NITROGEN POOLS IN A MANGROVE — SALTMARSH SYSTEM

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INTRODUCTION

It is only in comparatively recent times that the value of coastal wetlands has become recognised. In Australia, there is scant knowledge of how these ecosystems function and hence the best way that they can be managed and utilized. This is in contrast to the wealth of information for estuaries in North America (e.g., Pomeroy and Wiegert, 1981), where studies have emphasised the importance of estuarine ecosystems in the production of organic matter for detritus based food webs (Odum and de la Cruz, 1967; Lugo and Snedaker, 1974; Haines, 1979a). They have also stressed the fact that each estuarine system has a unique set of physical and biological characteristics (Haines, 1979a). Few of these characteristics have been investigated for temperate Australian estuaries and there is a paucity of information about the nutrient flux and pools in wetland communities.

Accordingly, a preliminary sampling of the nitrogen pools and other environmental characteristics was undertaken over a six month period in the Towra Point wetland.

STUDY SITES AND METHODS

Towra Point is located 16 km south of Sydney in New South Wales, Australia. It is in a low lying promontory of irregular shape jutting out from the northern side of the Kurnell Peninsula into Botany Bay. A large area of intertidal flats surrounded by low sand dunes contain the wetland communities. The study site transects the communities at Pelican Point (31°26', 152°55') (Fig. 1).

Six sample sites were subjectively chosen across the wetland, each of which was located in a homogenous zone of vegetation varying in species composition and tidal inundation (Fig. 2). Nitrogen contents were determined on soil, plant, tidal water and precipitation samples taken between March and August 1982. Soil redox potentials, pH, salinity, moisture content and organic carbon content were obtained at the same time as nitrogen measurements.

Precipitation and tidal water

Precipitation in mangrove and *Casuarina* stands was sampled as three components, openfall (free rain), throughfall (rain intercepted by the tree canopy), and stemflow (rain trickling down stems). Details of collection method are given in Clarke (1982). Tidal water was sampled at the same time as precipitation. Frozen samples were analysed within two weeks of collection for ammonia and nitrite. Dissolved ammonia was determined colorimetrically by the phenol-hypochlorite method and nitrite was determined by diazotization and colorimetry (American Public Health Association, 1975).

Above ground biomass

Above ground plant biomass was sampled at sites B, C, D, E, and F where 0.025m² quadrats were clipped at monthly intervals. Monthly sample sites were chosen at one metre intervals at 90° to the transect to avoid sampling overlap. Live and dead (litter) components were separated and dried to a constant weight at 70°C in a forced draught oven. At sites A and F, tree biomass was estimated from volume and average wood densities for *Avicennia* and *Casuarina* (Briggs, 1977; Ford pers. comm., 1982). Samples of litter, live leaves and stems were also taken at monthly intervals and dried. Subsamples of all desiccated plant components were analysed for Kjeldahl nitrogen by digestion with sulphuric acid and potassium sulphate using a mercury catalyst (Black, 1965). Further randomly picked samples were analysed with a Heraeus CHN analyser.

Soil

Soil samples were collected at low tide each month to minimise tidal differences. All sites were sampled in the same stratified pattern as for plant biomass.

Fresh soil samples were extracted for exchangeable inorganic nitrogen ions within five hours of being sampled. Subsamples of soil at 0-10 cm, 20-30 cm and 40-50 cm depth were extracted with 1M potassium chloride (pH 3) for one hour on an orbital shaker. The supernatant was analysed for ammonia and nitrite immediately, some being frozen and later analysed

for nitrate by the cadmium reduction method (A.P.H.A., 1975). Organic nitrogen was determined by the Kjeldahl method (as above).

Organic carbon content was measured by the Walkley-Black method (Black, 1965). Soil salinity was obtained by suspending a field moist soil sample in distilled water and measuring the salinity of the solution with a portable salinity meter. The concentration of salts was then calculated on a dry weight basis per gram of soil. Soil redox potential (Eh) and pH were measured in the field with platinum-calomel and glass- calomel electrodes respectively, redox measurements being adjusted for the calomel potential.

