9. RAINFALL INPUTS OF NUTRIENTS

Somewhat in excess of 2 metres of rain falls annually onto the central GBR (16-18°S) shelf. The mountain ranges and coastal catchments adjacent to the Tully box are the wettest in Australia, with precipitation in some places exceeding 11 metres per annum (Hausler, 1991). High rainfall is also recorded in and north of the Daintree River catchment, at the northern edge of the Cairns box. Long-term rainfall records over the shelf are available from three local sites: Low Isles (annual mean 1894-1990 = 2.1 m), Green Island (annual mean 1949-1990 = 2.06 m) and Fitzroy Island (annual mean 1962-1990 = 2.70 m). Most of this rainfall comes between January and March (Figure 53), with monthly mean falls increasing from November and declining through July. It is not clear how far the pattern of rainfall measured along the coast extends to sea.

Distributions of inorganic nutrient concentrations measured in rain samples are highly skewed toward low concentrations (Figures 54-56). Concentrations of silicate and phosphate in rainwater are usually very low, suggesting low levels of continental dust in the rainwater or seawater/seasalt contamination of samples. Ammonium and nitrate were the principal species of inorganic nitrogen measured in rain samples. It is unclear what factors were responsible for the very high ammonium and nitrate concentrations in a small number of samples. Considerable effort was made to minimize contamination of the samples and sampler. Organic nitrogen (=DON+PN) concentrations measured in a subset of the rainwater samples averaged approximately 4.5 μmol N l^{-1}.

Such high concentrations are not unprecedented (Williams, 1967; Knap et al., 1986), and would lead to, if generally occurring in all samples, an appreciable nitrogen flux into the water column. Because of the small number of samples analyzed, the precision of the estimate of organic nitrogen fluxes via rainfall must be viewed with caution until verified. No estimates have been attempted for dry deposition of nitrogen species in the central GBR region (e.g. Duce, 1986).

The median total phosphorus concentration measured in rainwater samples (0.18 μM) was similar to that measured in bulk precipitation samples collected at an isolated oceanic site in the central Pacific (0.18 μM; Graham and Duce, 1981). Graham and Duce (1981 and sources quoted therein) reported that non-reactive phosphorus in rainwater was present at concentrations equal to or greater than molybdate reactive phosphorus (PO_4). They found that dry phosphorus deposition was on the order of 20-40 percent of the phosphorus flux in rain. At sites near land, local atmospheric recycling of phosphorus could therefore contribute materially to total atmospheric phosphorus fluxes (Graham and Duce, 1981).

DIN/DIP ratios calculated for rainfall samples span a considerable range (Figure 57). Only seven of 48 calculated DIN/DIP ratios fell on or below the Redfield N/P ratio (16), with fifteen samples having DIN/DIP ratios between 50 and 100 (atoms).

Summary statistics for dissolved nutrient concentrations measured in rain samples are given in Table 24. Estimates of nutrient fluxes in rainfall are calculated from the median concentrations to minimize weighting by the few, very high concentrations measured. The Green Island rainfall estimate is used to compute the overall precipitation flux as most of the area considered is away from the coast and would not have any exaggerated topographic bias, such as might influence rainfall at Fitzroy Island which is located closer to the coast and the mountains of Cape Grafton. The input estimates are likely conservative, but not extremely so.

