Ecosystem Services for Poverty Alleviation: Marine & Coastal Situational Analysis

Appendix 1

Global Assessment

Acronyms used within this report

AC	Adaptive Capacity
BOD	Biological Oxygen Demand
CRED	Centre for Research on the Epidemiology of Disasters
D	Dependence
E	Exposure
EEZ	Economic Exclusion Zone
ES	Ecosystem Service
ESPA	Ecosystem Services & Poverty Alleviation
GDP	Gross Domestic Product
GIS	Geographical Information System
GLOBIO	Global Methodology for Mapping Human Impacts on the Biosphere
FAD	Fish Aggregation Device
FAO	Food and Agriculture Organisation
GEF	Global Environment Facility
ICPDR	International Commission for the Protection of the Danube River
IPCC	Intergovernmental Panel on Climate Change
ICZM	Integrated Coastal Zone Management Report
ISO	International Organization for Standardization
IUCN	International Union for Conservation of Nature
Km	Kilometre
LECZ	Low Elevation Coastal Zone
LOICZ	Land-Ocean Interactions in the Coastal Zone
MA	Millennium Ecosystem Assessment
MPA	Marine Protected Area
mt	Metric Tons
NCEAS	National Center for Ecological Analysis and Synthesis
NOAA	National Oceanic and Atmospheric Administration
OFDA	Office of U.S. Foreign Disaster Assistance
PEMSEA	Partnerships in Environmental Management for the Seas of East Asia
PI	Potential Impacts
PML	Plymouth Marine Laboratory
PPP	Purchasing Power Parity
S	Sensitivity
SIDS	Small Island Developing States
SOPAC	Pacific Islands Applied Geoscience Commission
SPC	South Pacific Community
SPREP	South Pacific Regional Environment Program
SURVAS	Synthesis and Upscaling of sea-level Rise Vulnerability
UN	United Nations
UNEP	United Nations Environment Programme
UNWTO	United Nations World Tourism Organisation
V	Vulnerability
VA	Vulnerability Analysis
WRI	World Resources Institute
WWF	World Wildlife Fund

1. Executive summary

This global analysis focuses on marine and coastal ecosystem services that benefit or impact the coastal poor. It has gathered existing scientific literature, along with global and regional databases, to identify important gaps in knowledge that need to be filled by future research. Geographic foci for this research were identified using a vulnerability analysis framework, using key data sources providing country-by-country information on marine and coastal ecosystem services. This analysis identified a number of regions within which countries showed high vulnerability to potential changes in marine and coastal ecosystem services:

- South Asia
- Southeast Asia
- Western Indian Ocean

Specifically, countries that showed consistent robustness to alternative vulnerability calculations, and hence featured consistently within the top 10 countries in each calculation were (in alphabetical order):

- Bangladesh
- Cambodia
- China
- Indonesia
- Philippines

The process also highlighted practical gaps where data and knowledge were either lacking, or where data were sparse.

The analysis did not aim to match the standards achieved by the Millennium Assessment – that was not the focus of the work. However, results echoed the same general issues, as outlined below. Specific data gaps, research questions and findings are highlighted throughout the report.

- **Global (country-by-country) data sets are still highly limited.**
  There are a limited number of consistent country-by-country global data sets on poverty or the range of ecosystem services specifically important to the poor. Few of the available data sets include time-series. While there are specific case studies, either thematic or geographic in focus, these cannot easily be expanded to the global scale. Indeed, the approach to ecosystem services and human well being has changed little since the MA.

- **Available data is generally focussed on provisioning ecosystem services.**
  Information on coastal and marine provisioning services is readily available through UN data sources. Information on other ecosystem services (regulating, supporting and in particular cultural) is relatively sparse, particularly at the country level. These may emerge from the work proposed within the QUEST Life Support Index study.

- **A key gap is the lack of robust mechanistic models.**
  While we have a good conceptual framework of how biodiversity (for example) underpins ecosystem services, and how these may be linked to human well being, we lack mathematical models of how these interact and react to changes. Current work under the NERC QUEST programme allows us to move in this direction, where experiments, field observations and remote sensing are integrated by mechanistic models based on first principles and benchmarked against historic phenomena. For marine and coastal ecosystem services specifically, while progress is rapid there are few physics-to-fish models; where they exist they only work for single low trophic level pelagic species. In turn, there are not yet physics-to-fish-to-fishers models.

- **A key link between 'science' and ESPA is typified by the earth-system analysis of QUEST**
  The QUEST programme offers an example of linking science with policy relevant advice. However, it must be noted that this bottom-up mechanistic approach may be very time-consuming.

- **There is a lack of consistent estimates of *coastal* poor.**
  Best available estimates were derived using available Low Elevation Coastal Zone (LECZ) population estimates, and local or country-level poverty metrics. Combining these required a number of assumptions, including that the distribution of poor across the country was equal, and hence not concentrated within the LECZ. Experience suggests that the poor may congregate in the coastal zone and coastal cities, however, making resultant estimates uncertain.

