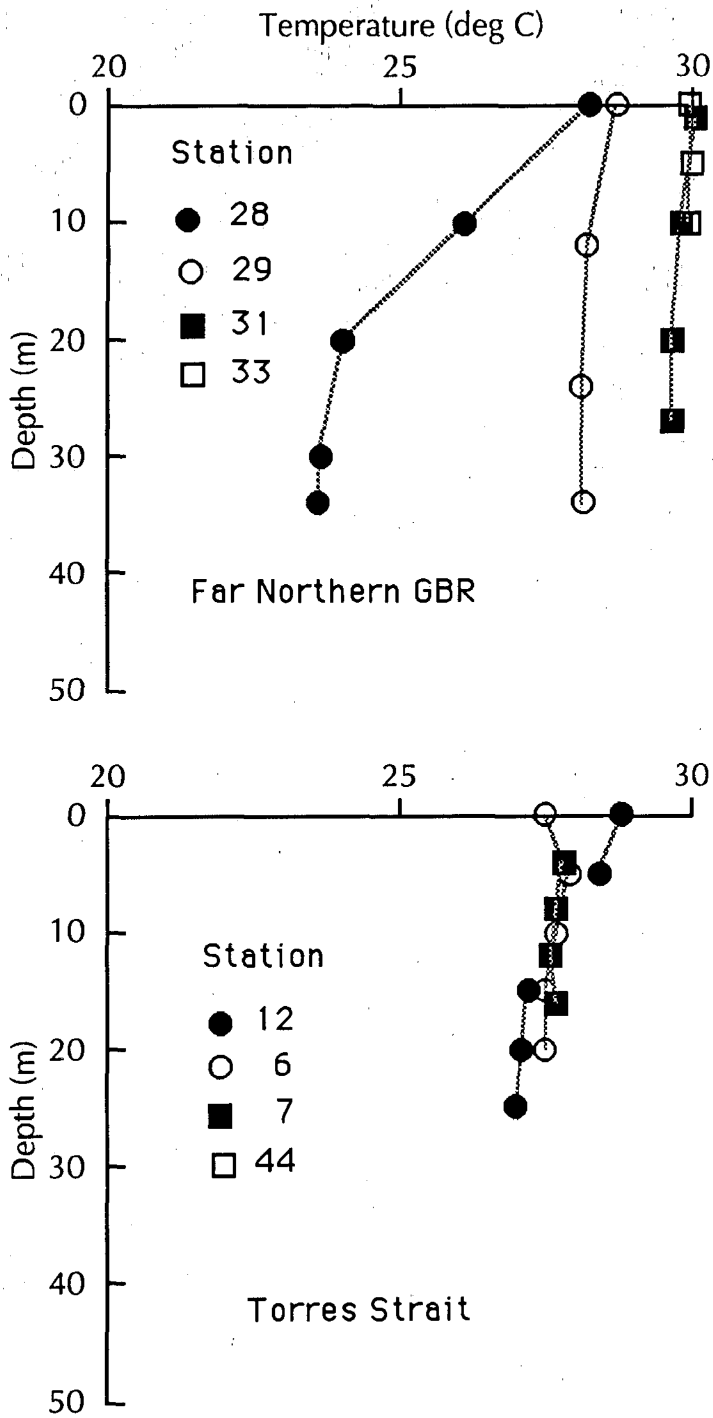

Figure 3. Vertical profiles of water temperatures at stations in the far northern GBR (February, 1990) and eastern Torres Strait (November, 1979).

The large inputs of freshwater into the Gulf of Papua (ca. 13,000 m^3 sec^{-1}; Wolanski *et al.*, 1984) lead to the formation of an extensive near-surface low salinity layer in the Gulf of Papua, which penetrates to some degree into the northeastern Torres Strait region. No evidence of this low salinity water was noted in the FNGBR transects occupied in 1979 and 1990. Comparable surveys in the western Torres Strait have yet to be made.

