

## 5. REGIONAL ASSESSMENT TABLES: SITE-SPECIFIC CARIBBEAN COASTAL ISSUES AND IMPACTS

These country tables have been compiled using available information. For each site they are in the format of the standardized LOICZ-Basins Regional Assessment (RA) Tables 1-7. In case certain tables, e.g., on sub-regional or full regional scale (tables 4, 5) are not used, the numbering still follows the sequence outlined in the methodology. For more information see Appendix I.

### 5.1. Caroni River, Trinidad, Trinidad and Tobago

*Peter Bacon and Rahanna Juman*

#### Table Summary

The Caroni River, with a drainage basin of 883 km<sup>2</sup>, flows through the Caroni mangrove swamp into the Gulf of Paria. Major land use within this river basin includes urbanization, industrial development, damming, agriculture and quarrying. These activities have downstream effects on the coastal zone. Deforestation for housing and quarrying have increased the sediment load in the coastal zone. Damming and alteration of the hydrology of the swamp have resulted in reduction of freshwater flow, salinization and the loss of freshwater habitats, resulting in reduced biodiversity. Effluent from residential areas, industrial and agricultural runoff have led to increased pollution and eutrophication. These land-based activities have impacted on the quality and quantity of the coastal resources, which in turn affects human utilization of the same resources.

Within the Caroni Swamp, oyster harvesting is an important economic activity. Impacts from the catchment such as pollution have resulted in reduced oyster populations. The quality of the oyster is also affected, since these organisms bio-accumulate pollutants, bacteria and viruses. The Caroni Swamp is also an important habitat for the Scarlet Ibises and an eco-tourism site for bird-watchers. Salinization in areas of the swamp has resulted in loss of habitats for these birds as well as for other species.

Though very little fishing occurs in the swamp itself, the Caroni River flows into the Gulf of Paria, which is the most active fishing area around the island. The Gulf of Paria is a shallow basin entirely enclosed by the west coast of Trinidad and the east of Venezuela. Water entering the gulf from the Caroni River basin contains nutrients, sediment, pesticide residues and heavy metals. These pollutants have intensified the decline in fish populations, which have serious economic implications for the people of Trinidad.

**Table RA5.1.1. Caroni River: major coastal impacts/issues and critical thresholds – overview and qualitative ranking.**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impact/ Issue	Critical Threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References/Data source
Pollution, Eutrophication, Sediment loading Salinization	Decline of fish stocks, 50% for economic loss	Currently about 30% loss	10	Boodoosingh 1992
Pollution, Eutrophication, Sediment loading Salinization	Decline of oyster harvest by 50% Bacterial contamination 5%	No distance	10	Boodoosingh 1992
Pollution, Eutrophication Habitat alteration Salinization	Loss of biodiversity, loss of species	No distance	8	Bacon 1993

**Table RA5.1.2. Caroni River: DPSIR matrix characterizing major catchment-based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class.**

State change dimension: major; medium; minor; 0 = no impact; ? = insufficient information.

Time scale: p = progressive (continuous); d = direct (spontaneous).

Driver	Pressures	State change (qualitative index)	Impact on the coastal system	Time scale
		Small basin, passive coast		
<b>Agriculture</b>	<ul style="list-style-type: none"> <li>Siltation</li> <li>Pesticide contamination</li> <li>Freshwater diversion</li> <li>Hypernutrification</li> </ul>	<b>major</b> <b>medium</b> <b>minor</b> <b>medium</b>	Declining water quality, biodiversity loss, salinization, eutrophication	<b>p</b>
<b>Damming</b>	<ul style="list-style-type: none"> <li>Siltation</li> <li>Flow increase</li> </ul>	<b>major</b> <b>minor</b>	Salinization	<b>d</b>
<b>Industries</b>	<ul style="list-style-type: none"> <li>Contamination</li> </ul>	<b>major</b>	Biodiversity loss, declining water quality	<b>p</b>
<b>Urbanization (point source effluents)</b>	<ul style="list-style-type: none"> <li>Sewage and</li> <li>heavy metal contamination</li> </ul>	<b>major</b> <b>minor</b>	Eutrophication, biodiversity loss	<b>p</b>
<b>Quarrying</b>	<ul style="list-style-type: none"> <li>Siltation</li> </ul>	<b>medium</b>	Water quality decline	<b>p</b>

**Table RA5.1.3. Caroni River: the link between coastal issues/impacts and land-based drivers– overview and qualitative ranking on local or catchment scale.**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impact/issue	Drivers	Impact category	Trend expectations	References/ data sources
<b>Declining water quality</b>	Agriculture Deforestation Industry Quarrying	8	↑↑	IMA 1999
<b>Salinization</b>	Agriculture damming	2	↑↑	Bacon 1993
<b>Biodiversity loss</b>	Agriculture Industry Urbanization	4	↑↑	Bacon 1993; Ramnarine 1997
<b>Eutrophication</b>	Agriculture Urbanization		↑↑	Siung-Chang 1987 IMA 1999

**Table RA5.1.6. Caroni River: scientific and/or management response to coastal impact/issues on catchment, sub-regional and regional scale.**

Response Catchment scale		Response Sub-regional/ Country scale		Response Regional scale	
Scientific	Management	Scientific	Management	Scientific	Management
Various studies by UWI, IMA	Designation of protected areas Caroni Swamp Management Committee	Various studies by UWI, IMA	National Wetlands Committee and Policy Specially Sensitive Areas Rules Effluent standards EMA	CARICOMP	UNEP-Regional Coordinating Unit

IMA Institute of Marine Affairs  
UWI University of the West Indies, St Augustine  
EMA Environmental Management Authority

## 5.2 The Buccoo Reef/ Bon Accord Lagoon System, Tobago, Trinidad and Tobago

*Peter Bacon and Rahanna Juman*

### Table Summary

The Buccoo Reef/ Bon Accord Lagoon system, located on the leeward coast of south-western Tobago, is the best example of contiguous coral reef, seagrass bed and mangrove swamp in the country. Unlike the Caroni Swamp, this coastal area has no riverine inflow, but instead several ephemeral streams and surface drains transport effluent from a cattle farm and sewage treatment plants. This coastal zone does not have a well-defined drainage basin like the Caroni River but has a drainage area, based on the surface hydrology. The terrestrial geology of the drainage area is a coralline limestone formation, which is highly fractured and faulted and facilitates chemical dissolution. The high porosity and transmissivity of this coral-algal limestone makes it unsuitable for liquid effluent/sewage disposal.

The Buccoo Reef has been recognized as an importance socio-economic asset for the country. It is one of the largest tourist attraction in Tobago with more than 50,000 visits per annum and the annual income generated by the reef tour trade exceeds TT \$1million. The major land use within the drainage area of this ecosystem complex is built development with include housing and resort development, as well as some agriculture. Buccoo Reef and Bon Accord Lagoon have been impacted by eutrophication mainly through sewage pollution, and the Reef has been physically damage by tourist-related activities such as reef walking, anchor damage and boat groundings.

**Table RA5.2.1. Buccoo Reef/ Bon Accord Lagoon: major coastal impacts/issues and critical thresholds – overview and qualitative ranking.**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impact/ Issue	Local site/region (contributing river basins)	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Pollution	Buccoo Reef/ Bon Accord Lagoon	Loss of bathing beach through bacterial (faecal coliform) contamination	No distance	10	IMA 1994, 1996; Laydoo <i>et al.</i> 1987
		Presence of diseased coral, reduction in coral cover, loss of biodiversity	No distance	8	CARICOMP data (IMA)
Eutrophication	Buccoo Reef/ Bon Accord Lagoon	Loss of hard corals cover and biodiversity	No distance	10	CARICOMP data (IMA)
		Reduction in fish stocks	Not known	?	Juman 2001
		Reduced seagrass productivity/ biomass	No distance	9	
Sediment loading	Buccoo Reef/ Bon Accord Lagoon	Loss of biodiversity	Not known	?	Juman 2001
		Loss of visibility/ aesthetics for divers (varies seasonally)	About 20% visibility during rainy season	6	

**Table RA5.2.2. Buccoo Reef/ Bon Accord Lagoon: DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class. (in this case small basins: passive coast).**

State change dimension: major; medium; minor; 0 = no impact; ? = insufficient information

Time scale: p = progressive (continuous); d = direct (spontaneous)

Driver	Pressures	State change (qualitative index)	Impact on the coastal system	Time scale
Agriculture	<ul style="list-style-type: none"> <li>Siltation</li> <li>Pesticide contamination</li> <li>Hypernutrification</li> </ul>	<b>minor</b> <b>minor</b> <b>major</b>	Declining water quality Biodiversity loss Eutrophication	<b>p</b>
Urbanization (Point source Effluents)/ Resort Development	<ul style="list-style-type: none"> <li>Sewage and</li> <li>heavy metal contamination</li> </ul>	<b>major</b> <b>minor</b>	Eutrophication Declining water quality Biodiversity loss	<b>p</b>
Tourism	<ul style="list-style-type: none"> <li>Mechanical damage to reef through tourist related activities on site</li> </ul>	<b>major</b>	Biodiversity loss	<b>p</b>

**Table RA5.2.3. Buccoo Reef/ Bon Accord Lagoon: the link between coastal issues/impacts and land-based drivers – overview and qualitative ranking on local or catchment scale.**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impact/Issue	Drivers	Impact category	Trend expectations	References/ data sources
Declining water quality	<ul style="list-style-type: none"> <li>• Agriculture</li> <li>• Urbanization</li> <li>• Tourism</li> </ul>	8	↑↑	IMA 1994, 1996
Eutrophication	<ul style="list-style-type: none"> <li>• Agriculture</li> <li>• Urbanization</li> </ul>	10	↑↑	Laydoo <i>et al.</i> 1987; IMA 1996; Juman 2001
Biodiversity loss	<ul style="list-style-type: none"> <li>• Agriculture</li> <li>• Tourism</li> <li>• Urbanization</li> </ul>	6	↑↑	CARICOMP data (IMA) Juman 2001

**Table RA5.2.6. Buccoo Reef/ Bon Accord Lagoon: scientific and/or management response to coastal impact/issues on catchment, sub-regional and regional scale.**

River catchment or island	Response catchment scale		Response Sub-regional/ Country scale		Response Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
Buccoo Reef/ Bon Accord Lagoon	Various studies by THA, IMA, UWI	Only Marine Park in Trinidad and Tobago. Designation a marine protected areas since 1973 under the Marine Preservation and Enhancement Act of 1970. A Management Plan was formulated in 1994 by the IMA. Manage by the THA	Various studies by UWI, IMA, THA	Tobago House of Assembly National Wetlands Committee and Policy Specially Sensitive Areas Rules Effluent standards EMA	CARICOMP	UNEP-Regional Coordinating Unit

IMA Institute of Marine Affairs

UWI University of the West Indies, St Augustine

EMA Environmental Management Authority

THA- Tobago House of Assembly

### 5.3 Kingston Harbour, Jamaica

*Trion Clarke and Dale Webber*

#### Table Summary

Kingston Harbour, Jamaica has been contaminated by domestic, industrial and fluvial effluent for the better part of the last three centuries, with the worst deterioration occurring in the last fifty years. Contamination has resulted in increased eutrophication, sedimentation and chemical pollution, with resultant decreases in biodiversity and aesthetic appeal.

Land-based activities are mainly responsible for the contamination. These include poor agricultural practices and sewage disposal. Sewage outfall from treatment plants is the most important source of pollution to Kingston Harbour, though volumetric flow rates are lower than other sources such as the Rio Cobre and Duhaney rivers. Nutrient, sediment and chemical inputs from these two rivers are significant.

The critical thresholds for proper system functioning for most of the indices have been surpassed and negative impacts on the coastal area are expected to increase in intensity over the near and medium future.

Extensive scientific work has taken place in Kingston Harbour, but little has occurred in the drainage basins. Various management entities have been established with direct responsibility for the harbour, but very little in terms of actual management has occurred. Scientific and management efforts continue.

Because all the land-based impacts are concentrated into one harbour basin, there is no need to provide a detailed table of coastal issues versus drivers (i.e. Table 1).



**Table RA5.3.2. Kingston Harbour: DPSIR matrix characterizing major catchment-based drivers/pressures on and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class (area influenced by small catchments).**

State change dimension: major; medium; minor; 0 = no impact; ? = insufficient information

Time scale: p = progressive (continuous); d = direct (spontaneous)

Driver	Pressures	State change (qualitative index)	Impact on the coastal system	Time scale
<b>Agriculture</b>	Nutrient, sediment and pesticide input	<b>major</b>	<ul style="list-style-type: none"> <li>• Eutrophication</li> <li>• chemical contamination, smothering of seagrass beds</li> <li>• increased turbidity</li> </ul>	<b>p</b>
<b>Industries</b>	Nutrient and chemical input	<b>medium</b>	<ul style="list-style-type: none"> <li>• Eutrophication and</li> <li>• chemical contamination</li> </ul>	<b>p</b>
<b>Deforestation</b>	Sediment input Habitat removal	<b>minor</b>	<ul style="list-style-type: none"> <li>• Smothering of seagrass beds</li> <li>• increased turbidity</li> <li>• decreased biodiversity</li> </ul>	<b>p</b>
<b>Navigation</b>	Nutrient and sediment resuspension Shoreline construction Chemical contaminant input	<b>medium</b>	<ul style="list-style-type: none"> <li>• Eutrophication</li> <li>• Siltation</li> <li>• pollution of water</li> <li>• Loss of aesthetic appeal</li> </ul>	<b>p</b>
<b>Urbanization</b>	Nutrient and sewage input	<b>major</b>	<ul style="list-style-type: none"> <li>• Eutrophication and</li> <li>• bacterial contamination</li> </ul>	<b>p</b>
<b>Fisheries</b>	Over-exploitation, destructive practices, food web attenuation	<b>medium</b>	<ul style="list-style-type: none"> <li>• Lowered biodiversity</li> <li>• loss of species and</li> <li>• loss of habitat</li> </ul>	<b>p</b>

**Table RA5.3.3. Kingston Harbour: the link between coastal issues/impacts and land-based drivers – overview and qualitative ranking on local or catchment scale.**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impact/ Issues	Drivers	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ Data sources
		Locations around Kingston Harbour in detail	Impact Category		
<b>Eutrophication</b>	a. Urbanization	a. Sewage input along shoreline.	10	↑↑	
	b. Agriculture	b. Rio Cobre basin	6	↑↑	
	c. Industries	c. Inflow through gullies.	2	↑↑	
	d. Navigation	d. Within harbour and along shoreline.	2	↑↑	
<b>Bacterial contamination</b>	a. Urbanization	a. Sewage input along shoreline	10	↑↑	
<b>Siltation (smothering)</b>	a. Agriculture	a. Rio Cobre basin	6	↑↑	
<b>Lowered biodiversity</b>	a. Deforestation	a. Along shoreline	4	↑↑	
	b. Fishing	b. Inside harbour	6	↑↑	
<b>Chemical contamination</b>	a. Agriculture	a. Rio Cobre basin	2	↑↑	
	b. Industry	b. Shoreline gullies	2	↑↑	

**Table RA5.3.6. Kingston Harbour: scientific and/or management response to coastal impact/issues on catchment, sub-regional and regional scale.** (n a. = not applicable).

<b>Response Catchment scale</b>		<b>Response Sub regional/ Country scale</b>	
Scientific	Management	Scientific	Management
Sediment loading data. Nutrient loading data. Bacterial Analysis. Sewage loading data. Plankton studies. Circulation and bathymetric studies. Sediment biota studies. Chemical pollution data. Water discharge data. Water quality data.	Establishment of various management entities such as:  Kingston Harbour Restoration Plan.  Kingston Harbour Rehabilitation Programme.	General monitoring and assessment by academic and governmental and non-governmental bodies and institutions.	Natural Resource Conservation Authority Act (1992) and the establishment of the National Environment and Planning Agency (2001).

Wade (1976); SENTAR (1993); Simmonds (1997); Mansingh and Wilson (1995); CIMAB (1997); Williams (1997); Ranston (1998); Webber and Webber (1998); Wilson-Kelly (in press);

## 5.4 Parque Nacional Morrocoy, Venezuela

*David Bone*

### Table Summary

Of Venezuela's approximately 2,875 km of continental coastline, 1,927 km (67%) are on the Caribbean Sea and 948 km (33%) on the Atlantic Ocean. The major shallow marine and coastal habitats are sandy beaches, rocky shores, seagrass beds, coral reefs, coastal lagoons and mangroves. Primary production is high, due to upwelling and additional nutrient supply by rivers and watersheds. Some of the ecosystems exist within a delicate dynamic equilibrium which is influenced by continental water masses, and interact by means of material and energy transfer. During recent decades, negative impacts from anthropogenic activities have reportedly affected coastal marine ecosystems.

A variety of economic activities take place, including fisheries, tourism and industrial output. Of special interest along this coast is the area of Golfo Triste, an extensive marine region located to the middle west of the country. This area is directly influenced by the discharges from the Aroa and Yaracuy river basins, which together have a catchment area of 4,720 km<sup>2</sup>. Human settlement in the basin areas have increased, from less than 100,000 inhabitants in 1950 to more than 800,000 in 1998. This population increase is related to urbanization, changing from 38% in 1950 to 76% in 1990. Urban centers including the state capital have developed in the central region of the basins. The main economic activities are agriculture and cattle-raising, with 85% of the total area dedicated to this activity. Mining also takes place, with copper and iron as the main products. Three dams have been built on these rivers: two on the Aroa River and the largest one on the Yaracuy River. At present, the Aroa and Yaracuy basins provide water for agriculture, industrial and urban activities, energy generation and dam construction, and the main river courses are used for effluent discharge. In addition, the basins have been subjected to intense deforestation, which increases soil erosion and causes deterioration downstream, where the amount of river sediment, nutrients, organic matter and pollutants have increased, eventually impacting the marine areas. The Parque Nacional Morrocoy and its surrounding areas represent by far the most important and complex marine ecosystem of this continental shore, with extensive coral reef areas, mangrove forests and seagrass meadows, estuarine and hypersaline environments. During the last two decades, these marine communities have been affected by a variety of man-made disturbances, locally and on the mainland, whereby poor land management has created serious erosion problems and sediments have been carried into the park by runoff and by coastal currents.

**Table RA5.4.1. Parque Nacional Morrocoy: major coastal impacts/issues and critical thresholds – overview and qualitative ranking.**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impact/ Issue	Local site/ region (contributing river basins)	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References / Data source
Sediment/ siltation	Aroa-Yaracuy River	Live coral cover >35% Biodiversity, >80%	Currently down to 5%  Currently reduced to 20% <b>No distance</b>	10	Bastidas <i>et al.</i> 1997
Pollution (heavy metals)	Aroa-Yaracuy River	ppb	Arising to ppm	7	Bastidas <i>et al.</i> 1997
Nutrients/ eutrophication	Aroa-Yaracuy River	High, but periodical	<b>No distance</b> (temporarily)	5	
Habitat alteration (reduction)	Aroa-Yaracuy River	High biodiversity	Overall 35% reduction	5	Losada 1998

**Table RA5.4.2. Parque Nacional Morrocoy: DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class (small basins on a tectonically passive coast).**

State change dimension: major; medium; minor; 0 = no impact; ? = insufficient information

Time scale: p = progressive (continuous); d = direct (spontaneous)

Driver	Pressures	State change (qualitative index)	Impact on the coastal system	Time scale
		Small basins: passive coast		
<b>Agriculture/ Cattle raising</b>	Increased runoff  Increased sediment input  Increased organic and nutrient input	<b>medium</b>	Nutrification  Eutrophication  Water quality change  Pollution  TSS increase	<b>p</b>
<b>Damming</b>	Nutrients and sediments sequestration	<b>minor</b>	River flow reduction	<b>d</b>
<b>Deforestation</b>	Increased runoff Increased sediment Increase organic and nutrient inputs	<b>medium</b>	Habitat degradation,  TSS increase	<b>p</b>
<b>Tourism</b>	Construction along shore- line. Increase sewage/solid waste input Extraction of commercial species Boating	<b>major</b>	Habitat reduction  Habitat alteration  Loss of biodiversity  Litter contamination	<b>p</b>
<b>Urbanization (Effluents)</b>	Construction along shore- line Increased contaminants and sewage inputs	<b>major</b>	Habitat reduction  Habitat alteration  Loss of biodiversity  Litter and solid contamination  Sewage	<b>p</b>
<b>Fishing</b>	Over-exploitation of commercial resources	<b>medium</b>	Loss of biodiversity  Loss of critical species  Habitat alteration	<b>P</b>

**Table RA5.4.3. Parque Nacional Morrocoy: the link between coastal issues/impacts and land-based drivers – overview and qualitative ranking on local or catchment scale.**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impact/Issues	Drivers	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ data sources
		River	Impact category		
Decline in water quality	Agriculture/cattle-raising Deforestation Industry Urbanization Damming	Aroa-Yaracuy River	8	↑↑	Bone <i>et al.</i> 1993
Habitat alteration	Urbanization Agriculture/ cattle Tourism	Aroa-Yaracuy River	8	↑↑	Bastidas <i>et al.</i> 1997 Losada 1998
Biodiversity loss	Urbanization Agriculture/cattle Tourism  Natural drivers?	Aroa-Yaracuy River	10  ?	↑↑	Losada 1998

**Table RA5.4.6. Parque Nacional Morrocoy: scientific and/or management response to coastal impact/issues on catchment, sub-regional and regional scale.**

River catchment	Response catchment scale		Response Sub-regional/ Country scale		Response Regional scale	
River	Scientific	Management	Scientific	Management	Scientific	Management
Aroa-Yaracuy rivers	Several studies by USB, UCV, MARNR	MARNR, Land use policies Basin use policies	Several studies by USB, UCV, MARNR	Declaring protected areas Land Use INPARQUE MARNR	CARICOMP	UNEP

## 5.5 Magdalena River, Colombia

*Juan Dario Restrepo*

### Table Summary

The Magdalena River is 1,612 km long and drains a 257,438 km<sup>2</sup> basin that occupies a major portion of the Colombian Andes. It is the largest fluvial system in Colombia and its headwaters are in the Andean Cordillera at an elevation of 3,300 m. The river discharges into the western Caribbean and forms a 1,690 km<sup>2</sup> triangular delta. It has the highest sediment yield of any medium or large river along the Caribbean and Atlantic coasts.