- **Definitions of both "ecosystem services" and "poor people" are varied, and contain considerable heterogeneity in their aggregate categories.**
  These cannot be discerned with current knowledge and science. Measuring and understanding the spatial and temporal distribution of the different compositions of both the ecosystems and coastal poor populations will provide greater insight into the nature and causality of the links between ecosystem services and human well being. For example, why do the poor flock to the coast? Is it because of the ready availability and easy access to common property land and natural resources? Inland ecosystem services are often inaccessible to the transient poor due to long-standing land tenure and sophisticated ownership patterns, which are less apparent for 'common pool' aquatic ecosystems. Moreover, definitions of poverty are varied, from populations living on under $1 per day, to definitions based on infant mortality rates and prevalence of child malnutrition (e.g. Socio-Economic Data and Applications Centre of the Center for International Earth Science Information Network). These tend to be based on country-level observations. While debate on the relevance of these as general metrics continue, there may be benefit in developing a poverty metric specifically relevant to marine and coastal ecosystem services. We also need analyses that understand the behaviour and decision making of the poor, along with the incentive and disincentive structures of the users of natural resources. This would clearly include some form of understanding of the distribution and harvest rate of natural resource users, both currently and in the future, in relation to the productivity of ecosystem services.

- **There is a critical need to link synthesis programmes together.**
  Bangladesh, for example, is critically reliant on, and exposed to, upstream effects in the Himalayas and in neighbouring countries (as examined in the India, Hindu Kush and Himalayan synthesis project). When selecting a geographic focus for future research, therefore, the inter-connection between ecosystem services important to the coastal poor that may be highly geographically separated, must be considered. This represents a 'mountain to the sea' approach.

- **Key geographic areas within the ESPA synthesis programme are not assessed.**
  The ESPA synthesis programme has selected specific areas of study. However, key regions with ecosystem services important to the poor have not been considered. Notably, these include inland lakes, particularly those in sub-Saharan Africa, which provide considerable ecosystem services and livelihood options to some of the poorest people in the world.

- **There is a lack of metadata for many data sets.**
  The lack of metadata (background information on the data set) represents a gap in information as to how specific data sets are developed, and whether they have been modified over time. For example, analyses performed here indicate that the rate of mangrove loss has been underestimated by 10% (FAO estimates global loss is 25%, our estimate is 35%). We need to know if a change in trend is real or an artefact of changing data collection or aggregation. However, without metadata describing the assumptions and issues behind the data, it is impossible to assess what the cause may be. Different levels of quality control and poor transparency of data collection and statistical methods of aggregation and analysis may be frequent.

- **Habitat data does not provide information on specific ecosystem services.**
  Habitats such as coral reefs and mangroves, which are studied in some detail within this report, can provide a wide range of different ecosystem services important to the poor. The habitats themselves may be studied in relative detail (e.g. estimates of area by country), and over time. However, the specific range of services provided by those habitats tend not to be studied either quantitatively or qualitatively, while changes in these services resulting from changes in habitat area (for example) are difficult to disentangle. Again, there is a need for scientific models that can be used to identify the links between changes in habitats, their multiple ecosystem services, and the poor.

- **The analysis is based upon a ‘snap-shot’ of available data.**
  The analysis is based upon a single ‘snap-shot’ of available data, due to the limited time series information available. This necessarily ignores the fact that resources vary over time, and may show cycles across seasons or long periods. The coastal poor will have diverse strategies to compensate for this, and do not necessarily limit their foraging, hunting and gathering to marine or coastal environment. They may take advantage of a variety of terrestrial inputs, either directly, or though extended family and/or trade arrangements. Furthermore, poor people may not be static, they may migrate along the coast or perhaps lead a sea-gypsy existence, and maximise the benefits of mobility by tracking seasonal abundance of marine and coastal resources.

- **The equitable allocation of ecosystem services is affected by their ownership.**
  Ecosystem service allocation is affected by ownership. For example, the development of beaches for tourism by government will reduce access to coastal ecosystem services by the poor. A further example is the balance between national income and local benefit. For example, do national resources like mangrove forests or fisheries get licensed for exploitation, generating high national export income, or are they managed sustainably on behalf of not just the current generation but also future generations? Given the value of ecosystem services, how do governments and agencies 'capture' sufficient rent to justify and enable management or equitable allocation of those services? Valuation of ecosystem services places a financial figure on their different benefits. However, these need to recognise the benefits and impacts on the local poor, whose use may have limited direct financial value, but be critical to their livelihoods. While governance is touched upon within the report, it is not studied in detail.

- **There is a need to bridge small-scale analyses, with wider-scale ecosystem service analysis.**
  The aims, scale and links between future research and policy, as well as wider scale ecosystem services and the more localised needs of the poor, need to be considered. We need to identify pertinent intermediate-scale forms of analysis, to work between local small-scale livelihoods analysis (which largely excludes any understanding of the productivity and wider sustainability of ecosystem services) and the type of analysis performed within this study, involving the data-mining of global databases (which while working at the appropriate scale to be strategic and policy relevant, often lacks sufficient mechanistic detail of causality to be sufficiently policy-relevant to effect change). Natural, social and economic scientists must undertake studies jointly; this has been missing to date.

2. Introduction

The multiple values of ecosystem services are often ignored when making decisions concerning natural resources (Wallace, 2008). This is particularly true when considering the importance of ecosystem services for the poor. The coastal region provides critical services for over 2 billion people worldwide who live within 100km of the coast or estuaries[1]. In turn, the degradation of coastal and marine resources poses critical challenges for the maintenance of ecosystem services and poverty alleviation. The *situational analysis* aims to assess the status, trends and drivers of change in ecosystem services associated with marine and coastal systems, and quantify how they support the livelihoods and well-being of human societies and particularly the rural and urban poor in developing countries, and the threats, opportunities and constraints to them. It will identify the key challenges for research, current gaps in knowledge and capacity in order to inform the development of a research strategy to support the maintenance of ecosystem services explicitly for poverty alleviation.