With the exception of silicate ($Si(OH)_4$), concentrations of dissolved inorganic nutrients (NH_4, NO_2, NO_3, PO_4) are generally low (Table 1), but significantly, readily measureable throughout the Torres Strait, Gulf of Papua and FNGBR. Based on single cruises to the respective areas, dissolved inorganic nitrogen (DIN = NH_4+NO_2+NO_3) concentrations were on average, two-fold higher in the Torres Strait than the FNGBR. DIN concentrations in both regions were much higher than found off Cooktown in October, 1987, but were closer to DIN levels found within the Whitsunday Island group (January, 1988). Shelfbreak intrusions and mixing processes inject relatively small amounts of nitrate (NO_3) onto the outer shelf in the FNGBR (Figure 4). This NO_3 appears to be rapidly utilized by local algal populations. Relatively little variability in nitrate concentrations was observed elsewhere in the Torres Strait region or FNGBR. Ammonia concentrations off the Fly River were similar to those measured in the FNGBR, but lower than measured in the Torres Strait . Nitrate concentrations were higher. This generalization does not account for any short-term variability associated with the individual cruises or systematic differences between data sets.

Dissolved organic nitrogen (DON) and particulate nitrogen (where measured) make up the largest pools of fixed nitrogen within the water column. DON concentrations in the Torres Strait are little different than those in the FNGBR.

Dissolved phosphorus concentrations also appear to be two-fold higher in the Torres Strait than immediately to the south, but were lower than in the northwestern Gulf of Papua. Vertical structure in PO_4 concentrations was generally absent. Particulate phosphorus was the predominant P species in FNGBR waters. Particulate P in the water column was not measured on the 1979 Torres Strait or 1990 Fly River cruises.

Silicate concentrations measured in Torres Strait waters are two- to greater than ten-fold higher than Si concentrations found elsewhere in the GBR (Figure 5; Table 1). In most cases, the highest silicate concentrations in the Torres Strait (maximum observed =12.3 *u*M) were measured at or near the surface. Higher concentrations still (to >30 *u*M) were measured during 1979 in the northern Gulf of Papua. Similar high levels were not reported by Robertson *et al.* (1990). Wolanski *et al.* (1984) demonstrated an inverse relationship between Si concentrations and salinity (Figure 6), indicating that the rivers flowing into the Gulf of Papua were the major source of this silicate. Similar relations were not found for chlorophyll or the other major nutrient species. As such, silicate offers considerable promise as a regional tracer for budgeting freshwater inputs to and residence times within the Torres Strait region and for estimating residence times of other dissolved chemical species.

Despite the presence of readily measureable nutrients in Torres Strait and FNGBR waters, pronounced blooms of phytoplankton associated with large nutrient inputs are not apparent. Inorganic N and P inputs from the Fly River system are not large,

Table 1. Summary of depth-weighted mean water column concentrations of dissolved and particulate nutrients in the NW Gulf of Papua, Torres Strait and northern GBR. Chlorophyll and suspended solids values from the Gulf of Papua are surface values only.

	NH4	NO2	NO3 umol/litre	DON	PON	PO4	DOP umol/litre	POP	Si(OH)4 umol/litre	Chl a ug/litre	Susp. Solids mg/litre
NW Gulf of Papua											
Mean	0.18		0.45			0.18			4.50	0.52	103.6
Std. Dev.	0.09		0.42			0.10			2.72	0.25	5.2
n	6		6			6			6	6	7
Torres Strait											
Mean	0.58	0.05	0.33	4.2		0.10	0.13		3.36	0.41	
Std. Dev.	0.34	0.04	0.13	1.1		0.03	0.05		1.82	0.22	
n	19	20	19	19		19	19		20	20	
F.N. GBR											
Mean	0.19	<0.01	0.10	4.1	3.7	0.05	0.02	0.10	1.14	0.66	1.1
Std. Dev.	0.09	0.01	0.39	1.3	1.3	0.04	0.02	0.04	1.31	0.38	0.4
n	55	55	55	43	55	55	42	55	55	55	52
Ribbon Reefs											
Mean	0.02	<0.01	0.06			0.01			0.06	0.31	
Std. Dev.	0.03	<0.01	0.09			0.02			0.07	0.13	
n	63	63	63			63			63	52	
Whitsunday Is.											
Mean	0.22	<0.01	0.20	4.1	2.0	0.23	0.42	0.09	1.72	1.17	
Std. Dev.	0.14	<0.01	0.14	0.6	0.3	0.03	0.07	0.03	0.41	0.25	
n	20	20	20	9	17	20	9	16	20	21	

