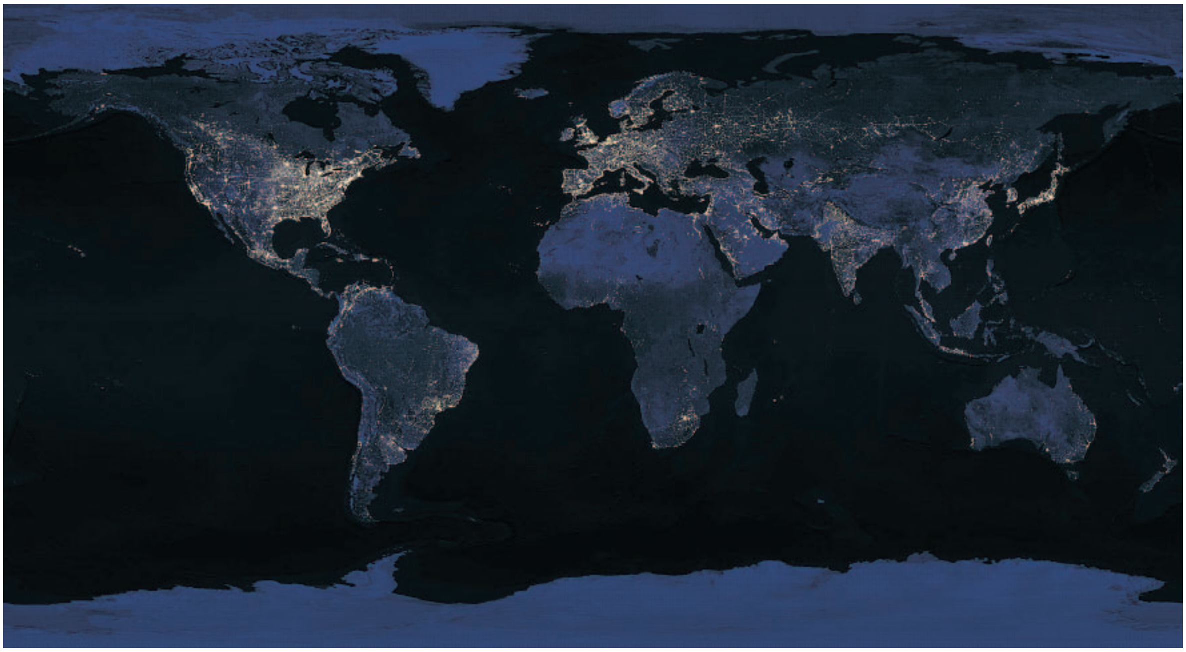

Fig. 1.5. Night light image of Earth (NASA, *http://www.gsfc.nasa.gov*)

population) living within 100 km of the coast. Using the relatively robust dataset for 1990 contained in the Gridded Population of the World Version 2 (CIESIN 2000 data; *http://sedac.ciesin.org/plue/gpw*), and an elevation model (*http://www.edcdaac.cr.usgs.gov/landdaac*), Nichols and Small (2002) estimated that 1.2×10^9 people (23% of global population) live in the "near coastal zone" (the coastal area within 100 m elevation and 100 km of the coast).

The LOICZ typology database (*http://www.kgs.ukans.edu/Hexacoral/Environdata/envirodata.html*), using gridded population data for the coastal domain derived from LandScan for 1998 (*http://www.ornl.gov/sci/gist/landscan*), yielded an estimated 2.69×10^9 people (44% of global population) within the coastal zone. For this technique, the coastal zone is contained within a grid of half-degree cells, representing a linear measurement at the equator of 100 km landward of the coastline (see Text Box 1.7). These estimates are still lower than the generalised value of $> 3 \times 10^9$ people often broadly ascribed to the coastal zone by various authors through the mid 1990s (e.g., Hinrichsen 1998). Improved data collection and application of consistent methodologies would provide robust estimates of the current coastal population for application to trend analyses, modelling and prediction of human pressures and changes in the coastal zone.

The coastal population is increasing disproportionately to the global population increase. In their analyses, Shi and Singh (2003) estimated an average population density for the coastal zone (within 100 km from the coastline) of 87 people km^{-2} in 2000 compared

Table 1.3. The coastal zone. Estimated and projected average population density for the coastal zone and inland areas (derived from Shi and Singh 2003) and projected global population estimates (UN/DESA 2001–03)

Date	Average population density (people km^{-2})		Estimated global population (billion)
	Coastal Zone	Inland	
1990	77		5.2
2000	87	23	6.1
2010	99	38	6.9
2025	115	44	7.9
2050	134	52	9.3

with 77 people km^{-2} in 1990 (UNEP/GRID database, *http://www.na.unep.net*). The average global population in 1990 was 44 people km^{-2}. Elevated population densities coincide with urban conurbations and "altered" landscapes (Burke et al. 2001). In 2000, 17 of the world's 24 megacities were coastal (Klein et al. 2003). There is a marked diminution of population density with distance from the coast, with 40% of the "near coastal" population occupying only 4% of the land area at densities > 1 000 people km^{-2}, with greatest densities in Europe and in South, Southeast and East Asia (Nicholls and Small 2002). Illustrated in Fig. 1.5, this highlights the additional observation by Nicholls and Small that "*… despite the concentration of people near coasts, at the global scale, the majority of land area within the 'near coastal zone' is relatively sparsely populated*". This coastal density imbalance is likely to increase with time

Text Box 2.4. Feedbacks associated with sea-level rise along Arctic coasts

Kenneth Dunton and Lee Cooper

Arctic shelves constitute 25% of the Arctic Ocean surface area and are the largest continental shelves in the world ocean. They are heavily influenced by coastal erosion, runoff from the large rivers and sea ice, which acts as a major geological agent. Increased rates of erosion, changes in river outflow and varying ice conditions have a direct influence on the input of nutrients, organic carbon and sediments (Rouse 2000, Chapin et al. 2000, Lammers et al. 2001). Such changes have important biological and biogeochemical implications (Fig. TB2.4.1), with respect to feedbacks to the ocean-ice-atmosphere system (Moritz et al. 1990, Tynan and Demaster 1997, Aagaard et al. 1999, Morison et al. 2000, Johnson and Polyakov 2001).