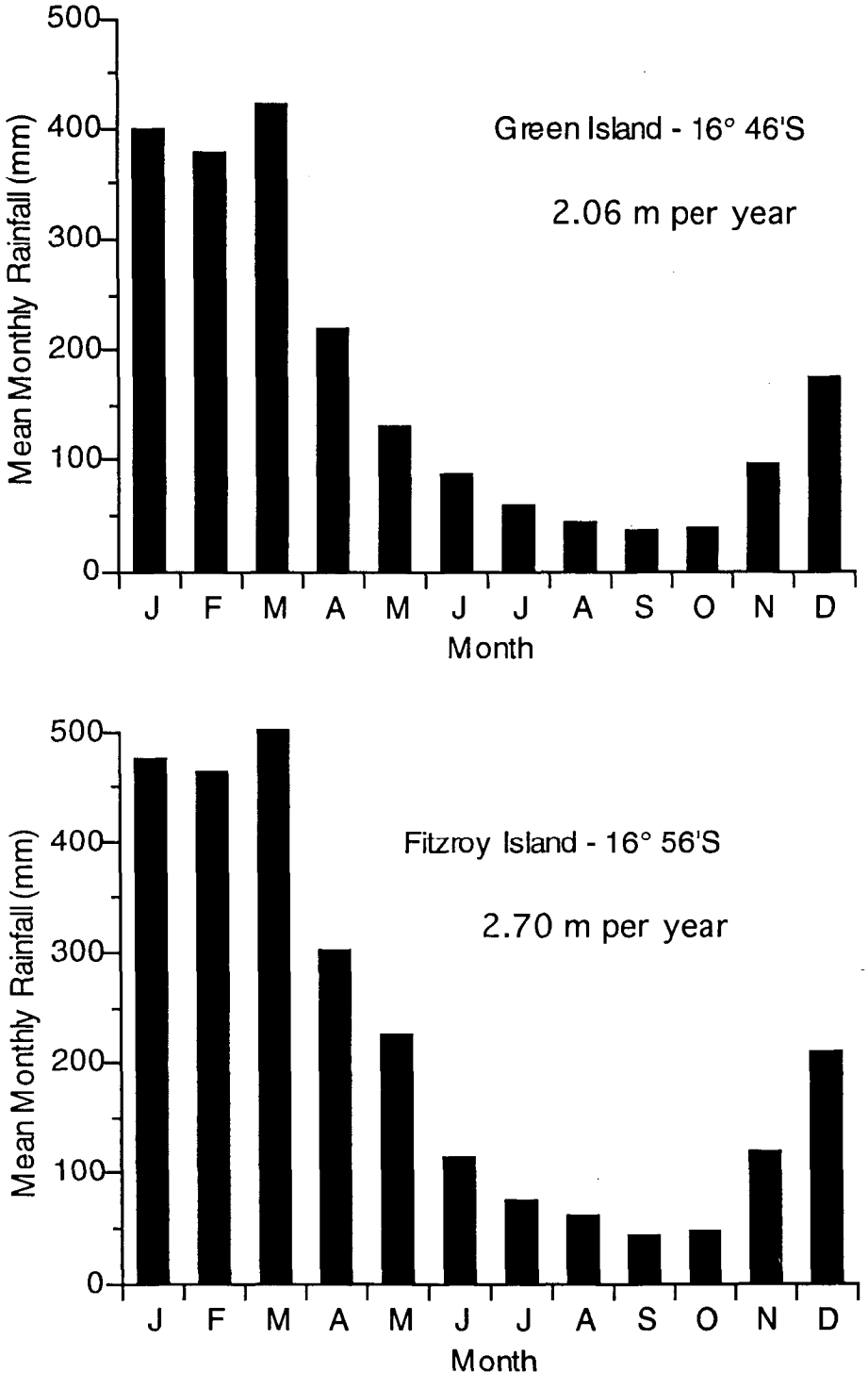

Figure 53. Mean monthly rainfall measured at Green Island (1949-1990) and Fitzroy Island (1962-1990).

