1. OVERVIEW OF WORKSHOP AND BUDGETS RESULTS

Key objectives of the Land-Ocean Interactions in the Coastal Zone (LOICZ core project of the International Biosphere-Geosphere Programme (IGBP) are to:

- gain a better understanding of the global cycles of the key nutrient elements carbon (C), nitrogen (N) and phosphorus (P);
- understand how the coastal zone affects material fluxes through biogeochemical processes; and
- characterise the relationship of these fluxes to environmental change, including human intervention (Pernetta and Milliman 1995).

To achieve these objectives, the LOICZ programme of activities has two major thrusts. The first is the development of horizontal and, to a lesser extent, vertical material flux models and their dynamics from continental basins through regional seas to continental oceanic margins, based on our understanding of biogeochemical processes and data for coastal ecosystems and habitats, and the human dimension. The second is the scaling of the material flux models to evaluate coastal changes at spatial scales to global levels and, eventually, across temporal scales.

It is recognised that there is a large amount of existing and recorded data and work in progress around the world on coastal habitats at a variety of scales. LOICZ is developing the scientific networks to integrate the expertise and information at these levels in order to deliver science knowledge that addresses our regional and global goals.

The Workshop on Australasian Estuarine Systems: Carbon, Nitrogen and Phosphorus Fluxes provided an important piece in the matrix of regional assessments being carried out by LOICZ. The Australasian region has in excess of 50 000 km of coastline (about 8% of the global coastline) and more than 750 estuaries and embayments, spanning about 35 degrees of latititude from the tropics to sub-temperate areas. In addition to the climatic gradient, there is a diversity of river flows (controlled and uncontrolled), human pressures and modifications in the drainage basins and coastal fringe, and a diversity of estuarine morphologies. This extensive coastal margin with its broad latitudinal range and diverse human influences backed by a recent history of sustained coastal science enterprise (hence, a rich database) provided an opportunity to:
a) evaluate comparatively regional biogeochemical budgets in the region; and
b) gain a picture of changes and variability in coastal biogeochemical processes in response to both natural and anthropogenic forcing functions.

The Workshop was held at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Land & Water laboratories in Canberra, Australia, on 12-14 October 1998. The objectives of the Workshop (Appendix VIII) and the activities (Appendix V) are provided in this report. Two resource persons (Prof Steve Smith and Dr Chris Crossland) worked with 19 scientists from a number of Australasian coastal