This global knowledge assessment aims to identify existing scientific literature and global and regional databases in order to identify key 'hot spots' where reliance of the poor on ecosystem services is high, and where the impacts on those ecosystem services has been (or will be) severe. The global assessment will ensure that issues not covered in the regional analyses are not overlooked.

The analysis aims to provide a focused assessment of existing knowledge about the current state and trends in marine and coastal ecosystems and the resultant ecosystem services. There is already a considerable body of work dealing with these issues, including the MA itself, particularly in its chapters on coastal and marine systems in the conditions working group report (chapters 18 and 19). However, whereas the MA focused broadly on ecosystem services and human well-being, the present assessment will focus very specifically on ecosystem services and the poor, and the implications for poverty alleviation. Thus concepts such as vulnerability will be central to the analysis.

2.1. Coastal and marine ecosystem services

The scientific literature highlights the significant and increasing importance of coastal and marine resources for human well-being: 26 million poor people fish for a living (FAO, 2007), while fish supplies >50% of the essential animal protein and mineral intake for 400 million people from the poorest African and South Asian Countries (FAO, 2007). This highlights the importance of aquatic ecosystem services to the poor.

There has been considerable recent debate over the definition and classification of ecosystem services (e.g. Wallace, 2008; Costanza, 2008). For consistency with existing texts, and as one of the key references on ecosystem services, we use the definitions and classifications from the Millennium Assessment (Millennium Ecosystem Assessment, 2005). This categorised ecosystem services into four groups. These were: provisioning services (e.g. food, water, timber, and fibre); regulating services (e.g. regulation of climate, floods, disease, wastes, and water quality); cultural services (e.g. recreation, aesthetic enjoyment, and spiritual fulfilment); and supporting services (e.g. soil formation, photosynthesis, and nutrient cycling).

Coastal and marine zones and their associated ecosystems specifically provide a wide range of ecosystem services across these groups: coastal protection, sink for domestic and industrial wastes, the maintenance of global biogeochemical cycles, source of income, and employment, destination for tourism and source of building materials, as well as sites of human habitation. The aim of this study is to identify the breadth and consistency of readily available data sources examining the ecosystem services provided by the marine and coastal environment at the global scale (i.e. consistent country-by-country data). This was undertaken in two stages:

[1] Note that in the face of future climate change and potential rising sea level, when identifying the poor at risk a measure of the number or density of the poor below a particular elevation may be more appropriate.

- In the first (sections 3 and 5) the literature was examined to identify sources of information on marine and coastal ecosystem services, the geographic and temporal extent and consistency of these data, and hence identify primary gaps in available knowledge.
- In the second (section 4), selected data were used within a vulnerability analysis to both test the suitability of these data, and to focus future research on marine and coastal ecosystem services in terms of geographical and thematic areas.

Particular issues are noted, both generically (section 7) and using key case studies to illustrate issues of coastal and marine ecosystem services important to the poor (section 6). Throughout, specific issues are expanded upon with text boxes.

3. Assessment of information sources

3.1. Geographical/spatial coverage

An *a priori* list of desired Ecosystem Services by group (supporting, regulating, provisioning, and cultural) was developed prior to data mining (see Annex 1, section 9). The World Wide Web and published and grey literature sources were then interrogated in an attempt to populate the resulting table. In this way, gaps in data sources could be easily identified.

The spatial scale of available information was identified during searches. If data identified to fill the desired list were available at the country level, no further searching was required. If data were found available at the regional or global average level, searching continued until a specific time limit was reached. In this way, Annex 1 represents a (time limited) representation of the availability of data on ecosystem services at the country level. These data were then extracted for analysis (sections 4 and 5).

3.2. Primary findings

There are key databases of country-by-country information. These are frequently housed by United Nations organisations, which maintain publicly available databases updated at regular (generally annual) intervals. An excellent example is that of the United Nations Environment Programme (UNEP), whose 'GEO data portal' (http://geodata.grid.unep.ch/extras/datasetlist.php) provided considerable information to this study. Global databases are generally focused on specific areas. For example, FAO focuses generally on provisioning ecosystem services. Earthtrends (WRI) covers numerous areas, from provisioning services (often based upon FAO data), governance, and indirectly cultural services (e.g. biodiversity).

Data from individual national sources may be available, but the overhead in data collation increases exponentially when compared to global data sets. In turn, the consistency of data between countries is a concern (although the consistency between country data within global data sets is also uncertain – see box 1). This is examined further for the data collated in Table 1.

Gridded geo-spatial data are available from GIS sources, for example ESRI (www.ESRI.com) provides data sets with their software, while NOAA satellite data provide detailed time series of environmental variables. In general, GIS data are often at a finer scale than country-level. To relate to countries, GIS manipulation is required to aggregate information. Decisions must then be made on the best way to aggregate and present resulting figures, be they averages, median values, extremes, etc.

There are a number of key projects examining changes and impacts on the biosphere at global levels. These include: GLOBIO (http://www.globio.info/), which aims to map the human impacts on the biosphere, and LOICZ (Land-Ocean interactions in the coastal zone; http://www.loicz.org/) which aims to provide science that contributes towards understanding the Earth system in order to inform, educate and contribute to the sustainability of the world's coastal zone. Both sites contain useful information, science, data sources and results, but may not provide the underlying information used to develop their findings, or while the information is available, it is protected and not available to the public.