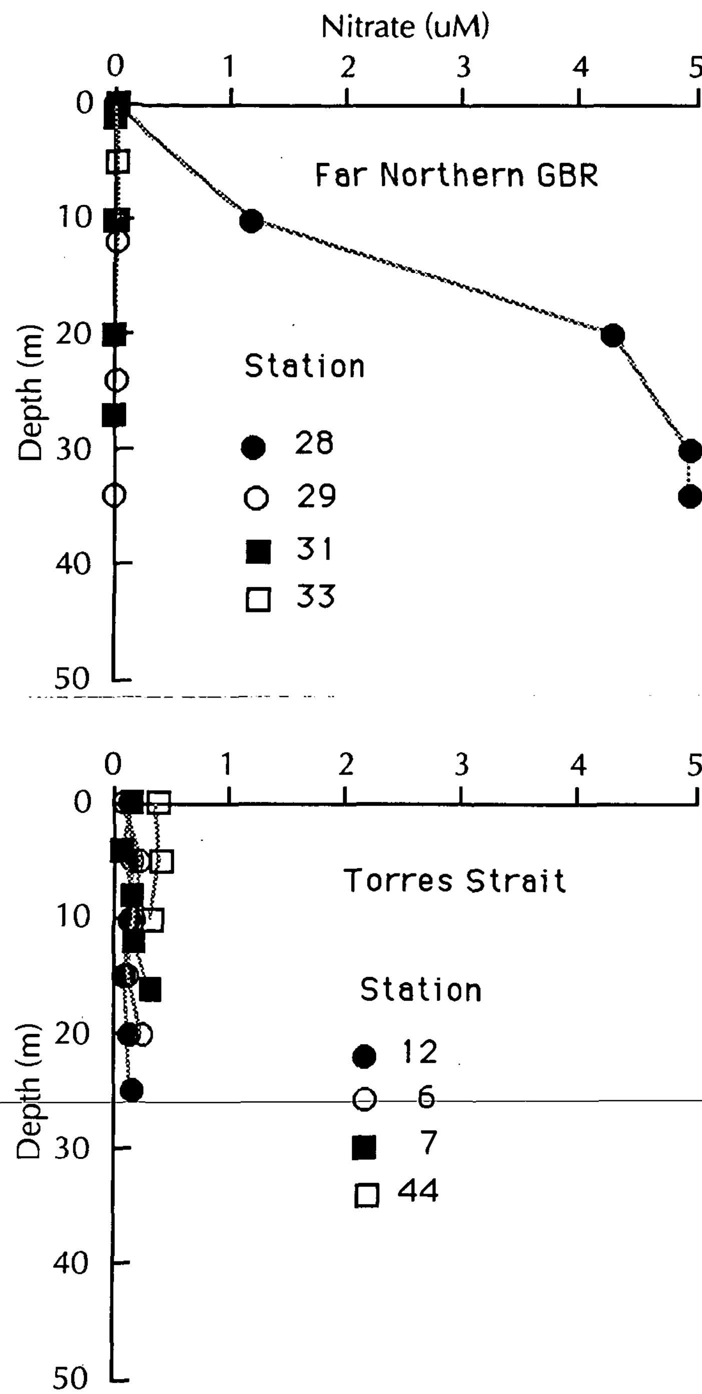

Figure 4. Vertical profiles of nitrate at stations in the far northern GBR (February, 1990) and eastern Torres Strait (November, 1979).