Nitrogen pools

Above ground, plant nitrogen contents were calculated from standing crop estimates and average nitrogen concentrations. Live root contents were based on biomass data by Hardiman and Lichacz (1982) and assume root concentrations are the same as average shoot concentrations. This assumption appears to be valid in saltmarsh plants (Congdon and McComb, 1980).

Soil nitrogen contents were calculated to a depth of 30 cm, using density data of Clarke and Hannon (1967). Live shoot mass was subtracted from the total soil mass so that the soil organic nitrogen content reflected the true detrital pool of nitrogen in the soil. It should be noted that all live roots were separated from the soil before organic nitrogen analysis.

RESULTS AND DISCUSSION

Precipitation and tidal water

The average nitrogen concentrations and pH (n = 5) in rainfall and tidal water from 29 May 1982 to 5 August 1982 are presented in Table 1. Concentrations of ammonia and nitrite did not appear to be significantly increased by the interception of the tree canopy, hence leaching of nitrogen from plants by rainfall is likely to be small. Levels of ammonia and nitrite in tidal water are within the range of values obtained by the State Pollution Control Commission (1979). The total tidal nitrogen pool, including inorganic and organic nitrogen, is estimated to be 0.0012g N/m² assuming a 30 cm coverage of soil. This estimate is based on the average values obtained by the S.P.C.C. (1979).

TABLE 1

Average nitrogen concentration and pH rainfall and tidal water components; standard deviations are in parenthesis

		Nitrogen (µg/l)					
Component	Site	NH_4^+ - N		NO_2^- - N		pH	
Openfall	C	57.9	(64.0)	29.2	(52.8)	5.1	(0.8)
Throughfall	A	27.5	(24.2)	5.9	(2.7)	5.5	(0.8)
	F	78.6	(51.9)	3.8	(1.4)	5.0	(0.9)
Stemflow	A	66.9	(51.6)	5.1	(1.5)	3.8	(0.7)
	F	73.4	(65.6)	6.5	(1.2)	4.8	(0.9)
Tide water	A	2.78	(1.06)	4.54	(1.51)	7.1	(0.2)

Soil

A summary of the soil analysis results is presented in Table 2. Soil pH decreases at sites of higher elevation which is consistent with increasing soil organic carbon content. Soil redox potentials decrease at those sites which have higher inundation frequencies. Soil salinity and moisture content also appear to be correlated with elevation above mean sea level. All soil characteristics show significant differences between the sites, and, to a lesser extent, depth (see analysis of variance results, Table 3).

The most abundant form of nitrogen found in the soil was organic nitrogen. Concentrations of inorganic nitrogen are small, nitrate being most abundant followed by ammonia and nitrite. High levels of nitrate in the anaerobic soils of the mangrove and the saltmarsh may be accounted for by the presence of nitrifying aerobic rhizospheres around the roots of wetland plants (Haines, 1979b).