Over the last fifty years the Magdalena River and associated coastal areas have been under increasing environmental stress. Economic development of Colombia between the 70s and 80s has increased demand for river control and utilization. Ongoing trends in the drainage basins have included:

- (1) escalating population densities along the basin and at river mouth. The main cities of Colombia including Bogotá, Medellín, Cali, and Barranquilla are located in the basin;
- (2) accelerating upland erosion rates due to poor agricultural practices and increasing deforestation; and
- (3) partly a result of points 1 and 2, increasing levels of pollution within the water.

All of these trends and impacts have produced a severe distortion of natural hydrographs leading to the potential loss of critical habitat, biodiversity and altered material transport.

Water and sediment discharges of the Magdalena River have strongly impacted the adjacent coastal ecosystems. Since 1954, the government of Colombia has dredged the Canal del Dique, a 114 km man-made channel from the Magdalena River at Calamar to Cartagena Bay. Because of the increased sedimentation in the bay during the 1970's, new canals were constructed from El Dique to Barbacoas Bay, and since then the suspended sediment load into Barbacoas has reached and impacted the El Rosario Islands, the second largest coral reef ecosystem in the Caribbean Sea of Colombia, and is probably responsible for most of the observed coral mortality. Water diversion due to the construction of a highway in the Magdalena delta/lagoon complex, the Ciénaga Grande de Santa Marta, has resulted in hypersalinization of mangrove soils and consequent die-off of almost 270 km<sup>2</sup> of mangrove forests over a 39-year period. The changes in the hydrological regime have also caused water quality changes in the lagoons and associated channels. In addition, urban, agricultural, mining and industrial waste inputs from the Magdalena basin have aggravated the conditions of the lagoon and coastal ecosystems. Biodiversity has been reported to be considerably lower in the area affected by mangrove mortality and in the coastal zone. Declining fisheries in the delta, from 63,700 tons in 1978 to 7,850 tons in 1998, indicate decreasing environmental conditions and water quality.

The Magdalena River is a major river for which the historic database is shockingly small. It deserves international attention because it has such a significant sediment yield (the largest on South America's Atlantic and Caribbean seaboards). In addition, it has a close teleconnection with the ENSO (La Niña events trigger high discharges and flooding events) and it has the most significant freshwater source for the Caribbean Sea. Thus, the fluvial inputs of the Magdalena River have great environmental and economic impacts on the adjacent coastal ecosystems.



**Table RA5.5.1. Magdalena River: major coastal impacts/issues and critical thresholds of fluxes – overview and qualitative ranking:**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impact/ Issue	Local site/region	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	References/ Data source
Eutrophication Pollution	Magdalena River Delta/ Lagoon-delta complex/ Caribbean coast of Colombia	Biological communities near the delta show signs of mortality. Declining yield in fish resources, with total catches from more than 63700 t/yr in 1978 to 7850 t/yr in 1998.	No distance – system functions already affected by excess nutrient supply; (drainage basin management - regulation of discharges and effluents - needed)	9	INVEMAR 1997; Beltran <i>et al.</i> 2000; INVEMAR 2000b.
Water discharge Sediment load diversion	Channelization of the lower Magdalena River and partial diversion of the river flow	Observed coral reef mortality (El Rosario Island- Caribbean Coast of Colombia)	Currently no distance but potential for mitigation; (diversion of river discharge will allow recovery of coral reef ecosystems)	10	Vernette 1985; INVEMAR 2000b; Restrepo and Kjerfve 2000
Hyper-salinization of mangrove soils	Magdalena River/ Lagoon-delta complex/ Ciénaga Grande de Santa Marta	Mortality of mangrove forest over 39-year period (272 km <sup>2</sup> )	Distance down to zero but slightly growing Re-diversion of fresh water into the lagoon-delta complex has allowed partial recovery of mangrove	8	Cardona and Botero 1998; INVEMAR 2000b
Erosion (coastal sediment budget)	Magdalena River Delta	Observed coastal erosion of 17 m/yr due to the construction of jetties in the Magdalena mouth.	Apparently no distance to the critical need of sediment accretion for coastal stability	8	Correa 1996; Martínez 1993

**Table RA5.5.2. Magdalena River: DPSIR matrix characterizing major catchment-based drivers/pressures and a qualitative ranking of related state changes having impact on the coastal zone.**

State change dimension: major; medium; minor; 0 = no impact; ? = insufficient information.  
Time scale: p = progressive (continuous); d = direct.

Driver	Pressures	State change (qualitative index)	Impact on the coastal system	Time scale
Agriculture	Soil conservation Poor agricultural practices	<b>medium</b>	Lost of coastal ecosystems due to accelerating upland erosion rates and eutrophication	<b>p</b>
Deforestation	Suspended sediment loads are now an order of magnitude greater than 60 years ago	<b>major</b>	Increased suspended sediment loads on coastal ecosystems – water quality/turbidity	<b>p</b>
Navigation and diversion	Channel construction and dredging in the lower Magdalena River	<b>major</b>	Discharge of suspended sediment load into coastal ecosystems	<b>P</b>
	Jetty construction in the Magdalena delta mouth	<b>?</b>	Imbalance in the coastal sediment budget	<b>P</b>
Urbanization (point source effluents)	Toxic contaminants (chlorinated and phosphorylated organic compounds) Higher levels of nutrients Inputs of untreated waters. Active elements, metals, and pesticides are known to have increased several-fold since the 1970s	<b>medium-major</b>	Contamination and eutrophication Fish, invertebrate and avian bio-diversity and biomass are much lower than 10 years ago	<b>p</b>

**Table RA5.5.3. Magdalena River: the link between coastal issues/impacts and land-based drivers – overview and qualitative ranking on local or catchment scale.**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impact/ Issues	Drivers	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ data sources
		River or other	Category		
Eutrophication and pollution	Agriculture	Magdalena River	8	↑	Colciencias-Fen 1989
	Deforestation	Magdalena River	10	↑	Colciencias-Fen 1989
	Urbanization (Point Source Effluents)	Magdalena River	10	↑	HIMAT- INGEOMINAS 1991; Cardona and Botero 1998.
Water discharge and sediment load diversion	Diversion	Magdalena River	10	⇒	Vernette 1985; Restrepo and Kjerfve 2000
Erosion (coastal sediment budget)	Navigation	Magdalena River delta	8	↑	Correa 1996; Martínez 1993
Hyper-salinization of mangrove soils	Diversion	Magdalena lagoon-delta complex	9	⇒	Cardona and Botero 1998.

**Table RA5.5.6. Magdalena River: scientific and/or management response to coastal impact/issues on catchment, sub-regional and regional scale.**

n.a. = not applicable

Response Catchment scale		Response Sub-regional/ Country scale	
Scientific	Management	Scientific	Management
Water discharge data (1940-2000). Sediment load data (1972-2000) Source: IDEAM (Colombia) Heavy metals 1980-1990 Source: HIMAT- INGEOMINAS 1999; Bustos (1999).	Quality criteria for waste water in the tributary basins. Source: Ministry of the Environment. Colombia.	In general: Monitoring programmes through hydrological and geological institutes.  Sources: IDEAM, HIMAT- INGEOMINAS  National Program of Monitoring Marine Ecosystems (SINAM) (INVEMAR 2000b and Ministerio del Medio Ambiente, Colombia)	Major rehabilitation program of the Magdalena Delta / Lagoon Complex, Cienaga Grande de Santa Marta (Colombian Government, GTZ- Germany and IDBank)

## 5.6 La Estrella River/Cahuita Reef, Costa Rica

*Ana Fonseca and Jorge Cortés*

### Table Summary

The main pressure to Cahuita Reef deterioration is siltation. Some eutrophication and pollution may be occurring, associated with the sediment. The main drivers of siltation are agriculture, cattle ranching and logging in the La Estrella river basin, and some coastal urbanization, so these seem to be the main sources of reef deterioration. Contamination comes basically from agriculture and coastal urbanization, and eutrophication from agriculture. Secondary pressures are harvesting, anchoring and reef-walking from fishing and tourism activities, all of which are increasing.. There is also a threat of marine oil exploitation in the future. There is some scientific response especially at the catchment and regional scale. There is no a strong national support for research yet. Management initiatives are in place at the country and regional scales; at the catchment scale specific actions to minimize impacts are very scarce. This means that the national and regional policies for conservation and management are not being implemented at the catchment scale.

**Table RA5.6.1. La Estrella River/Cahuilla Reef: major coastal impacts/issues and critical thresholds – overview and qualitative ranking.**

Coastal Impact/ Issue	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category (Impact code and relative class of importance)	References/ Data source
Siltation	Coral mortality (live coral cover is 11%) Change in coral species composition Low water quality Loss of biodiversity General reef deterioration	No distance Survivors are resistant species	9	Cortes 1993
Eutrophication	Non-coralline macroalgae overgrowth Low live coral cover General reef deterioration	No distance Algae are out-competing corals	Not measured	Cortes 1993
Pollution	Heavy metals on sea cucumbers and corals Low water quality General reef deterioration	Not known	5?	Abarca & Ruepert 1992 Guzman & Jimenez 1992
Harvesting	Low commercial stock populations	Low impact There are 10 active fishermen in Cahuilla using just line fishing	3	Mug 2000
Anchoring and reef walking	Destroyed reef structure	The problem is serious only locally in the shallow reef lagoon	2	Cortes 1993

**Table RA5.6.2. La Estrella River/Cahuita Reef: DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class (here a small basin in a tectonically active area).**

State change dimension: major; medium; minor; 0 = no impact; ? = insufficient information

Time scale: p = progressive (continuous); d = direct (spontaneous)

Driver	Pressures	State change (qualitative index)	Impact on the coastal system	Time scale
				<b>p</b>
<b>Agriculture</b>	Siltation Pesticides contamination Eutrophication	<b>major</b>	Declining water quality  Reef deterioration	<b>p</b>
<b>Ranching</b>	Siltation	<b>major</b>	Declining water quality  Reef deterioration	<b>p</b>
<b>Logging</b>	Siltation	<b>major</b>	Declining water quality  Reef deterioration	<b>p</b>
<b>Fishing</b>	Harvesting	<b>minor</b>	Reef deterioration	<b>p</b>
<b>Urbanization (Point Source Effluents)</b>	Siltation Bacterial contamination Waste solids contamination	<b>medium</b>	Declining water quality  Reef deterioration	<b>p</b>
<b>Tourism</b>	Destruction Extraction	<b>minor</b>	Reef deterioration	<b>p</b>
<b>Oil exploration</b>	Further oil exploitation	<b>?</b>	Declining water quality Reef deterioration	<b>d</b>

**Table RA5.4.3. La Estrella River/Cahuita Reef: the link between coastal issues/impacts and land based drivers – overview and qualitative ranking on local or catchment scale.**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impact/ Issues	Drivers	Impact category	Trend expectations	References/ data sources
<b>Siltation</b>	Agriculture	9	↑↑	ProAmbiente 1998
	Ranching	9	↑↑	
	Logging	4	↑↑	
	Urbanization	3	?	
<b>Eutrophication</b>	Agriculture	9	↑↑	ProAmbiente 1998
<b>Pollution</b>	Agriculture	9	↑↑	ProAmbiente 1998
<b>Harvesting</b>	Fishing	3	↑↑	Mug 2000
	Tourism	2		
<b>Anchoring and reef walking</b>	Tourism	2	↑↑	ProAmbiente 1998

Table RA5.6.6. La Estrella River/Cahuita Reef: scientific and/or management response to coastal impact/issues on catchment, sub regional and regional scale. n.a. = not applicable

Response Catchment scale		Response Sub-regional/ country scale		Response Regional scale	
Scientific	Management	Scientific	Management	Scientific	Management
Siltation and reef deterioration (1981-2000)	Some soil conservation practices are being considered by banana companies to get the green certificate ISO 14001 (vegetal cover of river borders and drainage channels, reduction of pesticides and fertilizers)	Research institutions for resources management and marine sciences	Forestry law (15 m along the rivers must be forest)	CARICOMP monitoring network (since 1999)	Green certificates for banana companies (ISO 14001)
Heavy metals in corals (1992)			Fishing law	AGRRA	Biological Corridor Project
Heavy metals in sea cucumbers ()			Green certificate for hotels (Costa Rican Institute of tourism-ICT)	Coral reef evaluation (2000)	CITES
River contamination (1992)	Quality criteria for wastewater One hotel in Cahuita has the green certificate (water treatment plant)			CaribBas (a component of LOICZ)-2002?	Red list of threaten species in Central America
Land use (1998)	Creation of Cahuita National Park (1975) and other protected areas at La Estrella river basin		Country was divided in Conservation Areas for its management (ACLAC)		Central America Water Tribunal
Fishing (2000)	Fishing is regulated inside the park (line fishing only is permitted)				
Tourist impact (2000)	Scuba diving is not allowed inside the park Creation of Commission for the Banano, Bananito and La Estrella River basin (1999) for watershed management Workshop on land use conservation with actors from La Estrella River basin and Cahuita Management Plan for Cahuita National Park				



## 5.7 Meso-American Barrier Reef System

*Bruce Hatcher*

### Table Summary

The Meso-American Barrier Reef System (MBRS) is an ecologically-bounded, marine bio-geographical entity that transcends approximately 30 river catchments in four adjacent nation states: Mexico, Belize, Guatemala and Honduras. It represents an appropriate geo-political unit for integrated regional management of coastal and ocean space (Hatcher 2000). Spanning more than 1100 km of coast, with more than 360 km of near continuous barrier reef, it is the largest barrier reef system in the northern and western hemispheres (second only in size to the GBR system of Australia) and is recognized as a major part of the global natural heritage of mankind. The necessity and potential of regional governance structures and actions to preserve the marine biodiversity and conserve the marine resources of the MBRS has led the governments of the four nations to formally commit management resources and authority to the common goal (the Declaration of Tulum, 1997). This initiative is supported through an international agency (the Central American Commission for the Environment and Development – CCAD), which will implement a new, US\$11 million GEF grant for the sustainable management of the MBRS.

Inputs to coral reef communities of nutrients, pollutants and contaminants in groundwater and rivers draining coastal catchments exposed to agricultural, urban and tourism development are identified as significant threats to the health of the MBRS (Sale *et al.* 1999; Dulan 2000). The health of coral reef ecosystems is generally assessed on the basis of their coral and fish community structures (e.g. Hughes 1994). Consequently, the largest component of the GEF grant is allocated to the establishment of a regionally coordinated environmental monitoring and information system that will identify and quantify anthropogenic change in the reef communities. A by-product of the initiative is a programme of bio-physical research aimed at measuring and modelling the ecological connections among coral reefs (ECONAR). The resulting models can be used to link land-based activities to change in coral reef ecosystems, and identify source-sink relationships at regional scales.

Importing this eco-regional approach to ecosystem-based management into the LOICZ Basins programme is logical and satisfying. The essential concept is to use a spatially coherent and socially valuable charismatic ecosystem (the MBRS) as a regional integrator of terrestrial biogeochemical inputs and anthropogenic stressors across an ecologically and politically defensible geopolitical management unit. The tables are arranged so as to reflect this perspective.

The stressors are all defined in terms of well-known negative changes in coral reef community structure and function. For illustration, only the impact issue of phase shifts in benthic coral reef community structure (i.e. from live hard coral to macroalgae) is considered here in detail, but this indicator of ecosystem health captures most of the documented responses and major stressors already established in other LOICZ Basins studies.

The regional basin is defined by the spatial domain of the MBRS. It is somewhat arbitrary (perhaps political) in the specification of its southern border, but the northern and eastern borders are well-delineated by the edges of reef structures. The western (landward) extent is defined by the upper edges of the groundwater tables and river catchments that border on the marine realm.

The sub-regional basins are defined physiographically and oceanographically as the NE coast of Honduras with its associated coastal fringing and shelf platform reefs; the Bay of Honduras with its shared catchments in northern Honduras, Guatemala and southern Belize and the southern extremity of the barrier reef; the barrier reef proper with its coastal lagoon bordering Belize and Mexico and its off-shelf atolls; and the Yucatan coast of Mexico with its associated fringing, shelf patch and atoll reefs. Current knowledge of the extent of river catchments, and ocean advection and transport in the region supports these sub-regional distinctions, but they will certainly change in response to new knowledge. The Gulf of Honduras, the barrier reef lagoon off Belize and southern Mexico, and the Yucatan groundwater system appear to be particularly robust sub-regional basin units.

The local basins consist of the individual river catchments in the three southern countries and are thus well-determined on the terrestrial side. Ignorance of the actual flow and transport data for these rivers is reflected in the tables, as is the current lack of clear management responsibilities. Much of these data may become available as the MBRS and ECONAR projects evolve. The appropriate partitioning of the individual groundwater basins within the eastern Yucatan is also far from obvious, and this is identified as a priority information gap.

The most problematic aspect of specification at the level of the individual basin is of course the coastal marine component. Here, the spatial scale of along- and cross-shelf advection exceeds and smears the outputs from individual catchments such that the delineation of the zone of influence is highly variable in space and time. This is where measurement and modeling the hydrodynamic environment is required to link source to sink, action to impact.

Finally, the ranking and prioritization of state changes and categories of impact and the identification of hot spots and trends in these tables reflects my own assessment. The values are not in general disagreement with the information presented in Sale *et al.* (1999) and Dulan (2000), but may differ from the better-informed views of scientists and managers with better local knowledge.

Table RA5.7.1. Meso-American Barrier Reef: major coastal impacts/issues and critical thresholds – overview and qualitative ranking:

Coastal Impact/ Issue	Local site/ region (contributing river basins)	Critical threshold (for system functioning)	Distance to critical threshold (qualitative or quantitative)	Impact category	Reference/ Data sources
Regime shifts in coral reef communities of the MBRS: macroalgae replace hard corals, reducing the quality and quantity of ecosystem goods & services. Thought to result from the synergistic effect of decreased herbivore abundance and increased loading of reefs with inorganic nutrients, organic material & inorganic sediments.	<b>Fringing reefs</b> adjacent to the groundwater aquifer of the E. Yucatan Peninsula, <b>Mexico</b>	Equivocal, but generally a <b>live hard coral cover (lhcc)</b> of <10%, a <b>coral disease</b> infection rate >10%, a <b>macroalgal cover</b> of >60%, and a <b>reef fish biomass</b> of <10gf.W.m <sup>-2</sup> is cause for serious concern on typical reefs of the MBRS region. Attempts have been made to specify critical thresholds for <b>Nitrate</b> and <b>Phosphate</b> concentrations in coral reef waters of 1.0uM and 0.1uM (resp.), but these are of dubious value.	Current values of <b>lhcc</b> are typically 12%, <b>disease</b> rates are 3%, and <b>macroalgal</b> cover is 44% at monitored sites in <b>Mexico</b> .	Impact category: downstream synergistic, direct & indirect.  Importance class: <b>8</b>  Justification: The MBRS is the largest coral reef ecosystem in the western hemisphere, part of the global heritage, providing multiple goods & services to the peoples of the four bordering nations.  Sedimentation & eutrophication due to watershed activities degrade the majority of reefs world-wide.	Lapointe 1997 suggests critical thresholds for nutrients.  Sale <i>et al.</i> 1999. Kramer & Kramer 2000 and Wilkinson 2000 review the status of reefs in the region.  Hatcher <i>et al.</i> 1989 review the threats to coral reefs.
	<b>Lagoon patch reefs &amp; barrier reefs</b> off Chetumal Bay, and the catchment of the Rio Hondo, <b>Mexico and Belize</b>		No data  N.B. spatial variance of % approximates the means.		
	<b>Lagoon patch reefs &amp; barrier reefs</b> off the Belize, Stann & Monkey river catchments of <b>Belize</b>		Typically, <b>lhcc</b> is 28%, <b>disease</b> rates are 5.5%, and <b>macroalgal</b> cover is 44% in <b>Belize</b> .		
	<b>Fringing &amp; barrier reefs</b> of the Sarstoon, El Porvenir & Motagua river basins of <b>Guatemala</b>		No data		
	<b>Fringing &amp; patch reefs</b> adjacent to the Bay Islands and off the Chamelecon, Uluá & Aguan river catchments of N. coast of <b>Honduras</b> .		Typically, <b>lhcc</b> is 21%, <b>disease</b> rates are 6%, and <b>macroalgal</b> cover is 53% in <b>Honduras</b>		

**Table RA5.7.2. Meso-American Barrier Reef: DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone versus catchment size class.**

State change index: major; medium; minor; 0 = no impact; ? = insufficient information, n/a = not applicable.