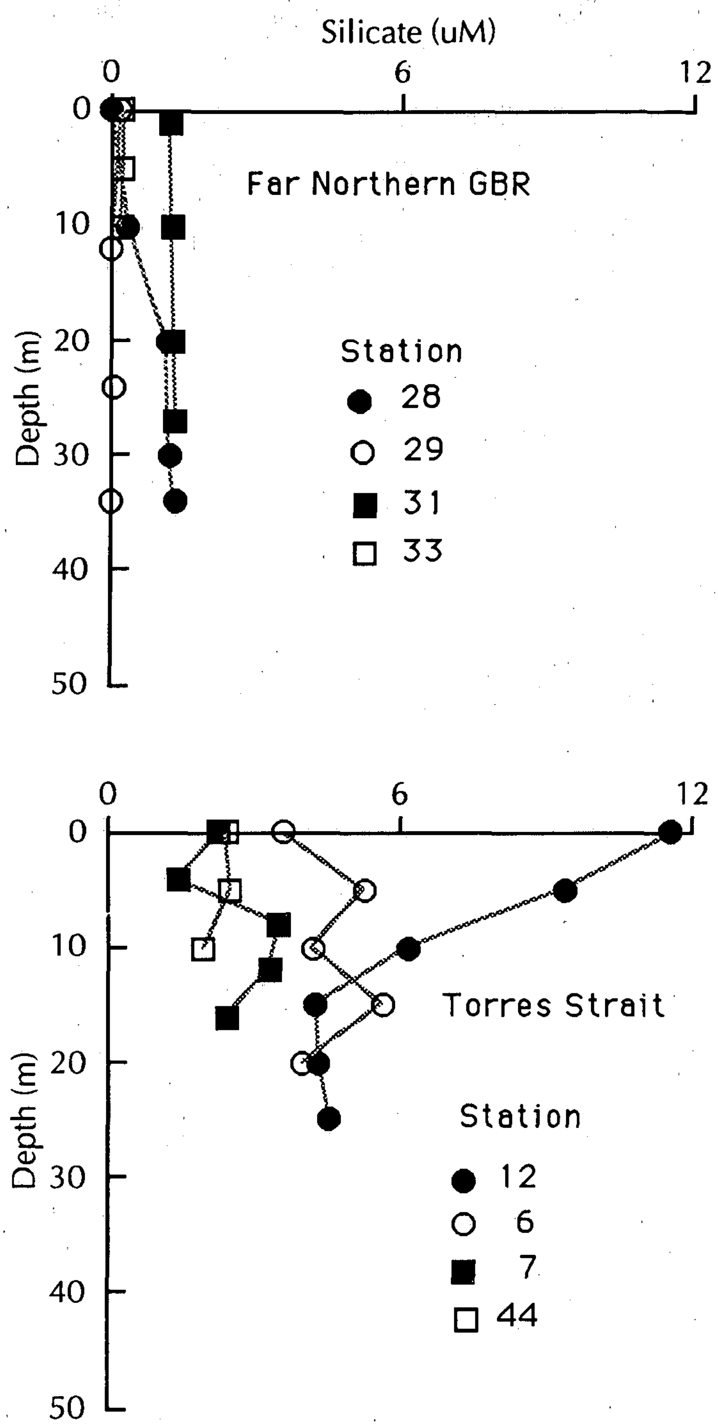

Figure 5. Vertical profiles of silicate at stations in the far northern GBR (February, 1990) and eastern Torres Strait (November, 1979).