Other data sources were too limited in their geographic scope for inclusion within the current study. For example, the SURVAS database (Synthesis and Upscaling of sea-level Rise Vulnerability Assessment Studies[2]) aims to synthesise available knowledge on sea-level rise threats at the regional and global scale. This offers a highly useful summary of available information. However, in its current form it is limited to 36 countries only. In turn, as noted on their website, "Many Vulnerability Analysis (VA) studies are qualitative - and hence the results are not suited to this type of database; many VA studies are quantitative but sub-national in scope; only eleven of the country results entered to date provide baseline data for comparison of impacts to the present situation (while a further six consider erosion under an evolving baseline). If a VA addresses the impact of a global sea-level rise scenario, the results are much more meaningful if equivalent information is given for the impacts of that hazard given today's situation. While the numbers in the VA studies are reported as given in the original source, the accuracy and uncertainties inherent in all these studies should be acknowledged". This demonstrates some of the issues with global datasets that need to be overcome before they can be used within the analysis attempted here.

Box 1. Data quality issues

When asked by members of the consortium to indicate numbers of poor at varying distances from the coast, this seemed a relatively straightforward task. However, at the ESPA workshop in Manila, national data on the number of poor in the Philippines was taken from an extrapolated statistic, and whilst useful as a guide to national trends, does not enable stratification by location, occupation or ethnicity.

The issue of non-stratification of poverty and ecosystem data is common in global data sets. The objective of gathering such data is presumably to provide a national statistic, rather than facilitate more complex analysis.

Global time series are often limited to a subset of countries and their usefulness is likely to be degraded as data collection methodologies and reporting procedures change. Indeed some surveys may not be monitoring per se, rather, they are temporal and spatial snapshots, and do not provide discrete data to assess demographic or ecosystem distributions within a given county.

FAO data, touted as a most useful source, is dependent upon the quality of nationally submitted data. Given that data for fisheries supplied by European countries is open to uncertainty, it would be surprising if all developing countries were able to consistently provide good reliable data. In turn, trend lines may change suddenly in one year. This is often due to a change in reporting to FAO, rather than resource use, but knowledge of the underlying data collection protocols (meta-data) is imperative in order to understand these changes.

Regional management bodies maintain a variety of data sets through their various management bodies, examples in Pacific include, SPC, SOPAC and SPREP. Similarly, individual countries may hold detailed reports from which useful information may be obtained. Detailed analysis of this sort falls outside the scope of the study.

The primary marine and coastal ecosystem service covered is provisioning. Information on catches of fish, crustacea and molluscs is available by country through FAO data sets (or the Seas Around Us Project). Provisioning services were by far the ecosystem service for which data sets were most commonly available. Data on other ecosystem services were less readily available. In part, this is because there are country-level data collection programmes on provisioning services driven by the requirements of the FAO. Other country-level information were primarily focused on ecosystems (e.g. coral reefs, mangroves), which are the subject of data collection programmes due to their impact on biodiversity, rather than the specific range of ecosystem services offered, or the impact of those services and the changes in them on the poor. This is a theme that runs throughout the work in this report.

These data sets, particularly at the country level, were not specifically collected with a poverty, and in many cases a coastal poor, focus. For all the data identified, therefore, it was necessary to extrapolate information and make strong assumptions to relate these data *to the coastal poor*.

[2] http://www.survas.mdx.ac.uk/content.htm)

A summary of the data identified for the vulnerability analysis is presented in Table 1, along with the wider range of coastal and marine ecosystem services for which data were sought. Further summaries and additional information is provided in Annex 1 (section 9). Annex 2 (section 10) presents the geographical extent of data investigated in more detail for consideration within the vulnerability analysis, and notes issues and gaps within these data.

Table 1. Summary of data on coastal and marine ecosystem services (by group) identified in this study. Initial data were used within the vulnerability analysis or presented in Annex 2. Additional data available at coarser geographic aggregation is also presented.

Description	Obtained	Source	Time series	Scope	Comments	Web Link	More data available?
Provisioning							
Fish Protein as % total supply	Earthtrends	FAO	1961-2000	Global	Data for 220 countries. Taken from fisheries statistics, of which small and subsistence fisheries data is sparse.	http://earthtrends.wri.org/searchable_db/index.php?theme=1	2002 latest
Daily food supply per capita from fish	Earthtrends	FAO	1961-2000	Global	Data for 220 countries. Taken from fisheries statistics, of which small and subsistence fisheries data is sparse.	http://earthtrends.wri.org/searchable_db/index.php?theme=1	2002 latest
Total fishery production		FAO FishStat	1950-2001	Global	Pre-1970 data still subject to some improvement	http://www.fao.org/fi/statist/FISOFT/FISHPLUS.asp	2006 latest
Aquaculture production		GEO Data Portal	1960-2005	Global	Includes all fish, molluscs, crustaceans, aquatic plants, aquatic animals and animal products, both freshwater and marine. "0.5" values are according to the provider considered as greater than zero, but less than 0.5 metric tons.	http://geodata.grid.unep.ch/mod_download/download_xls.php?selectedID=932	

Exposure							
Population	UNdata	UN Statistics Division	1950-2050	Global	Estimates and projections across four fertility variants for 262 countries.	http://data.un.org/Data.aspx?q=population+world&d=PopDiv&f=variableID%3a12%3bcrID%3a900	
Population density	UNdata	UN Statistic Division	1950-2050	Global	Estimates and projections for 262 countries population per sq km.	http://data.un.org/Data.aspx?q=population+density&d=PopDiv&f=variableID%3a14	Alternative data set available at http://earthtrends.wri.org/searchable_db/index.php?theme=4&variable_ID=431&action=select_countries
Rural Population growth rate	EarthTrends	UN Statistics Division	1950-2030	Global	5 year calculations, based on information from national sources. Projections based on exponential growth model. Data for 221 countries.	http://earthtrends.wri.org/searchable_db/index.php?theme=4&variable_ID=451&action=select_countries	
Population in low elevation zone	SEDAC	CIESIN	1990, 1995, 2005	Global	Some countries missing data, notably SIDS. Resolution of 1km used, likely to under-estimate population in LECZ	http://sedac.ciesin.columbia.edu/gpw/downloads/10mLECZ_GRUMPalpha.zip	
Population within 100km of coast	GEO Data portal	UNEP/DEWA/GRID-Europe	1990, 1995, 2000, 2005	Global		http://geodata.grid.unep.ch/mod_download/download_xls.php?selectedID=280	