Permafrost on land and in undersea deposits currently sequesters large amounts of radiatively active gases such as methane (Anisimov and Nelson 1996, Danilov 2000, Lee and Holder 2001). However, since many Arctic shorelines are erosional in nature, significant amounts of this methane and the oxidisable organic carbon stored in peat are available for release to the atmosphere. There is also a substantial dissolved organic matter component associated with the retreating shoreline, and allochthonous contributions appear to be of relatively greater importance in the Arctic than in other oceans (Wheeler et al. 1996, Wheeler et al. 1997, Guay et al. 1999, Opsahl et al. 1999). Release of greenhouse gases would have a positive feedback on the degradation of additional permafrost and release of more gas. Continuation of the current apparent decline in sea ice spatial extent and thickness (e.g., Rothrock et al. 1999) could increase water column productivity over the continental shelves, while retreat of sea ice beyond the continental shelf could lead to the disappearance of habitat for ice-associated organisms (e.g., gray whales, walruses, diving ducks and bearded seals). Shoreline erosion rates are also likely to increase with longer open-water periods without protection of sea ice from storm and wave damage. Many of these projected changes are likely to impact the communities that live near the land-sea boundary of the Arctic region.

Off-shore transport of organic matter is significant over the wide and shallow Siberian shelves (Semiletov 1999, Romankevich et al. 2000, Semiletov et al. 2001). Additional climate warming, increased precipitation and increased ultraviolet radiation fluxes could lead to higher remineralisation rates in oxidised waters and sediments on Arctic shelves (Dixon et al. 1994, Freeman et al. 2001). In the Laptev Sea, the supply of sediment and organic carbon from coastal erosion appears to exceed that from riverine input (Rachold et al. 2000), despite the outflow of the Lena River into the Laptev Sea, its mouth one of the world's largest deltas (Fig. TB2.4.2). The lengthening of the ice-free season in summer and the retreat of the summer minimum ice edge further away from the coasts during the past decade is likely to increase the transfer of wave and thermal energy to the coasts, potentially accelerating rates of coastal retreat in the future. Changes in the

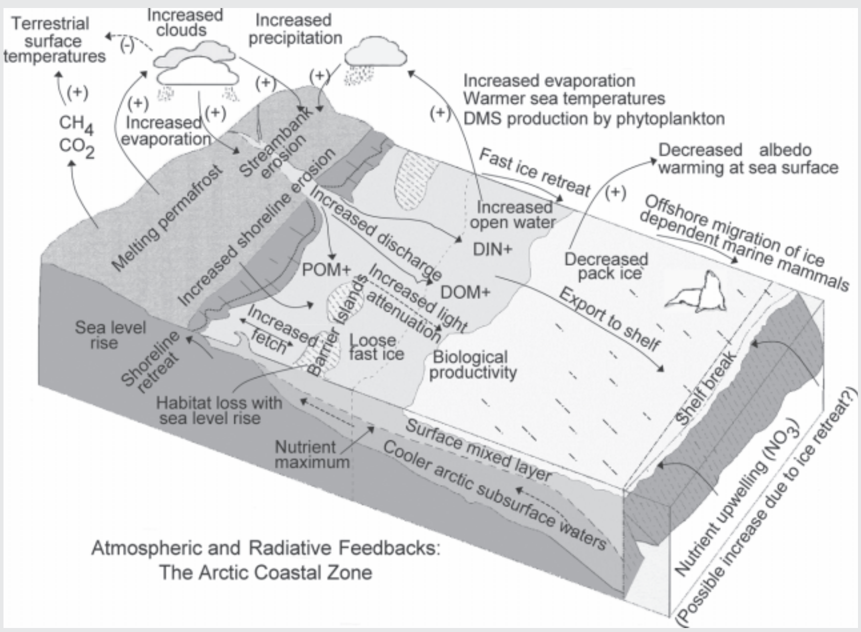

Fig. TB2.4.1. Major processes and feedbacks associated with climate change in high Arctic coastal ecosystems (from *http://arctic.bio.utk.edu/#raise*)

increased seasonal maximum temperatures (Hoegh-Guldberg 1999). In recent years, satellite-based SST anomalies have been used to predict and describe the spatial extent of mass coral bleaching events (Skirving and Guinotte 2001, see also *http://www.osdpd.noaa.gov//PSB/EPS/SST/climohot.html*), but less severe events have been more difficult to correlate with coral bleaching in other studies. Coral reefs may be differentially affected by bleaching events and in response show reduced coral and habitat diversity (McCarthy et al. 2001). In addition to bleaching in response to increasing temperatures, increased CO_2 has been predicted to reduce reef calcification rates to such an extent that its effect should be clearly manifested later in the 21st century (Kleypas et al. 1999, see Text Box 3.2 Chap. 3). A greater frequency of coral bleaching events together with a general reduction in coral reef calcification is likely to produce a geographically variable response to climate change and sea-level rise.

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Arctic atmosphere-ice-ocean system recorded during the past decade (Serreze et al. 2000, Huntington 2000) and the reduction in the ice season, combined with a shrinking and thinning of the Arctic sea-ice cover (Rothrock et al. 1999, Serreze et al. 2000), are likely to have profound impacts on the life cycle of marine mammals and impacts on infrastructure and development in the circum-Arctic.