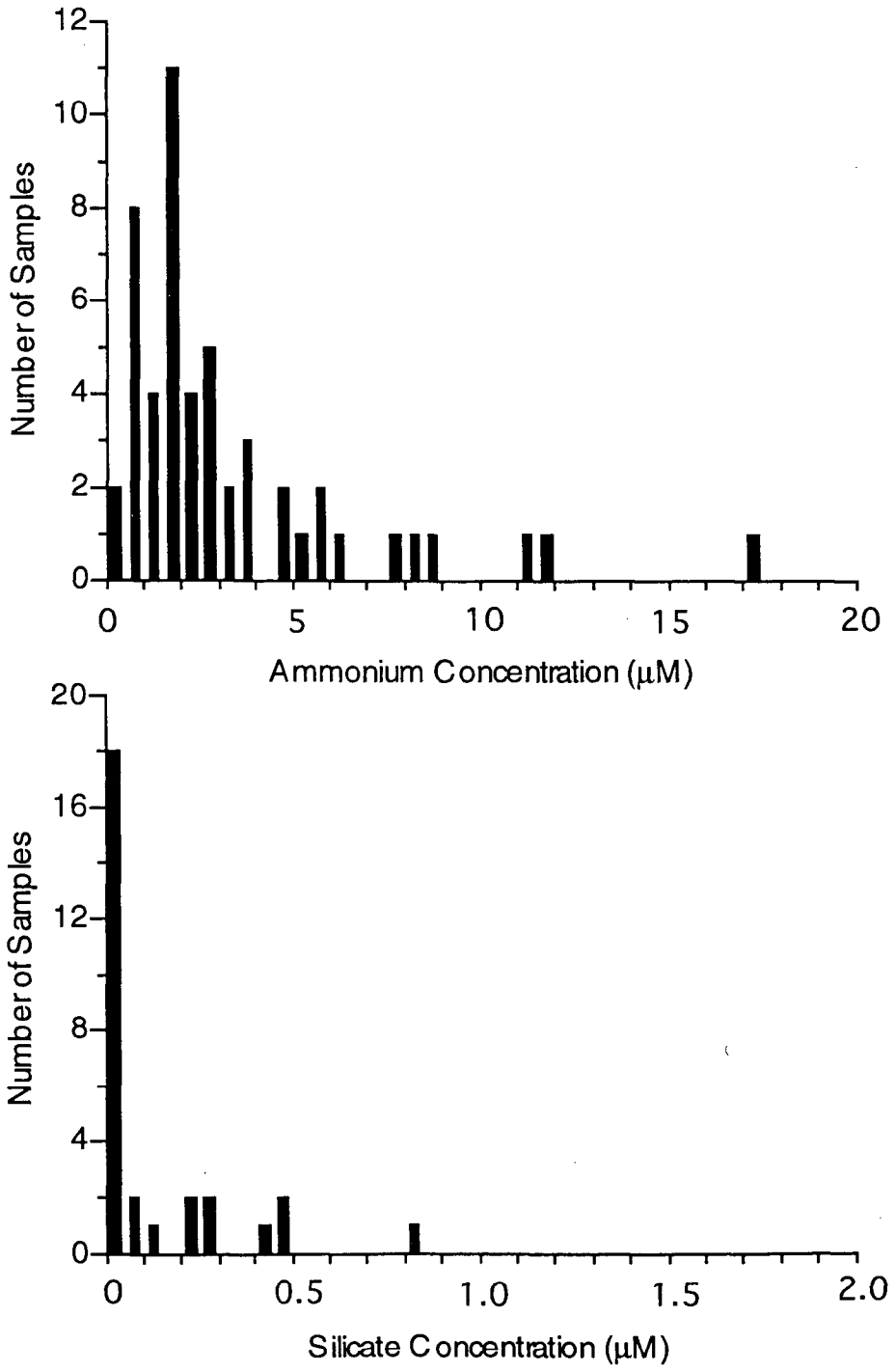

Figure 54. Frequency distributions of measured ammonium and silicate concentrations in rainwater collected at AIMS and in the western Coral Sea (GBR included). Bin widths for ammonium and silicate distributions are 2.5 and 0.5 μM respectively. Silicate concentrations in rain samples exceeded 2 μM on two occasions.