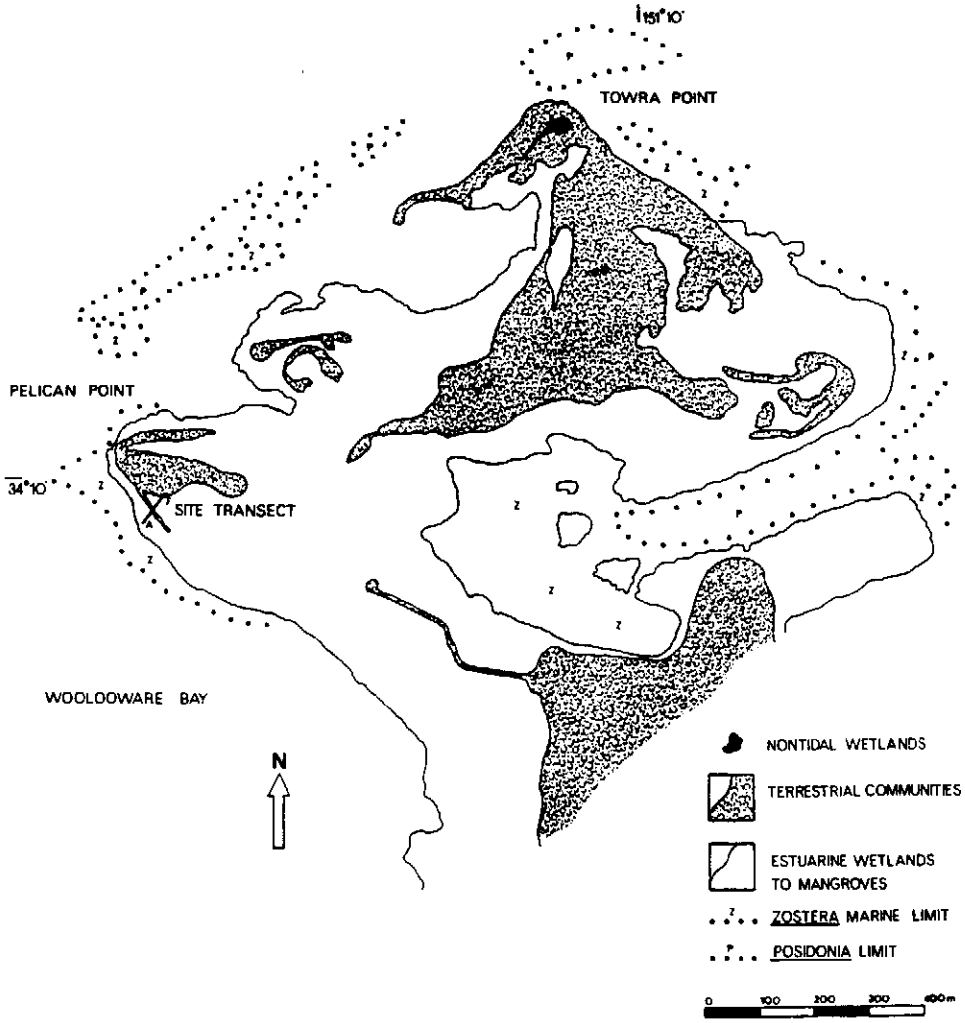

Figure 1. The location of the study site within the Towra Point wetland complex.

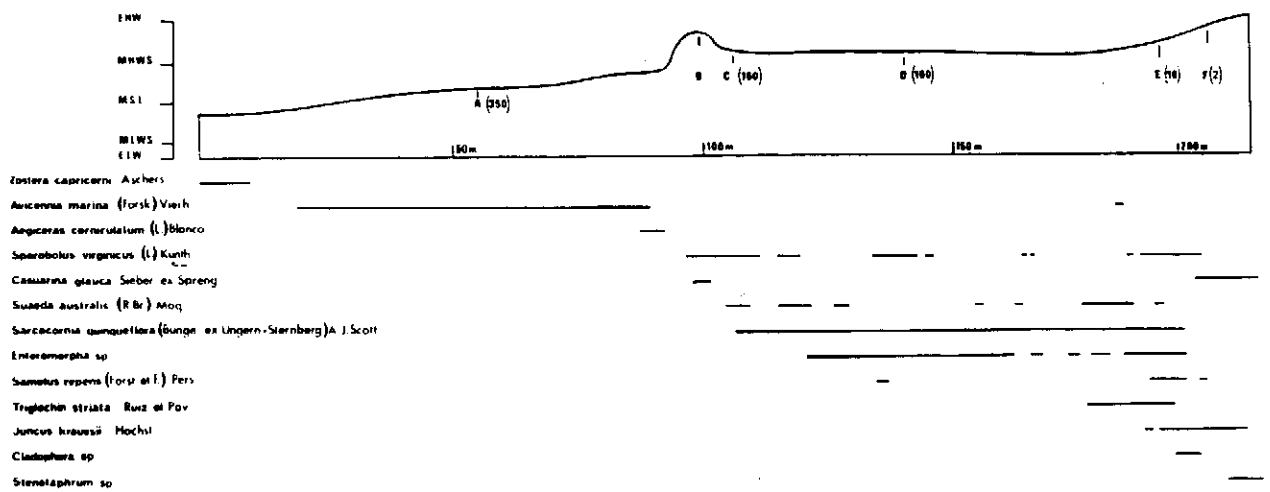

Figure 2. The topography and distribution of main plant species along the site transect. Estimated number of tidal inundations per year are in parenthesis.