Population % that are undernourished	EarthTrends	FAO	2yr averages at irregular intervals between 1969 - 2004	Global	Data only available for selected periods. Data from subsistence hunting/fishing/gathering not always included.	http://www.fao.org/es/ess/faostat/foodsecurity/Files/NumberUndernourishment_en.xls	
Gridded human impact on marine ecosystems index	GEO Data portal	NCEAS	various	Global	Geospatial data. 38 categories anthropogenic drivers of change. Drivers not used include; aquaculture, non-cargo shipping, recreational fishing, and tourism.	http://geodata.grid.unep.ch/mod_download/download_geospatial.php?selectedID=2032&temptxt=download/human_impact_egrid.zip	
Threats to reef index	GEO Data portal	WRI	1998	Global	Contains 55,000 reef locations. Threats categorised into coastal development, marine-based pollution, overexploitation, and inland pollution and erosion level.	http://geodata.grid.unep.ch/mod_download/download_geospatial.php?selectedID=383&temptxt=download/reefs_threat_e00.zip	
Regulating							
Biological oxygen demand	EarthTrends	DDG World Bank	1980-2002	Global	Estimates of biological oxygen demand focused on organic water pollution from industrial activities.	http://earthtrends.wri.org/searchable_db/index.php?theme=2&variable_ID=1226&action=select_countries	BOD in Rivers, lakes and groundwater available (GEO data)
Nutrient pollution (fertiliser)	GEO Data portal	NCEAS	Various	Global		http://geodata.grid.unep.ch/mod_download/download_geospatial.php?selectedID=2034&temptxt=download/nutri_drivers_egrid.zip	

Floods (mortality)	GEO Data portal	OFDA/CRED	1980-2007	Global		http://geodata.grid.unep.ch/mod_download/download_xls.php?selectedID=543	
Waves/Surges (mortality)	GEO Data portal	OFDA/ CRED	1980-2007	Global		http://geodata.grid.unep.ch/mod_download/download_xls.php?selectedID=603	
Mangrove Area	GEO Data portal	FAO	1980, 1990, 2000, 2005	Global	Countries with small mangrove area tend to be excluded, potentially concealing their sensitivity.	http://geodata.grid.unep.ch/mod_download/download_xls.php?selectedID=1253	Geospatial data available for 2000 from UNEP/ WCMC at GEO Data Portal
Cultural							
Marine Protected Areas	UNdata	WDPA	2007	Global	MPAs in km^2 available for 153 countries. When scaled by EEZ area (Earthtrends values), reduced to 110 countries.	http://mdgs.un.org/unsd/mdg/SeriesDetail.aspx?srid=785	
Tourism receipts	UNdata	UNWTO	2000-2005	Global		http://data.un.org/Data.aspx?d=UNWTO&f=srID%3A28300	

Adaptive Capacity							
Civil Liberties Index	EarthTrends	Freedom House	1972-2006	Global	192 Countries included. Methodology for index calculation has changed incrementally over time series.	http://earthtrends.wri.org/searchable_db/index.php?step=countries&cID%5B%5D=205&theme=10&variable_ID=508&action=select_years	
Democracy Index	EarthTrends	Polity IV Project	1970-2003	Global	More recent data less reliable, as indices are back-corrected as more data becomes available.	http://earthtrends.wri.org/searchable_db/index.php?theme=10&variable_ID=509&action=select_countries	
GDP per capita	EarthTrends	DDG World Bank	1960-2005	Global		http://earthtrends.wri.org/searchable_db/index.php?step=countries&ccID%5B%5D=0&allcountries=checkbox&theme=5&variable_ID=222&action=select_years	
Per capita GDP increase	EarthTrends	DDG World Bank	1961-2005	Global		http://earthtrends.wri.org/searchable_db/index.php?step=countries&ccID%5B%5D=0&allcountries=checkbox&theme=5&variable_ID=641&action=select_years	

GDP Purchasing power parity	GEO Data portal	World Bank	1975-2005	Global	Many SIDS missing	http://geodata.grid.unep.ch/mod_download/download_xls.php?selectedID=81	Alternative world bank data with less omissions available at EarthTrends
Infant mortality rate	UNdata	UN Statistics Division	1960-2005 in 5yr increments	Global	Mortality rate for children under five per 1000 births for 193 countries.	http://data.un.org/Data.aspx?q=Child+mortality&d=MDG&f=seriesRowID%3a561	Under 5 mortality rate projection available at GEO Data
Ecological footprint	GEO Data portal	WWF	2001	Global	Measures of the consumption of renewable natural resources by population.	http://geodata.grid.unep.ch/mod_download/download_xls.php?selectedID=1897	
Marine production exports (trade balance)	EarthTrends	FAO	1976-2005	Global	Calculable from marine imports and exports	http://earthtrends.wri.org/searchable_db/index.php?theme=1&variable_ID=1430&action=select_countries	
Net migration rate	GEO Data portal	UNPD	1950-2050 in 5yr intervals	Global	Protected data	http://geodata.grid.unep.ch/mod_download/download_xls.php?selectedID=1422	

