10. INTRUSIONS FROM THE CORAL SEA

Near-bottom intrusions of cool, sub-thermocline waters occur episodically along the shelfbreak of the GBR (Andrews and Furnas, 1986). These events occur predominantly during the summer months (October - April) and the available data suggests that intrusion events can be temporally coherent along hundreds of kilometres of the shelfbreak (Andrews and Furnas, 1986).

The temperature-salinity (T/S) characteristics of the water masses immediately seaward of the GBR in the East Australian Current (**EAC**) are relatively well defined (Figure 14). In the western Coral Sea, a layer of warm, low-density Coral Sea Surface Water (**CSSW**) overlies a discrete layer of cooler, high-salinity water known as Subtropical Lower Water (**SLW**), which in turn, sits atop a broad layer of Antarctic Intermediate Water (**AIW**; Pickard et al., 1977). The salinity and temperature characteristics of CSSW change seasonally in response to solar heating, evaporation and precipitation. Subtropical Lower Water is formed in the oceanic regions to the east of the Coral Sea and is advected westward until reaching the Australian continent. In contrast to CSSW, the T/S characteristics of SLW in the region adjacent to the GBR are relatively stable. The core of the SLW layer is characterized by temperatures within the range 20.0-22.5°C and salinities between 35.6 and 35.7 °/$_{oo}$. The depth of the salinity maximum which identifies the core of the SLW layer normally falls between 100 m and 150 m immediately seaward of the reef, moving vertically in response to dynamic factors such as the strength of the poleward flowing EAC, transport in the South Equatorial Current and internal tides. At any one time, the transition zone between the CSSW and SLW is characterized by a gradient of mixtures between CSSW and SLW. Accordingly, parcels of water within the transition zone can be partitioned on the basis of their T/S characteristics into constituent proportions of CSSW and SLW. Water and nutrients intruded onto the shelf largely comes from this transition layer between surface waters and SLW.

Surface waters within the GBR also exhibit a cross-shelf gradient of temperatures and salinities (Figure 13). T/S characteristics of inshore water and water within the GBR lagoon are affected by seasonal changes in solar heating, mixing, evaporation, coastal runoff and precipitation (Pickard et al., 1977; Wolanski and Jones, 1981). For the purposes of budget calculations, a seasonally varying water type, Lagoon Water (**LW**; Andrews, 1983) is operationally defined. As with vertical profiles, the T/S characteristics of surface water parcels within the reef matrix can be partitioned into their relative proportions of LW and CSSW.

Calculated volumes of intruded SLW within a 1-metre wide cross shelf section in both the Cairns and Tully boxes exhibit a general linear relation to both shelfbreak bottom water temperature and the difference between the bulk mixed layer and minimum shelfbreak water temperatures observed in a given section (Figure 58). Variations in near-bottom shelfbreak temperature or the vertical temperature range account for 48-64 percent of the variability in calculated SLW water volume on the shelf (Table 25). For the mean cross-shelf bathymetries of the Cairns and Tully boxes, the largest of the Palm Passage intrusions would have injected slightly less than 5 x 10^5 m^3 of SLW per metre of coastline onto the shelf, a volume on the order of 22 percent of the volume of the Cairns box and 16 percent of the Tully box (Figure 59). Volumes of SLW imported by most intrusion events, however, were considerably smaller. The total volume of water transported onto the shelf by an intrusion event, however, would be considerably greater as the SLW proper would be diluted by CSSW within the intruded transition layer.