Rates of coastal erosion in the Alaskan and central and eastern Siberian Arctic have been estimated as several meters to tens of meters per year (Are 1999). Paradoxically, a shortened ice season not only results in a loss of protection of the coastline but also increases the action of ice as both an erosional and transport agent. Sea ice plays a major role in the transport of eroded terrigenous sediments onto the Arctic shelf (Stierle and Eicken 2002, Reimnitz et al. 1993, Pfirman et al. 1997, Eicken 2004). The importance of ice transport processes is likely to grow with increases in wind fetch due to reduced ice cover and more frequent and stronger storm events (Proshutinsky et al. 1999). The increase in coastal erosion will be offset locally around the mouths of Arctic rivers that are expected to deliver more sediment with the warming of the hinterland (Syvitski 2002).

Arctic coastal communities depend on access to the sea and to sea ice, but are vulnerable to flooding and erosion. Key human impacts identified by arctic residents include coastal erosion, recent declines in ice extent and thickness, less stable shore-fast ice, changes in permafrost depth, gouging of shelves and coast by sea ice, pile-up of ice on shore, sea-level rise and storm hazards, including flooding. Because of the ice content of coastal sediments, rapid coastal erosion is highly variable and will not be uniform in terms of how it affects individual settlements.

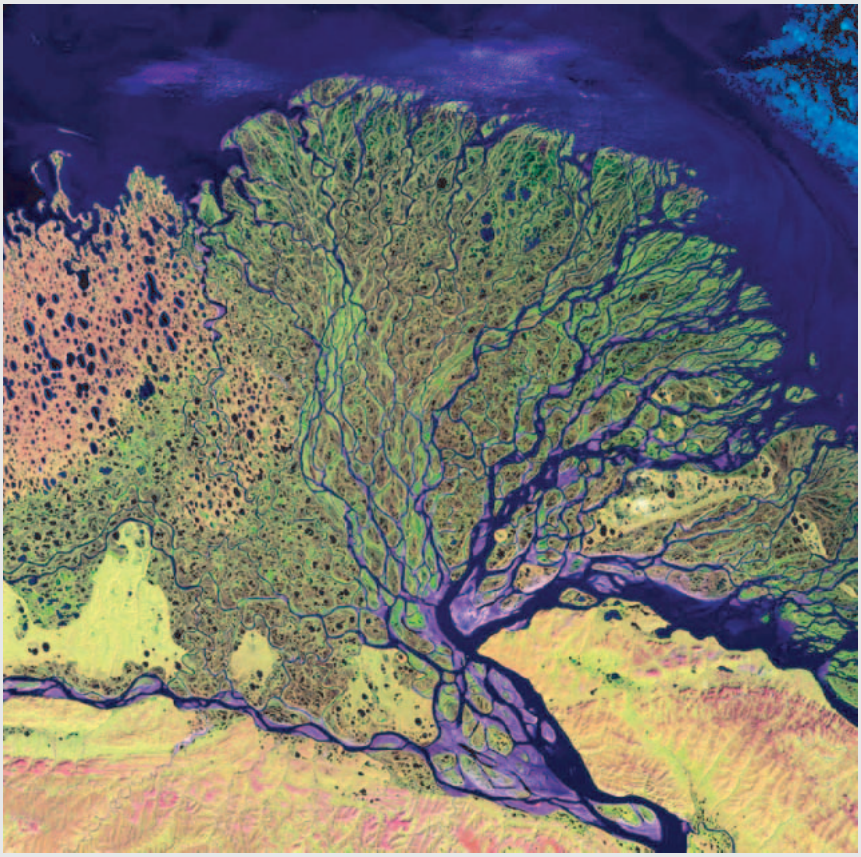

Fig. TB2.4.2. LandSat 7 image of the Lena River delta, northeastern Siberia (from *http://www.visibleearth.nasa.gov/cgi-bin/viewrecord/18024*)

2.2.2.3.5 *High-latitude Coasts*

Climate models predict a higher than average temperature rise in high latitudes. High-latitude coasts are particularly susceptible to increased periods of ice thaw leading to a reduction of sea ice, creating greater wave exposure and exposing unlithified coastal sediments (see Text Box 2.4). There is evidence of rapid cliff recession in Siberian glacial and peri-glacial deposits in response to ice thaw (Bird 1996) and a seasonally determined active-thaw layer in high-latitude beaches and nearshore zones (Nairn et al. 1998). Any increase in global temperatures will have the effect of extending the periods of thaw and consequently increasing coastal vulnerability. Evidence of this is beginning to emerge from the rapidly eroding sandy coasts in the Gulf of St Lawrence where severe erosion in recent years has been linked to warmer winters (Forbes et al. 1997).

4.2.4 Conclusions – South America

River basins of all sizes are, or are becoming, increasingly affected in particular by diversion of waters and/or damming for energy generation and/or irrigation purposes, basin deforestation and pollution from agriculture, urban and industrial effluents. Figure 4.7 is a sub-regional synthesis of main river catchment-coastal change issues, and provides an expert judgement-based ranking and trend analysis.

A number of case studies, from across the South American sub-continent are summarised in Table 4.3 and address key issues and scales that occur at the land-sea interface. An overall evaluation of the data in Table 4.3 supports the conclusion that across South America issues of water quality followed by a series of sediment-related issues and aspects driven by demands for water resource availability are the most important.