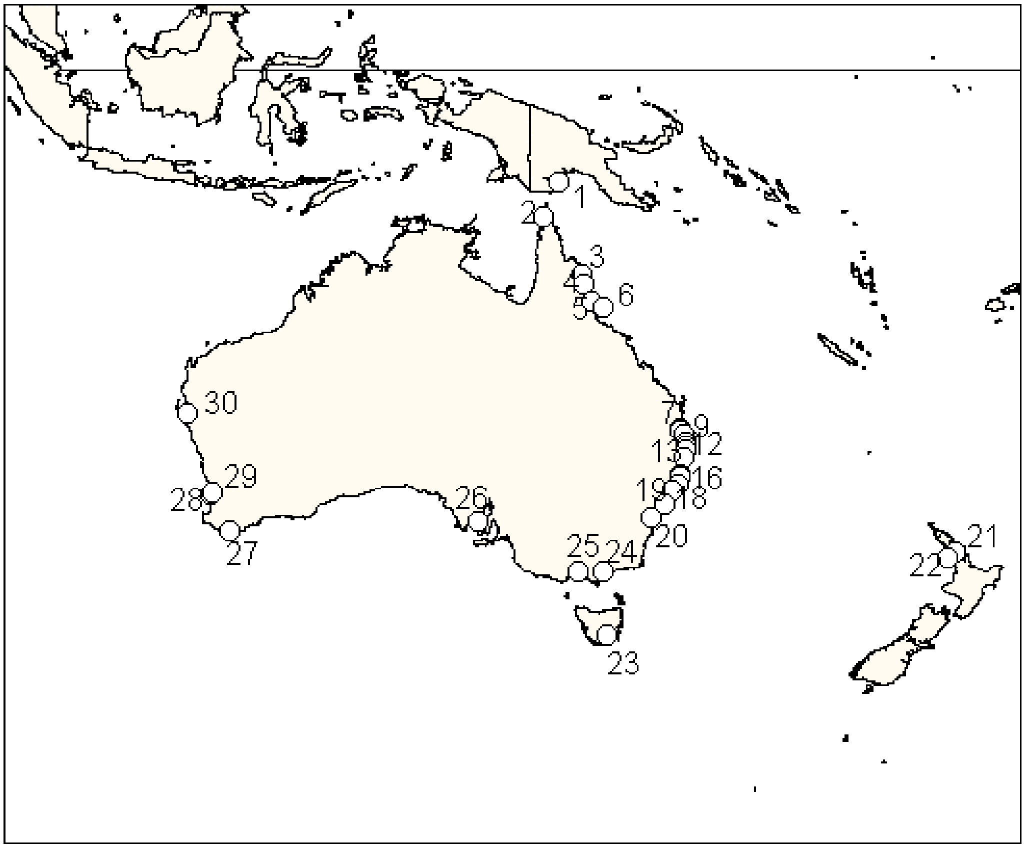

Figure 1.1 Location of LOICZ Australasian sites used for biogeochemical budgeting. (The numbered circles identify site locations identified in Tables 1.1-1.3 and in the text. Note: because of space, not all of the circles are individually numbered. However, the numbering sequence is clear.)

science agencies and universities (Appendix VI) to consider, develop and assess biogeochemical budgets for more than 30 estuaries in the region. The participating scientists contributed necessary data and knowledge about the estuarine systems, and identified additional sites for budget work based on existing databases. The outstanding success of the Workshop derived not only from the budget contributions to the LOICZ programme, but also from the opportunities to explore and discuss conceptual and methodological issues (Appendices I and III), to consider patterns of biogeochemical processes and to expand the network of researchers relating to LOICZ in the region.

The initial session of the Workshop dealt with the LOICZ approach to the global questions of horizontal fluxes of materials. An overview of the special nature of estuarine systems in Australia and a number of unifying concepts was presented by Dr Graham Harris (Appendix I) and supported by a description and discussion about the classification system that could be applied to the Australasian coastal systems (Appendix II).

Table 1.1 Budgeted Australasian sites, numerical designations, locations, sizes, water exchange times. (Class designations as follows: I--wet tropical; II--wet/dry tropical; III--wet/dry subtropical, IV--transitional; V--wet temperate; VI--dry temperate; VII--Mediterranean; VIII--dry tropical-subtropical; (S)--open shelf.)

Site no.	Class	Name	Long. (E = +)	Lat. (N = +)	Area (km^2)	Depth (m)	Exchange time (days)
1	I	Fly River	143.50	-8.50	500	5	13
2	II	Jardine	142.20	-11.15	5.6	1.4	8
3	II	Annan	145.27	-15.53	2.2	1.2	15
4	II	Daintree	145.43	-16.28	5.0	5.1	20
5	II	Moresby	146.12	-17.60	5.3	3.0	13
6	II (S)	Central Great Barrier Reef #	147.00	-18.00	14 000	37	nd
7	III	Caboolture	153.03	-27.15	2.1	2.2	410
8	III	Brisbane	153.17	-27.37	13	10.2	295
9	III	Logan	153.33	-27.68	3.6	4.9	412
10	III	Tweed	153.55	-28.17	6.3	3.4	115
11	III	Brunswick	153.55	-28.53	1.3	0.7	43
12	III	Richmond	153.58	-28.88	10.1	5.7	85
13	III	Clarence	153.35	-29.43	26.2	6.1	125
14	III	Bellinger	153.03	-30.65	1.8	2.6	16
15	III	Nambucca	153.02	-30.65	4.6	2.6	55
16	III	Hastings	152.87	-31.42	4.9	4.1	26
17	III	Macleay	153.05	-30.90	6.9	4.1	41
18	III	Manning	152.50	-31.87	14.5	5.1	88
19	IV	Hawkesbury-Nepean	151.80	-32.90	34	3	15
20	IV	Lake Illawarra	150.80	-34.00	35	2	55
21	V (S)	Hauraki Gulf	175.00	-36.50	5800	16	58
22	V	Manukau	174.30	-37.00	317	4	16
23	V	Derwent	147.30	-42.90	172	16	10
24	V	Lake Victoria	147.00	-38.00	100	5	47
25	V	Port Phillip	145.00	-38.00	1900	13	290
26	VI	Spencer Gulf #	137.00	-34.30	21 700	21	246
27	VII	Wilson Inlet #	117.30	-35.00	48	2.5	142
28	VII	Cockburn Sound	115.80	-32.20	114	12	150
29	VII	Swan Canning	115.90	-32.00	33	5	17
30	VIII	Shark Bay #	114.00	-26.00	4300	7	360

# = existing site budgets on LOICZ website
nd = not determined

Table 1.2 Budgeted Australasian site numbers, class designations, and land (including atmosphere) nutrient loads.