TABLE 2

Analytical data for soil over a six month period. Standard errors are in parentheses. n=6. T,M, and B denote samples taken at 0-10, 10-30, and 40-50 cm intervals.

SITE		A	B	C	D	E	F
Horizontal distance to M.S.L. (m)		0	76	83	120	172	184
Field Eh (m.v.)	T	201 (22)	340 (13)	369 (14)	396 (21)	439 (28)	501 (51)
	M	120 (36)	359 (13)	351 (10)	367 (13)	415 (18)	480 (22)
	B	77 (18)	–	330 (15)	371 (12)	–	–
Field pH	T	6.45 (0.19)	6.81 (0.23)	6.62 (0.09)	6.67 (0.15)	5.57 (0.27)	4.80 (1.03)
	M	6.59 (0.07)	6.62 (0.17)	6.48 (0.42)	6.46 (0.34)	4.76 (0.57)	3.78 (0.81)
	B	6.47 (0.55)	–	6.42 (0.34)	6.48 (0.29)	–	–
Salinity (mg g^{-1} dry wt.)	T	19.5 (2.7)	5.9 (1.7)	21.6 (2.8)	31.7 (3.5)	26.9 (6.8)	19.1 (5.7)
	M	19.8 (2.2)	8.8 (1.9)	10.6 (2.5)	14.1 (2.5)	12.7 (2.7)	21.8 (6.4)
	B	24.1 (2.6)	–	15.8 (2.8)	15.3 (2.4)	–	–
Moisture (% dry wt.)	T	22.4 (3.9)	7.6 (3.5)	23.6 (3.9)	25.5 (4.2)	34.7 (9.2)	25.4 (8.6)
	M	21.6 (3.8)	14.6 (2.7)	14.8 (3.5)	18.1 (4.2)	22.6 (6.5)	31.0 (8.0)
	B	–	–	19.1 (4.0)	17.4 (3.5)	–	–
Organic carbon (% dry wt.)	T	2.1 (0.3)	0.8 (0.1)	3.3 (0.4)	6.5 (1.6)	13.3 (2.2)	22.9 (2.3)
	M	1.9 (0.4)	1.5 (0.3)	0.8 (0.3)	0.6 (0.2)	6.2 (1.9)	12.3 (1.8)
Loss on ignition (% dry wt.)	T	8.3	2.6	3.1	6.3	40.1	27.8
	M	3.6	4.8	2.9	2.8	5.6	6.3
Kjeldahl-N (μg g^{-1} dry wt.)	T	849 (118)	409 (113)	1794 (308)	2172 (259)	3242 (959)	3308 (1075)
	M	864 (124)	968 (303)	574 (59)	658 (41)	1341 (494)	3967 (648)
NH_4^+-N (as above)	T	0.29 (0.09)	0.18 (0.02)	0.39 (0.04)	0.55 (0.15)	0.54 (0.09)	0.70 (0.3)
	M	0.38 (0.08)	0.35 (0.11)	0.20 (0.06)	0.29 (0.04)	0.42 (0.01)	0.48 (0.11)
	B	–	–	0.15 (0.03)	0.28 (0.06)	–	–
NO_2^--N (as above)	T	0.05 (0.01)	0.06 (0.02)	0.08 (0.02)	0.09 (0.02)	0.09 (0.03)	0.09 (0.03)
	M	0.12 (0.02)	0.26 (0.02)	0.08 (0.03)	0.09 (0.04)	0.06 (0.01)	0.09 (0.03)

Table 2 (continued)