Time scale: p = progressive (continuous); d = direct (spontaneous)

Driver	Pressures	State change (qualitative index)					Impact on the coastal system	Time scale
		Large basins	Medium basins	Small basins: active coast	Small basins: passive coast			
Tourism development	Shoreline construction, altered circulation, sediment & sewage inputs, recreational impacts.	n/a	minor	n/a	medium		Focus on coral reef communities of the Mesoamerican Barrier Reef System (MBRS)	
						Localized & mostly independent of basin size & tectonic regime.	Habitat destruction & degradation. eutrophication, loss of biodiversity & aesthetics.	d 1-10 years
Agriculture	Increased runoff, organic & nutrient inputs.	n/a	major	n/a	medium		Nutritication / eutrophication, coralgal phase shifts, loss of biodiversity, rare & keystone species.	p 10-100 years
						Scales with off-shore distance	Salinity & sediment stress, habitat degradation, loss of biodiversity & rare species.	p 10-100 years
De-forestation	Increased runoff, sediment & organic inputs. Increased CO <sub>2</sub> / decreased CaCO <sub>3</sub>	n/a	major	n/a	major		Habitat destruction & degradation, eutrophication, loss of biodiversity, productivity & aesthetics.	d 1-10 years
						Comments as for Agriculture		
Port operations & Maritime navigation	Shoreline construction, altered circulation, collisions with benthos, contaminant inputs.	n/a	minor	n/a	minor		Habitat destruction & degradation, eutrophication, loss of biodiversity, productivity & aesthetics.	p 10-100 years
						Localized & often independent of basin size & tectonic regime.		
Urbanization & Industrial development (Point source effluents)	Shoreline & watershed construction, altered circulation, sediment, contaminant & sewage inputs.	n/a	major	n/a	minor		Habitat destruction & degradation, eutrophication, loss of biodiversity, productivity & aesthetics.	p 10-100 years
						Transport to reefs more likely in large basins & active coasts		
Fishing	Over-exploitation, food web attenuation, destructive practices & gears.	n/a	major	n/a	medium		Loss of productivity, biodiversity & keystone species, coralgal phase shifts, destruction of critical habitat.	p 1-10 years
						Widespread & largely independent of basin size, tectonic regime		
Aquaculture development	Shoreline & watershed construction, altered circulation, sediment & organic inputs, disease & species introductions.	n/a	minor	n/a	major		Habitat degradation & destruction, over-exploitation of feed species, loss of biodiversity, rare & keystone species.	p 1-10 years
						Reefs off small watersheds more susceptible		

**Table RA5.7.3. Meso-American Barrier Reef: The link between coastal issues/impacts and land based drivers – overview and qualitative ranking on local or catchment scale.**

Impact category and relative class of importance: 1 = low – 10 = high.

Coastal Impacts / Issues	Drivers	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ Data sources
		Catchment / River basin	Category		
Shoreline construction, altered circulation, sediment & sewage inputs, recreational impacts.	Tourism development	Cancun, Cozumel and Central east coast Yucatan, Mexico. Roatan, Honduras	10 7 5 6	↑ Rapid, patchy spread & intensification on certain coastlines and on offshore islands and cays.	Sale <i>et al.</i> 1999; Sealy & Bustamante 2000
Shoreline & watershed construction, altered circulation, collisions with benthos, sediment, contaminant & sewage inputs.	Urbanization, Industrial development, fort operations & Maritime navigation	Chetumal Bay, Mexico. Belize City. Bahia de Amatique & Manabique, Guatemala. Roatan, Honduras	8 6 4 7 6	↑ Steady, progressive spread & intensification along coastlines and up river catchments. Hot spots related to population density and economy.	Sale <i>et al.</i> 1999; Sealy & Bustamante 2000
Increased runoff, sediment & organic inputs. Increased CO <sub>2</sub> / decreased CaCO <sub>3</sub>	Agriculture and deforestation	Belize, Sibun, Stann & Monkey basins, Belize. Sarstoon & Motogua basins, Guatemala. Chamelecon, Uluu & Aguan basins, Honduras.	5 3 6 8 8 5	↑ Steady, progressive spread up river catchments. Most severe developments in Guatemala & Honduras, where hurricane impacts are amplified.	Sale <i>et al.</i> 1999; Sealy & Bustamante 2000
Over-exploitation, Food-web attenuation, destructive practices & gears. Shoreline & watershed construction, altered circulation, sediment & organic inputs, disease & species introductions.	Fishing and aquaculture development	Chetumal Bay, Mexico. Corozol Bay, Big Creek, Punta Gorda, Belize. Bahia de Amatique & Manabique, Cerro san Gil Guatemala. Gulf of Honduras.	7 5 3 5 7 4 6	= Static artisanal & ↓ declining industrial fisheries are offset by sporadic and patchy ↑ expansion of coastal and aquatic aquaculture.	Sale <i>et al.</i> 1999; Sealy & Bustamante 2000

**Table RA5.7.6. Meso-American Barrier Reef: scientific and/or management response to coastal impact/issues on catchment, sub regional and regional scale.**

River catchment or Islands	Response Catchment scale			Response Sub-regional/ Country scale		Response Regional scale	
	Scientific	Management		Scientific	Management	Scientific	Management
River/Island							
Cozumel, Mexico	Basic monitoring CNA	Single govt agency: SEMARNAP					
Cancun & N. Yucatan coast, Mexico	Detailed monitoring CNA	Multiple govt agencies & NGOs		<u>Yucatan:</u> Patchy monitor-ing by: CNA, INE, INP INEGI, CZMI, DOE-EWQMP DOF, LIC-CEDS	<u>Yucatan:</u> National Government authorities: SEMARNAP UCANP, PROFEPA, CZMA, DOF	MBRS: Patchy monitoring of sea level & meteorology: CPACC.	MBRS: World Bank – GEF – CEC Project: Conservation & sustainable use of the Meso-american barrier reef system (MBRS) in Mexico, Belize, Guatemala & Honduras (2001).
S. Yucatan coast Mexico & Amergris Caye, Belize	Ditto + Research: CINVES-TAV, UNAM, CEA, UCB	Ditto plus: LADSK, CEA, CZMA, DOF, BAS				Limited involvement in other international environ-mental monitoring programmes: AGRAA C-GOOS LOICZ, WOCE Etc.	
Chetumal Bay, Mexico	Basic monitoring CNA ECOSuR	Single govt agency: SEMARNAP					
Rio Hondo, Mexico	?	ditto		<u>N.Barrier Reef System:</u> Patchy monitor-ing by Govt. agencies: CNA, INE, INP CZMI, DOE-EWQMP DOF, LIC-CEDS, NMS, Universi-ties UCB ECOSuR	<u>N.Barrier Reef System:</u> No international management structure at this scale, but BBRC co-ordinates management in the Belize section.		Components: Regional monitoring & environ-mental information system; Sustainable tourism; Conservation of shared fish stocks; Network of marine protected areas; Harmonized legislation & regulation.
Corozal Bay, Belize	?	?					
New River	?	?					
N. coast lagoons, Belize	?	?					
N. barrier reef lagoon, Belize	?	Multiple govt agencies & NGOs: CZMA, DOF, BAS					
Belize River	Basic monitoring by DOE, NMS, WRISCS	Minimal: DOE					

Table RA5.7.6 continued

River catchment or Islands	Response Catchment scale			Response Sub-regional/ Country scale		Response Regional scale	
	Scientific	Management		Scientific	Management	Scientific	Management
River/Island	Limited monitoring by INE, UNA	Single govt agency: SEMARNAP					
Offshore atolls, Mexico	Local monitoring & research CCC, DOF, STRI WCS	Multiple govt agencies, with co-ordination by CZMA & BBRC		Outer MBRS: Patchy monitoring & research by Gov't. agencies: INE, INP, INEGI, CZMI, DOF, Universities: CINVE-STAV, ECOSuR, UNAM, UCB, & NGOs: BAS, CCC, WRISCS	Outer MBRS: Management is nationalized across this sub-region. Unified in the case of Mexico through the SEMARNAP. Fragmented in the Case of Belize. There is no unified management protocol for these offshore sections of the MBRS.	As above	As above
Offshore reefs, atolls & islands, Belize	ditto	ditto					
Barrier reefs & islands, Belize							
Sibun River	Flow NMS	?				As above	As above
Central Coastal lagoons, Belize	?	?					
Mullins River, Belize	Flow NMS	?					
North Stann Creek	Total catchment monitored by WRISCS	?		Central MBRS	Central MBRS Lagoon: Multiple Gov't. agencies, with limited co-ordination by CZMA & BBRC		
Stann Creek Basin		?		Lagoon: Patchy monitoring by DOE-EWQMPNMS			
Sittee River		?		WRISCS			
South Stann Creek		?					
Mango Creek	?	?					
Big Creek	Monitored by NMS, DOE-EWQMP & TIDE	Community-based management TIDE					
Monkey River, Belize							
Punta Yucos Lagoon	?	?		Gulf of Honduras: Patchy monitoring by Gov't. agencies & NGOs coordinated by TRIGOH TNC	Gulf of Honduras: Fragmented management Authority contracted to local NGOs CONAMA & CONADES. Support from RECOSMO - PROARCA / Costas	As above	As above
Deep River	Flow NMS	?					
Port Honduras	?	?					
Rio Grande	Flow NMS	?					
Moho River	?	?					
Temash River, Belize	Flow NMS	?					

Table RA5.7.6 continued

River catchment or Islands	Response Catchment scale		Response Sub-regional/ Country scale		Response Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
Rio Sarstun, Guatemala	Some monitoring by UNEPA, UdV, CEMA-USAC, FUND-AECO	Local NGOs: FUNDAECO Contracted by CONAMA / CONAP	As above	As above	As above	As above
Lago de Izabel y Golfete	As above	As above				
Punta de Manabique	As above	As above				
Bahia de Amatique	Fisheries monitoring by UNEPA, CEMA-USAC	As above				
Rio Mario Dary	Monitoring by FUND-ARY	Local NGOs: FUNDARY Contracted by CONAMA / CONAP				
Rio Motagua, Guatemala	?	?				
Rio Chamelecon	Patchy monitoring by UdV, USAC, PROLA-NSATE, WCS	Local NGO: PROLAN-SATE contracted by CONAMA / CONAP				
Rio Ulua,						
Punta Sal lagoon, Honduras						
Rio Izopo, Honduras						
Rio Salado	?	?				
Rio Cangrejal	?	?				
Laguna de Guaimoreto	?	?				
Rio Aguan	?	?				
Islas de la Bahia, Honduras	Detailed monitoring by BICA, CCC, CRIPCACSSMEMMP BI, HCRF, RIMS	Competing Gov't. agencies & NGO's: DIGIPESCA, DAPVS, BICA, EMPBI	NW.Honduras: Patchy monitoring by Gov't. agencies & NGOs. Some coordination by PROAR-CA / Costas	NW.Honduras: Management authority contracted to local NGOs from CONAMA & CONADES, with support from WWF, TNC, RECOSMO - PROARCA / Costas		



## Acronyms and abbreviations used in Table RA5.7.6

AFE	Administración Forestal del Estado: Honduras
AGRRA	Atlantic and Gulf Rapid Reef Assessment: monitoring protocol
ALIDES	Alianza Centroamericana Para el Desarrollo Sostenible (part of CCAD)
ASOREMA	Alliance of NGOs responsible for managing protected areas in Guatemala
BICA	Bay Islands Conservation Association: Honduran NGO
BAS	Belize Audubon Society: manages several national parks
BBRC	Belize Barrier Reef Committee, N-STAC for MBRS project, Belize
CARICOMP	Caribbean Coastal Marine Productivity Program: monitoring protocol
CCAD	Comisión Centroamericana de Ambiente y Desarrollo: Guatemala
CCC	Coral Cay Conservation: United Kingdom NGO
CEA:	Centro Ecológico de Akumal: Mexican NGO
CECON	Centro de Estudios Conservacionista de la Universidad de San Carlos, Guatemala
CEDS	Conservation and Environmental Data System: Belize Ministry of Natural Resources and Environment, LIC
CEMA	Centro de Estudios del Mar y Acuicultura Conservacionista de la Universidad de San Carlos: Guatemala
CFRAMP	CARICOM Fisheries Resource Assessment and Management Program, Belize
CHAMP	Coral Health and Monitoring Program, NOAA
CICIMAR	El Centro Interdisciplinario de Ciencias Marinas, México
CINESTAV	Centro de Investigación y de Estudios Avanzados, México
COCCYTAC	Comite Consultor Científico y Tecnico de los Arrecifes Coralinos de México
COHDEFOR	Comisión Hondureña de Desarrollo Forestal: sub-unit of SERNA, Honduras
CONAB	Comisión Nacional de la Biodiversidad, Guatemala
CONADES	Consejo Nacional de Desarrollo Sostenible, Honduras
CONAMA	Comisión Nacional del Medio Ambiente, Guatemala
CONAP	Consejo Nacional de Areas Protegidas, Guatemala
CONCYT	Consejo Nacional de Ciencia y Tecnología: Guatemalan research funding agency
CNA	Comisión Nacional del Agua, México
CPACC	Caribbean: Planning for Adaptation to Climate Change: support organization funded by GEF/World Bank and executed by OAS
CRIP	Centro Regional de Investigación Pesquera: INP, México
CSSMM	Consortio Safege-Sogreah-Moncada y Moncada: consortium of two large Honduran NGOs funded by the IDB
CZMA	Coastal Zone Management Authority, Belize
CZMI	Coastal Zone Management Institute, Belize
CZMU	Coastal Zone Management Unit, Belize
DAPVS	Departamento de Areas Protegidas y Vida Silvestre, Honduras
DiBio	Dirección de Biodiversidad, SERNA, Honduras
DIGEPESCA	Dirección General de Pesca y Acuicultura, Honduras
DOE:	Department of Environment, Belize
DOF	Department of Fisheries, Belize
ECONAR	Ecological Connections Among Reefs: proposed component of MBRS project
ECOSUR	El Colegio de la Frontera Sur, México
EMPBI	Environmental Management Program of the Bay Islands, Honduras
EWQMP	Environmental Water Quality Monitoring Programme, DOE, Belize
FUNDAECO	Fundación para el Ecodesarrollo y la Conservación: Guatemalan NGO
FUNDARY	Fundación para la Conservación del Medio Ambiente y los Recursos Naturales, Mario Dary Rivera: Guatemalan NGO
GCRMN	Global Coral Reef Monitoring Network
GOOS	Global Ocean Observing System: global system for observations, modeling and analysis of marine and ocean variables coordinated by IOC, WMO, UNEP, and ICSU.
HCRF	Honduran Coral Reef Foundation: Honduran NGO
ICRI	International Coral Reef Initiative
ICSU	International Council for Science

IDB	Inter-American Development Bank
IGN	Instituto Geográfico Nacional, Guatemala
INE	Instituto Nacional de Ecología, SEMARNAP, México
INEGI	Instituto Nacional de Estadística, Geografía y Infomática, México
INGAUT	Instituto Guatemalteco de Turismo, Guatemala
INSIVUMEH	Instituto Nacional de Sismología Vulcanología Meteorología e Hidrología, Guatemala
INP	Instituto Nacional de Pesca, SEMARNAP, México
IOC	Intergovernmental Oceanographic Commission
LADSK	Los Amigos de Sian Ka'an A.C.: Mexican NGO
LIC	Land Information Centre, Belize Ministry of Natural Resources and Environment
LOICZ	Land-Ocean Interactions in the Coastal Zone
MAGA	Ministerio de Agricultura, Ganadería y Alimentación, Guatemala
MBC	Mesoamerican Biological Corridor: World Bank-GEF project
MBRS	Mesoamerican Barrier Reef System: World Bank-GEF project
NARMAP	Natural Resource Management and Protection Project: USAID, Belize
NGO	Non Governmental Organization
NMS	National Meteorological Service, Ministry of Energy, Science, Technology & Transportation, Belize
N-STAC	National Science and Technology Advisory Committee, Belize
OAS	Organization of American States
OCRET	Oficina de Reservas Territoriales, Guatemala
PRADEPESCA	Programa Regional de Apoyo al Desarrollo de la Pesca en el Istmo Centroamericano: European Union funded regional fisheries programme.
PROARCA/ Costas	Programa Ambiental Regional para Centroamerica Componente de Manejo de la Zona Costera: consortium of TNC, WWF, Univ. Of Rhode Island, and local NGOs, supported by USAID-G/CAP
PROFEPA	Procuraduría Federal de Protección al Ambiente, SEMARNAP, México
PROLANSATE	Fundación para la Protección de Lancetilla, Punta Sal, y Texigaut: Honduran NGO
RARE	RARE Center for Tropical Conservation: U.S. NGO
RECOSMO	Region de Conservación y Desarrollo Sostenible Sarstun-Motagua: an official government agency of CONAP, governed by a board of four members (UNDP, CONAP, CONAMA, MAGA), and managed by the UNDP
REHDES	Red Ecológica Hondureña Para el Desarrollo Sostenible, Honduran NGO
RIMS	Roatán Institute for Marine Science
SEMARNAP	Secretaría de Medio Ambiente, Recursos Naturales y Pesca, México
SERNA	Secretaría de Estado en el Despacho de Recursos Naturales y Ambiente, Honduras
STRI	Smithsonian Tropical Research Institute, at Carrie Bow Cay, Belize.
TIDE	Toledo Institute for Development and Environment: Belize NGO
TNC	The Nature Conservancy: international environmental conservation agency based in U.S.
TRIGOH	Tri-national Alliance for the Gulf of Honduras: international consortium of NGOs, Belize, Guatemala and Honduras
UCANP	Unidad Coordinadora de Areas Naturales Protegidas, INE, México
UCB	University College of Belize
UdV	Universidad de Valle, Guatemala
UNAM	Universidad Nacional Autónoma de México
UNEPA	Unidad de Ejecución Pesquera y Acuicola, Fisheries Division of MAGA, Guatemala
USAC	Universidad de San Carlos de Guatemala
WCS	Wildlife Conservation Society, international wildlife conservation society based in New York
WOCE	World Ocean Circulation Experiment: international project studying ocean circulation
WMO	World Meteorological Organization, United Nations agency
WRISCS	Watershed-Reef Interconnectivity Scientific Study, conducted by Raleigh International, Ambios Environmental Consultants and University of Exeter
WWF	World Wildlife Fund: International wildlife conservation organization

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## APPENDICES

### Appendix I Human dimensions of land-based fluxes to the coastal zone: the LOICZ-Basins approach

by H.H. Kremer, Wim Salomons and C.J. Crossland

The following appendix provides a general introduction in methodology of the regional assessment and synthesis of human dimensions of land-based fluxes to the coastal zone as performed in the LOICZ-Basins core project. In using a common methodology, harmonized assessment protocols and project designs for research on global scales, the LOICZ-Basins framework aims to assist in interregional exchange and acquisition of funding opportunities on local, sub-regional and regional scales.