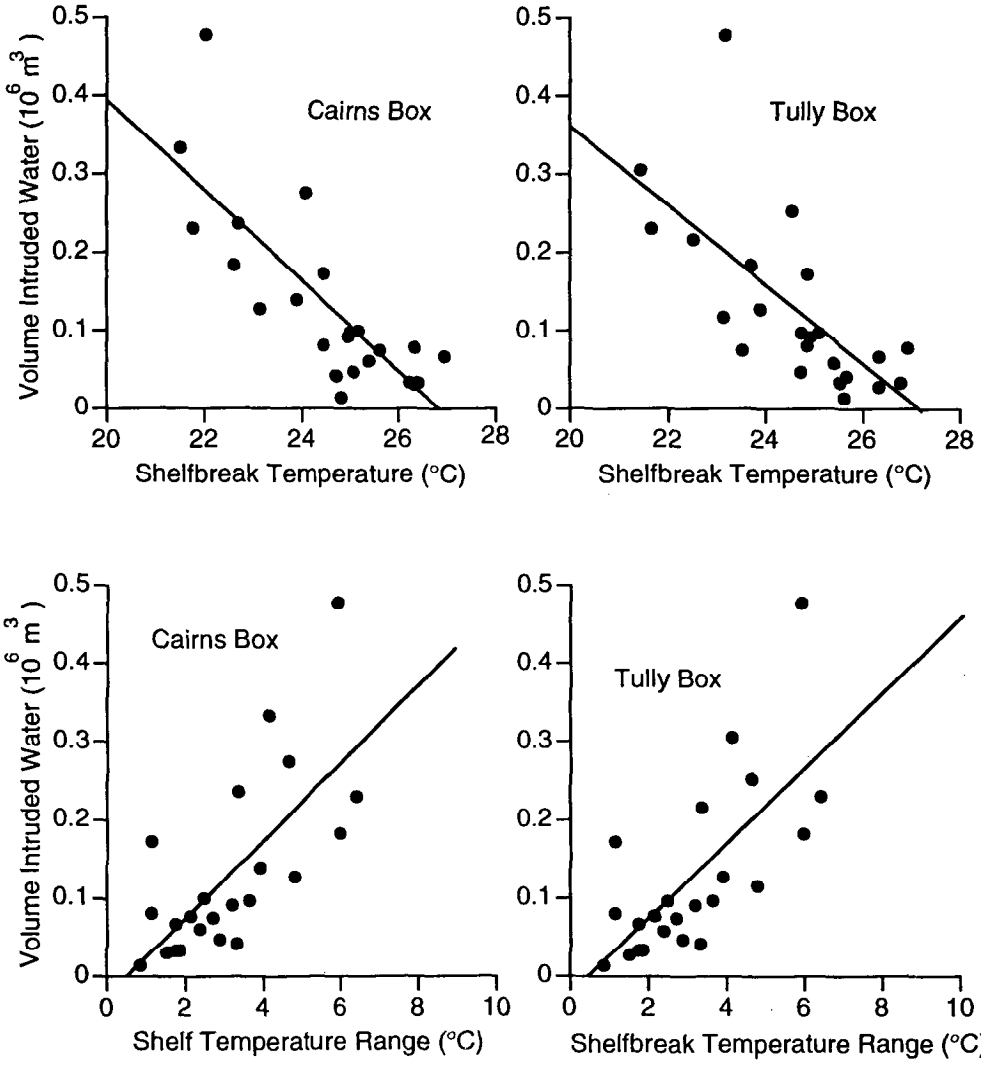

Figure 58. Calculated volumes of undiluted Subtropical Lower Water (SLW) per linear metre of shelf in the Cairns and Tully boxes in relation to (Top) calculated bottom water temperature at 58 m near Euston Reef and (Bottom) the calculated near-surface to bottom temperature difference at the shelfbreak near Euston Reef. Near-bottom temperatures and SLW volumes were calculated from masked Palm Passage sections.

Table 25. Empirical relationships derived for estimating volumes of Subtropical Lower Water and stocks of nitrate and phosphate intruded onto the shelf in the Cairns and Tully boxes from measured near-bottom shelfbreak water temperatures.