SITE		A	B	C	D	E	F
	B	–	–	0.15 (0.01)	0.18 (0.01)	–	–
NO_3^--N (as above)	T	0.75 (0.16)	0.86 (0.18)	1.10 (0.15)	1.55 (0.69)	2.40 (0.88)	1.89 (0.26)
	M	0.69 (0.20)	0.80 (0.19)	0.65 (0.13)	1.07 (0.24)	1.45 (0.30)	0.75 (0.30)
	B	–	–	0.68 (0.14)	0.91 (0.17)	–	–
Mass of soil (less live roots)(kg m^{-2})	T	53.2	56.9	77.7	77.2	90.0	53.7
	M	50.6	152.7	63.7	63.2	123.0	153.8
Soil nitrogen content (gN m^{-2}) ± 1 s.d.	T	45.2 (5.8)	23.3 (6.4)	139.2 (23.9)	168.5 (20.1)	291.8 (86.3)	177.6 (57.0)
	M	43.7 (6.3)	147.8 (46.2)	37.1 (3.8)	47.6 (2.6)	164.9 (60.8)	606.9 (99.7)
C:N Atom ratio	T	23.6	19.5	18.4	29.9	41.0	69.3
	M	22.0	15.5	13.9	9.1	46.2	31.0

Figure 3. Percentages of nitrogen pool in different components through wetland transect.

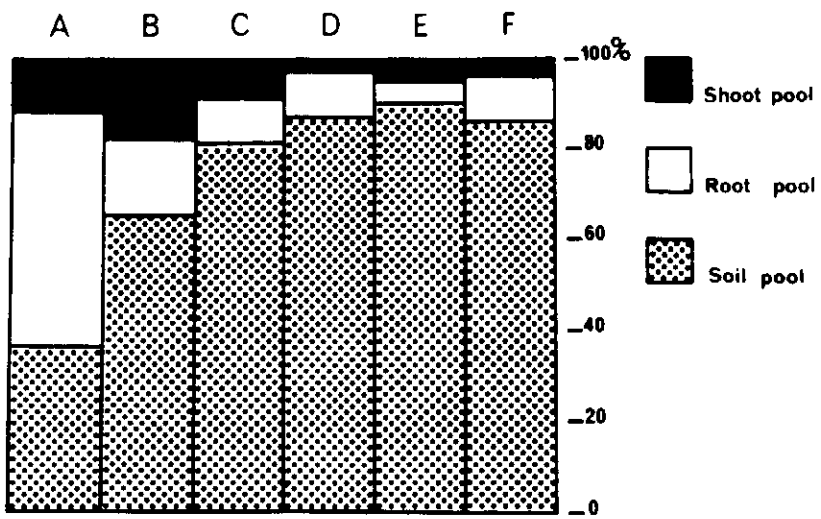

TABLE 3

Results for analysis of variance on soil parameters

Source		d.f.	F	Significance
pH	Zone	5	102.24	***
	Depth	2	5.63	**
	Zone x Depth interaction	7	1.61	n.s.
	Residual	72		
eH	Zone	5	37.88	***
	Depth	2	2.64	n.s.
	Zone x Depth interaction	7	0.80	n.s.
	Residual	79		
Salinity	Zone	5	3.99	***
	Depth	2	4.39	**
	Zone x Depth interaction	7	2.37	*
	Residual	70		
Moisture	Zone	5	2.82	**
	Depth	2	0.50	n.s.
	Zone x Depth interaction	6	0.93	n.s.
	Residual	70		
Organic carbon	Zone	5	30.66	***
	Depth	1	19.17	***
	Zone x Depth interaction	5	3.59	**
	Residual	55		
Kjeldahl nitrogen	Zone	5	9.74	***
	Depth	1	3.80	*
	Zone x Depth interaction	5	2.44	*
	Residual	98		
Ammonia	Zone	5	2.42	*
	Depth	2	0.17	n.s.
	Zone x Depth interaction	6	0.49	n.s.
	Residual	70		
Nitrate	Zone	5	4.10	***
	Depth	2	4.64	**
	Zone x Depth interaction	6	0.78	n.s.
	Residual	70		

*** Significant at $0.001 < P < 0.01$

** Significant at $0.01 < P < 0.026$

* Significant at $0.025 < P < 0.05$

n.s. Not significant at $P < 0.05$

All soil nitrogen concentrations decrease from land to sea (Table 2) and there is also a significant decrease in the amount of nitrogen from the surface (0-10 cm) to that at depth (20-30 cm). The total nitrogen content in the soil ranged from 0.04% to 0.37% which is comparable to other marsh systems (e.g., Congdon and McComb, 1980; Ranwell, 1972). Soil carbon-nitrogen ratios do not vary with depth for those sites of high inundation frequency, while the C:N ratio increases at the surface of sites which have plant litter accumulation.