Population % living below $1	GEO Data portal	DDG World Bank	1979-2003	Global	Much missing data in time series for most countries.	http://geodata.grid.unep.ch/mod_download/download_xls.php?selectedID=1850	Averaged values between 1989-2004 available at EarthTrends
Potential Data Sources							
Supporting							
Nutrient Cycling – wind, climate, and other weather data		NOAA	Various	Various global locations	Some free data, some subscription only. Journals vary in content and data scope.	http://www.ncdc.noaa.gov/oa/mpp/freedata.html	
Nutrient Cycling – River discharge		SAGE	Various	3500 locations worldwide	Stations contain times series between 3 and 100 yrs of monthly mean river discharge	http://www.sage.wisc.edu:16080/riverdata/	By country at http://www.rivdis.sr.unh.edu/download.html
Primary productivity	OceanColor	NASA	Various	Global	Changes in ocean productivity estimates	http://oceancolor.gsfc.nasa.gov/	http://web.science.oregonstate.edu/ocean.productivity/
World maps of supporting ES		UNEP	Various	Global	Maps of mangroves, coral disease, seagrasses, and MPAs.	http://www.unep-wcmc.org/	

Mangrove Area		FAO	Global	1980-2005	Forestry paper on current and past extent of mangroves worldwide.	http://www.fao.org/docrep/010/a1427e/a1427e00.htm	
Regulating							
Sea level rise	BODC	GLOSS	Various locations world-wide	1991-2002	Data from coastal tide gauges and bottom pressure recorders.	http://www.bodc.ac.uk/data/online_delivery/international_sea_level/	Map showing potential loss of land through varying levels of sea rise. http://www.globalwarmingart.com/sealevel
Coastal protection		CHRR/ CIESIN	Global	1985- 2003	Geospatial representation of foods worldwide. Some poor and missing data in early/mid 1990s.	ftp://ftp.ciesin.columbia.edu/pub/hotspots/gdfld.zip	>1000 locations of reefs worldwide at ocean color. http://oceancolor.gsfc.nasa.gov/cgi/landsat.pl?t=321&path=36&row=77
Actual renewable water sources	EarthTrends	FAO/ AQUASTAT	Global	2006, 2007	Maximum amount of water per person data, for each country. Accuracy and reliability of the information vary greatly among regions, countries, and categories of information, as does the year in which the information was gathered.	http://earthtrends.wri.org/searchable_db/index.php?theme=2&variable_ID=3&action=select_countries	

Sea level vulnerability	SURVAS	Variety	Country by Country	Various	Vulnerability indicators for 36 countries in sea level rise VA. Data gathered from a variety of sources.	http://www.survas.mdx.ac.uk/content.htm	
Emergency events		EM-DAT	Global	1988-2007	Database of disasters at a national level.	http://www.emdat.be/index.html	
Waste disposal and processing	EIONET	ETC/ RWM	Europe	1980-2003	WasteBase includes data on quantities, policies, and sectors across 15 European countries. Also includes some related international data.	http://waste.eionet.europa.eu/facts/wastebase	Australian data http://awd.csiro.au/
Waste disposal (Asia)	Ingenta Connect	JMCWM	Asia		Paper in Journal of Material Cycles and Waste Management available through Ingenta.	http://www.ingentaconnect.com/content/klu/10163/2004/00000006/00000002/art00004	South African report http://wis.octoplus.co.za/?menu=16
Freshwater storage and retention	EarthTrends		Global	2000	Proportion of internal renewable water resources withdrawn on an annual basis data, compiled over a period of 15-25 years. Some agricultural water use not included.	http://earthtrends.wri.org/searchable_db/index.php?theme=2&variable_ID=6&action=select_countries	

Freshwater and water quality	UNSD	UNEP/ AQUASTAT	Global	Various	Variety of freshwater data, including resources, supply, and waste. Also includes pollution data and emissions.	http://unstats.un.org/unsd/environment/qindicators.htm	Data from 3000 stations available at http://www.gemstat.org/ only rivers, lakes and ground-water
Pollution	EarthTrends	Various	Global	Various	Pollution can be inferred from data on use of pesticides, fertiliser etc.	http://earthtrends.wri.org/index.php	Similar data on FAOSTAT http://faostat.fao.org/default.aspx
Provisioning							
Fisheries		FAO	Global	Various	Production from marine, freshwater, aquaculture, fleet, and subsequent trade data available.	http://www.fao.org/fishery/statistics/programme/3,1,1	More fisheries and aquaculture data at http://earthtrends.wri.org/index.php
Nutrition		FAO	Global	1961-2003	Data on consumption of crops, livestock and fish. e.g. Protein % per capita from cephalopods etc.	http://faostat.fao.org/site/345/default.aspx	Nutrition data also at EarthTrends http://earthtrends.wri.org/index.php
Aquarium trade	UNEP/ WCMC	Various	Various Companies World-wide	Various	Contains records of species traded from a country, to a importing country, and the date.	http://www.unep-wcmc.org/marine/gmad/index.html	USA Trade data maybe available under Freedom of Information Act