Cairns box		
Volume intruded (10^6 m^3)	= 1.55 - 0.058 (Temp)	r^2 = 0.64
Volume % SLW	= 69.7 - 2.6 (Temp)	"
Volume intruded (10^6 m^3)	= 0.0494 (delta Temp) - 0.0233	r^2 = 0.49
Volume % SLW	= 2.22 (delta Temp) - 1.05	"
Percent change in N per m of shelf	= 87.9 - 3.28 (Temp)	r^2 = 0.64
Percent change in P per m of shelf	= 233-8.7(Temp)	r^2 = 0.64
Tully box		
Volume intruded (10^6 m^3)	= 1.38 - 0.059 (Temp)	r^2 = 0.48
Volume % SLW	= 46.2 - 1.71 (Temp)	"
Volume intruded (10^6 m^3)	= 0.0480 (delta Temp) - 0.0230	r^2 = 0.49
Volume % SLW	= 1.61 (delta Temp) - 0.77	"
Percent change in N per m of shelf	= 38.4 - 1.43 (Temp)	r^2 = 0.63
Percent change in P per m of shelf	= 53.9 - 2.01 (Temp)	r^2 = 0.63

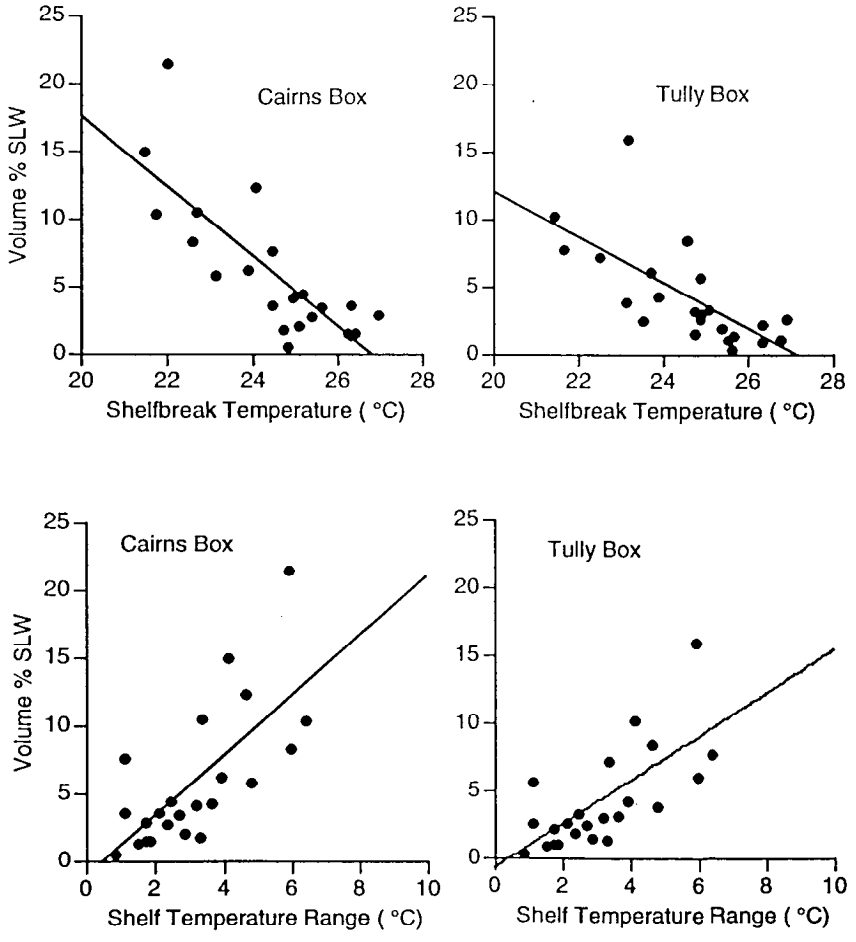

Figure 59. Calculated volume percentages of undiluted Subtropical Lower Water (SLW) per linear metre of shelf in the Cairns and Tully boxes in relation to (Top) calculated bottom water temperature at 58 m near Euston Reef and (Bottom) the calculated near-surface to bottom temperature difference at the shelfbreak near Euston Reef. Near-bottom temperatures and SLW volumes were calculated from masked Palm Passage sections.