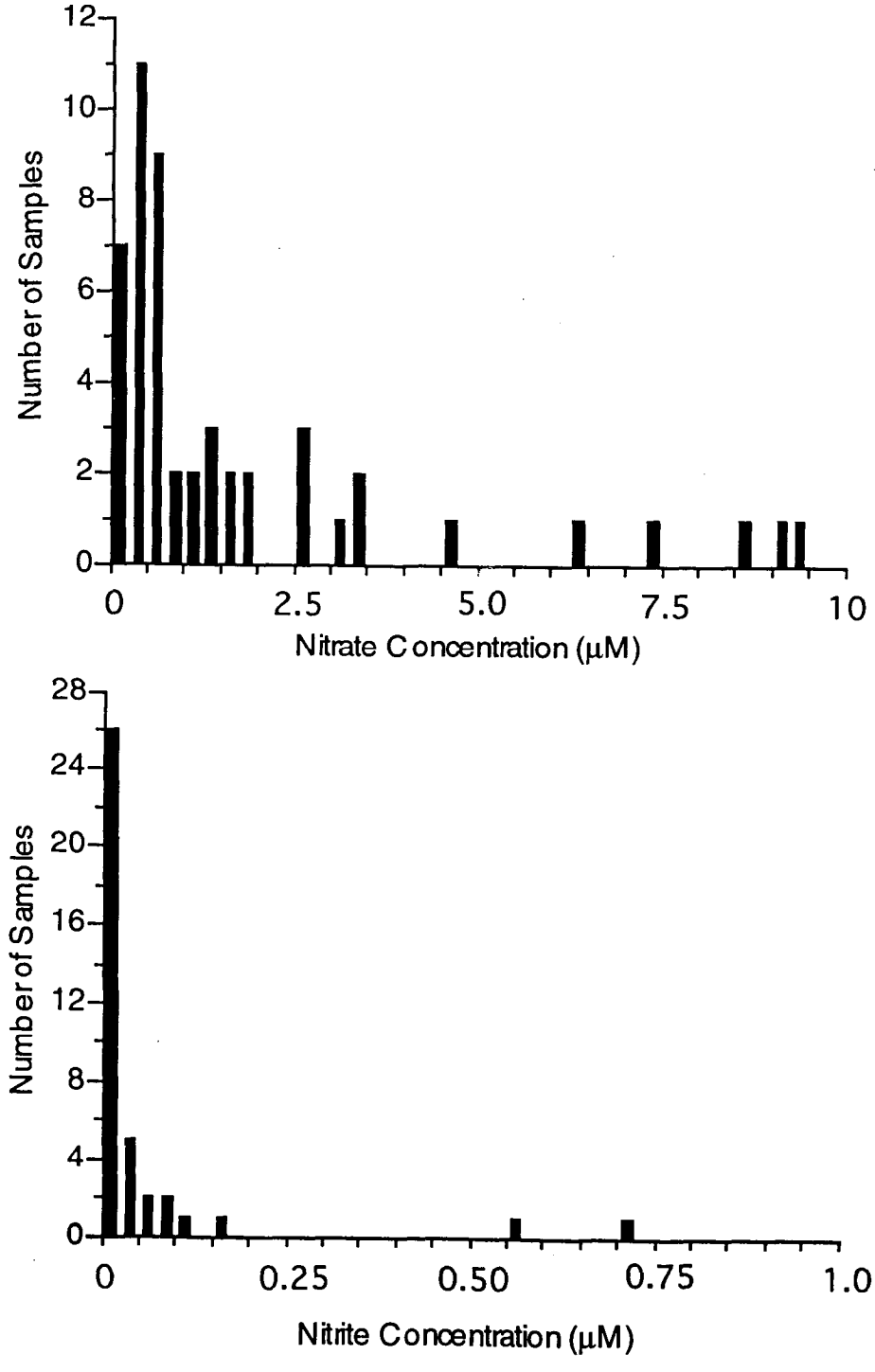

Figure 55. Frequency distributions of measured nitrate and nitrite concentrations in rainwater collected at AIMS and in the western Coral Sea (GBR included). Bin widths for nitrate and nitrite distributions are 0.125 and 0.025 µM, respectively.