Salt production	Salt Institute		Top ten producers	1985- 2006	Top ten countries production of salt. Also includes world salt production. USA back to 1949, and back to 1900 at http://minerals.usgs.gov/ds/2005/140/salt.pdf	http://www.saltinstitute.org/36.html	Europe trade data under SITC code 27830 at http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do
Invasive Species	Conserve Online	Molnar et al.	232 Marine Eco-regions		Non-native and 'harmful' non-native species count across marine ecosystems. Taken from 'Assessing the global threat of invasive species to marine biodiversity', Molnar at al 2008	http://conserveonline.org/workspaces/global.invasive.assessment	Some limited, assorted data at http://www.issg.org/database/reference/index.asp Some specific location data at http://www.invasivespeciesinfo.gov/aquatics/databases.shtml
Cultural							
Marine Protected Areas	MPA Global		Various Regions		List of MPAs under country, programme, or geographical region. Includes area in km^2, designation, and date created.	http://www.mpaglobal.org/home.html	Geospatial data available at http://sea.unep-wcmc.org/wdbpa/

Poverty metrics							
Population % below poverty line	UN		Global	Various	Data for varying years across 82 countries.	http://data.un.org/Data.aspx?q=poverty&d=MDG&f=seriesRowID:581	
Adaptive Capacity							
Fecundity	UNData	UN Statistics Division	Global	1950-2050 in 5yr intervals	Estimates and projections of crude births per 1000 population, using four variants of fertility.	http://data.un.org/Data.aspx?q=birth&d=PopDiv&f=variableID:53	

3.3. The country-specific focus of research funders

One potential reason for the variation in data availability is the focus of research funding organisations within a particular country, and the changes in that focus over time. To examine this further, the thematic areas in which the World Bank had produced reports for the top quartile of vulnerable coastal countries (as estimated in section 4.4) was evaluated (Table 2; see also Annex 3 (section 11)). The World Bank website was examined, and the available time series of reports related to ecosystem services for each country were collated into 6 different general categories.

An obvious signal from this research is that agriculture-related research is a primary focus for the World Bank in the majority of countries. Fisheries and marine and coastal issues are covered to a much lower extent, but do feature notably in countries such as the Maldives and the Philippines. For the majority of identified vulnerable countries, however, fisheries, marine and coastal issues are not an area of focus.

This exercise focused on one key international research funder. Being a Bank, there may be bias in the results since money may be lent only to those developing countries that are likely to repay loans. However, the exercise does illustrate one reason why so many data gaps on marine and coastal ecosystem services remain.

Table 2. Thematic areas for World Bank reports by country

Country	Marine & Coastal	Freshwater	Forestry	Agriculture	Fisheries	Other[1]
Maldives	4				1	2
Cambodia						
China		1		5		
Bangladesh	1			7	1	
Indonesia			1	13		
Sierra Leone				2		1
Philippines	3 + 6* (9)	1	1		2 + 6* (8)	1
Angola				1		
Vietnam	1	2		2	2	3*
Nigeria		1		7		1
Thailand	1		1	7	2	4 + 3* (7)
Senegal		1		4	1	1
Ghana				9		1
DR Congo			1	3		
Cameroon		1	1	11		
Malaysia			2	2	1	
India		6	4	23	1	5
Tanzania	2	1	2	10	1	2
Gambia			1	2		
Rep. Korea		1		1		
Solomon Islands	1			1	1	1
Liberia				1		
Sri Lanka		1		3		2
Guinea				4		
Egypt		1		3		
Mozambique	1			5	1	
Togo				2		
Madagascar			1	3		
Guyana						1

* indicates multiple hits from serial annual reports.

[1] includes factors that could not be linked to specific ecosystems, mainly focussing on pollution (general, urban environment pollution), eco-tourism, biodiversity conservation etc.

4. Assessment of Ecosystem Services (Vulnerability analysis)

To develop recommendations for future research on marine and coastal ecosystem services, and to test the suitability of identified data sets, a global vulnerability analysis was performed (Adger, 2006).

The analytical framework was based on that used by the Intergovernmental Panel on Climate Change (IPCC) and the Millennium Ecosystem Assessment (McCarthy et al. 2001; Kasperson et al. 2005). Examination of future states at local levels in particular proved unrealistic given data availability and the limited capacity for defensible predictions of future states at smaller scales (e.g. IPCC, 2007). While recognizing the multi-scaled, multi-faceted nature of vulnerability, the 'global' analysis is constrained to the scale of national economies. This choice of scale is not entirely a pragmatic one driven by the availability of data; the purpose is to identify those countries that are most vulnerable because their poor have a relatively high level of exposure to future change (e.g. due to a changing climate), high dependence on ecosystem services, and low capacity to respond to social and economic change. While many communities are characterised by adaptability to seasonal and environmental variability, it is difficult to capture and quantify exposure, ecological and societal sensitivity and adaptive behaviour and coping strategies at local scales in a comparable and systematic manner across nations. Additionally, focusing at the national scale captures additional factors influencing the vulnerability of national economies to change, such as national and regional policies and trade flows.

Vulnerability comprises three key elements, which may be combined in a composite vulnerability index. The potential impacts of changes in ecosystem services important to the poor depend upon the extrinsic exposure (E) to those changes, the degree of intrinsic sensitivity to those changes (S), or their dependence of the poor upon those ecosystem services, and the extent to which adaptive capacity (AC) enables these potential impacts to be offset. There are no objective, independently derived measures of exposure, sensitivity, or adaptive capacity, and so their relevance and interpretation depend on the scale of analysis and the particular sector under consideration. Therefore, measures were developed to best capture the issues under these factors for ecosystem services important to the poor, based upon available data.

To enable the analysis, identified data (Table 1) were extracted at the country level. These data were related to corresponding ISO 3166 country codes to ensure consistency between data sets and ease of analysis. Selection of those data sets to comprise the three components of vulnerability is detailed below.