Figure 60 illustrates calculated estimates of the net amounts of nitrogen and phosphorus which would be imported per linear metre of shelf into the Cairns and Tully boxes by the intrusion events sampled in Palm Passage and their relation to minimum water temperatures monitored with near-bottom TDR moorings at Euston Reef. Details of nitrogen and phosphorus speciation associated with intrusion events are discussed below. Because the water masses intruded and displaced are presumed to have a constant nutrient composition, the magnitude of nitrogen and phosphorus imports are linearly related to shelfbreak temperature in a manner analogous to the volume of intruded SLW (Figure 58). This is obviously a simplification, but necessary as detailed nutrient (dissolved and particulate) inventories for *in situ* source and outer shelf surface waters are not available for each event.

For very large intrusion events (ca. 5 x 10^5 m^3 SLW per metre of shelf), net inputs of 2.43[0.28] and 2.49[0.26] kmol of N[P] would be imported into the Cairns and Tully boxes, respectively. Inputs of this order would represent 20[70] and 16[20] percent of existing summer N[P] stocks per linear metre of shelf. The large difference in relative phosphorus imports is due to the large apparent difference between DOP stocks in the two boxes. Reasons for the high DOP concentration in the Tully box are unresolved.

Near-bottom water temperatures were recorded over a two-year period near the shelfbreak at the entrances to Grafton Passage (Euston Reef, Figure 61) and Trinity Opening (Norman Reef, Figure 62). The Grafton Passage record is slightly cooler than the Trinity Opening record, reflecting the slightly deeper location of the temperature recorder (56-58 m vs. 52 m). Near-bottom temperatures varied seasonally in a sinusoidal pattern at both sites. Small spikes aside, the time-averaged maximum water temperature during the summer of 1989-90 was approximately 1°C higher than that recorded during the summer of 1990-91. Reasons for this difference are unresolved at this time. The Euston Reef TDR mooring is being maintained to observe possible interannual fluctuations in shelfbreak water temperatures. The Norman Reef mooring was shifted to the passage between Green Island and Arlington Reef in December 1991. Over the ensuing nine months, two intrusion events (not shown) were recorded in near-bottom waters (41 m depth) adjacent to Green Island.

One large, extended intrusion event was monitored during each of the two summers sampled. A second smaller event was also observed during the summer of 1990-91. Short-lived events occurred during November 1989 and December 1991. Minimum near-bottom temperatures of 26°C and 24.4°C were measured at the Norman Reef site. At Euston Reef, minimum temperatures of 25.1°C (sustained 25.6°C) and 23°C were measured. The onset of the major intrusion during the summer of 1990-91 coincided with the occurrence of Cyclone Joy (25 December 1990). Thereafter, a period of unsettled, monsoonal weather developed which lasted approximately 6 weeks and which likely contributed to much of the observed near-bottom temperature variability over the 1990-91 summer season. A detailed analysis of the temperature record in relation to the local wind dynamics remains to be carried out.

Estimates of **net** nitrate and phosphate inputs to the shelf from intrusions are based upon the assumption that these nutrients are delivered rapidly during the event and that all intruded nutrients are subsequently dispersed within shelf waters. The extent to which intruded water (and nutrients) are returned offshore at the end of an intrusion event by horizontal mixing processes not associated with upwelling or offshore subsidence following the intrusion event is currently unknown. It is highly likely that some intruded water and nutrients are subsequently mixed back off the shelf into the EAC without contributing to shelf productivity in any significant fashion.