#### Background

Coasts worldwide are subject to many pressures which are expected to continue or increase in the future. Natural flows of water, nutrients and sediments to the coast are largely and increasingly influenced by past and planned physical changes in rivers (e.g., damming). In addition, the increase in tourism, fisheries, urbanization and traffic will offer challenges for the coastal zone managers and regulators. The management issues and their solutions require an integrated approach of the natural and socio-economic sciences (Turner *et al.* 1998; Salomons *et al.* 1999). Numerous studies (often mono-disciplinary) have been conducted to deal directly with these issues but could benefit from more integrated assessment. This integration of the results of past studies requires a simple and harmonized framework for assessment and analysis. For the integration LOICZ-Basins uses the DPSIR framework:

LOICZ-Basins faces three major challenges:

- 1) to determine the time delay between changes in land-based material flows (due to socio-economic activities, morphological changes or regulatory measures) and their impact on the coastal zone system.
- 2) to generate an improved understanding of the complexities of the coastal sea environments and to derive from this complex environment the “critical loads”.
- 3) to consider the multiplicity of interests and stakeholders affected by transboundary issues, particularly when local, regional, national, and multi-national governmental bodies with conflicting interests are involved.

#### The DPSIR framework

The Driver-Pressure-State-Impact-Response or DPSIR scheme (Turner *et al.* 1998; Turner and Bower 1999), provides a standardised frame for site assessment and evaluation. It ultimately enables the calculation and modelling of the impacts of change on the delivery and use of environmental goods and services expressed in scientific and monetary terms. The scheme sets up a platform for independent review and feedback evaluation of political and managerial response and options. The elements of this framework are:

**Drivers:** resulting from societal demands the sectoral activities with consequences for the coastal zone include:

- urbanisation
- aquaculture
- fisheries
- oil production and processing
- mining
- agriculture and forestry
- industrial development
- land use change.

**Pressures:** processes affecting key ecosystem and social system functioning (i.e., natural and anthropogenic forcing affecting and changing the state of the coastal environment):

- damming and other constructions
- river diversion, irrigation and water abstraction
- industrial effluents (industrialisation), agricultural and domestic wastes (urbanisation)
- navigation and dredging
- sea-level rise induced by land-based activities and affecting the coastal zone (e.g., decrease of riverine sediment load leading to instability of coastal geomorphology)
- other forcing functions (not primarily anthropogenic) such as climate change.

**State and State change:** the indicator functions and how they are affected:

- water, nutrient and sediment transport (including contaminants where appropriate) observed in the coastal zone as key indicators for trans-boundary pressures within the water pathway. Indicators are designed to give an overview of the environmental status and its development over time and enable ultimately derivation of critical load information
- geomorphologic settings, erosion, sequestration of sediments, siltation and sedimentation
- economic fluxes relating to changes in resource flows from coastal systems, their value, and changes in economic activity including the valuation of natural resources, goods and services.

**Impact:** effects on system characteristics and provision of goods and services:

- habitat alteration
- changes in biodiversity
- social and economic functions
- resource and services availability, use and sustainability
- depreciation of the natural capital.

**Response:** action taken on political and/or management level:

- scientific response (research efforts, monitoring programs)
- policy and/or management response to either protect against changes such as increased nutrient or contaminant input, secondary sea level rise, or to ameliorate and/or rehabilitate adverse effects and ensure or re-establish the chance for sustainable use of the system's resources.

The pressures are manifold, so we narrow them down within the LOICZ context, which deals with changes in biogeochemical cycles as major indicators. The LOICZ-Basins project therefore deals with the impact of human society on the material transport such as water, sediments, nutrients, heavy metals and man-made chemicals to the coast. It assesses the loads and their coastal impact and tries to provide feasible management options together with an analysis of success and failure of past regulatory measures. Since changes in fluxes are mostly land or catchment-based (including whole islands as single catchments in some cases), the catchment–coastal sea system is treated as one unit – a water continuum. In applying this scale to loads and coastal change phenomena this means that beyond activities from agriculture, fisheries, urban development, industry, transport, tourism also morphological changes made to a catchment (e.g. damming) have to be taken into account.

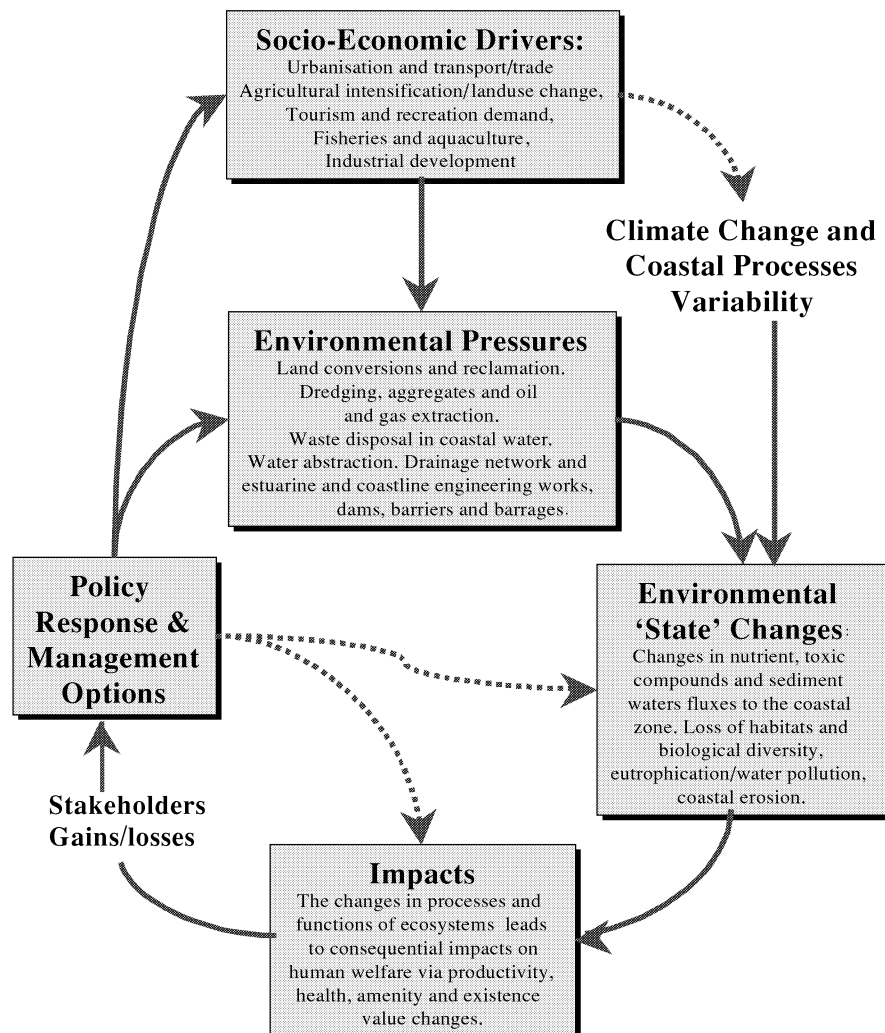
In particular the following parameters will be assessed:

- material flow of water, sediments, nutrients and priority substances (past, current and future trends);
- socio-economic drivers which have changed or will change the material flows;
- indicators for impacts on coastal zone functioning; and to derive from them
- a "critical load" for the coastal zone and "critical thresholds" for system functioning.

### **Linking coastal response to socio-economic drivers**

This critical load and threshold concept being developed within the UN/ECE CLRTAP convention will develop this link. (The "United Nations Economic Commission for Europe's convention on Long-Range

Transboundary Air Pollution” has held several workshops and produced handbooks on the critical load concept for terrestrial and freshwater systems. In LOICZ-Basins these concepts are extended to the marine environment). In a systems approach it can be used (as has been done for atmospheric pollution abatement) for a cost-benefit analysis of management options. Scenario-building is an integral part of this analysis. Critical loads provide key information for the development and application of indicators for monitoring purposes as required, for example for the implementation of the Coastal Global Observation System, C-GOOS, of UNESCO’s IOC.



**Figure A1.1. Description of the Driver-Pressure-State-Impact-Response (DPSIR) Framework.**

LOICZ-Basins employs different approaches to identify **targets and indicators** for the coastal response:

- The most simple “policy-oriented” approach is taking the critical loads which have been agreed upon in international treaties (e.g. the 50% reduction scenario within the Rhine Action Plan, also adopted for the North Sea).
- The “ecosystem” approach uses historical data on the response of the coastal system to changing loads and identifies indicators. This approach will incorporate an attempt to discriminate between the natural state and an anthropogenically altered state.
- The “regional management” approach is based on consultation with local authorities and identifies their criteria for indicators or critical loads. This incorporates other indicators than those based on scientific arguments alone.

The indicators and targets will be used to derive critical concentrations. Taking into account transformations and dispersion in the coastal environment, a critical load to the coastal zone can be calculated. This critical load, the **critical outflow** of the catchment/island, is a combination of inputs by socio-economic activities and transformations in the catchment and its delta/estuary. Once these links and



the transformations of the loads have been established it will be possible to carry out scenarios for cost-benefit analysis and trade-offs. This will require the integration of existing modelling tools from the natural and social sciences.

The DPSIR framework is applied to determine critical loads of selected substances, under different development scenarios, with diverse biophysical and socio-economic settings, triggering the discharge into the coastal seas. It aims to provide the interdisciplinary platform for participatory approaches jointly with natural, social and economic scientists, and to incorporate representatives of stakeholders including industry, agriculture, environmental organizations and citizens.

Large catchments seem to be obvious examples to be addressed within a global LOICZ synthesizing effort (e.g. Amazon, Nile, Yangtze, or in the Caribbean case the Magdalena and Orinoco Rivers). However, from the perspective of coastal change on regional and global scales, considerable if not major influence from land-based flows is generated in small to medium catchments with high levels of socio-economic activity. In island dominated regions surface run off of a whole island contribute to the coastal zone or in other words the whole land area is a coastal zone subject to influences generated by both anthropogenic drivers and global forcing. Changes in land cover and sectoral use need much shorter time-frames to translate into coastal change and usually exhibit more visible impacts than in large catchments where the “buffer capacity” against land-based change is higher simply as a function of catchment size. Thus, small and medium catchments are in principle of equal priority to the global LOICZ-Basins assessment.

## **The approach**

### **Regional networks, assessment workshops/desk studies**

Through two-stage regional workshops, LOICZ-Basins builds up regional multidisciplinary networks of scientists who bring their experience and existing information into the synthesis process. The first workshop identifies the pertinent regional issues and provides a first ranking order of current and predicted impacts with trend analysis, based on expert judgement and published scientific information. A second workshop finalises the first regional synthesis, improves the geographical and thematic coverage and assists in preparing research proposals for local and regional funding. Emphasis is given to close coupling of biogeochemical and physical sciences with human dimensions. Workshops have been held and networks established in Europe, South America, East Asia and Africa, while desk studies cover the Oceania Region and the Russian Arctic.

In February 2001 the European Catchments (EuroCat) project, funded by the European Union, started (<http://www.iia-cnr.unical.it/EUROCAT/project.htm>) as a direct result of a LOICZ assessment. The EuroCat design, objectives and modelling approaches serve as templates for the development of other regional catchment-coastal zone projects currently being developed for Africa (in implementation with support from START as a pilot study phase 2002/03 – four catchments), and Latin America. In East Asia a similar development is foreseen for the near future.

A **LOICZ Basins** WWW page is now available at the GKSS Research Center, Geesthacht, Germany, ([http://w3g.gkss.de/projects/loicz\\_basins/](http://w3g.gkss.de/projects/loicz_basins/)) and through the LOICZ web-site ([www.nioz.nl/loicz/](http://www.nioz.nl/loicz/)). It is updated continuously and provides copies of reports for downloading.

Proposals and projects that develop from regional LOICZ-Basins efforts contribute to the global LOICZ assessment. They also contribute to the Integrated Coastal Area Management initiative, ICAM, as well as to the Coastal GOOS “Global Ocean Observing System” of UNESCO/IOC. Links to the typology up-scaling effort considering global river run off and coastal biogeochemistry (a joint project of LOICZ and BAHC through the University of New Hampshire, are being pursued (<http://www.kgs.ukans.edu/Hexacoral/Tools/tools.htm>). Watching briefs exist with other global efforts such as GIWA, the WWAP and Millennium Assessment. Increasing the links with the Regional Seas initiatives under UNEP and the GPA is under consideration.

## The framework for LOICZ Basins Synthesis and Project Development

Since LOICZ-Basins workshops have a regional focus, assessment and ranking follow a hierarchy of scales finally allowing a full regional picture to be generated – the scales increase from:

- local catchments via
- sub-regional or provincial scales up to
- regional scale which could also be a country (e.g., Continental China) or a sub-continent or continent.

To facilitate thinking and to guide the evaluation of existing information, the Driver/Pressure/State/Impact/Response scheme (DPSIR) has proven to be an appropriate descriptive framework. The steps taken are:

- a) set up a **list of coastal change issues** of and **related Drivers** in the catchment (plenary-task).
- b) characterize and provide a ranking order of the various issues of change based on either **qualitative information** (i.e., expert judgement - if there are no hard figures) or **hard data** coming from investigations or archived material; this includes identifying **critical load** and **threshold** information for system functioning.
- c) derive a list of current or prospective **“hot spots”** representative of a type or class of catchment-coast system, from which to develop a **proposal** for future interdisciplinary work.

In other words LOICZ-Basins aims to provide an **expert typology** of the current state and expected trends of coastal change under land-based human forcing and natural influences. The assessment follows a set of key questions which cover the various aspects and scales of the DPSIR analysis and follow a sequence of **regional assessment tables**, participants are asked to fill in prior to the workshops. A generic scheme is shown below. All major assessment tables closely follow this scheme, and allow inner and interregional comparison within the global LOICZ-Basins effort, although the entries to the tables can be different.

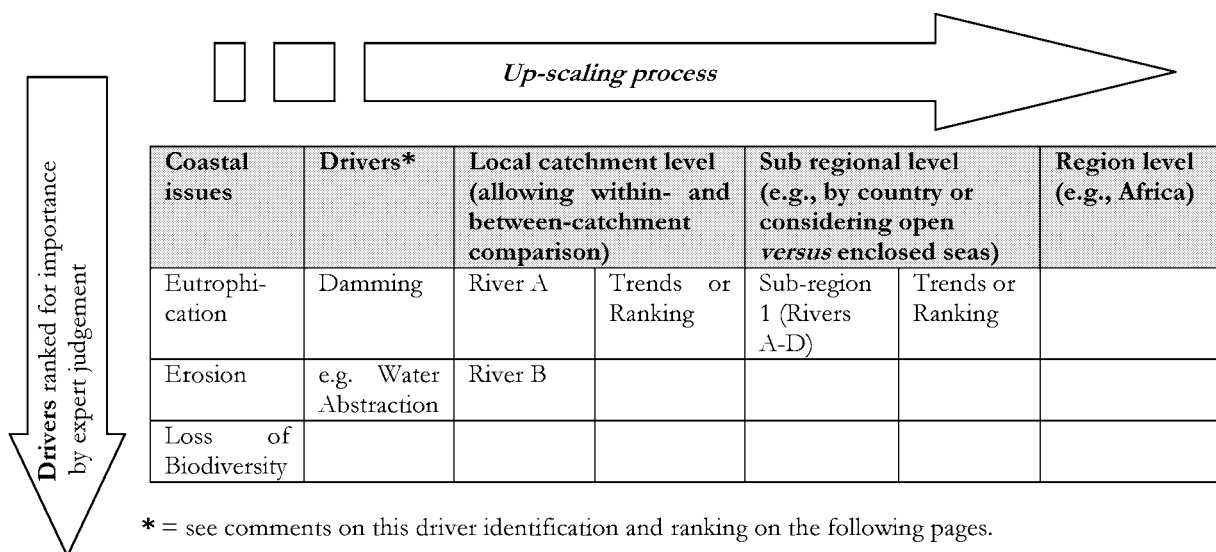


Figure A1.2. Basic schema of assessment tables.

## Ranking and classification

The OSPAR 2000 quality status report (<http://www.ospar.com>) lists human pressures on the coastal sea in a ranking order with four classes according to their relative impact on the regional ecosystem - including sustainable use. Pressures are attributed to various drivers or pressure classes.

Table A1.1 shows a few examples compiled along the OSPAR guidelines, adapted to fit the LOICZ-Basins concept. It focuses on issues, which link to land-based activities.

**Table A1.1. Examples of impacts, pressures and driver/pressure settings in the LOICZ context.**

Impact priority	Priority classes of human pressures	Driver/Pressure settings - sectoral; land- or catchment- or sea-based
<b>A (highest impact)</b>	Input of organic contaminants – land-based	Various economic sectors
	Inputs of nutrients – land-based	Various sectors, urbanization, (wastewater, agriculture)
<b>B (upper intermediate impact)</b>	Input of oil and PAH – land-/sea-based	Oil industry/Shipping
	Input of other hazardous substances – land-/ sea-based	Industry/Shipping/various sectors
<b>C (lower intermediate impact)</b>	Input of nutrients, organic material, antibiotics etc.	Mariculture
	Mineral extraction – land/ sea based	Engineering, Mining
	Inputs of radio nuclides from land	Energy and other sectors
<b>D (lowest impact)</b>	Input of waste/litter	Recreation, Tourism

From these and other examples, adapted to the LOICZ needs and relying strongly on regional expert judgement and - if available - regional quality standard protocols and agreements, the LOICZ-Basins task group has developed a set of **Basins Regional Assessment tables** for global application.

#### **LOICZ-Basins Regional Assessment Tables (RA 1- 7) and key questions for workshops, synthesis and project development**

The tabulated DPSIR analysis has proven to be an appropriate descriptive framework for this purpose. The questions leading through the tables have usually been addressed in the first phase of the Basins workshops. The tables ensure a standardize approach within the global LOICZ-Basins effort. They allow integration of the regional assessments and expert typologies into the global scales and help to fill gaps and harmonise the synthesis. Data included in the first workshop are reviewed and confirmed in light of new information delivered to the second workshop. Detailed source references for data or critical load information is included wherever possible (they can, however, also rely on expert knowledge to a considerable extend).

##### Table Input

Major data needed for the assessment are material flows and loads (historic data and those of relatively unimpacted systems if possible). Fluxes to be considered are:

- Water
- Sediments
- N, P, C (Si)
- Contaminants

The trend information on expected changes in the DPSIR scenarios across the various scales (how will drivers change and will this affect the loads to the coastal sea?) provide preliminary assessment that sets the stage for dynamic scenario analysis.

The critical thresholds information can be derived from: ecological (State/Impact relationship) as well as political and managerial information (Response) which refers to environmental quality standards, regulations, water directives and other comparable instruments.

The steps taken are outlined in the following tables.

**Table RA1. Major coastal Impacts/Issues and critical thresholds in coastal zones – Overview and qualitative ranking**  
based on change in the region following the key questions

- What are major impacts (coastal issues) along the coastal zone?
- How close are they to a critical threshold of system functioning?

Coastal impact/issue e.g.	Local site/region (contributing river basins) e.g.	Critical Threshold (for system functioning) e.g.:	Distance to Critical Threshold (qualitative or quantitative) e.g.:	Impact category (Impact code and rank of importance e.g. 1-10)	References/ data source
Erosion (coastal geomorphology)	River (Island) ABC - Delta	<ul style="list-style-type: none"> <li>• For coastal stability; Sustained delivery of xy t per year</li> <li>• .....</li> </ul>	Qualitative or quantitative information about the amount needed for coastal security. (e.g., no distance since the sediment delivery due to damming has been reduced to such a level that coastal erosion becomes a continuous process)	Erosion - 10	Database xyz, Reference abcd, 19.....
Eutrophication (habitat loss)	Bay ACEF – (rivers draining into the Bay a,b,c,...)	<ul style="list-style-type: none"> <li>• Seagrasses show signs of destruction;</li> <li>• Occurrence of anoxia or low oxygen in estuaries;</li> <li>• Nutrient load is at the threshold.</li> </ul>	Further increased nutrient load by 20-30% will change the system	Eutrophication - 8	
Pollution	Rivers (Islands) XYZ				

Notes for use

This table is a first priority list of issues for the regional coast based on riverine (i.e. catchment and/or island - based) forcing. It serves to compile as much information as possible on critical fluxes, loads and thresholds for systems functions. It provides a first overview of a remaining capacity for material input or withdrawal that a target ecosystem might be able to handle without observable change. This can refer to a single function such as the stability of a coastal area against erosion. It can also refer to a multicausal impact affecting for example fisheries or water quality. These critical load and threshold estimates return in tables 6 and 7 as part of the “hot spot” and response assessment.

The ranking involves 4 main categories: values 1-3 no or minor importance, values 4-6 = medium importance, values 7-9 = major importance and value 10 = critical.