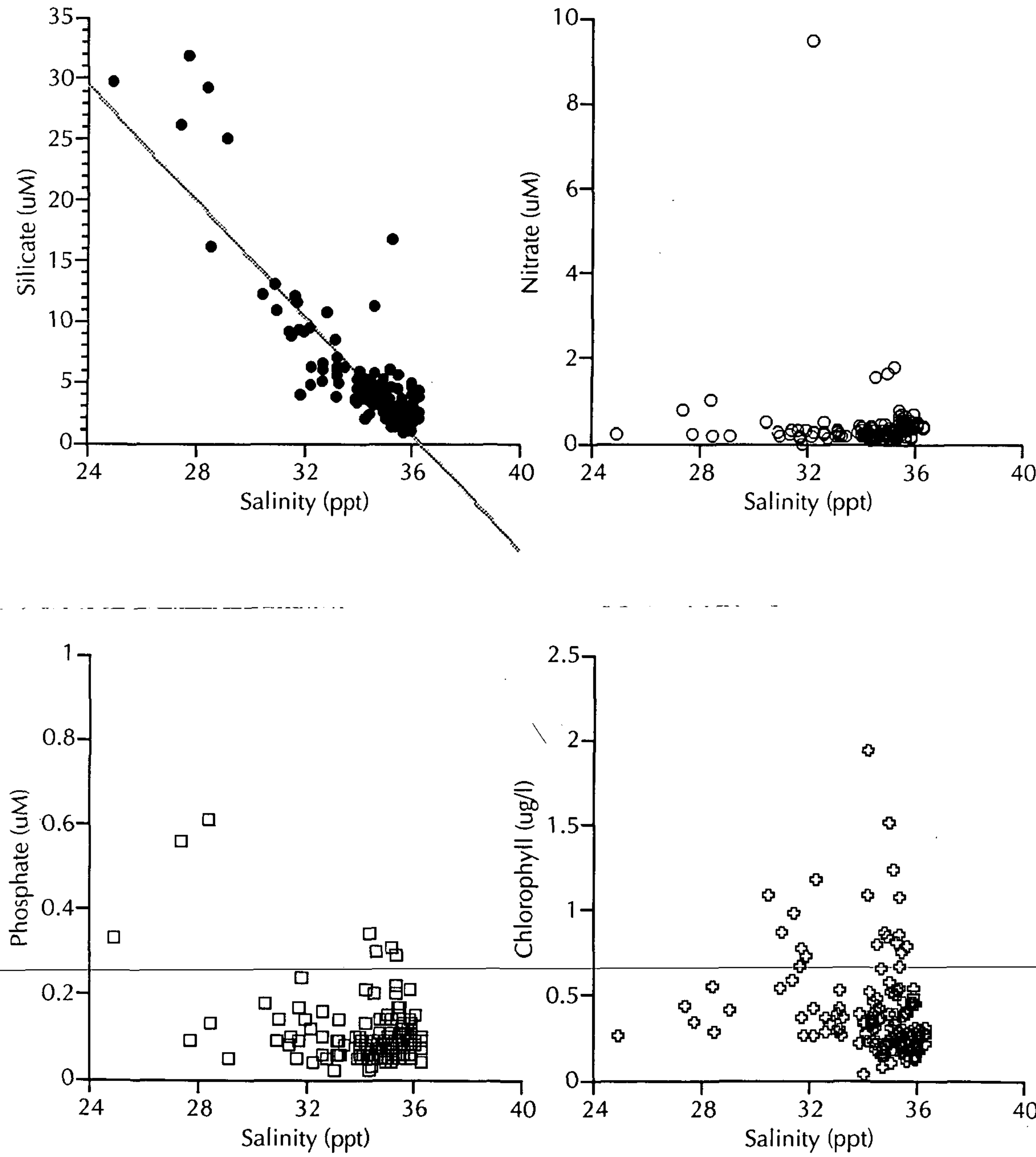

Figure 6. Scatter plots of near-surface (depth ≤ 20 m) silicate, nitrate, phosphate and chlorophyll concentrations in relation to salinity at Torres Strait and Gulf of Papua stations (November, 1979).

but substantial amounts of organic N and P enter the Gulf of Papua from the rivers flowing into it (Robertson *et al.*, 1990, this volume). Depth-averaged chlorophyll concentrations in the northwestern Gulf of Papua, Torres Strait and FNGBR are similar to near-shore chlorophyll concentrations found elsewhere in the GBR (Figure 7; Table 1). Maximal chlorophyll concentrations in vertical profiles were most frequently measured in near-bottom or midwater samples. With the exception of anecdotal observations by Hallegraeff and Jeffrey (1984), nothing is known regarding phytoplankton community structure in this area.

Vertical profiles of subsurface light intensity in the FNGBR indicate that concentrations of suspended particulate matter are low and that substantial irradiance fluxes reach the bottom to support the growth of rich benthic algal communities (E. Drew, pers. comm.). In contrast, water clarity varies considerably in the northwestern Gulf of Papua. Robertson *et al.* (1990) report Secchi disk depths off the Fly River delta ranging from 1.6 to 26 m ($k = 0.055$ to $0.9\ m^{-1}$). Comparable light profiles are not available for the Torres Strait, which should be a transition zone between the two regimes. Wolanski *et al.* (1984) report that poor water clarity in some portions of the Torres Strait limited the usage of satellite imagery. In contrast, Harris (1988) was able to use aerial photographs to study sediment bedforms. In the southwestern Torres Strait, the presence of substantial beds of seagrass at depths on the order of 15 metres (Poiner *et al.*, 1989) vouches for the general clarity and low suspended matter loads of waters in particular areas.