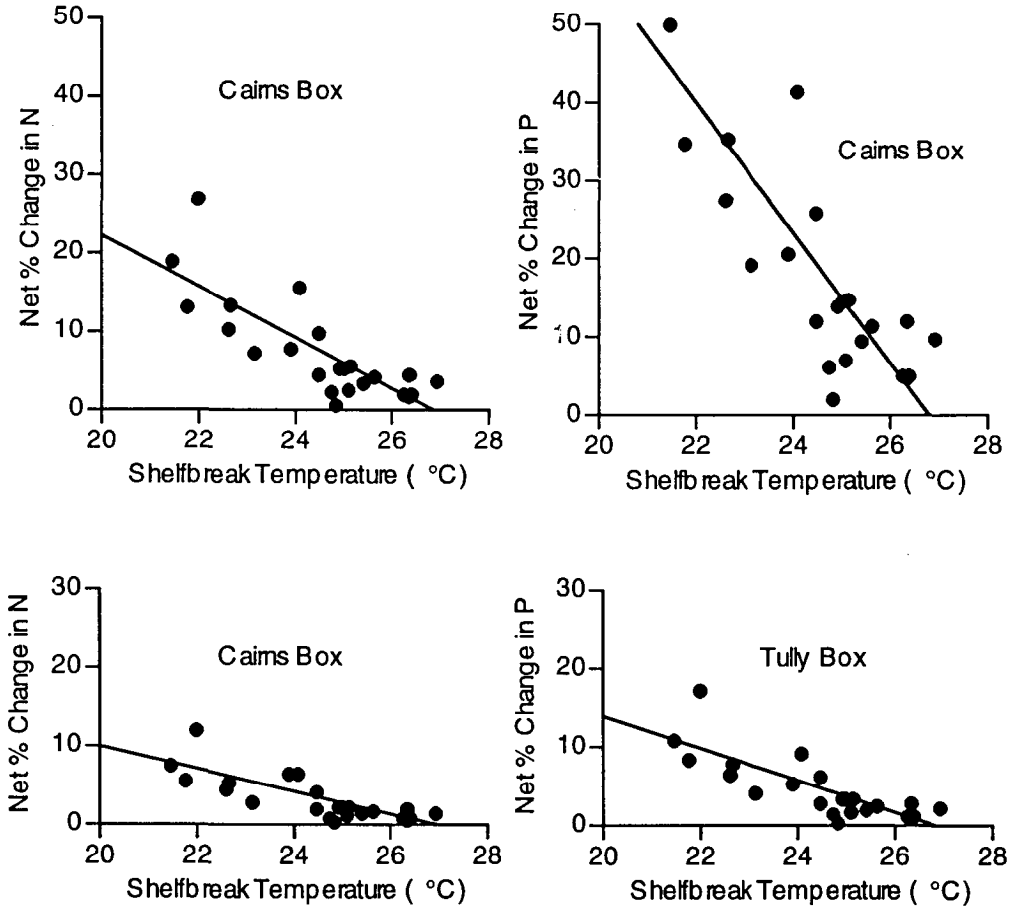

Figure 60. Calculated net changes in nitrogen (Top) and phosphorus (Bottom) stocks per linear metre of shelf in the Cairns and Tully boxes in relation to calculated shelfbreak bottom water temperatures near Euston Reef. Temperatures were taken from masked Palm Passage intrusions.