4.3 Africa

4.3.1 Overview of African River Catchment-Coastal Zone Systems – Geography and Climate

The environmental and socio-economic issues of Africa's coastal zone are influenced by both natural and anthropogenic marine-related pressures, such as relative sea-level rise which exacerbates coastal erosion and flooding around Lagos in Nigeria. The coastal zone is also directly influenced by the pressures of human activities, notably urban and industrial growth causing pollution (e.g., Alexandria in Egypt) and eutrophication (e.g., Saldanha Bay in the Western Cape). Around much of Africa, however, many of the coastal issues are linked to human activities and climatic variability that are far away in the continental hinterland. Such continental pressures have altered the nature of the drainage through the river systems – large and small – impeding the flow of freshwater, transported sediment and organic matter. They have also affected the quality of the water, mainly through the addition of nutrients and pollutants from domestic sewage and industrial and agricultural chemicals.

On the basis of geomorphic and climatic characteristics, eight sub-regions were evaluated (Fig. 4.8a, Text Box 4.5) within which representative catchments were chosen for assessment (Fig. 4.8b; Arthurton et al. 2002). The various sub-regions differ widely not only in the biophysical nature of their catchments but also in the availability and quality of existing data relating to their material fluxes. The catchments in South West and South East Africa have generally been well-studied especially over the last few decades and there exists an abundance of accessible high-quality monitoring data, both terrestrial and marine. Data for the Congo, by contrast, is sparse – a matter of concern in view of the obvious importance of such a large catchment in a regional synthesis of river catchment-to-coastal sea fluxes.

4.3.2 Assessment of Land-based Drivers, Pressures and Coastal Impacts

All of Africa's largest river basins – Niger, Congo, Nile and Zambezi – are included in the assessment, as are the important trans-boundary basins of the Senegal, Volta, Cross and Gariep rivers on the west coast and the Limpopo and Incomati on the east coast. Representative medium and small basins have also been assessed, including:

- the Sebou and Moulouya rivers in Morocco
- the Olifants and Berg rivers (west of the Cape of Good Hope) in South Africa,
- the Tana and Sabaki rivers in Kenya,
- the Rufiji in Tanzania, and
- the Thukela, Great Fish, Kromme and Groot Brak in South Africa east of the Cape.

4.3.2.1 *Drivers and Pressures*

Apart from climate change, the principal internal drivers of environmental change within African catchments are agricultural development, urbanisation, and their related activities – deforestation, damming and industrialisation (Table 4.4, Fig. 4.9; UNEP 2002a). Forest clearance and the general reduction in vegetation cover are consequences of agricultural expansion into marginal land, fuel-wood gathering and rapidly growing urban sprawl (e.g., around Nairobi and Johannesburg). Damming, water diversion and groundwater extraction are practices that have increased significantly in Africa during the last 50 years, particularly in South Africa, in response to development demands for agricultural irrigation, freshwater supply (particularly to fast-growing urban areas) and hydroelectric power (World Commission on Dams 2000).

All of these land-based human activities within Africa have produced substantial socio-economic benefits at local to regional scales. They have also resulted in considerable negative impacts, both socio-economic (e.g., the disruption of communities and their livelihoods) and environmental (e.g., the alteration of natural flooding regimes, the degradation of agricultural land by increased soil erosion, the destruction of habitats and the loss of biodiversity). The pressures exerted by these activities

Text Box 4.5. Africa: catchment sub-regions

From Arthurton et al. (2002)

Sub-region 1. North West Africa: relatively arid, medium basins with seasonal runoff. North West Africa is characterised by young mountains and numerous medium and small drainage basins with strong slopes, while the alluvial plains are few and of limited extent. River runoff and precipitation are irregular and may be high. Poorly vegetated steep slopes are prone to surface runoff resulting in soil erosion and high levels of fluvial suspended sediment transport – probably among the highest in Africa. The Sebou and Moulouya catchments (located in Morocco) are representative of the medium drainage basins that characterise the semi-arid Maghreb area. Many large dams have been built over recent decades. The resulting sediment entrapment has not only reduced the reservoir capacity, but has also become a principal cause of coastal erosion. The main sources of coastal eutrophication and pollution are untreated domestic and industrial wastewater and fertilisers. Most urban sewage is discharged without treatment. Human health issues also arise from the discharge of untreated sewage (related to urbanisation), while loss of biodiversity (or biological functioning) is seen as a complex interplay of all the principal drivers.

Sub-region 2. West Africa: featuring large trans-boundary basins (Niger, Volta, Senegal) including the medium-sized basin of the Cross River. Coastal erosion is a problem in all catchments, with critical thresholds exceeded in the Volta and Niger. Damming, deforestation and agriculture all contribute, with damming the prime cause in the Volta. Coastal sedimentation is a common issue, especially at the mouth of the Senegal River. Algal blooms are a manifestation of eutrophication, particularly in the Volta and Niger, with urbanisation (or human settlement) and, to a lesser extent, agriculture the principal drivers. Oil-related pollution is an important issue in the Cross River basin, while aquatic weeds, such as *Nypa* palm, infest all catchments. Critical thresholds for the loss of biological functioning have been exceeded in the Volta and Niger and especially in the Senegal. Human health issues, including the incidence of water-related diseases attributed to urbanisation, have been reported in all catchments, with critical thresholds being exceeded in the Volta and Senegal.

Sub-region 3. Congo: the second largest river in the world on the basis of annual flow, extending over a distance of 4 700 km from Lake Tanganyika to the Atlantic Ocean. The dominant characteristic of the Congo River is the remarkable regularity of its regime. The lower reaches of the basin (i.e., below Kinshasa and Brazzaville, some 300 km upstream) are free of major urban and industrial developments. Near the coast human activities involve fishing, gathering medicinal plants and subsistence cropping. The loss of habitat and biodiversity as a consequence of mangrove use for fuel wood is a major issue.