**Table RA2. DPSI matrix characterizing major catchment-based Drivers/Pressures and a qualitative ranking of related coastal State changes Impacting the coastal zone *versus* catchments size class.**

State change dimension: major; medium ; minor ; no impact; ? = insufficient information.  
Time scale: p = progressive (continuous); d = discrete (spontaneous) n.a. = not applicable

Key questions and examples:

- What are the major (max. 10) driver/pressure settings on river catchment level causing coastal change?
- Can we identify spatial scales on which certain driver/pressure settings dominate coastal issues?

Driver	Pressures	State change			(qualitative index)	Impact on the coastal system	Time scale
		Large basins	Medium basins	Small basins: active coast			
Agriculture	<ul style="list-style-type: none"> <li>Waste/nutrient (excess fertilizer)</li> <li>Increasing sediment transport</li> <li>Water extraction</li> </ul>	minor	medium	major	Small basins: passive coast major	<ul style="list-style-type: none"> <li>Eutrophication;</li> <li>Contamination;</li> <li>Siltation, etc....</li> </ul>	p
	<ul style="list-style-type: none"> <li>Nutrient and sediment sequestration</li> <li>Changing hydrological cycles</li> </ul>	?	major	n.a.	medium	<ul style="list-style-type: none"> <li>Coastal erosion;</li> <li>Nutrient depletion;</li> <li>Salinization</li> </ul>	d
Deforestation	<ul style="list-style-type: none"> <li>Sediment budget alteration</li> <li>....</li> </ul>	minor	major	major	major	<ul style="list-style-type: none"> <li>Siltation;</li> <li>Sediment accretion/ Erosion</li> </ul>	p
etc	etc					etc	

#### Notes for use

Please refer to the basins/islands in your sub-region or for which you have information and make a judgement on how intense the effects of the various drivers on these catchments are and to what extent this may impact on the coastal zone. Ranking here refers to the categories in tables 1 and 3-5; however, it is less detailed here combining in category “minor” importance rank-order 1-3, “medium: importance rank-order 4-6, major importance rank-order 7-10.

State changes in coastal zones driven by a catchment/island – based process will vary according to catchment size, for example: Deforestation even on large scale if conducted in a huge catchment such as the Orinoco will cause a rather moderate if any coastal signal as compared to effects originating from pressures on small catchments or islands where even minor deforestation can dramatically influence the sediment budget in the coastal zone. So, deforestation in some large catchments could be scored a “minor” while in a small catchment it could go score a “major” ranking. Where your information is referring to only one catchment type or class (e.g., large >200.000 km<sup>2</sup>, medium 10.000 – 200.000 and small <10.000 km<sup>2</sup>), delete or ignore the other columns.

Active/passive coast refers to geomorphology, tectonics and climate. Small rivers along the Pacific coast of Latin America for example are in a tectonically rather active area exhibiting high slopes but they also feature high amplitudes of seasonal runoff variation on a yearly time-scale while small rivers draining to other coastal areas and some of the islands are located in tectonically rather passive areas.

**Table RA3. Linking coastal issues/Impacts and land based Drivers in coastal zones – Overview, qualitative ranking and trend expectations on local or catchment scale.**

Key questions:

- What are the major pressure/driver settings at catchment level causing coastal impacts?
- What are the future trends (based on hard data or expert judgement)?

Coastal Impact/issues	Drivers	Local catchment (allowing within and between catchment comparison)	Trend expectations	References/ Data sources
<b>Erosion</b>	Damming	River A/Island A <ul style="list-style-type: none"> <li>• Area...</li> <li>• Volume...</li> <li>• Run off reduction...</li> <li>• .....</li> </ul>	Increasing	XYZ, 2000
	Deforestation	<ul style="list-style-type: none"> <li>• Area...</li> <li>• Residual TSS production...</li> <li>• .....</li> </ul>	stable	
	Diversion	<ul style="list-style-type: none"> <li>• Little, area...; effect on water flow...</li> <li>• .....</li> </ul>	decreasing	
<b>Erosion total</b>	All drivers	In River A	Overall trend	
<b>Eutrophication</b>	Agriculture	River A/Island A Residual nutrient production...	Category	
	Mariculture	Local residual nutrient production...	9	
	Municipal waste	Local urbanisation areas... ; xy t/tear	5	
<b>Eutrophication total</b>	All drivers	residual production In River A	Ranking weighted from information above	
<b>Further issues</b>			Overall trend	
<b>etc</b>				

*Notes for use.*

After finishing River (Island) A, continue with River B,C etc. Where possible please treat pollution separately from eutrophication.

The ranking involves four main categories with values 1-3 = no or minor importance; values 4-6 = medium importance; values 7-9 = major importance and value 10 = critical.

**Table RA4. Linking coastal issues/Impacts and land-based Drivers in coastal zones – Overview, qualitative ranking and trend expectations on country or sub-regional scale;**

Key questions and example:

- What are the major pressure/driver settings on country or sub-regional level causing coastal impact observed?
- What are the future trends (based on hard data or expert judgement)?

Coastal impact/issues	Drivers	Sub-regional (i.e. by country or comparing open versus enclosed seas)	Trend- expectation	References/ data sources
Erosion	Damming	Sub Region A <ul style="list-style-type: none"> <li>• Catchments involved</li> <li>• Area...</li> <li>• Volume...</li> <li>• Run off reduction...</li> </ul>	stable	
	Deforestation	<ul style="list-style-type: none"> <li>• Area...</li> <li>• Residual TSS production...</li> </ul>	increasing	
	Diversión	<ul style="list-style-type: none"> <li>• Little, area...; effect on water flow...</li> </ul>	increasing	
Erosion (total in sub-region A)	All drivers and rivers weighted	b Region A Ranking weighted from information above		
Eutrophication	Agriculture	Residual nutrient production...		
	Mariculture	Local residual nutrient production...		
	Municipal waste	Local urbanisation areas... ; xy t/year residual production		
Eutrophication (total in sub-region A)				
etc.	etc.	etc.		

*Notes for use:*

If you have information about more than one sub-region e.g., Central America, Gulf of Mexico, please treat them separately. Information involved here should summarize the coastal issues for the whole region and consider all the rivers reaching the coast.

The ranking involves 4 main categories: values 1-3 = no or minor importance, values 4-6 = medium importance, values 7-9 = major importance and value 10 = critical.

**Table RA5. Linking coastal issues/Impacts and land-based Drivers in coastal zones – Overview, qualitative ranking and trend expectations on whole regional or continental/sub-continental scale;**

Key questions:

- What are the major pressure/driver settings at whole regional, continental/sub-continental level causing coastal impact observed?
- What are the future trends (based on hard data or expert judgement)?

Coastal impact/issues	Drivers	Full regional (continent or sub-continent)	Trend-expectation	Reference/data source
Erosion	Damming	e.g. Africa or South America <ul style="list-style-type: none"> <li>• Sub-regions involved</li> <li>• Area...</li> <li>• Volume...</li> <li>• Runoff reduction...</li> </ul>	increasing	
	Deforestation	<ul style="list-style-type: none"> <li>• Area...</li> <li>• Residual TSS production...</li> </ul>	stable	
	Diversion	<ul style="list-style-type: none"> <li>• Little, area...; effect on water flow...</li> </ul>	increasing	
Erosion (total in the region)	All Drivers weighted	all region scale	Ranking weighted from info above	
Eutrophication	Agriculture	<ul style="list-style-type: none"> <li>• Residual nutrient production...</li> </ul>	4	
	Mariculture	<ul style="list-style-type: none"> <li>• Local residual nutrient production...</li> </ul>	5	
	Municipal waste	<ul style="list-style-type: none"> <li>• Local urbanisation areas... ; xy t/tear residual production</li> </ul>	10	
Eutrophication (total in the region)				
etc.	etc.	etc.		

*Notes for use:*

This table should be filled in during the workshop since it will help synthesising the working group discussions on up-scaling individual catchment and sub-region based information. The ranking involves 4 main categories: values 1-3 = no or minor importance, 4-6 = medium importance, 7-9 = major importance and 10 = critical.



**Table RA6. Scientific and/or management Response to coastal impact/issues in (continental region) coastal zones on catchment, sub-regional and regional scale.**

Assessment of scientific and/or management Response on the various scales: overview of monitoring programmes and scientific investigations as well as (if applicable) management interventions, environmental quality standards, legislation, river and other commissions).

Key questions:

- What is the current status of response taken at scientific policy and/or management levels against the major coastal issues in the region?

River catchment	RESPONSE Catchment/island scale		RESPONSE Sub-regional/ country scale		RESPONSE Regional scale	
	Scientific	Management	Scientific	Management	Scientific	Management
River (Island) A	e.g. monitoring programme 19--2001, Data: ...; Source:	e.g. commission established; thresholds set; legislation in place... Source:	e.g. (combining catchments A-B-... Programs? Data? Source:	e.g....	e.g. UNEP Regional Seas programme Source:	e.g. quality criteria for the regional waters? Source
River B						
River C						
River D						
River E						

*Notes for users:*

This table describes the current activities dealing with the issues on either a scientific or a policy level. This can include databases and monitoring efforts, local GOOS networks or simply investigations. On policy and management levels, this focus can be on guidelines, threshold values and environmental standards (political critical loads). The scale to which these measures are being applied or should apply should be mentioned.

The information and ranking of DPSIR scenarios (tables 1-5) together with this "Response" information should lead to the identification of "hot spots" to be listed in Table 7.

**Table RA7. “Hot spots” of land-based coastal Impact and gaps in understanding; a first overview of issues to be addressed in future research (identifying the appropriate scale for the design of a new scientific effort).**

Key questions:

- What are the major gaps in our current understanding of river catchment - coastal sea interactions?
- Which “hot spots” should be addressed in a future integrated scientific effort (natural and socio economic disciplines)

River catchment/ island	“Hot spot” catchment/island scale		“Hot spot” sub regional/ country scale (e.g., a certain island group or the Meso- American Reef region)		“Hot spot” regional scale	
	Key trend and gaps	Scientific approach	Key issue, Trend and gaps	Scientific approach e.g....	Key issue, Trend and gaps	Scientific approach ...
River (Island) A	...	<ul style="list-style-type: none"> <li>• Biogeochemical studies</li> <li>• Residual calculation by economic sectors</li> <li>• Critical flux investigation</li> <li>• Stakeholder and scale analysis</li> <li>• ACTION</li> <li>• ....</li> </ul>			...	...
River B						
River C						
River D						

Notes for use:

This table extracts from the regional assessment the potential demonstration sites, which can be included in a proposal for a future Regional Catchment/Coast Assessment Project - “...Cat”. Ideally the sites should represent different settings which are typical for a special sub-region. This would allow up-scaling of the findings to comparable “classes” of catchment/coastal systems at a later stage. An accompanying note may be given informing about ongoing activities, link suggestions and key contact persons.

Emphasis should be on the human dimensions of catchment-coastal sea interaction considering the co-evolution of natural and societal systems (i.e. involving natural and socio-economic sciences).

## **Appendix II    CariBas I and II Meeting Reports**

Both the CariBas regional study and the Oceania Basins desk research were a direct follow-on from the 4<sup>th</sup> LOICZ Open Science Meeting, held in Bahia Blanca, Argentina, in November 1999. There, a global island regions working group recommended regional Basins assessments of island-dominated regions, to be included in the first LOICZ global synthesis planned for late 2002.

The Caribbean Basins (CariBas) assessment and synthesis was carried out in two phases. Based on a desk study commissioned to the University of South Carolina and key scientists of the CARICOMP network a first, general workshop (CariBas 1) was held in Trinidad, in December 2000. A second workshop, CariBas 2, held in Miami, Florida in June 2001, refined the earlier assessment and focussed on the human dimension. CariBas 2 also worked towards a sound scientific basis on which to develop project proposals addressing indicators for coastal monitoring as well as river/island-based and coastal management issues.

### **CariBas 1 - Institute of Marine Affairs, Chaguaramas, Trinidad, 7-9 December 2000**

The regional assessment (CariBas 1) conducted in Trinidad, together with the preceding desk study, provided a comprehensive overview of the current understanding of catchment–coastal sea interaction in the Caribbean encompassing both island-based coastal issues such as in Trinidad and Jamaica and issues along the Caribbean mainland coasts, such as the Meso American Barrier Reef. Using geomorphologic and hydrologic characteristics, the working groups provided initial descriptions of the key drivers and their pressures on the catchment coast continuum. Impacts were analyzed and critical threshold information was identified. The DPSIR scheme (Turner *et al.* 1998) was evaluated and applied to standardize the descriptive approach and enable inter-regional comparison across various spatial and temporal scales.

The information compiled in this process was to be developed further to an “expert typology” of the regional systems and their change under various forcing in a second step. This should include a DPSIR-based ranking to derive from the further synthesis refined threshold information and a trend analysis. Issues addressed covered:

- Coastal geomorphology
- Coastal habitats/biodiversity
- Climate influence
- People relationships (demography and drivers)
- Catchment size and seasonal runoff features
- Land use and cover characteristics

The information obtained before and during the workshop was to be distilled using a set of LOICZ-Basins assessment tables, and made available for the second workshop in 2001.

### **CariBas 2 - Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Florida, USA, 28-30 June 2001**

Following a welcome address provided by Dean Prof. Otis Brown and Assistant Prof Liana Talaue McManus, on behalf of the Rosenstiel School, an introduction to LOICZ by Dr Hartwig Kremer provided the background of the progress made since 1999 towards a new globally applied LOICZ-Basins assessment of catchment/island - coastal sea interaction and human dimension studies. Developments made in the methodology since CariBas 1 in 2000 were presented, in particular the standardised regional assessment tables developed for global application. The strong focus on driver/pressure and response aspects characterising the evaluation of changes reflected the increasing recognition of community issues in the LOICZ work.

Prof Bjorn Kjerfve summarised the key findings of the first meeting (see above) and Dr Kremer commented on the relevance of the LOICZ-Basins approach and findings for the global efforts of

UNESCO/ IOC in their Integrated Coastal Area Management, ICAM and C-GOOS initiatives. He pointed out that the overall regional engagement of LOICZ would be supported by the IOC and should therefore be seen also as a contribution to the activities of their IOCARIBE Sub-Commission. While initially supported also by the Inter American Institute for Global Change Research (IAI), CariBas results will also be communicated to the regional scientific agendas developed by the IAI for future global change research in the Americas. The results generated on regional levels and pilot studies to be addressed in future research under the aegis of LOICZ would prove valuable within IOC's and IAIs' networks. IOC will support further development of CariBas-related project proposals in South America.

A detailed introduction and subsequent discussion provided the background and scientific rationale of the key questions leading through the set of seven assessment tables. Dr Kremer explained the input expected for each of the tables and how to process available information for up-scaling from local to regional scales. Critical loads and thresholds were emphasised. These allow determination of the current state of coastal systems in the context of expected trends of change and, where information is sufficient, the derivation of semi-quantitative measures of critical loads status and metrics needed for sustained system functions. Examples were shown (from earlier SAmBas assessments) and it was pointed out that a parallel study on the purely island or atoll dominated Oceania region was underway which may prove valuable for island-based studies in the Caribbean.

Presentations of catchment/island-coast biogeochemical critical threshold and socio-economic information was evaluated posing the key LOICZ questions:

- how are humans altering the mass balances of water, sediment, nutrient and contaminant fluxes, and what are the consequences?
- how do changes in land use, climate and sea level alter fluxes and retention of water and particulate matter in coastal zones, and affect morphodynamics?
- how can we apply knowledge of processes and impacts of biogeochemical and socio-economic changes to improve integrated coastal management?

Site descriptions, regional synthesis and key driver evaluation were provided for river/island - coast systems in various sub-regions, including:

#### **General Caribbean:**

- Approaches and analytical tools for integrated assessments of Caribbean river basins

#### **Island based issues**

- Caroni River Basin, Trinidad
- Buccoo Reef and Bon Accord Lagoon, Tobago
- Kingston Harbor, Jamaica

#### **Mainland Caribbean coast**

- Parque Nacional Morrocoy, Venezuela
- Magdalena River and other Caribbean rivers of Colombia
- La Estrella River basin and soil erosion effects on the Cahuita Reef system, Costa Rica
- Caribbean economies with particular reference to the role of the tourism industry
- Meso-American Barrier Reef (Mexico, Guatemala, Belize, Honduras)

#### **Driver evaluation**

- Caribbean economies with particular reference to the role of the tourism industry

In breakout groups, draft versions of assessment tables produced prior to the meeting were revised and amended taking into consideration both the results of other LOICZ-Basins workshops and new information. Gaps from the first phase were the paucity of information on island systems and on socio-economic background data. Special attention was paid to indicators and critical loads and how to apply a

system view to allow determinations between land-based (anthropogenic) and more globally driven (climate and sea-level change) pressures and impacts. While there is some information on fluxes and land-use patterns, in some cases covering reasonable time-frames of data-sampling, indicators reflecting human development and their influence on water and material transports are rather scarce. The issue of integrated indicators was highlighted since it was recognised that while the Caribbean is quite data-rich, the quality and scope of data is often inappropriate for integrated systems analyses.

### **Outcomes and Wrap-up**

- Assessment tables including the latest information available to the participants (chapter 2 and 5) were produced, covering sites, sub-regional and regional scales. Trend information on future changes and the current status of response were included where possible. Critical load/threshold information was provided for some sites.
- The meeting agreed to produce its findings in the form of a multi-authored LOICZ R&S volume, providing first regional pictures designed using the DPSIR framework. Expansion of the extended executive summaries to full scientific publication for joint publication in the peer-reviewed journal “Regional Environmental Change” by Springer publishers was an option welcomed by the participants.
- The CariBas network has encouraged the development and design of regional proposals for holistic future work. This work (and optional task proposals, see Chapter 3) would be promoted through LOICZ working closely with UNESCO/IOC. Earlier work conducted along these lines such as the SARCS/WOTRO/LOICZ project in South East Asia and the European Basins project “EuroCat” will provide a sound template for the draft of a “CariCat”. Prof. Bacon agreed to coordinate this effort in the region in cooperation with Profs Kjerfve and Wiebe. The meeting agreed further to pursue formal and/or operational links with ongoing international efforts such as the ICAM (Integrated Coastal Area Management) and GOOS (Global Ocean Observation System) of UNESCO/IOC, and the IAI, providing for global application and use of the outcomes.

CariBas participants and the LOICZ IPO expressed their special thanks to Prof. Liana McManus and her team namely Marlen Solotongo for the excellent organization, support and hosting of this second CariBas workshop. Financial support from UNESCO/IOC and LOICZ was gratefully acknowledged.

### **Appendix III. CariBas I and II Workshop Agendas and Participants**

#### **CariBas I**

**Institute of Marine Affairs, Chaguaramas, Trinidad, 7-9 December 2000**

##### **Agenda**

##### **6 December 2000**

Arrival of participants

##### **7 December 2000**

0900-0930 Welcome address by Ms. Hazel McShine, Director, Institute of Marine Affairs  
0930-1000 Caribbean basins and coastal impacts: the LOICZ perspective - B. Kjerfve  
1000-1030 Reception arranged by the Institute of Marine Affairs  
1030-1130 Caroni Basin - Peter Bacon and Rahanna Juman  
Morrocoy - David Bone  
Kingston Harbour - Trion Clarke and Dale Webber  
Cahuita - Ana Fonseca and Jorge Cortés  
1130-1200 Review of workshop objectives  
1330-1530 Work Session at the IMA  
1600-1730 Work sessions at the IMA

##### **8 December 2000**

0830-1000 Work session at the IMA  
1030-1230 Work session at the IMA  
1230-1830 Field trip through the Caroni basin and swamp to the coast  
1900-2300 West Indian dinner surprise at the home of Rahanna Juman

##### **9 December 2000**

0830-1000 Work session at the IMA  
1030-1200 Work session at the IMA  
1330-1530 Work session at the IMA  
1600-1730 Concluding session at the IMA

##### **10 December 2000**

Departure of participants

#### **CariBas I Workshop participants**

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Figure AIII.1. Participants from left to right: Peter Bacon, Trion Clarke, David Bone, Rahanna Juman, Eugene Ramcharan, Lloyd Gerald, William J. Wiebe, Ana Fonseca, Björn Kjerfve, Dennis Pantin.

**CariBas II Workshop**  
**Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, Florida, USA,**  
**28-30 June 2001**

**Agenda**

**27 June 2001**

Travel to Miami, Florida, USA

**28 June 2001**

09:00-09:30 Workshop registration, RSMAS, University of Miami

09:30-10:00 Opening session

Presentation by H. Kremer, LOICZ

Welcome address by RSMAS Dean O. Brown

Welcome address by local host L. T. McManus

Address by CariBas Task Leader B. Kjerfve

1100-1230 Plenary Session on Coastal Issues, Drivers, Pressures and State/State-Changes in the Wider Caribbean – and overview of CariBas I results and gaps

1400-1730 Introduction to the LOICZ regional Basins Assessment Tables Issues/Impacts (critical thresholds, trends and ranking – building an expert typology) based on coastal change in the region of concern.