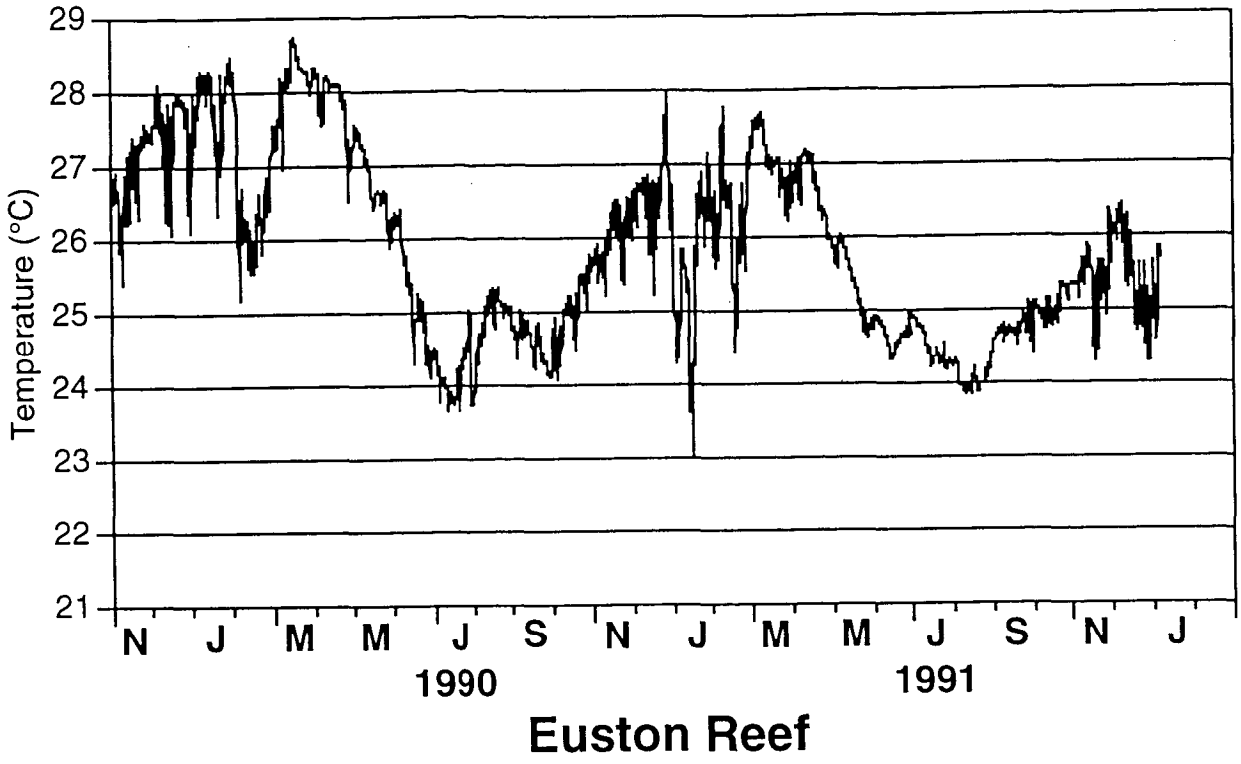

Figure 61. Near-bottom shelfbreak water temperatures recorded near Euston Reef (58 m depth) near the seaward end of Grafton Passage.