Sub-region 4. South West Africa (Namibia to Cape): mostly dominated by the upwelling system of the Benguela current; cool and temperate small (Berg) and medium (Olifants) catchments in the south and an arid large catchment (Gariep, formerly Orange) in the north. The major perennial river basins that influence the coastal zone include the Kunene, the Gariep, the Olifants and the Berg. Urban nodes, which also have a significant influence on the coastal zone, include Walvis Bay, Saldanha Bay, Table Bay and False Bay. The Gariep estuary is one of southern Africa's most important coastal wetlands; the dynamics of its deltaic mouth are affected by upstream impoundments and associated water-use practices. Human activities in the Olifants catchment appear to have a limited impact on its estuary and coastal zone, although damming and agriculture have led to a reduction of fresh-water inflow. In the Berg River, flow is very seasonal and the high concentration of dissolved inorganic nitrogen in the winter (wet season) is attributed largely to fertiliser from agricultural runoff. Urban and industrial nodes are associated with the progressive deterioration of water quality. Eutrophication attributed to industrial development around Saldanha Bay is of considerable concern. Of the urban node embayments, only False Bay receives significant basin drainage, with 11 small catchments discharging to the bay. Near the coast, human activities include fishing, gathering medicinal plants and subsistence cropping. The loss of habitat and biodiversity as a consequence of mangrove use for fuelwood is regarded as a major issue.

Sub-region 5. Nile: trans-boundary river system, the damming of which has led to profound changes in fluxes through the Nile delta and in the associated Mediterranean Sea. These changes are exacerbated by a rapid growth of urbanisation and industrialisation around Cairo and changes in agricultural practice in the Nile River valley and its delta region. All of these socio-economic drivers, together with the natural driver of climate change, have produced significant impacts at the coast. Notable among these has been the acute coastal erosion around the mouths of the Rosetta and Damietta distributaries of the delta, largely attributed to the almost complete cessation since the 1960s of coarse sediment flux below the Aswan dam. Damming is also responsible for the increasing salinisation of groundwater in the delta area. Other important coastal issues include eutrophication and pollution of the coastal waters from the discharge of urban and industrial wastewater (Mex Bay and Abu Qir Bay) and the loss of habitat resulting from the land-filling of coastal lagoons.

Sub-region 6. East Africa (Somalia to northern Mozambique): medium basins, seasonally flushed by rainfall principally occurring during the transitions between the north-east and south-east monsoons in April and October. All basins discharge on a coast that is characterised by fringing or patch coral reefs with an associated rich biodiversity. The Rufiji discharges through a delta dominated by mangrove forest into coastal waters that include the largely pristine Mafia Marine Park. Both the Sabaki and Tana rivers intermittently discharge sand and fines, the sand being transferred to beaches thence in part to dune systems that characterise the coast of northern Kenya. Coastal erosion and the discharge of sediment are two important issues on this coast. Fine sediment carried in suspension as plumes through the coastal waters may settle and smother growing coral. The contributions that damming, deforestation and changes in agricultural practice make to sediment input have been the subject of several studies in the Tana and Sabaki. The Tana headwaters are already dammed and additional dams are proposed, as they are for the Rufiji. Pollution is recognised as being a significant issue in the Tana and Sabaki basins with agriculture, industry and urbanisation all contributing. In the Rufiji, pesticides used in rice cultivation and the impacts of prawn farming are matters of concern, as are the impacts of population growth and the clearing of mangroves for agriculture. Pollutants and nutrients (untreated or partially treated sewage) delivered to coastal creeks from the urban-industrial centres of Mombasa and Dar es Salaam may be significant.

Sub-region 7. Central/south Mozambique: medium (Incomati) and large (Zambezi, Limpopo) catchments with high seasonality in runoff and subject to extreme cyclonic events; an estuarine/deltaic coast characterised by beach plains and mangrove-fringed creeks. The assessed catchments (Zambezi, Limpopo and Incomati) are trans-boundary systems. The rivers discharge on a predominantly alluvial coast formed mainly of older beach deposits and barrier bars and spits with associated creek systems, mangrove swamps and sand dunes. Most of the coastal issues and impacts are ascribed to damming and agricultural drivers/pressures, with reduction in stream flow a significant to acute and increasing problem. The middle course of the Zambezi River has been interrupted by two major artificial impoundments – Lake

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Kariba and Lake Cahora Bassa – which cover 5364 km^2 and 2739 km^2, respectively. Coastal erosion reported for the Zambezi delta and the Incomati River is attributed solely to damming. Loss of biological productivity, particularly in the Zambezi system, is partly a consequence of water abstraction for irrigation. The increasing salinisation of agricultural land flanking the Incomati estuary and the nutrient depletion in the coastal seas off the mouths of the Zambezi and Incomati are regarded as impacts of damming.

Sub-region 8. South-east Africa: ranging from sub-tropical in the north to warm temperate on the Cape coast and characterized by medium (Thukela, Great Fish) and small (Groot Brak, Kromme) catchments. The catchments assessed in this region comprise one medium basin (the Thukela, discharging on to the sediment-based, biologically significant Thukela Bank on the east coast) and three small basins (the Great Fish, Kromme, Groot Brak). The coast adjoining all these systems is dominated by oceanic processes being open and subject to strong wave action and longshore drift. The Thukela is the largest east coast system and is a source of water (via inter-basin transfer) for industries in the Johannesburg area and irrigation along the Vaal River, a tributary of the Gariep. The Great Fish lies in relatively arid areas and its flow has been enhanced and stabilised by the inter-basin transfer of water from the Gariep. This has significantly changed salinity gradient patterns in the estuary. The Kromme is a small system which, despite a greatly reduced freshwater input because of dam construction, retains an open mouth because of the local coastal morphology. The reduced freshwater supply has resulted in a marine-dominated, clear-water system totally different from the original estuarine community. The Groot Brak is a small system significantly impounded but also extensively investigated and manipulated to protect housing developments in the lower reaches.

on the hydrological regimes within river basins cause changes that are being translated through drainage systems into the coastal zone, including the adjacent seas.