Site no.	Class	DIP load	DIN load	ΔDIP	ΔDIN	ΔDOP	ΔDON
		mmol m^{-2} yr^{-1}					
1	I	13	1577	39	-60	-4	409
2	II	21	595	33	-329	-29	-913
3	II	17	355	-5	9	-5	-1400
4	II	19	815	-2	-43	10	-1894
5	II	13	1567	-15	-456	0	0
6	II (S)	2	51	-4	-64		
7	III	201	2077	-83	366	14	620
8	III	927	7973	-136	922	-59	-755
9	III	1169	5759	-525	-1126	-75	6
10	III	166	712	-63	1137	-10	72
11	III	101	1612	-46	-225	-30	-15
12	III	531	3420	-26	-1194	-81	912
13	III	119	2396	-27	-38	-33	-188
14	III	319	3723	148	1038	47	2260
15	III	218	3355	-96	-536	-171	-404
16	III	325	7777	-153	-1501	-49	-1722
17	III	440	7110	-4	322	-176	-475
18	III	117	1120	-40	-161	-9	-135
19	IV	6	329	-44	-252		
20	IV	8	86	7	120		
21	V (S)	1	13	9	-91		
22	V	47	623	-33	524		
23	V	25	223	10	-159		
24	V	5	36	-6	-50		
25	V	28	173	-3	-172		
26	VI	0	0	-2	-1	0	-18
27	VII	3	65	-3	-33		
28	VII	202	1035	-193	1018		
29	VII	77	2585	4	843		
30	VIII	0	0	-1	-1		
	mean	171	1905	-42	-6	-37	-202
	std dev	278	2382	111	623	59	974
	median	38	925	-6	-47	-20	-77
	min	0	0	-525	-1501	-176	-1894
	max	1169	7973	148	1137	47	2260

Table 1.3 Budgeted site numbers, class designations and estimated (*nfix-denit*) (based on both total dissolved nutrients and dissolved inorganic nutrients, if available) and (*p-r*). (All stoichiometric flux calculations are based on an assumed Redfield C:N:P ratio of reacting particles.)

Site no.	**Class**	**(*nfix-denit*)** with DIN, DIP	**(*nfix-denit*)** with total N, P	**(*p-r*)**
		mmol m^{-2} yr^{-1}		
1	I	-684	-211	-4134
2	II	-857	-1306	-3498
3	II	89	-1231	530
4	II	-11	-2065	212
5	II	-216	-216	1590
6	II (S)	0		424
7	III	1694	2090	8798
8	III	3098	3287	14 416
9	III	7274	8480	55 650
10	III	2145	2377	6678
11	III	511	976	4876
12	III	-778	1430	2756
13	III	394	734	2862
14	III	-1330	178	-15 688
15	III	1000	3332	10 176
16	III	947	9	16 218
17	III	386	2727	424
18	III	479	488	4240
19	IV	452		4664
20	IV	8		-742
21	V (S)	-235		-954
22	V	1052		3498
23	V	-319		-1060
24	V	46		636
25	V	-124		318
26	VI	31	13	212
27	VII	15		318
28	VII	4106		20 458
29	VII	779		-424
30	VIII	15		106
	mean	666	1172	4452
	std dev	1681	2400	11 731
	median	68	611	583
	min	-1330	-2065	-15 688
	max	7274	8480	55 650

Participants briefly outlined the estuarine systems and the status of constructed budgets for their contributing sites. The implications of any special conditions, such as episodic river flows and flushing, the rigour of supporting databases, and problems in deriving the budgets following the LOICZ approach were highlighted and discussed. Two systems (Richmond estuary in New South Wales, Swan Canning in Western Australia; see Appendix IV) were described and budgets derived using non-LOICZ approaches. These provided a comparison with companion evaluations which used the LOICZ approach and which are described in the body of the report.

The group moved from plenary to further develop the site budgets individually and in small working groups, returning to plenary sessions to discuss the budget developments and to debate points of approach and interpretation. Through this process, valuable contributions resulted which will assist the LOICZ methodology, including a consideration of limitations to the stoichiometric approach to interpretation of budgets and a cautionary note on the handling of spatial and temporal variations in systems (Appendix III).