**29 June 2001**

09:00-12:30 Plenary and working group sessions (working on tables): Coastal Issues & land based forcing – catchment & bigger sub-regional and regional scales

14:00-17:30 Identification of “Hot spots” and key scientific questions for future work;

Discussion of LOICZ/CariBas/CariCat proposal ideas

**30 June 2001**

09:00-11:30 Planning for LOICZ/CariBas proposal

- What, Why (Regional and Global Relevance), Where,
- How, (incl. structure),
- Who, (identify co-ordinators and get commitment to finish and submit proposal/s),
- Funding, Timelines.

11:30-12:30 Concluding Plenary

- Approval in plenary of products, proposal suggestions, commitments, timelines
- Strengthening the CariBAS Network
- Conclusion
- Outlook

**1 July 2001**

Departure of participants

**CariBas II Workshop participants**

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**Figure AIII.2. CariBas II participants (left to right): Björn Kjerfve, Hartwig Kremer, Marlene Attzs, Ana Fonseca, David Bone, Rahanna Juman, Peter Bacon, Trion Clarke, Bill Wiebe, Juan Restrepo, Bruce Hatcher.**

## Appendix IV Terms of Reference

### LOICZ Caribbean Basins (CariBas)

#### **Concluding workshop (CariBas II) on horizontal material fluxes (river and island runoff) to the coastal zone and human dimensions of change (Impacts of land-based activities on coastal seas of the Wider Caribbean)**

**Rosenstiel School of Oceanography, University of Miami, Florida, USA  
28-30 June 2001**

CariBas, the regional assessment and synthesis of land-based drivers and their coastal impact and related change, was conducted in a two-step approach (desktop study and first scoping workshop and concluding workshop). While the TOR given below apply in principle to the whole process, they guided in particular the last concluding workshop held in Miami. The results of the first meeting and desk research were reviewed and synthesised in this second meeting.

#### **1. Introduction - the LOICZ-Basins background**

The discussion on global change issues in coastal zones and integrated coastal management focuses increasingly on the interplay between river catchments and the coastal sea. Coastal zone processes and issues are reviewed as a systemic, i.e. receiving, part of the whole water continuum. This reflects in an increasing number of targeted programs and key actions such as the new European 5<sup>th</sup> Framework Program as well as among UNESCO, UNEP and GEF based/supported initiatives. The International Geosphere Biosphere Program, IGBP, responds through concentrating considerable effort on the human dimension of global change issues taking the whole water cascade as a scale. Some of these issues are addressed in the “water group” initiative of IGBP, to which LOICZ contributes on various levels such as the Sediment/Runoff Group (J. Syvitski) and the Basins core project (Wim Salomons, H. Kremer).

#### **2. The LOICZ-Basins Strategy**

The LOICZ-Basins core project is working *inter alia* to develop a global evaluation of the importance of coastal seas as receiving bodies of land-based and globally driven changes of horizontal material fluxes such as carbon, nitrogen and phosphorus as well as water and sediments. The scale applied to assess these pathways including groundwater is the river catchment scale (or whole islands, if appropriate). Beyond giving an overview on coastal zone functioning as sink or source for nutrients and carbon, priority attention is paid to the relative importance of these materials and their biogeochemical cycles as indicators. In other words, to what extent do they represent environmental functioning and sustainability of goods and services provision under the dynamic natural and anthropogenic forcing of change. Assessment and modelling therefore aim to focus on residual transports of materials (C, N, P, sediments, others) as key indicators. This is usually referred to as the human dimension of coastal change. Changing fluxes impacting the state of the environment and their feedback on the socio-economic system functioning are to be reviewed against the conceptual question of critical thresholds of loads reaching the coastal zone and their potential to force systems to flip.

One challenging aspect in this kind of assessment is to review coastal changes and issues from the perspective of catchment-based *drivers, pressures and state changes* (fluxes and material cycles). Another is to derive from those figures some information on *critical thresholds* for the coastal change issues of concern based on

- a) political regulations,
- b) environmental monitoring including historical information and
- c) stakeholder perception and requirements for coastal use (land- and sea-based).

Beyond the regional studies, the LOICZ commitment to global assessment of coastal change requires a basis for interregional and global comparison and up-scaling. LOICZ-Basins therefore continues to identify classes or defined types of coastal sea/river systems and to describe interaction and change through qualitative or semi-quantitative ranking of drivers and pressures applied to a catchment (or island) scale. These can also be linked to classes or types of state changes observed in the coastal zone. The latter refers to biogeochemical but also biological state parameters and may also encompass changes in human use such as sediment increase affecting aquaculture business for example. The ranking into categories as done by the experts of the various regional networks is under parallel development within the South American, Asian, African and European Basins studies. It is intended that the information, the categorization and the ranking will eventually – after further refinement and quantification – be used as an entry into the LOICZ typology clustering tool, which is under continuous refinement. This effort is conducted in co-operation with parts of the IGBP BAHC (Biospheric Aspects of the Hydrological Cycle) programme (see [www.nioz.nl/loicz/](http://www.nioz.nl/loicz/) or <http://www.kgs.ukans.edu/Hexacoral/Tools/tools.htm>).

As with other regional LOICZ-Basins efforts, Caribbean Basins will continue improving the level of standardization of approaches in addressing the coastal issues in a holistic way. For this purpose, the simple DPSIR: *Drivers, Pressures, State (State Change), Impact, Response* framework (OECD 1993 and LOICZ R&S No. 11, 1998) provides the underlying descriptive framework helping to sketch the various forcing functions and boundary conditions. In a mid-term perspective this approach is seen to enable assessment and modeling of coastal change on the delivery and use of environmental goods and services, their scientific and monetary equivalents and to review the political *response* and options. Caribbean Basins expands on earlier assessment efforts in the wider American region: South American Basins (SAmBas) held in late 1999 in Bahia Blanca and May 2001 in Fortaleza, Brazil (LOICZ R&S Report 21) and the CariBas desk study which commenced in 2000 and is in its final stage.

### 3. Links and Synergies

Within the broader context of the IGBP, LOICZ-Basins provides the scientific frame in which mid- and long-term collaboration with other core projects such as BAHC (Biospheric Aspects of the Hydrological Cycle – see typology), LUCC (Land Use and Cover Change) and PAGES (Past Global Changes) as well as with the IHDP and WCRP will be developed and strengthened. Implications and links with new global change programmes expected under the second phase of the IGBP (2003+) such as the Land and Ocean programmes will be investigated as appropriate.

With regard to science exploitation and application, the issue-driven and human dimensions-oriented character of LOICZ-Basins investigations on catchment or island scales and related coastal zones have an implication for coastal zone management. Engaging with users in policy advisory groups and with the private sector therefore is a necessity for the demonstration projects resulting from the current study. In Europe the operational example is (EuroCat: <http://www.iiia-cnr.unical.it/EUROCAT/project.htm>). The approach and the results have good potential to serve the objectives of intergovernmental organizations and LOICZ-Basins therefore continues to build its working relations with UNESCO/IOC and its ICAM (Integrated Coastal Area Management) and C-GOOS (Coastal Global Oceans Observing System) programs. On sub regional scale this might find operational links with the IOCARIIBE and IAI activities.

However, LOICZ-Basins results, particularly from the *Response* aspect (i.e. policy and management response to coastal change), may also fertilize discussion on more local management needs dealing with catchment/coast interaction issues or classes of those. Response investigations provide insight into how society acknowledges the *Pressure - State-change and Impact relation* and how this is reflected in either success or failure of sustainable coastal use/management, especially when the time between at least two investigations at the same location is considered. A global synthesising effort such as LOICZ can thus provide decision-makers with relevant scientific indicators and trend analysis to enable this judgement, while remaining a neutral platform for joint discussion and generation of joint ownership of issues among science and users. Examples in Europe are a Rotterdam – Rhine project dealing with forecasting of sediment quality, where LOICZ-Basins provides a scientific frame for trend analysis and interdisciplinary catchment scale approaches against concrete user needs ([http://w3g.gkss.de/ia/dredged\\_material/index.html](http://w3g.gkss.de/ia/dredged_material/index.html)).

#### 4. Specific Workshop Objectives

1. Review, complete and/or develop further, the state of the art reports of river catchment – coastal sea interactions as developed in the Bahia Blanca 1999. Set up a first qualitative or semi-quantitative system to categorise key pressures and state change settings providing a ranking order as a data entry for up-scaling purposes on regional scale (see 2).
2. Scale up the information to broader regional and global synthesis using the ranking system provided (and adapted to regional conditions when necessary) by identifying and clustering areas of similar change features. This may benefit from the use of typology tools and the Drivers, Pressures, State, Impact, Response framework, DPSIR, for standardised site classification.  
Due to the large differences in coastal change, uses, management status and legislation among the different countries in the Caribbean region, up-scaling using a typology approach may not be a simple exercise. Finding the best proxy for observed coastal change and adapting and optimising to the regional reality should also constitute a major objective of the present workshop in close relation to the other LOICZ core projects, e.g., the regional biogeochemical budgeting effort (UNEP/GEF).
3. Provide the regional data and information base for an interregional/global LOICZ-Basins core project synthesis by the principal investigators, to summarize the available regional information to an overall *global LOICZ Basins synthesis* planned for publication in 2003.
4. Review, based on earlier and new information, the set of pilot areas discussed in Bahia Blanca and those expected to be part of the CariBas report as well as identify possible new ones. This is aimed to develop proposals for specific case studies integrating natural and socio-economic sciences and to elaborate on the “human dimensions” of global change along the catchment–seawater continuum.
5. strengthen a regional Caribbean or if appropriate Latin American Basins network to continue the science and synthesis, to strengthen existing and to seek new value-added links to other projects and organisations such as UNEP, GIWA, IOC-UNESCO (GOOS and ICAM), START and IHDP. This will be facilitated through the LOICZ platform; but will only be possible with the involvement of national scientific programs and agencies.

#### 5. Focus of workshop

To achieve the objectives outlined the workshop aims to work along the framework of the DPSIR scheme. The process of *assessment, analysis, categorisation and indexing* will make use of a tabulated approach which is applied also in other regional Basins studies and is developed along a set of key questions. (see Basins approach and regional assessment tables in Appendix I).

##### For clarification of nomenclature in the DPSIR scheme as a descriptive framework:

Catchment-based activities (land use and land use change) with consequences for the coastal zone are **DRIVERS** such as:

- Effects of damming and other huge constructions;
- River diversion and effects of irrigation and water supply activities (abstraction);
- Influence of industrial, agricultural and domestic wastes (urbanisation, tourism);
- Mining activities.

They cause **PRESSURES** on ecosystem and social system functioning, affecting the **STATE** and hence **changing** the **STATE** of the coastal environment due to natural and anthropogenic forcing. This follows the scientific guidelines of the LOICZ global synthesising experiment taking:

- Water, nutrient and sediment transportation throughout the catchments/islands as key indicators for change across the boundaries of the water pathway. (Indicators are designed to give an overview of the environmental status and its development over time and finally allow the development of the critical load information and index systems linked to pressures);
- Geomorphologic settings, erosion, sequestration (retention times in the catchment); as well as
- Economic fluxes relating to changes in resource flows from coastal systems, their value and changes in economic activity.

**IMPACTS**, which are observed effects on coastal systems and how they are expressed, i.e., habitats, biodiversity, social and economic functioning and resource and services availability and use. They translate into the **COASTAL ISSUES** from which the assessment process embarks. And finally the

**RESPONSE**, reflecting action taken (coastal management) to either protect against change such as increased nutrient or contaminant input, secondary sea-level rise by means of reduced sediment loads etc, ameliorate adverse effects and ensure sustainable use of system's resources.

## 6. Products and Expectations

Successful Caribbean Basins assessment will lead the way to:

- Provision of the information needed for the LOICZ *regional synthesis* the backbone of which will be a LOICZ R&S series volume along the workshop focus addressing key issues of the following topics:

LOICZ R&S Volume – Caribbean Basins

LOICZ Global Change Assessment and Synthesis of River Catchment (Island) – Coastal Sea Interaction and Human Dimensions of Change

1. COASTAL IMPACT/ISSUES (environmental and socio economic focus)
    - 1.1 Providing an expert based ranking
    - 1.2 Categorise the relevance of Impacts
  2. DRIVERS
  3. PRESSURES
    - 2.1 Providing an expert based ranking
    - 2.2 Categorise the relevance of Pressures
  4. STATES and STATE-CHANGES (Fluxes, Material cycles)
  5. RESPONSE
    - 5.1 Socio-economic and Political/Legal settings
    - 5.2 Changes of these settings
  6. REGIONAL UP-SCALING
    - 6.1 Typology development – Driver/Pressure/State/Impact/Response scenarios employing ranking of the various aspects (optional – subject to data availability);
  7. TREND ANALYSIS
    - 7.1 Expert prediction of future trends of key parameters and developments of change;
  8. GAPS
    - 8.1 Data and Information gaps;
    - 8.2 Efforts/Commitments needed to fill these gaps.
- 

- drafting of a *follow-up proposal* (optional for the CariBas network) aimed at integrated cross-disciplinary, i.e. combining natural and social science, pilot studies complementing those under parallel development within the other regional Basins efforts.  
(As outlined earlier a key criterion for their selection is the potential for up-scaling i.e. to be representative for a certain type of catchment - coastal sea systems and driver interaction that is characteristic for a sub region)
- information flow into the first *global LOICZ-Basins synthesis* and provide the input for the respective LOICZ Synthesis Book Chapter.

## 7) Workplan (tentative)

- The workshop is to be held 28-30 June 2001, in Miami, USA;
- Background documents, (SAmBas I report (Meeting Report Vol. 37, 1999), LOICZ R&S report No 11 and first draft report CariBas (currently in the editing process); further information will either be delivered prior to the meeting or made available through the web R&S No. 11 on Integrated Modelling and the DPSIR can be downloaded as a pdf file from <http://www.nioz.nl/loicz/>

- Participants will be asked to start filling the LOICZ-Basins regional assessment tables against the key questions outlined prior to arrival to enable targeted working through those key questions during the first half of the meeting.
- Participants list will be circulated subject to expression of interest returned to the organizers.
- Products foreseen will be a LOICZ Reports & Studies volume (R&S) published jointly with the partner organisations the draft to be prepared during the meeting and finalised within four months after the workshop. Special publications in peer-reviewed journals are encouraged.
- The meeting will agree on timelines and approve the schedule for and contents of products to be delivered.
- Pilot areas will be identified at the meeting and drafting of the proposals will be a participant's task already in the meeting – subject to approval by the meeting.

## **8. Participants**

The scientists who have been or will be approached for expression of interest are researchers from Latin America and elsewhere who are exposed through their field of research to the issues of relevance. The workshop is supposed to be highly product-oriented and attendance will therefore be limited to a maximum of 20 to 25 participants including LOICZ resource scientists and organisers and plus technical secretarial support (preferably asked from the local organiser). Invitation and support will be based on expression of interest and approval of this TOR – especially the workplan - expressed to the organisers.

## **9. Concluding Remark**

Appropriate inclusion of socio-economic information in the analysis and development of pressure–state–response indices usually turns out to be the major challenge and to have the biggest gaps in appropriate networking and should therefore be a priority issue in the process of network formation and further development. The network is therefore encouraged to identify respective capacities in their surrounding and encourage the participation of the appropriate people.

In the process of verifying and approving demonstration sites for which to draft holistic project proposals, emphasis will be put on both the potential to up-scaling and management relevance and on the broader contribution to global and regional projects.

## **10. Further Working Documents**

A draft program for the workshop will be circulated by email; further background information, the key questions and related LOICZ-Basins regional assessment tables will be provided with some examples and a set of empty forms for preparation work.

## Appendix V List of acronyms and abbreviations used

AfriBasins	African Basins Programme (LOICZ)
BAHC	Biospheric Aspects of the Hydrological Cycle
CariBas	Caribbean Basins Programme (LOICZ)
CARICOMP	Caribbean Coastal Marine Productivity project
C-GOOS	Coastal Global Ocean Observing System
CONICET	National Scientific Investigation Research Council (Colombia)
DEFINITE	Decisions on a Finite Set of Alternatives, software for multi-criteria analysis
DPSIR	Driver-Pressure-State-Impact-Response Framework
EC\$	Eastern Caribbean dollar
EuroCat	European Catchment Project/part of the “European Land Ocean Interaction Studies”, ELOISE cluster, DG Research
GEF	Global Environmental Facility
GIWA	Global International Waters Assessment
GOOS	Global Ocean Observing System
IAI	Inter American Institute for Global Change
ICAM	Integrated Coastal Area Management
ICZM	Integrated Coastal Zone Management
IOCARIBE	Caribbean regional sub-commission of IOC
IDEAM	Institute of Hydrology, Meteorology and Environmental Studies of Colombia
IGBP	International Geosphere-Biosphere Programme; A Study of Global Change
IHDP	International Human Dimensions Programme on Global Change
ILTER	International Long-Term Ecological Research Network
IMF	International Monetary Fund
INGEOMINAS	National Institute of Mining and Geology, Colombia
IOC	Intergovernmental Oceanographic Commission (UNESCO, Paris)
INVEMAR	Institute of Marine Research, Punta Betin, Colombia
LOICZ	Land Ocean Interactions in the Coastal Zone
LTER	Long-Term Ecological Research
LUCC	Land Use and Cover Change
MONERIS	Modelling Nutrient Emission in River Systems
OSM	Open Science Meeting
PAB	Policy Advisory Board
SAmBas	South American Basins Programme (LOICZ)
SARCS	South Asia Committee for START
SeaWiFS	Sea Viewing Wide Field of view Sensor project
SINAM	National Program of Monitoring Marine Ecosystems, Colombia
START	Global change system for Analysis, Research and Training
SWOL	SARCS/WOTRO/LOICZ – South East Asian LOICZ core project 1996-99
UNDP	United Nations Development Program
UNEP	United Nations Environment Programme
UNESCO	United Nations Education and Cultural Organization
WCRP	World Climate Research Programme
WOTRO	The Netherlands Foundation for the Advancement of Tropical Research
WP	Work Package

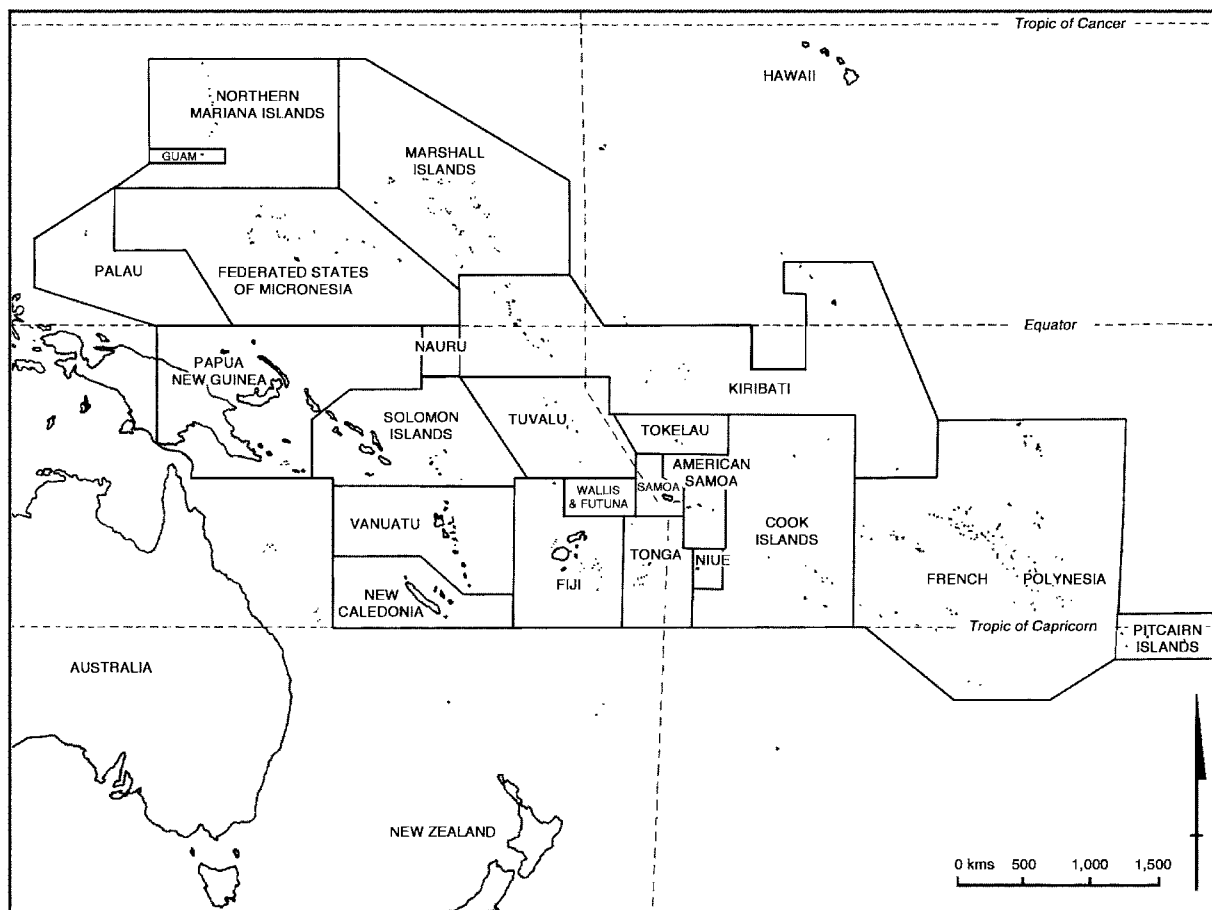




## II. Literature review and categorization (development of indices) of natural and anthropogenic material fluxes and their impact on environmental and socio-economic systems in the coastal zone of islands in the Oceania Region.