4.3.2.2 *Coastal Issues – State Changes and Impacts*

Coastal Geomorphology (Erosion, Siltation)

Changes to the geomorphology of the coast in the vicinity of river mouths are common in the region. The processes may be erosion, as around the deltas of many of the major rivers (e.g., Volta, Nile, Zambezi) or, more unusually, accretionary (e.g., the Malindi shore in Kenya, adjoining the Sabaki). While human activities in the catchments, notably damming, water diversion and abstraction, undoubtedly play a major role, other drivers including extreme climatic events, climatic variability (e.g., monsoonal), sea-level rise and coastal engineering may also contribute. The case of the Nile is perhaps the best documented, with a clear demonstration of the linkage between the commissioning of the Aswan Dam in 1968 and rapid shoreline retreat at the mouths of the main distributaries to the Mediterranean Sea.

Reductions in river flow and discharge due to damming have caused sedimentation in many lower reaches and estuaries (e.g., Senegal and Southwest Africa). In some cases (Morocco, Southeast Africa) a lack of significant discharge has led to temporary closure or partial closure of estuary mouths by beach accretion. Reductions in river flow are held to be responsible for the growing problem of aquatic weeds (e.g., in Senegal and Volta deltas). They may also be the cause of increasing groundwater salinisation leading to losses in agricultural productivity in several estuarine situations (e.g., Moulouya in Morocco, Senegal, Incomati in Mozambique), though this effect might be exacerbated by sea-level rise.

The commonly twinned drivers/pressures of deforestation and agriculture generally have a medium though increasing impact at the coast. These activities tend to increase both the severity of flooding and the amount of sediment carried as river bed load and in suspension. The problem is acute in the small to medium catchments of Morocco (Sebou and Moulouya) and East Africa (Tana, Sabaki and Rufiji). Settling plumes of suspended sediment discharged from the Sabaki have threatened the health of the coral reef in the Watamu Marine Park at Malindi in Kenya.

The increased mobilisation of sediment resulting from agriculture and deforestation has an important bearing on the sustainability of damming in many parts of the region. In Morocco, particularly, some reservoirs are rapidly becoming operationally ineffective due to siltation.

Pollution and Eutrophication

Eutrophication at the coast as a consequence of agriculture is generally a medium-ranking, though increasing, issue for many rivers including the Moroccan rivers, the Niger and Cross rivers in Nigeria and the East African rivers. The Nile is considered to be a hotspot although such pollution is decreasing.

Eutrophication and contamination at the coast from urbanisation (or other human settlement) and industry are middle-ranking, though increasing. Acute areas are the Volta in Ghana where there are related human health issues, and the Cross River where there are serious issues of oil-related pollution. Some of the most acute problems of coastal pollution and eutrophication are derived from urban-industrial nodes within the coastline area itself, including the coastal strip at Casablanca in Morocco, Saldanha Bay and Cape Town in South Africa, the Alexandria coastal strip in Egypt and the industrial centres of Mombasa and Dar es Salaam in East Africa.

Salinisation

In the North West and West Africa, increasing salinisation is a serious issue caused variously by urbanisation and

Table 4.4. Africa. Links between coastal issues/impacts and land-based drivers; overview and qualitative ranking at regional/sub-continental scale. (Category: *1*, low; *10*, high. Trend: ⇒ stable, ⇑ increasing, ⇓ decreasing; numerals for sub-regions refer to Text Box 4.5, Fig. 4.8a)

Coastal impact/ issues	Anthropogenic drivers	West Coast			Nile Delta		East Coast		
		Category	Trend expectation	Sub-regions particularly affected	Category	Trend expectation	Category	Trend expectation	Sub-regions particularly affected
Erosion	Damming/ diversion	8	⇑	(2) Senegal, Volta, Niger	8	⇑	5	⇑	(7) Zambezi
	Deforestation	7	⇑	Most sub-regions (small and medium size catchments)			6	⇑	Most sub-regions (small and medium size catchments)
Sedimentation	Damming/ diversion	6	⇑	Major in (1, 2)	(local)		4	⇑	(6) Malindi coast, Kenya – major
	Deforestation	(4–5)	⇑	Most sub-regions (small and medium size catchments)			4–5 (7 local)	⇑	Most sub-regions (small and medium size catchments) locally major
	Agriculture	3–4	⇑	(2) Cross, (4) Gariep, Olifants, Berg			6	⇑	(6) Tana, Sabaki, Rufiji
Eutrophication	Agriculture	6–7	⇑	Major or medium ranking for most sub-regions, in particular in small and medium size catchments in 1	5–?	?	3–5	⇑	Minor most sub-regions, medium in particular in small and medium size catchments in (6)
	Urbanisation	8	⇑	Mostly in (1, 2)	8–?	?	3–5	⇑	
Pollution	Agriculture	2–7	⇑	Minor for most sub-regions, in particular in small and medium size catchments in 1, major in 2	7	⇓	6	⇑	Medium ranking for most sub-regions, in particular in small and medium size catchments in (6)
	Urbanisation/ industrialisation (incl. mining locally)	6	⇑	Mostly more coastal (1, 2, 4)	7	⇒	4	⇑	Mostly more coastal (6)
Salinisation	Damming/ diversion/ multiple drivers	6	⇑	(1) Moulouya, (2) Niger delta			7–8 (local)	⇑	(6) Tana, (7) Incomati
Nutrient depletion	Damming						5–8	⇑	(7) Southern Mozambique, (8). KwaZulu-Natal
Biodiversity loss	Various drivers	7	⇑	Almost all sub-regions	8	⇑	5–8	⇑	Almost all sub-regions
Human health issues	Various drivers	7	⇑		8	⇒/⇓	5	⇒/⇑	