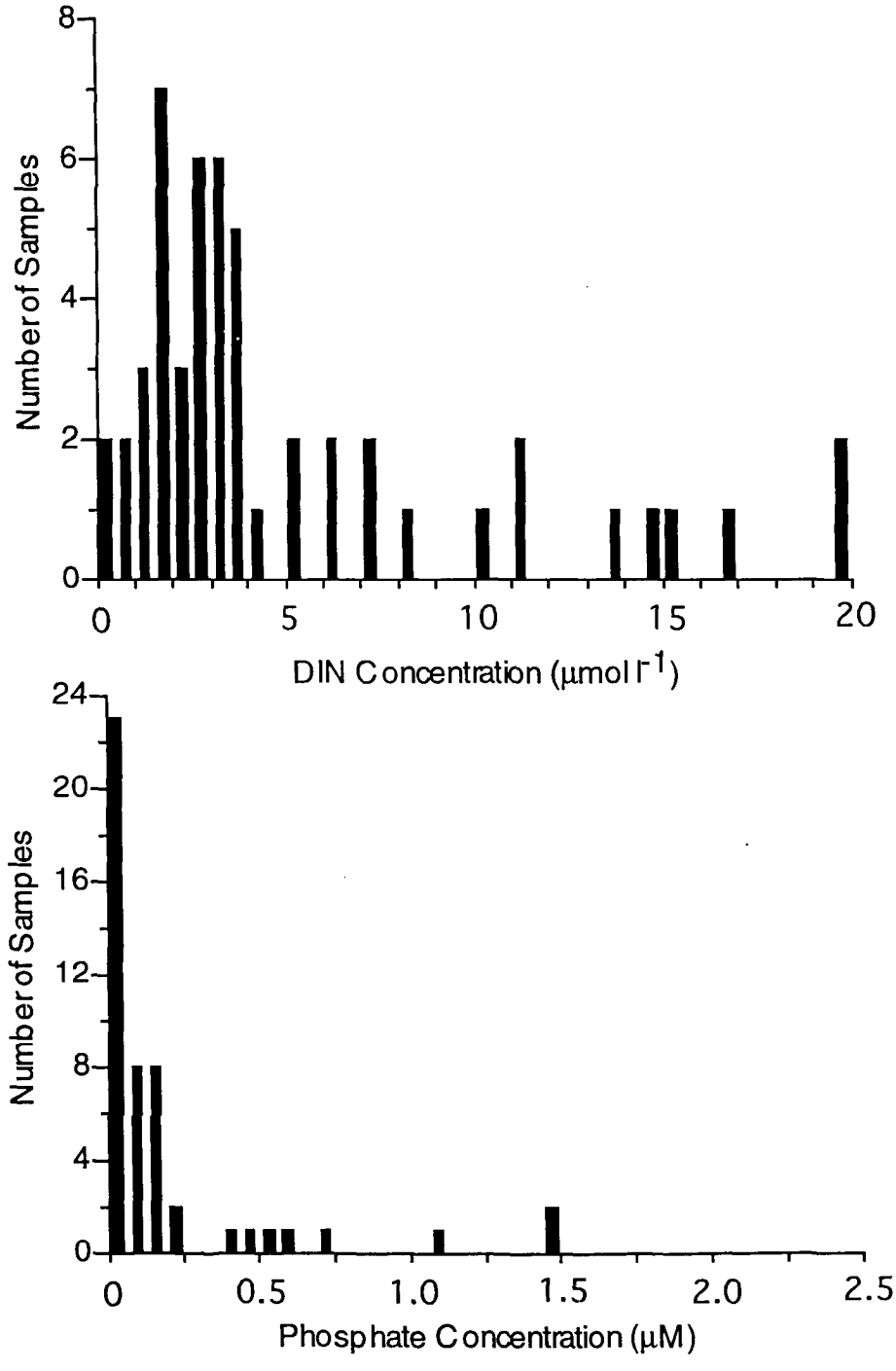

Figure 56. Frequency distributions of dissolved inorganic nitrogen (DIN=NH_4+NO_2+ NO_3) and phosphate concentrations in rainwater collected at AIMS and in the western Coral Sea (GBR included). Bin widths for DIN and phosphate distributions are 0.5 and 0.05 µM, respectively.