Some 25 budgets were developed during the Workshop (Figure 1.1, Table 1.1); further advances were discussed for the budget assessments represented in four sites already posted on the LOICZ website (Central Great Barrier Reef, Spencer Gulf, Wilson Inlet and Shark Bay). In the subsequent three weeks, the detailed budgets and written descriptions were fine-tuned and provided for this report and for posting to the LOICZ Biogeochemical Budgets website (www. nioz.nl/loicz). Also, an additional site budget (for the Manukau Harbour, New Zealand) was developed and contributed.

The biogeochemical budgets reported here have been prepared usually by a group whose full authorship is duly acknowledged. The common element in the budget descriptions is the use of the LOICZ approach to budget development, which allows for global comparisons. The differences in the descriptive presentations reflect the variability in richness of site data, the complexity of the site and its processes, and the extent of detailed process understanding for the site. In some instances, the researchers have second-order and third-order details for the system and its biogeochemical functioning e.g., Port Phillip Bay, Victoria. Additional budgets are being developed for other estuarine systems in the region. It is anticipated that these, and the ones reported here, will be available from LOICZ in CD-ROM form by mid-1999. Support information for the various estuarine locations, describing the physical environmental conditions and related forcing functions including the history and potential anthropogenic pressure, is an important part of the budget information for each site. These data and their wider availability in electronic form (CD-ROM, LOICZ website) will provide opportunity for further assessment and comparisons, and potential use in consideration of wider scales of patterns in system response and human pressures.

The budget information for each site is discussed individually and reported in units that are convenient for that system (either as daily or annual rates). To provide for an overview and ease of comparison, the key data are presented in an “annualised” form and non-conservative fluxes are reported per unit area (Tables 1.2 and 1.3).

The budgeted Australasian sites occupy and represent a broad range of locations, size, and water exchange times (Table 1.1). The 35 degree latitudinal range covers tropical and sub-temperate climates (especially along the east coast of Australia), an east-west trend in aridity, and different states (continuous, ephemeral, monsoon-driven) and seasons of river flow. System sizes range from around 1 km^2 to thousands of km^2 in large gulf and open coastal shelf. All the systems are relatively shallow – a characteristic of the region (see Appendix I), and have water exchange times extending between about a week and a year.

This diversity of physical attributes provides opportunity for assessment of trends in patterns of estuarine performance and response to key forcing function, both natural and anthropogenic. Preliminary inspection of the budget and site data suggests some apparent trends:

1. A relationship between DIN and DIP loadings which is close to the Redfield ratio (16:1), and a latitudinal gradient in water column DIN:DIP ratios; higher in the tropical sites than the temperate sites.

2. A negative relationship between DIP loading and ΔDIP is apparent, such that the estuaries may be trapping, on average, about 30% of the DIP load. While the loading also forces sorption, the relationship strongly suggests that the elevation of inorganic P loading may be driving systems towards net autotrophy.

3. An apparent latitudinal trend wherein ΔDIP (or its stoichiometrically converted form, *[p-r]*) tends to show extreme values at mid-latitudes (between 25^{o}S and 35^{o}S). While these systems tend to be relatively dry, compared with both the lower and higher latitude systems, these latitudes are also the region of most of the heavy land use in the Australasian coastal region.

4. The majority of the temperate systems seem to be apparent net nitrogen fixers (according to the stoichiometric conversions used in the LOICZ budgets). Interestingly, the lack of a clear pattern in DIN suggests that it is too closely controlled by internal process of nitrogen fixation and denitrification to show much response to external load i.e., biotic aspects of the ecosystem type may prove far more important.

A larger data set for this region, in combination with other global data, will allow further testing and evaluation of these trend indicators and hypotheses. This work is in progress.

The Workshop was co-sponsored and hosted by CSIRO Land & Water which is the leading national scientific research agency in Australia addressing whole system, land-water interrelationships. LOICZ is grateful for this support and the opportunity to collaborate in working to mutual goals, and is indebted to Dr Graham Harris and staff for their contributions to the success of the Workshop. Dr Bradley Opdyke (and family) did sterling work as the local organiser for LOICZ, bringing together the group and ensuring that the daily interaction extended well into the evenings in conducive environments.

Cynthia Pattiruhu, LOICZ IPO, and Jan Marshall Crossland have contributed greatly to the preparation of this report. Finally, thanks are due to the participating scientists who made the effort to meet deadlines and to continue to interact beyond the meeting activities in order to ensure that the Workshop sum is greater than the individual products.