To date, no measurements of water column productivity and associated biological processes: grazing, organic sedimentation, nutrient uptake and mineralization have been reported for the Torres Strait proper. Mid-day water column primary production rates measured at five shelf sites in the FNGBR during February 1990 ranged between 73.6 and 205.8 mg C $m^{-2}\ hr^{-1}$. These rates translate to daily primary production rates of 0.59 - 1.65 g C m^{-2}, approximately equivalent to annual production rates of 215 - 600 g C m^{-2}. Such an annual production rate is similar to calculated primary production rates in temperate shelf systems supporting established fisheries (Yoder *et al.*, 1985) or seagrass beds in Australia (Larkum *et al.*, 1989), though the latter estimates are strongly biased toward temperate and sub-tropical systems. The highest water column production rates measured in the far-northern GBR (610-675 mg C $m^{-2}hr^{-1}$) occurred within deeper embayments immediately seaward of the reef, likely through high production rates occurring over a deeper water column and assisted by episodic upwelling of nutrient at the shelfbreak. Robertson *et al.*, (1990) measured water column primary production rates between 0.13 and 0.34 g C $m^{-2}\ d^{-1}$ in the northwestern Gulf of Papua (annual production equivalent 47 - 124 g C m^{-2}). Although low relative to production rates measured in the FNGBR, these rates are dwarfed by water column respiration rates (0.14-2.1 g C $m^{-2}\ d^{-1}$) fuelled by riverine carbon inputs. The extent to which water masses influenced by this this balance of production and consumption processes intrude into the Torres Strait is unknown.

Information on plankton communities and dynamics in the Torres Strait region is very limited. Macrozooplankton populations at stations in the southeastern Torres Strait were found to be dominated numerically by copepods, gastropod larvae and larvaceans. Zooplankton community standing crop estimates at Torres Strait stations ranged between 17 and 411 mg m^{-3} (mean = 110 $\pm$ 113 mg m^{-3}, 1 SD, n=12 sta.).