agriculture (by over-abstraction of groundwater) and the natural drivers of climate change and sea-level rise. Salinisation is seen as a problem in the Niger and Cross, where the drivers are unclear, and the Senegal, where climate change (drought) is regarded as the cause. In South West Africa, during prolonged low-flow periods, salinisation in the lower reaches, particularly of the groundwater resources, has become a concern.

Biodiversity and Harvestable Resources

Loss of biodiversity and reduction in habitat are issues for all sub-regions. Generally, the linkages to drivers or pressures appear to be complex, with a wide range of contributions from land-based and coastal human activities as well as climate change. However, nutrient depletion has been identified as one key pressure associated with reduced fresh-water discharge. Damming and water abstraction result in serious reduction or depletion of land-sourced nutrients and organic matter in estuarine and coastal waters. The impacts of such depletion result in the increasing loss of biodiversity in the waters off Mozambique (Zambezi delta, Sofala bank) and KwaZulu, Natal.

4.3.3 State Changes, Impacts and Future Trends

Among the usual human activities that affect catchments, damming is the most significant driver/pressure through marked reductions in the volumes of fresh water discharged and by disruption of natural flooding regimes.

The main points from the regional synthesis are:

- Coastal erosion and sedimentation are significant and progressive impacts in nearly all sub-regions, the problems being acute on the Nile Delta and West African lagoon systems. Damming is the principal driver, with reductions in river flow and sediment flushing;
- Damming (with reductions in river flow) contributes to estuarine salinisation (sea water intrusion into groundwater; e.g., the Incomati river in Mozambique), and to nutrient depletion in the coastal sea with the consequent loss of biodiversity (e.g., off KwaZulu, Natal);
- In most sub-regions deforestation and agriculture are important drivers, particularly with respect to coastal sedimentation from medium and small catchments (e.g., the Tana and Sabaki rivers in Kenya);
- In the large West African catchments, human settlement is a major contributor to eutrophication and the proliferation of aquatic weeds;
- Serious levels of eutrophication and pollution are mostly restricted to coastal urban-industrial sources (e.g., Alexandria, Mombasa, Saldanha Bay and Cape Town); and
- Loss of biodiversity or biological functioning is a common issue, related to a complex interplay of human and natural drivers.

In ranking the coastal issues and impacts, it has proved difficult to achieve a consistency in standards between, and even within, sub-regions. Even in simple cases, the ranking of the issues and impacts and the state changes has largely been a process of expert judgement within the limitations of the often sparse data. This applies to scientific data and particularly to socio-economic infor-

Table 4.5. Africa. Major activities, present status and trends affecting the coastal zone. (Trend: ⇒ stable, ⇑ increasing, ⇓ decreasing; *numerals* refer to sub-regions described in Text Box 4.5, Fig. 4.8a)

Anthropogenic drivers	Major state changes and impact	Present pressure status	Trend expectations	Sub-regions particularly affected
Damming and diversion	Erosion sedimentation	Major	⇑	Almost all sub-regions, with (2) and (5) as particular "hot spots"
	Salinisation	Local	?	(1, 7)
	Nutrient depletion			(7, 8)
Various drivers	Biodiversity loss	Major	⇑	Almost all sub-regions
Deforestation	Erosion sedimentation	Medium		Medium ranking for most sub-regions, however, major for coastal impact generated in small and medium size catchments in (1) and (6)
Agriculture	Eutrophication pollution			
Urbanisation				Medium overall but major in 5
Industrialisation	Pollution			As above, but in most cases more coastal than catchment-based (more pronounced in 4, 5, 6)

Table 4.6.
Africa. Priority driver/pressure features by country and corresponding "hot spots" (*numerals* refer to sub-regions described in Text Box 4.5, Fig. 4.8a)

Country	Driver/pressure	Hot spots
Morocco (1)	Damming	Sedimentation through reduced flushing especially on Mediterranean coasts; salinisation of coastal plains
	Human settlement, agriculture and industrialisation	Eutrophication, pollution on Mediterranean and Atlantic coasts
Senegal (2)	Damming	Sedimentation, invasion by aquatic weeds and loss of biodiversity in Senegal River; estuarine ecosystem destroyed
	Human settlement	Human health issues
Ghana (2)	Damming	Erosion of Volta delta and invasion by aquatic weeds
	Human settlement	Eutrophication and human health issues in Volta
Nigeria (2)	Industrialisation	Oil-related pollution in Cross and Niger
South Africa (4, 8)	Damming and diversion	Nutrient depletion off southeast coast with resulting biodiversity loss; sedimentation and loss of habitat on southwest coast
	Urbanisation and industrialisation	Eutrophication and pollution at Saldanha Bay
Egypt (5)	Damming and diversion	Erosion of Nile delta
	Urbanisation and industrialisation	High levels of pollution and eutrophication in Abu Qir Bay, Mex Bay and on Alexandria city coast
Kenya (6)	Damming	Deterioration in Tana water quality
	Deforestation	Siltation at mouth of Sabaki
Tanzania (6)	Deforestation	Siltation at mouth of Rufiji
	Agriculture	Deterioration of Rufiji water quality
	Aquaculture	Pollution from prawn fisheries
Mozambique (6, 7)	Damming and abstraction	Biodiversity loss in Zambezi delta and on Sofala Bank
		Salinisation of Incomati
		Erosion of Zambezi delta

mation. Time-series data generated from routine monitoring programmes are rare. Information regarding the coastal environmental state within the region varies greatly in both its quality and availability. The scarcity of data, apart from South Africa, is a serious impediment to the understanding of the driver-impact linkages throughout much of the continent. This may have influenced the assessment output. However, for Africa a preliminary ranking order of the principal land-based drivers and pressures was drawn up together with expected future trends in impacts (Table 4.5).