Plant material

Standing crop values for shoot and root components of different plant species occupying the sites are given in Table 4. Below ground biomass figures are from an unpublished report by Hardiman and Lichacz (1982). The total tree mass for *Avicennia marina* is comparable with that found in studies by Attwill and Clough (1974), Briggs (1977) and Goulter and Allaway (1979). Estimates of total mass for *Casuarina* communities were not possible as root mass in those areas consisted of many species. Biomass figures obtained for the saltmarsh species *Juncus kraussii* and *Sarcocornia quinqueflora* are similar to the values obtained in Western Australia for the same species (Congdon and McComb, 1980).

TABLE 4

Results for plant biomass and plant nitrogen content

SPECIES	SITE	COMPONENT	Biomass kg/m² ± 1 S.E.M (n = 8)		Nitrogen concentration (Kjeldahl Method) % N ± 1 S.E.M. (n = 5)		Nitrogen concentration (Heraeus CHN analyser) % N	Carbon-Nitrogen Ratio	Nitrogen Content gN/m²
Avicennia marina	A	Stems	2.2	-	1.50	(0.06)	1.42	35.1	33.0
		Leaves	0.2	-	0.91	(0.25)	1.86	21.5	1.8
		Below ground live to 30 cm	10.2	-	1.20	-	-	-	122.4 157.2
Casuarina glauca	B	Stems	3.4	-	0.90	(0.22)	1.58	-	30.6
		Branchlets	0.3	-	1.01	(0.24)	0.85	-	3.0
Sporobolus virginicus	B	Live culms	0.43	(0.05)	1.57	(0.38)	1.17	36.2	6.7
		Dead culms	0.55	(0.06)	1.42	(0.20)	1.33	36.0	7.8
Mixed roots	B	Total below ground live to 30 cm	3.40	-	1.22	-	-	-	41.5 89.6
Sarcocornia quinqueflora	C	Live stems	0.68	(0.06)	1.90	(0.53)	1.71	20.5	12.9
		Dead stems	0.30	(0.05)	1.67	(0.39)	1.44	32.1	5.0
		Below ground live to 30 cm	1.30	-	1.78	-	-	-	23.1 41.0
Sarcocornia quinqueflora	D	Live Stems	0.50	(0.05)	1.19	(0.41)	1.43	23.3	5.9
		Dead stems	0.21	(0.05)	1.23	(0.37)	0.97	43.1	2.6
		Below ground live to 30 cm	1.80	-	1.21	-	-	-	21.8 30.3
Juncus kraussii	E	Live culms	0.73	(0.17)	1.25	(0.64)	1.14	38.9	9.1
		Dead culms	1.06	(0.13)	1.42	(0.43)	0.83	41.5	15.0
		Below ground live to 30 cm	1.60	-	1.32	-	-	-	21.1 45.2
Juncus kraussii	F	Live culms	0.27	(0.05)	1.32	(0.41)	1.35 (0.08) n=5	35.1	3.5
		Dead culms	0.77	(0.21)	1.34	(0.28)	1.55	44.5	10.3
Casuarina glauca	F	Stems	2.4	-	0.90	(0.21)	1.58	-	21.6
		Branchlets	0.2	-	-	(0.24)	0.85	42.5	2.0
Mixed roots	F	Below ground live to 30 cm	7.8	-	1.14	-	-	-	88.9 126.3

Carbon-nitrogen ratios calculated from results of analyses using the Heraeus CHN analyser.