### 1. Introduction

In May 2001 LOICZ commissioned the Department of Geographical and Environmental Studies, Adelaide University, Australia to undertake a desk-top study to describe the significance, cycling and expected trends of water, sediment, nutrient, carbon and contaminant fluxes in the coastal zone of the Oceania Region (Figure 1). Details on the activities and output required can be found in the consultancy brief, which is appended to this report (Appendix II).



**Figure 1. The Oceania region.**

For the purposes of this study, the Oceania Region was defined as including the following nations, dependencies and territories (Table 1).

Oceania is served by the Secretariat of the Pacific Community (SPC) and the South Pacific Regional Environmental Program (SPREP). The SPC is a non-political organisation delivering technical development assistance, training and applied research to the region through advisory and consultative activities; and SPREP is a regional organisation established by the governments and administrations of the Pacific region to protect its environment. This is reflected in the Mission Statement of SPREP which calls on the organisation, 'to promote cooperation in the South Pacific region and to provide assistance in order to protect and improve its environment and to ensure sustainable development for present and future generations'. Although reference (in the literature) is often made to the study area as 'the South Pacific', Oceania is a more precise description, since Micronesia and other island groups extend well north of the equator.

**Table 1. Nations, dependencies and territories in Oceania.**

<b>Nations</b>	<b>Dependencies and Territories</b>
Fiji	American Samoa
Kiribati	Cook Islands
Marshall Islands	French Polynesia
Micronesia	Guam
Nauru	New Caledonia
Palau	Niue
Papua New Guinea	Northern Mariana Islands
Samoa	Pitcairn Islands
Solomon Islands	Tokelau
Tonga	Wallis and Futuna Islands
Tuvalu	
Vanuatu	

The popular view that Oceania is a vast tropical paradise is misleading, since much of the region has environmental problems such as widespread destruction of mangrove forests and coral reefs around population centres, runaway urbanization, overfishing, deforestation of upland and coastal forests, soil erosion, misuse of pesticides, pollution of rivers and drinking water supplies, improper disposal of industrial and municipal wastes, lack of sewage treatment facilities and biological impoverishment (Hinrichsen 1998). The environmental and human impact of nuclear fallout from British, American, French and Soviet bombs and radiation (leaking from nuclear dumpsites) may never be known (Danielsson 1984; Henningham 1995; Hinrichsen 1998).

Due to a paucity of published information on the cycling of water, sediment, nutrient, carbon and contaminant fluxes in the coastal zone of the Oceania region, the study focussed on and expected trends. The investigation of nutrient fluxes in the coastal zone of the Oceania region was excluded due to a lack of information, but a section on chemicals and hazardous waste was added.

## **2. Natural and anthropogenic fluxes**

### **2.1 Water**

#### *Significance*

Oceania has a chronic freshwater shortage (Dahl 1984; Hinrichsen 1998). In the Marshall Islands (an extreme example) the lack of fresh water is a serious problem for both rural and urban areas (Price and Maragos 2000), so that water rationing has been imposed and water is routinely supplied for only one hour every second day (Hinrichsen 1998). Urbanisation, domestic sewage and solid waste, agricultural wastes and industrial wastes all threaten the quality and supply of fresh water, in particular to low islands (Cocklin and Keen 2000; UNEP 2000).

Polluted rivers and drinking water supplies are common in Oceania. Fresh water is often polluted from untreated municipal waste, urban sewage, agricultural runoff (Dahl 1984; Brodie and Morrison 1984; Convard 1993; Hinrichsen 1998) and mining (Bains and Morrison 1990; Maun 1994; Henningham 1995; Hinrichsen 1998; Overton and Scheyvens 1999). In Papua New Guinea, the Fly River has been polluted by the BHP OK Tedi mine since 1984, with millions of tonnes of polluted tailings every year (Hinrichsen 1998; Harper and Israel 1999). During the years 1984-1989 the mining company was given virtually free rein on dumping waste into the Fly (Harper and Israel 1999). These wastes contained significant levels of copper, a toxic metal for aquatic ecosystems (Harper and Israel 1999).

Accidental spillages of cyanide into the Fly River (Viner 1984; Baines and Morrison 1990; Hinrichsen 1998; Harper and Israel 1999) have killed thousands of fish and crustaceans and scores of saltwater crocodiles. Contamination of aquatic life in the Fly River has caused losses of important food sources for the locals

living along the river (Overton and Scheyvens 1999). The extensive environmental damage finally resulted in a multi-million dollar compensation court ruling in June 1996 in favour of the local communities (Hinrichsen 1998; Harper and Israel 1999); \$320 million to be used for pollution control and \$32 million to relocate whole villages (Hinrichsen 1998).

The effect of the Bougainville Copper Mine (ceased 1990) on the Jaba River (Papua New Guinea) is a similar tragedy (Baines and Morrison 1990; Henningham 1995; Hinrichsen 1998; Overton and Scheyvens 1999). The Jaba River was routinely polluted with sediments and heavy metals from mining operations (Hinrichsen 1998:137). An estimated 135,000-150,000 tonnes of contaminated tailings were dumped into the Jaba River every day (Hinrichsen 1998; Baines and Morrison 1990), and in 1988 alone approximately 48 million tonnes was disposed of into the Jaba River system in the form of tailings (Henningham 1995). In New Caledonia, rivers turned orange-red from soil from open-pit mines (Hinrichsen 1998); and in Guam high levels of heavy metals, in particular mercury, have been found in water supplies (Zucker 1984).

Coastal waters in the Oceania region are also polluted by industry (Brodie and Morrison 1984; Convard 1993; Hinrichsen 1998; Cocklin and Keen 2000; UNEP 2000). Industries such as fish canning, sugar milling, beer brewing and edible oils processing are significant regional pollutants of marine waters (Convard 1993 in UNEP 2000).

Quantitative information (where available) on industrial pollutant loadings reaching marine waters is available for each country and industry (UNEP 2000). Table 2 shows the industrial pollutant loadings for Papua New Guinea, as an example.

**Table 2. Industrial pollutant loadings for Papua New Guinea.** Data taken from UNEP (2000).

Country	Process	B.O.D. t/yr	S.S. t/yr	Oil T/yr	N t/yr	P t/yr	Other t/yr
Papua New Guinea	Edible oils	246,6	974,6	764,3			
	Brewing	48,9	8				
	Sugar milling	213,44	100,8				

Many hazardous and toxic wastes such as solvents and heavy metals associated with medium-scale industrial bases in Fiji and Papua New Guinea are not well-documented (UNEP 2000). Industrial waste loading in Oceania is increasing, as is the toxicity (Convard 1993).

Domestic activities are the major contributor to marine pollutant loads in Oceania (UNEP 2000). Suva Harbour, in Fiji, is toxic from untreated domestic and industrial effluent, organic chemicals, heavy metals and toxics (Hinrichsen 1998; UNEP 2000). Elsewhere discharge of sewage directly into lagoons or onto reefs, and toilets built directly over the sea on some atolls is common (Thistlewaite and Votaw (1992), cited in Cocklin and Keen (2000)).

Public health problems that arise from the degradation of fresh and marine water quality are serious issues in Oceania. Problems through water-related diseases (e.g., diarrhoea and gastrointestinal illness) and contamination of resources, plus the increased economic costs for treatment, result in significant socio-economic implications for the region (UNEP 2000). For example in Suva, 95% of mangrove shellfish collected at eight sites were found to exceed World Health Organization limits for human consumption" (Bryant-Tokalau (1995), cited in Cocklin and Keen (2000)).

Milliman *et al.* (1995) suggest that 3900 km<sup>3</sup> yr<sup>-1</sup> of water is discharged from the islands of Oceania, but this figure includes the Philippines, New Zealand and Taiwan.

#### *Expected trends*

The amount of fresh water in Oceania is unlikely to increase and there is little evidence to suggest that polluted drinking water, rivers and coastal waters will be restored. There is, however, potential for sewage,

municipal and industrial wastes to be treated, which would directly affect fresh and coastal waters. However, the cost of building and maintaining such treatment facilities may be beyond many oceanic nations, dependencies and territories.

Pollution of fresh, coastal and marine waters is now recognized in Oceania, and the SPREP Action Plan may provide an effective way forward with respect to environmental concerns. In particular, the objectives from the Action Plan for Managing the Environment (SPREP 2000) suggest research programs to protect freshwater, coastal and marine ecosystems while ensuring ecologically sustainable utilisation of resources; and reducing land-based, freshwater and marine pollution. If the Action Plan (SPREP 2000) can be successfully implemented, Oceania waters (fresh, coastal and marine) may greatly improve.

In American Samoa, legislation is in place for water quality standards, land-use regulation, waste disposal and other environmental issues (Craig *et al.* 2000). In addition, the establishment of Marine Protected Areas in Vanuatu, New Caledonia, Tonga and the Samoa group is encouraging (Zann and Vuki 2000).

The potentially irreversible environmental destruction caused by mining in Oceania, and the economically damaging compensation ruling (e.g., Ok Tedi) may serve as a warning for other companies, perhaps making potential mining companies acutely aware of their environmental responsibilities. Currently mining is limited to a few countries in Oceania (i.e. Papua New Guinea, Fiji, Nauru and Solomon Islands). Phosphate, nickel, copper and gold are mined in Oceania. However, prospecting is occurring in a number of areas, so mining may spread to other countries (UNEP 2000).

## 2.2 Sediment

### *Significance*

Sedimentation is a natural process in the marine environment, but low and/or high sediment loads can damage coastal habitats. Sediment yields relative to catchment size are high in Oceania, exceeding those of Africa by an order of magnitude (Appendix 1; Asquith *et al.* 1994; Bird *et al.* 1995). Sediment yield and mobility are linked to climate through rainfall and runoff. High erosion and sediment transport rates are understandable considering the geologic youth and massive rainfall of the region e.g., Viti Levu, Fiji receives 1400 mm/month.

Sediments can transport pollutants such as heavy metals, pesticides and other organic substances. Sediment supply can be increased by logging activities, rapid coastal development, mining, intensive agriculture and natural events (Convard 1993; Asquith *et al.* 1994). However, distinguishing natural volumes of sediment from human influences is extremely difficult, and little if any data exists for Oceania. One of the primary causes of increased sedimentation in Oceania is changes in land use such as logging, urbanisation, reclamation (Baines and Morrison 1990; Asquith *et al.* 1994; Convard 1993; UNEP 2000; Zann and Vuki 2000). Other modifications to the land include agricultural practices, construction activities, mining operations and coastal erosion (Nitttrouer *et al.* 1995; UNEP 2000).

Pollution due to sedimentation is a major problem in Oceania, in particular for coral reefs and mangroves (Lal 1984; Asquith *et al.* 1994; Hinrichsen 1998; UNEP 2000). About 60% of islands in Oceania suffer soil degradation (Hinrichsen 1998). Coral reefs situated near Suva have been lost due to sediment from logging and upland farming, municipal and industrial pollution and dredging for sand (Hinrichsen 1998). Development-related problems in Fiji have also resulted in loads of sediments (by rivers and streams) smothering coral reefs and mangroves (Lal 1984).

In addition, the Gulf of Papua (GOP) receives sediment from the Fly and the Purari rivers, two of the world's top 20 rivers in terms of sediment discharge, with approximately  $340 \times 10^6$  t yr<sup>-1</sup> entering the marine environment (Bird *et al.* 1995). The Ok Tedi mining project has caused extensive environmental damage by discharging substantial quantities of sediment in river systems (Harper and Israel 1999). However, comparative data regarding natural and human influenced sources of sediment are not available.

### *Expected trends*

With pressures from economic development and a rapidly expanding population, Oceania is likely to continue large-scale deforestation and more intensive agriculture, resulting in continued sediment inputs to rivers and coastal waters (Baines and Morrison 1990); land degradation also appears to be worsening (Hinrichsen 1998, Zann and Vuki 2000). However, the Action Plan for Managing the Environment (SPREP 2000) has as one objective the monitoring and assessment of the state of the environment in the region, including the impacts of human activities on the ecosystems, and intends to encourage development undertaken to be directed towards maintaining or enhancing environmental qualities. If this action plan is successfully implemented, it may have significant impact in improving pollution due to sedimentation.

## **2.3 Carbon**

### *Significance*

Extrapolating results from a study by Milliman and Syvitski (1992), Bird *et al.* (1995) calculate that the total flux of particulate organic carbon (POC) to the world's oceans from the islands of Oceania is  $\sim 90 \times 10^6 \text{ t yr}^{-1}$  or twice the flux of riverine POC from the major rivers of North America, South America and Africa combined. Oceania's rate of discharge is three times higher than the next highest, the Amazon ( $31 \times 10^{12} \text{ g C yr}^{-1}$ ). The rivers of Oceania therefore represent a major but poorly documented source of sediment and organic carbon to the global ocean. However, Milliman and Syvitski include the Philippines, New Zealand and Taiwan in 'Oceania'. In addition, estimates of total organic carbon transported from land to the ocean via the world's rivers vary considerably (see Table 3).

**Table 3. The quantity of organic carbon runoff from land via rivers. Data from Schlünz and Schneider (2000).**

	Quantity of organic carbon
Degens <i>et al.</i> 1991	$334.5 \times 10^{12} \text{ g C yr}^{-1}$
Meybeck 1993	$368 \times 10^{12} \text{ g C yr}^{-1}$
Ludwig <i>et al.</i> 1996	$380 \times 10^{12} \text{ g C yr}^{-1}$

Chester (2000) ranks Oceania fourth in annual discharge of particulate organic carbon, but does not cite Bird *et al.* 1995 or Schlünz and Schneider (2000). However, data obtained by Schlünz and Schneider (2000) for Oceania from Nitttrouer *et al.* 1995 is confusing, and varying definitions of Oceania in these papers is also problematic.

### *Expected trends*

There is no reason to expect that rates of organic carbon discharge from Oceania will decrease; particularly with increasing economic development and a rapidly expanding population.

## **2.4 Chemicals and hazardous wastes**

### *Significance*

Oceania has a history of mismanaging chemical and hazardous wastes (Brodie and Morrison 1984; Convard 1993; Hinrichsen 1998; Burns *et al.* 2000). Large stockpiles of persistent organic pollutants (e.g., pesticides, polychlorinated biphenyls, industrial, medical and laboratory wastes, oil and bitumen) exist on islands in Oceania. Pesticides such as DDT are still commonly used (Hinrichsen 1998) and therefore pesticide spills into lagoons (e.g., Fiji: Tokelau; Truk) have caused significant environmental damage (Brodie and Morrison 1984).

The Australian Agency for International Development (AusAID) identified from a study of waste management issues that the greatest need (for Oceania) was for management of waste chemicals. As a result

of this AusAID study, the Persistent Organic Pollutants in Pacific Island Countries (PoPs in PICs) project was established. All SPREP member countries except Papua New Guinea were assessed.

The objective of the PoPs in PICs project is to establish management of chemical and hazardous wastes. In Phase I, the assessment of stockpiles of waste and obsolete chemical and the identification of contaminated areas was undertaken. Over 100 potentially contaminated sites were identified, and 86 of these warranted extensive investigation (Burns *et al.* 2000). A summary of the total volume of unwanted chemicals and chemical contaminated sites (Table 4) and of the waste and obsolete chemicals and chemical contaminated sites (Table 5) demonstrates “significant examples of inadequate chemical management practices” in Oceania (Burns *et al.* 2000:13).

**Table 4. Summary of total volume of unwanted chemicals and chemical contaminated sites.** Data from Burns *et al.* 2000.

(PCB's = polychlorinated biphenyls)

Country	Agricultural chemicals (kg)	Oil + PCB's (L)	Laboratory chemicals (kg)	Waste oil (L)	Obsolete chemicals (kg)	Waste bitumen (L)	Timber chemicals (L)	DDT (kg)	Number of sites
Cook Islands	5,700	4,000	380	20,000					2
Federated States of Micronesia	7,430	55,000	36,400	126,000					18
Fiji	21,210	Nil	>800 L	>8,000	75				19
Kiribati <sup>#</sup>	700	5,500	2,270	7,000		200,000			6
Marshall Islands	60	800		800+		20,000			4
Niue	1500	1000		Nil		Nil			1
Palau <sup>*</sup>	100	18,000	7,300	10,000		5,200			2
Samoa <sup>^</sup>	200	9,000	400				10,000		8
Solomon Islands	11,000 excl. DDT	1,200	300 L	>4,000	750			9,000	8
Tonga	Nil	6,000		2,000					3
Tuvalu	Nil	8,000		1,500 +		60,000			4
Vanuatu	300 excl. DDT	13,000	> 100 L	>15,000			122,000 kg	900	4

<sup>#</sup> Kiribati has 1000 L of copper/chromium/arsenic sludge.

<sup>\*</sup> Palau has 300 m<sup>3</sup> of asbestos.

<sup>^</sup> Samoa has 3,000 kg of buried agricultural chemicals

In addition, the management and disposal of laboratory chemicals and the management of infectious medical wastes was of great concern. Phases II and III should see the development of safe storage facilities in each country and disposal activities respectively (Burns *et al.* 2000). However, disposal operations are more urgently required than storage facilities.

**Table 5. Waste and obsolete chemicals and chemical contaminated sites.** Data from Annex: B1-List of sites in each Country (Burns *et al.* 2000).

Country	Total number of sites	Number of sites with surplus chemicals	Number of sites that were contaminated
Cook Islands	18	17	3
Fiji	19	16	11
Fed. States of Micronesia			
Chuuk	8	6	4
Kosrae	10	4	6
Pohnpei	14	9	8
Yap	19	8	6
Kiribati	22	13	12
Marshall Islands	6	4	4
Nauru	9	7	5
Niue	6	5	1
Palau	21	12	8
Samoa	17	12	10
Solomon Islands	15	9	10
Tonga	3	1	3
Tuvalu	9	7	4
Vanuatu	17	11	8
Totals	213	141	103

#### *Expected trends*

Chemical and hazardous waste management should continue to improve in Oceania, with the focus on long-term strategies. The move towards implementing the Basel, Waigani, Rotterdam and Persistent Organic Pollutants (POP's) conventions will be fundamental to the removal of toxic chemical and other hazardous wastes in Oceania. In particular, the Basel and Waigani conventions provide a legal framework (SPREP 2000).

### **3. Conclusions**

There is a distinct lack of basic and ongoing research in Oceania. Data obtained from the scientific literature, specific texts and literature of the South Pacific Regional Environment Programme (SPREP) suggest that several major problems should be addressed by the Oceania region, as a whole:

- ◇ Pollution from untreated municipal waste and urban sewage
- ◇ Deforestation and the effect of sediment transport
- ◇ Mining and its environmental impacts
- ◇ Chemical and hazardous waste management
- ◇ Effects of urbanization

Most of these problems are highlighted by the Action Plan for Managing the Environment (SPREP 2000). The success of this Management Plan may be critical for long-term environmental improvement in Oceania. Specific impacts and issues affecting Oceania are tabulated in the standardised assessment tables (Tables 6-9). Basin-level analysis for Oceania is problematic, since many of the island groups in Oceania have no established drainage networks in which sediment can be mobilised and transported (Asquith *et al.* 1994).