Taking account of these limitations, the identification of areas calling for increased future scientific and/or management attention still seems appropriate, at least to inform future agendas. One needs to be aware of the risk that local, possibly short-term acute issues may have attracted higher rankings, while more spatially widespread and longer-term impacts that have been assigned lower rankings may turn out to be the more significant. With this in mind, a first-order list of future areas of concern has been developed, some of which are now foci for a new START/LOICZ "AfriCat" pilot project (*http://www.loicz.org*).

4.3.4 Conclusions – Africa

In general the AfriBasins data are typical of developing economy situations where economic growth and water use exceed the development of the necessary urban and industrial infrastructure. This finding parallels those for the South American and East Asian Basins assessments (Lacerda et al. 2002; Hong et al. 2002). However, heterogeneity of the sub-regions seems to be more pronounced in Africa than in other continents, making the ranking of issues and drivers in Africa a more complex challenge.

Within Africa, damming is the most significant driver/pressure resulting in marked reductions in the volumes of freshwater discharged and disruption of natural flooding regimes. During the last 50 years, damming, water diversion and water extraction have become common practices within the region, particularly in South Africa, principally for agricultural irrigation but also importantly for potable water supply and hydroelectric power generation. New dams and diversions are in their planning stages. In all the sub-regions, dam-related impacts at the coast were, with few exceptions, reported as show-

Sub-region 1 · North-West Africa – no info.: Algeria and Tunisia involved			
Driver	Major coastal impact	Present pressure status	Trend expectation
Damming/ diversion	Salinisation	Major	?
	Nutrient depletion		?
	Erosion/ sedimentation		⇑
Various	Biodiversity loss	Major	⇑
Deforestation	Erosion/ sedimentation	Major	⇑
Agriculture	Eutrophication/ pollution	Major	⇑
Urbanisation	Eutrophication/ pollution	Medium	⇑
Industrialisation	Pollution	Medium	⇑

Sub-region 5 · the Nile			
Driver	Major coastal impact	Present pressure status	Trend expectation
Damming/ diversion	Erosion/ sedimentation	Major "hot spot"	⇑
Various drivers	Biodiversity loss	Major	⇑
Urbanisation	Eutrophication/ pollution	Major	⇑
Deforestation	Erosion/ sedimentation	Medium	⇑
Agriculture	Eutrophication/ pollution	Medium	⇑
Industrialisation	Pollution	Medium (locally major)	⇑

Sub-region 2 · West Africa			
Driver	Major coastal impact	Present pressure status	Trend expectation
Damming/ diversion	Erosion/ sedimentation	Major (hot spot)	⇑
Various	Biodiversity loss	Major	⇑
Deforestation	Erosion/ sedimentation	Medium	⇑
Agriculture/ urbanisation	Eutrophication/ pollution	Medium	⇑
Industrialisation	Pollution	Medium	⇑

Sub-region 6 · East Africa - Somalia to northern Mozambique			
Driver	Major coastal impact	Present pressure status	Trend expectation
Damming/ diversion	Erosion/ sedimentation	Major	⇑
Various drivers	Biodiversity loss	Major	⇑
Deforestation	Erosion/ sedimentation	Major (small catchm.)	⇑
Agriculture	Eutrophication/ pollution	Medium	⇑
Urbanisation	Eutrophication/ pollution	Medium	⇑
Industrialisation	Pollution	Medium (but local)	⇑

Sub-region 7 · Central East Africa / south Mozambique			
Driver	Major coastal impact	Present pressure status	Trend expectation
Damming/ diversion	Erosion/ sedimentation	Major	⇑
	Salinisation;		?
	Nutrient depletion		?
Various drivers	Biodiversity loss	Major	⇑
Agriculture/ urbanisation	Eutrophication/ pollution	Medium (locally major)	⇒

Sub-region 3 · Congo (note of caution: limited information on land based drivers and trends!)			
Driver	Major coastal impact	Present pressure status	Trend expectation
Deforestation	Biodiversity loss	Major	⇑
Urbanisation	Biodiversity loss	Minor	⇑
Industrialisation	Pollution	Minor	⇑

Sub-region 4 · South-West Africa			
Driver	Major coastal impact	Present pressure status	Trend expectation
Damming/ diversion	Erosion/ sedimentation	Medium	⇑
Agriculture	Eutrophication/ pollution Biodiversity loss	Medium	⇑
Urbanisation	Eutrophication/ pollution	Medium (but local)	⇒

Sub-region 8 · South-East Africa			
Driver	Major coastal impact	Present pressure status	Trend expectation
Agriculture	Eutrophication/ pollution	Medium	⇑
Various drivers	Biodiversity loss		⇑
Industrialisation	Pollution	Medium	⇒
			⇑ (locally)
Damming/ diversion	Erosion/ sedimentation; Salinisation; Nutrient Depletion	Minor (locally medium)	⇑
Urbanisation	Eutrophication	Minor (locally medium)	⇒

Fig. 4.9. Africa. Sub-regional synthesis and typology of river catchment–coast interactions

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