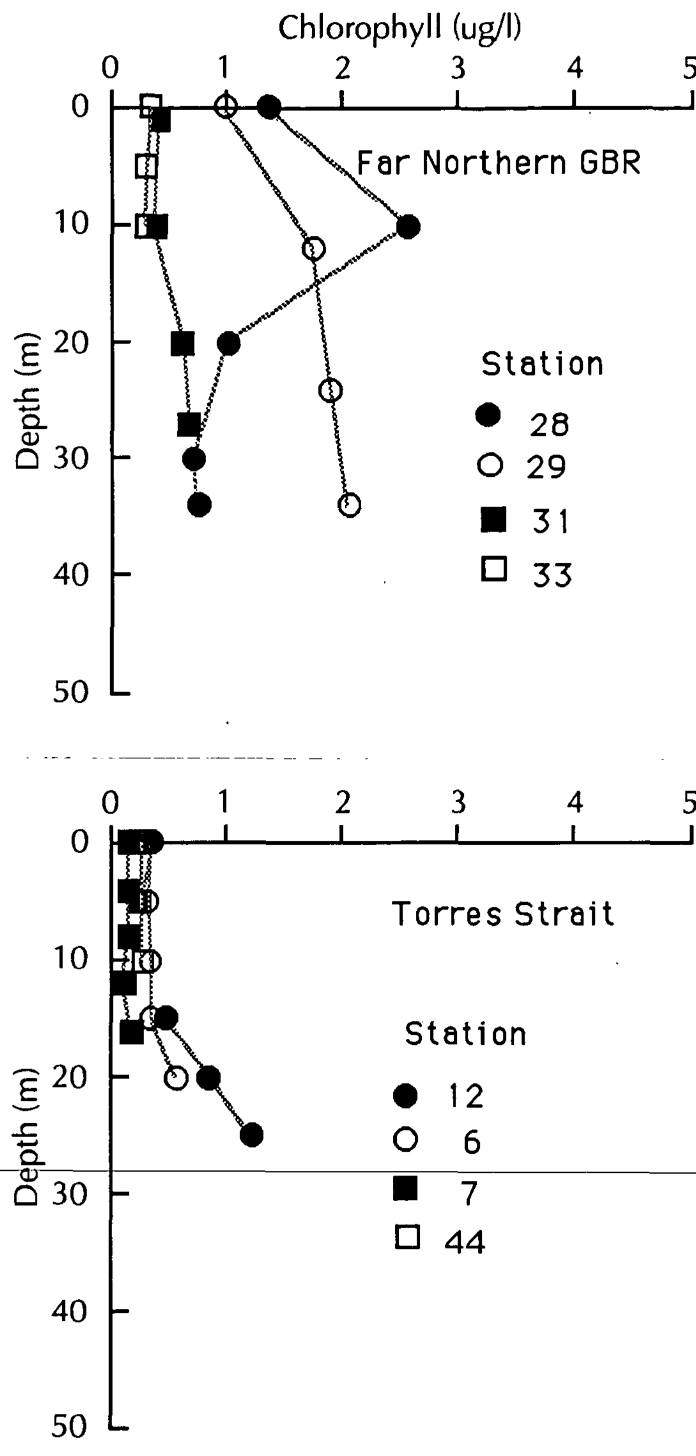

Figure 7. Vertical profiles of chlorophyll at stations in the far northern GBR (February, 1990) and eastern Torres Strait (November, 1979).

The numerical dominance of copepods mirrors the pattern found elsewhere in the GBR (Liston, unpubl.) and Gulf of Papua (Robertson *et al.*, 1990). Zooplankton standing crops in the FNGBR were found to be lower, ranging between 2.0 and 49.5mg dry weight m^{-2} (mean = 18.5 $\pm$10.9 : 1 SD, n=40 sta.). In the turbid waters of the northwestern Gulf of Papua, zooplankton standing crops ranged between 44 and 83 mg m^{-3} (mean = 69 $\pm$ 21 mg m^{-3}, n=3).

Benthos – water column interactions – within the Torres Strait system are likely to be complex and to play an important role in biological and geochemical processes within the region. Sediment and bottom types within the region are spatially variable, ranging from riverine muds deposited in basins to hard coral reef substratum (Harris, 1988). Strong tidal currents in some areas (Wolanski, 1986; Wolanski *et al.*, 1988) have winnowed sediments in high transport areas to less mobile gravels (Harris, 1988). Because of the overall shallowness of the region, the Torres Strait system has a high benthic area to volume ratio. Benthic influences upon water column biological and chemical processes can therefore be expected to be significant. Apart from measurements related to fisheries investigations, little is known regarding benthic biogeochemical processes in the Torres Strait proper. Poiner *et al.*, (1989) estimated that 3579 km^{-2} of seagrasses were present within the Torres Strait region. Microbial rate processes within seagrass beds, as measured by Moriarity and Boon (1989) in the Gulf of Carpentaria should be applicable to these areas, provided that sedimentation and overlying production rates are roughly similar. Robertson *et al.*, (1990) reported that offshore sediments in the Gulf of Papua are active sites of organic material processing and nutrient diagenesis. Sediment – water column and benthic biogeochemical processes – within the Torres Strait region will therefore fall along a number of gradients between end-members typified by seagrass beds, fine riverine sediments, coral reefs and relict carbonate sediments. Whether metabolic rates similar to those found elsewhere in the GBR (Alongi, 1989) are applicable remains to be determined.

In summary, relatively little is known regarding the biological and chemical oceanographic characteristics of the Torres Strait region. The published data is largly derived from three cruises, only one of which was actually carried out within the Torres Strait proper. Within the Torres Strait, there exists a dynamics boundary between the freshwater influenced Gulf of Papua, the open Arafura sea and the far northern GBR shelf system. As such, water column properties exhibit some features of all adjoining systems.

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