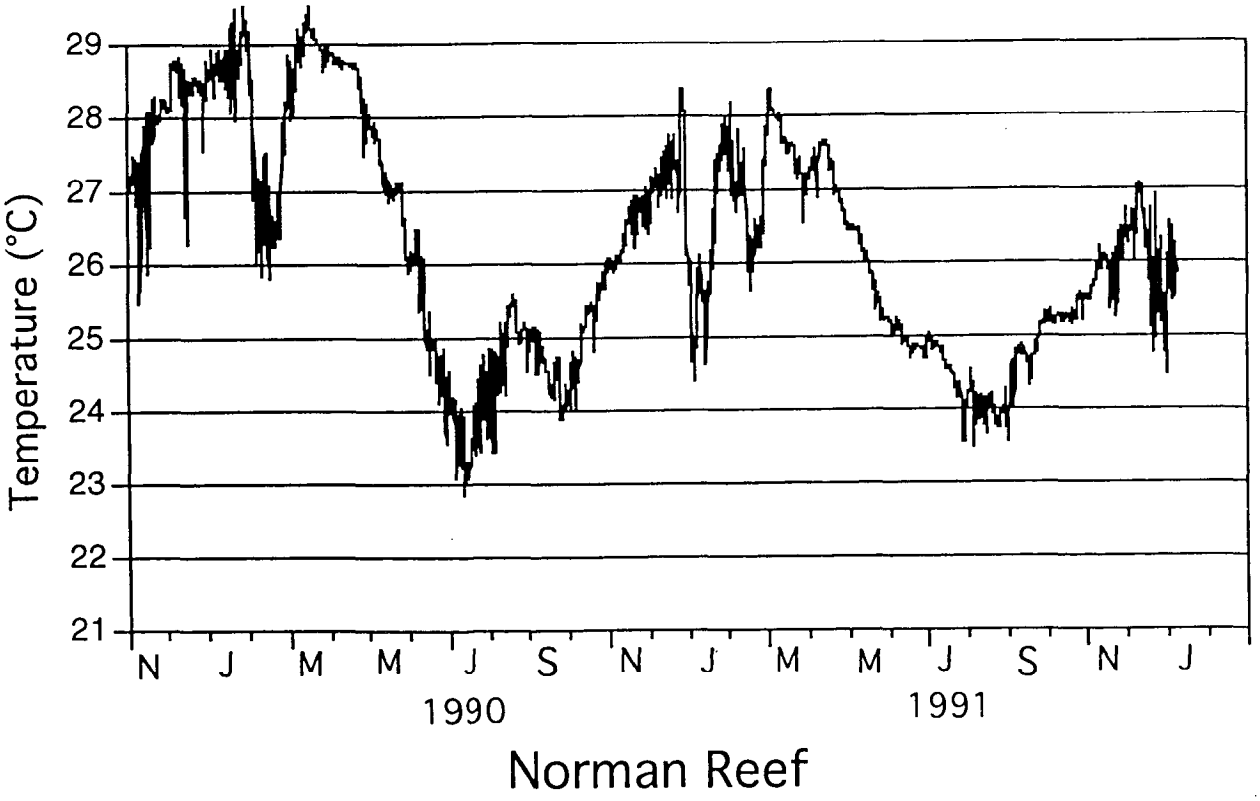

Figure 62. Near-bottom shelfbreak water temperatures recorded near Norman Reef (58 m depth) near the seaward end of Trinity Opening.

Table 26 summarizes calculated estimates of net nitrogen and phosphorus inputs to the Cairns and Tully boxes as a result of individual intrusion events. Most of the nitrogen inputs from intrusions (50 percent) are in the form of nitrate, with the remainder largely as DON (43 percent). Concentrations of DIN (NH_4+NO_2+NO_3) in intruded SLW are > 20 times the DIN concentrations in outer shelf surface water which is displaced offshore. Net onshore-offshore fluxes of ammonium, however, are close to being in balance. Offshore exports as a result of displacement during intrusion events were overwhelmingly as DON (86 percent), with most of the remainder in the form of PN (11 percent). PN and DON concentrations in displaced outer shelf surface waters are on the order of 1.3-1.5 and 2 times PN and DON concentrations in the intruded SLW. Overall, net nitrogen inputs to the Cairns box from the intrusion of high nitrate SLW are on the order of 1.3 times the size of nitrogen stocks exported in displaced outer shelf waters. The calculation of net nitrogen fluxes associated with intrusion events is therefore highly sensitive to the estimate of the concentration of DON in outer shelf surface waters.

Table 26. Estimates of gross and net nitrogen and phosphorus inputs to outer-shelf waters of the Cairns and Tully boxes from intrusions during the summers of 1989-90, 1990-91 and 1991-92.

		Nitrogen		Phosphorus	
		Mmol	metric tonnes	Mmol	metric tonnes
Cairns box					
	1989-90	53.3	747	6.8	211
	1990-91	85.5	1198	12.9	400
	1991-92*	61.7	864	6.4	198
Tully box					
	1989-90	91.9	1287	9.6	297
	1990-91	197.9	2773	20.7	641
	1991-92*	81.3	1139	8.5	263
Cairns box					
	1989-90	25.1	352	3.6	112
	1990-91	40.3	565	6.4	198
	1991-92*	43.7	612	1.9	59
Tully box					
	1989-90	65.1	912	2.8	87
	1990-91	140.3	1966	6.0	186
	1991-92*	57.6	807	2.4	74
	* - partial year				

Virtually all the phosphorus imported onto the shelf by intrusions (Table 26) is in the form of PO_4 (> 97 percent). DOP and PP concentrations in the SLW source water approach the operational detection limits. Exports by displacement during intrusion events are generally balanced between PO_4, DOP and POP (37, 37 and 26 percent, respectively).