### **4. Recommendations for pilot studies:**

- ◇ Examine the cycling of water sediment, nutrient, carbon and contaminant fluxes in the coastal zone of the Oceania region
- ◇ Examine nutrient fluxes in the coastal zone of the Oceania region

- ◊ Commitment to community education programs on the impact of pollution on the river, coastal and marine environment
- ◊ Examine the social implications of water rationing
- ◊ Examine potential water (fresh) saving approaches
- ◊ Look at the impact of fresh water discharge from Islands in Oceania
- ◊ Examine the potential to establish water quality monitoring of rivers and lagoons
- ◊ Examine the use and management of pesticides
- ◊ Identify the proportion of sediments that occur naturally from those that are not
- ◊ Examine logging and the effect on increased sediment load
- ◊ Assess the effects of sediments carrying pollutants such as heavy metals and pesticides
- ◊ Examine the effect of intensive agriculture and how it is contributing to sediment loads in rivers and the marine environment
- ◊ Examine the impact of runoff on the coastal and marine environment
- ◊ Investigate the possibility of using sediment loads as a pollutant indicator.

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**Table 6. Major coastal impacts/issues and critical thresholds in South Pacific Coastal Zones – Overview and qualitative ranking.**

Impact code and relative class of importance e.g. 1- 10

Coastal Impact/ Issue	Local site/Region (contributing river basins)	Distance to critical threshold	Impact category	References/ Datasource
Erosion (Coastal geomorphology)	Tarawa Atoll, Kiribati.	Betio-Bairiki causeway and channel infilling.	8	Nunn 1994
Eutrophication	Fly, Ok Tedi and Jaba Rivers, PNG.	Contaminated sediment loads have changed the rivers ecosystem.	10	Hinrichsen 1998, Bains and Morrison 1990
Pollution	a. Fly, Ok, Tedi, and Jaba Rivers. b. Rivers in Southern New Caledonia. c. Coastal waters around Suva. d. Coral reefs in French Polynesia. e. Nubukulou Creek, Suva. f. Coastal waters around the Coo Islands. g. Lagoon and oceans in Tonga. h. Coral reefs in the Solomon Islands.	a. Cyanide (past), copper, heavy metals, cadmium, sediment. b. Laterite clay. c. Logging and farming upland, municipal and industrial waste, sand dredging. d. Raw sewage, industrial waste, dredging and sand mining. e. Effluents from electricity plant and septic tanks. f. Dieldrin used for fishing, washing of spray equipment in streams. g. Refuse and urban sewerage. Siltation due to logging.	10	Viner 1984, Asquith <i>et al</i> 1994, Baker <i>et al</i> 1990, Bains and Morrison 1990 Hinrichsen 1998, Lal 1984, Dahl 1984, Overton and Scheyvens 1999, Henningham 1995, UNEP 2000
Biodiversity loss and/or decreasing biological productivity	a. Fly River, PNG. b. Jaba River, PNG. c. Rivers in Southern New Caledonia. d. Coastal waters around Suva.	a. Fish stock reduced by up to 80%. b. Biologically dead. c. Mangrove loss, reef death and estuaries filled. Tree cover stripped away Fish population decline and coral reefs lost.	10	Asquith <i>et al</i> 1994, Bains and Morrison 1990, Nunn 1994, Hinrichsen 1998, Lal 1984, UNEP 2000
Sedimentation	a. Fly and Jaba Rivers, PNG. b. Coastal waters around Suva, from rivers c. Rivers in New Caledonia.	a. Before 1990, Jaba River 135,000 metric tons of mine tailing/day. b. Coral reef loss from logging upland and poorly planned developments.	10	a. Lal 1984, Hinrichsen 1998, Bains & Morrison 1990, Harper & Israel 1999 b. Hinrichsen 1998, Bains & Morrison 1990, Lal 1984. c. Labrosse <i>et al.</i> 2000
Contamination	a. Marshall atolls: Bikini and Eniwetok. b. Guam coastal waters. c. Tuamotu Group, French Polynesia	a. Nuclear testing (not current). b. Radioactivity in marine food chain increased to 100 times ambient levels. c. Radioactive waste, treat to human health	10	Branch 1984, Henningham 1995, Hinrichsen 1998.

**Table 7. DPSIR matrix characterizing major catchment based drivers/pressures and a qualitative ranking of related state changes impacting the coastal zone**

State change dimension: 3 = major; 2 = medium; 1 = minor; 0 = no impact; ? = insufficient information.

Time scale: p = progressive (continuous); d = direct (spontaneous)

Driver	Pressures	State change	Impact on the coastal system	Time scale
		Large-medium basins		
<b>Climate (rainfall)</b>	<ul style="list-style-type: none"> <li>Increased sediment transport</li> </ul>	3	Siltation Erosion	<b>p</b>
<b>Agriculture</b>	<ul style="list-style-type: none"> <li>Fertilizer (nutrient) effluent</li> <li>Land clearing and reclamation</li> <li>Water extraction increase</li> <li>Increased sediment transport</li> <li>Changes to water balance and runoff regime</li> <li>Intensive agriculture along coastal areas</li> </ul>	1 3 3 3 3 3	Eutrophication Pollution (heavy metals) Siltation Biodiversity loss Erosion of stream banks and increased sedimentation	<b>p</b>
<b>Deforestation</b>	<ul style="list-style-type: none"> <li>Increased sediment loads</li> <li>Alteration to water balance</li> <li>Changes to runoff regime</li> <li>Siltation</li> <li>Ecological damage</li> </ul>	3 2 3 3 3	Siltation of coral reefs and mangroves Sediment accretion Erosion Biodiversity loss	<b>p</b>
<b>Mining</b>	<ul style="list-style-type: none"> <li>Increased sediment loads</li> <li>Changes to hydrological cycle</li> </ul>	3 3	Pollution (heavy metals) Siltation Eutrophication Sediment accretion Erosion Contamination Biodiversity loss	<b>p</b>
<b>Urbanization (point source effluents)</b>	<ul style="list-style-type: none"> <li>Pollution discharge</li> <li>Population growth</li> <li>Increased sediment runoff</li> <li>Water extraction</li> </ul>	3 3 3 2	Pollution Eutrophication Contamination Biodiversity loss	<b>p</b>
<b>Nuclear Tests</b>	<ul style="list-style-type: none"> <li>Radioactive residues</li> </ul>	3	Pollution Contamination Biodiversity loss	<b>d</b>

**Table 8. The link between coastal issues/impacts and land based drivers in South Pacific Coastal Zones – Overview and qualitative ranking on local or catchment scale.**  
Category: (1 low – 10 high)

Coastal Impact/Issues	Drivers	Local catchment (allowing within and between catchment comparison)		Trend expectations	References/ Data sources
		River	Category		
<b>Eutrophication</b>	Agriculture	Rewa River, Fiji.	7	Increase	Bains & Morrison 1990
	Deforestation	Rivers of Fiji.	7	Increase	Asquith <i>et al.</i> 1994
	Urbanization	Rivers of Fiji.	8	Increase	Asquith <i>et al.</i> 1994
	Mining	Fly, Ok Tedi and Jaba Rivers, PNG.	10	?	Hinrichsen 1998, Bains & Morrison 1990, Hettler and Lehmann 1995
<b>Erosion</b>	Agriculture	Streams in Fiji (pesticides).	7	Increase	Brodie and Morrison 1984
	Deforestation	Streams in Fiji, New Caledonia and Solomon Is.	7	Increase	Brodie and Morrison 1984
	Urbanization	Tarawa Atoll, Kiribati.	6	Stable	Nunn 1994
	Mining	a. Jaba River, PNG. b. Rivers in New Caledonia.	10	?	a. Nunn 1994, b. Nunn 1994, Hettler & Lehmann 1995
<b>Pollution</b>	Agriculture	Rewa River, Fiji.	8	Decreasing	Bains & Morrison 1990
	Deforestation	Rivers in southern New Caledonia.	10	Increase	Hinrichsen 1998
	Urbanization	a. Rewa River, Fiji (sewage), Tarawa Lagoon, Kiribati (sewage). b. Vatuwaga River, Fiji (sewage). c. Nubukulou Creek (electricity and septic tanks). d. Suva Harbour, Fiji (sewage).	8	Stable	a. Brodie & Morrison 1984 b. Lal 1984 c. Hinrichsen 1998 d. Hinrichsen 1998
	Mining	a. Fly, Ok Tedi and Jaba Rivers, PNG. b. Rivers in southern New Caledonia.	10	?	a. Bains & Morrison 1990, Asquith <i>et al.</i> 1994, Nunn 1994, Hettler & Lehmann 1995, Hinrichsen 1998, Harper & Israel 1999 b. Nunn 1994, Hinrichsen 1998
<b>Sedimentation</b>	Agriculture	a. Rewa River, Fiji. b. Waimanu River, Fiji.	5	Increase	a. Bains & Morrison 1990 b. Vuki <i>et al.</i> 2000
	Deforestation	Streams in Fiji, New Caledonia and Solomon Is.	10	Increase	Brodie and Morrison 1984
	Urbanization	Qaraniqio River, Fiji.	8	Increase	Lal 1984
	Mining	a. Fly, Ok Tedi and Jaba Rivers, PNG. b. Rivers in New Caledonia.	10	?	a. Asquith <i>et al.</i> 1994, Bains & Morrison 1990, Hettler & Lehmann 1995, Hinrichsen 1998 b. Labrosse <i>et al.</i> 2000

**Table 9. The link between coastal issues/impacts and land-based drivers in South Pacific coastal zones – overview and qualitative ranking on local, sub regional or country scale.**

Category: (1 low – 10 high)

Coastal Impact/Issues	Drivers	Sub-regional (i.e. by country or considering open versus enclosed seas)		Trend-expectation	References/ Data sources
		Sub-region A	Category		
<b>Eutrophication</b>	Agriculture	Rewa River, Fiji.	7	Increase	Bains & Morrison 1990
	Deforestation	Rivers in Fiji.	7	Increase	Asquith <i>et al.</i> 1994
	Urbanization	Rivers in Fiji.	8	Increase	Asquith <i>et al.</i> 1994
	Mining	Fly, Ok Tedi and Jaba Rivers, PNG.	10	?	Hinrichsen 1998, Bains & Morrison 1990
<b>Erosion</b>	Agriculture	Streams in Fiji.	7	Increase	Bains & Morrison 1990
	Deforestation	Streams in Fiji, New Caledonia and Solomon Is.	7	Increase	Brodie & Morrison 1984
	Urbanization	Tarawa Atoll, Kiribati.	6	Stable	Nunn 1994
	Mining	Jaba River, PNG; Rivers in New Caledonia.	10	?	Nunn 1994
<b>Pollution</b>	Agriculture	Streams in Fiji (pesticides).	8	Decreasing	Brodie & Morrison 1984
	Deforestation	Rivers in southern New Caledonia.	10	Increase	Hinrichsen 1998
	Urbanisation	a. Rewa River, Fiji (sewage), Tarawa lagoon, Kiribati (sewage). b. Vatuwaga River, Fiji (sewage). c. Nubukulou Creek (Electricity and septic tanks). d. Suva Harbor, Fiji (sewage).	8	Stable	a. Brodie & Morrison 1984 b. Lal 1984 c. Hinrichsen 1998 d. Hinrichsen 1998
	Mining	e. Fly, Ok Tedi and Jaba rivers, PNG. f. Rivers in southern New Caledonia.	10	?	a. Bains & Morrison 1990, Asquith <i>et al.</i> 1994, Nunn 1994, Hettler & Lehmann 1995, Hinrichsen 1998 b. Nunn 1994, Hinrichsen 1998
<b>Sedimentation</b>	Agriculture	a. Rewa River, Fiji. b. Waimanu River, Fiji.	5	Increase	a. Bains and Morrison 1990 b. Vuki <i>et al.</i> 2000
	Deforestation	Streams in Fiji, New Caledonia and Solomon Is.	10	Increase	Brodie & Morrison 1984
	Urbanisation	Qaraniqio River, Fiji.	8	Increase	Lal 1984
	Mining	a. Fly, Ok Tedi and Jaba rivers, PNG. b. Rivers in New Caledonia.	10	?	a. Asquith <i>et al.</i> 1994, Bains and Morrison 1990, Hettler and Lehmann 1995, Hinrichsen 1998 b. Labrosse <i>et al.</i> 2000

## Appendices

### Appendix 1. Regional sediment yield calculations for Oceania, using the Fournier (1960) method. (Data from Asquith *et al.* 1994).

Islands and island groups	Drainage area, km <sup>2</sup>	Calculated sediment yield				
		Volume m <sup>3</sup> km <sup>-2</sup> x 1000	Minimum T km <sup>-2</sup> yr <sup>-1</sup> x 1000	Maximum T km <sup>-2</sup> yr <sup>-1</sup> x 1000	Total Min. t yr <sup>-1</sup> x 1000	Total Max. t yr <sup>-1</sup> x 1000
American Samoa						
Tutuila	145	1.74	3.66	4.43	530.27	656.60
Ofu	0					
Olosenga	0					
Tau	0					
Cook Islands						
Atiu	0					
Mangaia	0					
Rarotonga	67	1.43	2.99	3.71	201.10	248.97
Federated States of Micronesia						
Kosrae	108	2.95	6.20	7.67	669.28	828.58
Pohnpei	334	2.33	4.89	6.06	1634.43	2023.37
Chuk	61	1.17	2.45	3.93	149.39	184.93
Yap	98	2.11	4.44	5.49	436.66	540.63
Fiji						
Viti Levu	10389	3.43	7.21	8.93	74915.08	92758.17
Vanua Levu	5538	2.73	5.73	7.10	31754.89	39314.26
Taveuni	435	2.27	4.76	5.90	2072.30	2565.60
Ovalau	125	1.95	4.10	5.08	410.30	507.90
Koro	108	1.95	4.10	5.08	443.12	548.53
Gau	100	1.95	4.10	5.08	512.88	634.88
Kadavu	408	1.83	3.85	3.77	1571.21	1945.44
French Polynesia						
Tahiti and Moore	1052	3.06	6.42	7.95	6750.68	8358.14
Tahaa	88	1.38	2.89	3.58	254.23	314.78
Raiatea	194	1.38	2.89	3.58	560.47	694.05
Rurutu	28					
Nukuhiva and Uapou	435	5.08	1.07	1.32	446.58	575.07
Hivaoa and Tauhata	370	9.54	2.00	2.48	741.11	917.60
Marshall Is.	0					
Nauru	0					
New Caledonia	171	1.70	3.56	4.40	61274.01	75440.52
Niue	0					
Northern Marianas						
Saipan	5	2.43	5.09	6.31	25.47	31.54
Palau						
Babelthuap	396	2.27	4.76	5.90	1886.07	2337.20
Papua New Guinea (mainland provinces)						
Oro	22800	2.56	5.37	6.65	122390.40	151551.60
Milne Bay	14000	1.90	3.99	4.95	55916.00	69230.00
Central and N. Capital	29740	1.80	3.78	4.68	112506.42	139302.16
Morobe	34500	1.20	2.51	3.11	68829.50	107260.50
E. Sepic and	79100	1.30	2.73	3.35	215784.80	267152.34

Sanduan						
Mandang	29000	2.44	5.10	6.34	147958.00	183831.00
W. Highlands and Enga	21300	1.51	3.17	3.92	67414.50	83474.70
S. Highlands	23800	1.47	3.09	3.83	73565.80	91082.60
E. Highlands and Simbu	17380	1.54	3.24	4.00	56259.06	6924.28
Gulf	34500		1.73		59581.50	
Western	99300		1.06		105124.46	
<b>Island provinces</b>						
New Britain	39807	6.06	12.72	15.74	506146.01	626681.60
New Ireland	9974	2.30	4.84	5.99	48264.19	59754.23
Bougainville	9300	1.90	3.99	4.94	37088.40	45923.40
Lorengau/ Manus	01943	1.65	3.47	4.30	6748.04	8354.90
<b>Pitcairn</b>	0					
<b>Solomon Islands</b>						
Choisel	2590	1.32	2.78	3.44	7200.20	8914.78
Santa Isabel	4122	2.45	5.15	6.38	21228.30	26281.87
Malaita and Marimasike	4900	3.49	7.33	9.07	35902.30	44447.90
San Cristobal	3125	2.27	4.76	5.90	14887.50	18431.25
Guadal-canal	6400	2.48	5.20	6.44	33292.80	41241.60
New Georgia Group	4250	2.71	5.69	7.05	24186.75	29945.50
<b>Tokelau</b>	0					
<b>Tonga</b>						
Eua	15	1.06	2.23	2.76	33.44	41.40
Tofua	28	2.00	4.11	5.08	114.97	142.35
Kao	1	2.00	1.41	5.08	4.11	5.08
<b>Tuvalu</b>	0					
<b>Vanuatu</b>						
Espirito Santo	3680	1.64	3.44	4.26	12655.52	15669.44
Malekula	2023	2.11	4.43	5.49	8967.96	11102.22
Tanna	549	1.95	4.10	5.09	2252.55	2791.67
Aneityum	65	2.37	4.98	6.17	323.90	401.16
Ambrym	665	3.11	6.53	8.08	4339.79	5373.73
Epi	444	1.53	3.22	3.99	1429.24	1763.41
Erromanga	975	1.95	4.10	5.08	3998.77	4950.08
Efate	915	2.43	5.09	6.31	461.01	5770.91
Pentecost	438	3.70	7.77	9.62	3402.62	4212.77
Aoba	339	3.04	6.38	7.90	2163.71	2678.88
Maewo	269	2.50	5.26	6.51	1414.62	1751.43
Vanua Lava	308	2.11	4.43	5.49	1365.36	1690.30
<b>Western Samoa</b>						
Saval'i	503	2.61	5.48	6.79	2756.44	3412.86
Upolu	708	2.90	6.09	7.54	4309.60	5335.49
<b>Regional Mean</b>		2.33	4.63	5.76		
<b>Regional Total</b>					2015673.05	2486186.63

## Appendix II. Consultancy Brief

### Land Ocean Interactions in the Coastal Zone (LOICZ) International Project Office

#### Consultancy

Literature review and categorization (development of indices) of natural and anthropogenic material fluxes and their impact on environmental and socio-economic systems in the coastal zone of islands in the Oceania Region.

LOICZ is working *inter alia* to develop a global evaluation of the importance of coastal seas as receiving bodies of land based changes of horizontal material fluxes such as carbon, nitrogen and phosphorus as well as water and sediments. The scale of transport pathways applied is the river catchments (including horizontal island runoff) and groundwater fluxes and their natural and anthropogenic drivers.

Beyond providing an overview on whether the coastal zones function as sinks or sources for nutrients and carbon, the goal is to elaborate on the relative importance of these materials and their biogeochemical cycles under the dynamic natural and anthropogenic changing forcing functions. Changing fluxes impacting the state of the environment and their feedback on the socio-economic system functioning are to be reviewed against the conceptual question of critical loads reaching the coastal zone and forcing systems to flip.

Current efforts in LOICZ are making advances in addressing these issues in a standardized way by applying the simple **DPSIR**: Drivers, Pressures, State (State Change), Impact Response scheme (OECD 1993 and LOICZ R&S No. 11, 1998) as a descriptive framework in which to sketch the various forcing functions and boundary conditions. The mid-term goal is to involve the calculation and modelling of effects on the delivery and use of environmental goods and services, their scientific and monetary expressions and to review the political response and options.

While earlier LOICZ BASINS efforts have concentrated on river catchments throughout Europe, South America and Africa, to date, LOICZ has not attempted to properly evaluate the significance of the flux changes, their drivers and critical loads to coastal zones of island dominated areas. Following the recommendations of the Global Island Working Group of the 4<sup>th</sup> Open Science Meeting, Bahia Blanca, Nov. 1999, LOICZ now seeks to commission an expert literature review to address these issues for the Oceania region.

#### Activities

Prepare a literature review and a qualitative/semi quantitative index system describing the significance, cycling and expected trends of water, sediment, nutrient, carbon and contaminant fluxes in the coastal zone of the Oceania Region, including:

- Establishing the relevance of island coastal areas for natural and anthropogenic forcing of flux changes through river catchments (or depending on size the whole island), groundwater and other land based inputs;
- Identify impacts on ecosystems in reach of these fluxes, and as far as possible the critical loads with respect to expected change of functions and goods and services and regulatory response (legislation, private sector needs); and
- Provide recommendations for representative pilot studies for higher order integrated modelling with their potential to regional upscaling

#### Output

1. A report describing the source, significance and magnitude of water, sediment, carbon, nutrient and contaminant fluxes, their pathways and commentary on classification and significance of their major drivers and expected trends. This to be provided with a system of indices of drivers and pressures applied to a catchment (island) scale showing their links to state change and critical loads observed in the coastal zone providing the interface to up-scaling in the LOICZ typology.
2. An electronic copy of the report suitable for web-site listing.
3. A scientific article for peer-reviewed publishing.