Concentrations of organic nitrogen in the shoot component of the wetland vegetation fall within the range of values obtained for other sites in Australia. Reported values for *Avicennia* leaves vary from 0.32-1.9% N dry weight (Bunt, 1982). The range of values obtained in this study were 0.90-1.5% N dry weight. Concentrations of nitrogen in the saltmarsh rush *J. kraussii* (1.0-1.5% N) and in the saltmarsh grass *Sporobolus virginicus* (1.2-1.3% N) are generally higher than those given by Congdon and McComb (1980) for a Western Australian marsh.

NITROGEN POOLS

Soil nitrogen pools increase substantially from the mangrove zone through to the fringe *Casuarina* zone (Table 5) (Fig. 3). This gradient is consistent with increasing levels of organic matter in the soil. Most of the soil nitrogen is in the organic form which is not readily available to plants. Inorganic forms of nitrogen contribute less than 0.1% of the total pool of nitrogen in the wetland (Table 5).

TABLE 5

Nitrogen pools through the wetland
(gN/m^2)

SITE	A	B	C	D	E	F
Soil organic nitrogen (0-30 cm)	88.9	171.1	176.3	211.1	456.7	784.5
Plant live root nitrogen (0-30 cm)	122.4	41.5	23.1	21.8	21.1	88.9
Plant shoot nitrogen	34.8	48.1	17.9	8.5	24.1	37.4
Soil inorganic nitrogen (0-30 cm)	0.1	0.3	0.2	0.3	0.5	0.3
Total in system	246.2	261.0	217.5	241.7	502.4	911.1

Plant components of the total nitrogen pool ranged from 65% in the mangroves to 7% in the saltmarsh (Fig. 3). The large plant pool for the mangrove zone can be compared with terrestrial sclerophyll forests where the major stock of nitrogen is found in the plant biomass (Hannon, 1956; Westman, 1978; Langkamp *et al.*, 1981). This contrasts with saltmarsh and associated fringe communities where plant stocks are small in comparison with the soil. A marsh study in Western Australia has shown a similar result in the areas of small tidal amplitude (Congdon and McComb, 1980).

The reduced pool of soil nitrogen in the mangrove community can be accounted for by the tidal removal of mangrove litter. This influence is also reflected in the difference between nearshore (site B) and farshore (site F) *Casuarina* zone soil nitrogen contents (Table 5). It is likely that the bulk of the detritus produced in the mangrove is exported to the open water rather than deposited in the higher marsh. Onsite observations did not reveal any accumulation of mangrove litter along strand lines, and strand line soils at site B did not have elevated levels of nitrogen or carbon. Loss of soluble inorganic and organic nitrogen in the lower wetland is also expected as the concentration of inorganic ions in the soil is higher than the total nitrogen concentration in the tidal water column.

Higher saltmarsh and fringe she-oak communities appear to accumulate organic matter and nutrients. This would act as a nutrient sink where gain would exceed loss for most of the year. These fringing communities may be an important source of nutrients to nearshore wetland vegetation during periods of heavy rain or extreme tides.

CONCLUSIONS

Some pools of nitrogen such as the algae and heterotrophs remain to be quantified. However, it is unlikely that they are of major quantitative importance as their biomass is small in comparison with the vascular plant pool. Plant stocks represent a small component of the total nitrogen pool at those sites which accumulate organic matter. By contrast, the nearshore mangrove community which is regularly inundated by tides has the major stock of nitrogen in the biomass. It would appear that most of the production in the form of leaf litter is exported from the mangrove to the estuary. Similarly, much of the soluble nitrogen in the soil would be lost from the mangroves and saltmarsh sediments by diffusion into the water column. This export must be maintained by: sediment, nitrogen fixation, ground water and precipitation inputs. Further study of the flux of nitrogen through the wetland is crucial to the understanding of the qualitative and quantitative importance of the wetlands to the estuary.

It is clear that mangroves contain and maintain major nutrient stocks which can be exported to the estuary. Any reduction of this pool could have a major influence on the nutrient economy of the estuary as detritus can form the energy base for food webs which support many commercial fish species. Similarly, disturbance of fringe saltmarsh and she-oak communities will affect nutrient pools in the soil that may be significant in the maintenance of mangrove and seagrass productivity.

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