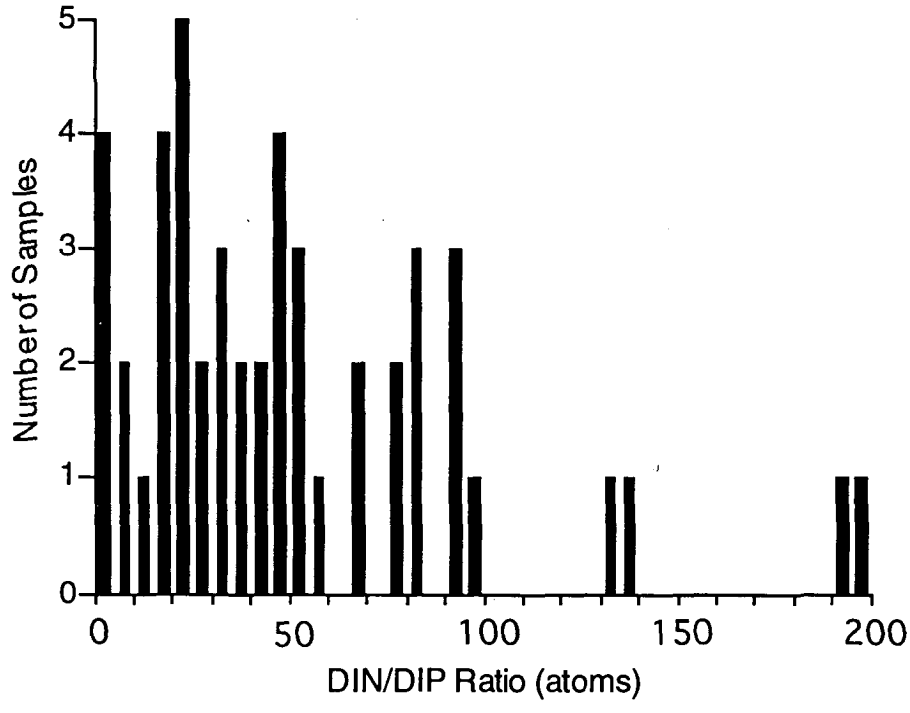

Figure 57. Frequency distribution of DIN/DIP ratios in rainwater collected at AIMS and in the western Coral Sea (GBR included). Bin widths for ratio frequencies are 5.

Table 24. Dissolved nutrients in rainfall collected at sites throughout the GBR and western Coral Sea. Fluxes are estimated from the median concentration to devalue the importance of extreme values. Annual rainfall for the shelf is taken as the long-term (1949-90) average recorded at Green Island.

	NH_4	NO_2	NO_3	Tot N	PO_4	Tot P	Silicate
Mean (µM)	3.31	0.67	1.31	6.47	0.28	0.24	0.35
Std. Dev.	3.33	1.81	2.31	3.62	0.48	0.16	0.99
no. samples	51	51	51	9	51	12	45
Median (µM)	2.01	0.01	0.36	6.85	0.09	0.18	0.01
Annual rainfall (m)	2.06	2.06	2.06	2.06	2.06	2.06	2.06
Rain Inputs (mmol m^{-2} $year^{-1}$)	4.14	0.02	0.73	14.11	0.18	0.37	0.02
Inputs (kmol)							
Cairns box	24583	122	4342	83777	1070	2212	122
Tully box	32404	161	5723	110433	1411	2915	161
Inputs (m.t.)							
Cairns box	344	2	61	1174	33	69	3
Tully box	454	2	80	1547	44	90	5

Ammonium is the principal inorganic nitrogen species deposited in rainfall. We calculate that atmospheric precipitation deposits approximately 29,000 and 38,000 kmol of inorganic nitrogen (NH_4+NO_2+NO_3) per year in the Cairns and Tully boxes, respectively. Estimated organic nitrogen (=DON + PN) inputs of 55,000 and 72,000 kmol from rainfall into the Cairns and Tully boxes are larger than the estimated inorganic nitrogen inputs, but should be viewed with caution until more measurements of DON and PN in rain are made.

Duce (1986) estimated annual atmospheric nitrogen inputs to the subtropical North Pacific Ocean fall between 8 and 26 µmol m^{-2}. Extrapolated to the areas of the Cairns and Tully boxes, this range of fluxes would translate to annual nitrogen inputs of 48-150 and 63-200 x 10^3 kmol, respectively, which bracket the estimated fluxes to these areas based on local measurements.

Inorganic phosphorus inputs from rainfall slightly exceed 1,000 kmol per year for both the Cairns and Tully boxes. Estimated fluxes of inorganic and organic phosphorus (=DOP and PP) are approximately equal. Duce (1986) estimated that atmospheric phosphorus fluxes to the central North Pacific Ocean fall between 0.005 and 0.012 µmol m^{-2} day^{-1}. Over an annual time period, these atmospheric fluxes would be equivalent to total atmospheric inputs of 11-26 kmol and 14-34 kmol of phosphorus into the Cairns and Tully boxes, respectively. Duce's estimated total fluxes are approximately 1-2 percent of the atmospheric input fluxes to the GBR calculated from rainfall collections. Reasons for the discrepancy are unresolved at present. Most of Duce's sampling sites were located on small islands in the middle of the Pacific Ocean where terrestrial contamination could be expected to be small. Collateral geochemical measurements to establish levels of dust contamination of the rain have yet to be made, but need to be done.