4.1. Exposure

An exposure index was created to represent the degree to which the poor within a country will be affected by changes in marine and coastal ecosystem services.

Two approaches were considered. The first was the potential to examine trends in the ecosystem services important to the poor at a country level. However, time series data on ecosystem services was sparse in geographical coverage, temporal extent, and documented quality (section 5). As a result, alternative metrics of exposure were concentrated upon.

Metrics for exposure were based upon the population (and poor) within the coastal zone, as a measure of both exposure of the poor to changes in coastal and marine ecosystem services and of the potential pressure on those services, and the number of people exploiting coastal and marine resources, namely the number of people within a country employed within the fisheries and aquaculture sectors.

Coastal population

The coastal population was calculated using the low elevation coastal zone (LECZ[3]) dataset (McGranahan et al., 2007). This dataset (see section 10.1) provides country-level estimates of urban, rural and total population and land area within the coastal zone, using remote sensing data. The total population estimate was used to estimate the population within the area potentially affected by severe

[3] http://sedac.ciesin.columbia.edu/gpw/lecz.jsp

future climate change related sea level rise, yet potentially limited in their adaptation options in the face of natural disasters.

Geographic coverage of these data and the top 10 countries within each metric are presented in section 10.1. This data source provides information for 182 countries.

Coastal poor

Ideally, values for the number of people living in poverty within the coastal zone are needed to best define exposure within the analysis. However, there are no country level global databases detailing the number of coastal poor. The closest database to achieving a specific geographically disaggregated estimate of poverty is that within the CIESIN programme. However, this poverty data is based on infant mortality rates and prevalence of child malnutrition. Neither of these are coastal poverty focused, nor directly relevant to ecosystem services. Similar metrics are considered within section 10.3.

To estimate the number of coastal poor for the analysis, a number of assumptions were required. For example, using country-level poverty rates assumed that the poor remained uniformly distributed across the country, and did not congregate along the coastline or in cities. To test the impact of these assumptions, two alternative metrics of coastal poverty were calculated to examine the sensitivity of the estimated exposure to the assumptions made.

The population within the low elevation coastal zone (see above) was multiplied by two alternative poverty metrics:

- The percentage of the population living under $1 per day
- The percentage of the population living under the national poverty line

These metrics were selected from the poverty indicators identified (see section 10.3).

It must be noted that these poverty metrics are extremely limited in geographic scope, and become more limited when multiplied by the data available for coastal population (Figure 19). As a result, estimated levels for the coastal poor were only available for:

- Population living on <$1 per day: 67 countries
- Population below national poverty line: 57 countries

Further limitations resulted from a lack of these metrics within global databases referring to small island developing states. It was noted that estimates may be available by region (e.g. from organisations such as South Pacific Community), but there are often inconsistencies in the ways in which data are calculated between countries and in particular regions, which must be considered within the style of analysis performed here.

At present, the lack of consistent and readily available information on the number and distribution of the coastal poor in each country represents a key gap in information.

Employment in fisheries and aquaculture

A further measure of the potential exposure of countries to a decline in key marine and coastal ecosystem services is the number of fishers that are present in the country. This metric will be strongly influenced by the extent of the country's population and therefore needs to be scaled appropriately. Two alternative approaches were taken, calculating the number of people employed relative to the extent of coastline (i.e. a density measure), and by the proportion of the population living in the low elevation coastal zone (i.e. the importance of fisheries to the coastal population). Resulting metrics are presented in section 10.6. These metrics were available for the majority of countries:

- Number of fishers/km coastline: 176 countries
- Number of fishers % coastal population: 177 countries

It must be noted that the fishers metric is defined as 'People employed in fishing and aquaculture includes the number of people employed in commercial and subsistence fishing (both personnel on fishing vessels and on shore)'. However, occasional and full time fishers, i.e. those fishing for subsistence versus income, may not be separated accurately. In particular, subsistence/occasional fishers may be very difficult to identify, either directly or through census, and hence the importance of fisheries as a source of employment and individual income within a country may be underestimated.

Exposure calculation

The availability of information at a country level and relevance of information for the potential exposure of countries to changes in coastal and marine ecosystem services were considered when developing the overall exposure metric. Given the disparity in geographic data coverage, the following metrics were used to calculate two alternative measures of exposure:

- Low elevation coastal zone population (2000)
- Increase in coastal zone population (1990-2000)
- Number of people involved in fisheries and aquaculture (2000)
- Estimated coastal population living under $1 per day

The <$1 per day poverty metric was selected due to the slightly increased number of countries for which the information was available.

The first measure was based upon the total coastal population, its rate of change, and the number of people involved in fisheries and aquaculture. The resulting metric was available for 167 countries (Figure 1).

The second measure substituted the total population with the estimated population living on under $1 per day in the coastal zone. The resulting metric was available for 64 countries (Figure 1).

Both metrics are dominated by countries with large and increasing population within their low elevation coastal zones (Table 3), as well as a large number of individuals involved within the fishing and aquaculture industry (Figure 1). The inclusion of the poverty metric did not have a large effect on the overall order, although Nigeria, Pakistan and Egypt were then included in the top 10. The top quartile is dominated by Asian countries, as well as South America. Southeast African countries, including Mozambique, Tanzania and Madagascar, are also included within exposure metric 1. Taking poverty into account, the focus is on Asia, Brazil, Mexico, and African countries such as Madagascar, Nigeria, Ghana and Tanzania (see Figure 1)

It is noteworthy that when the number of fishers is scaled by the total population estimate within the low elevation coastal zone, a number of small island developing states are included within the top 10 (see section 10.6).

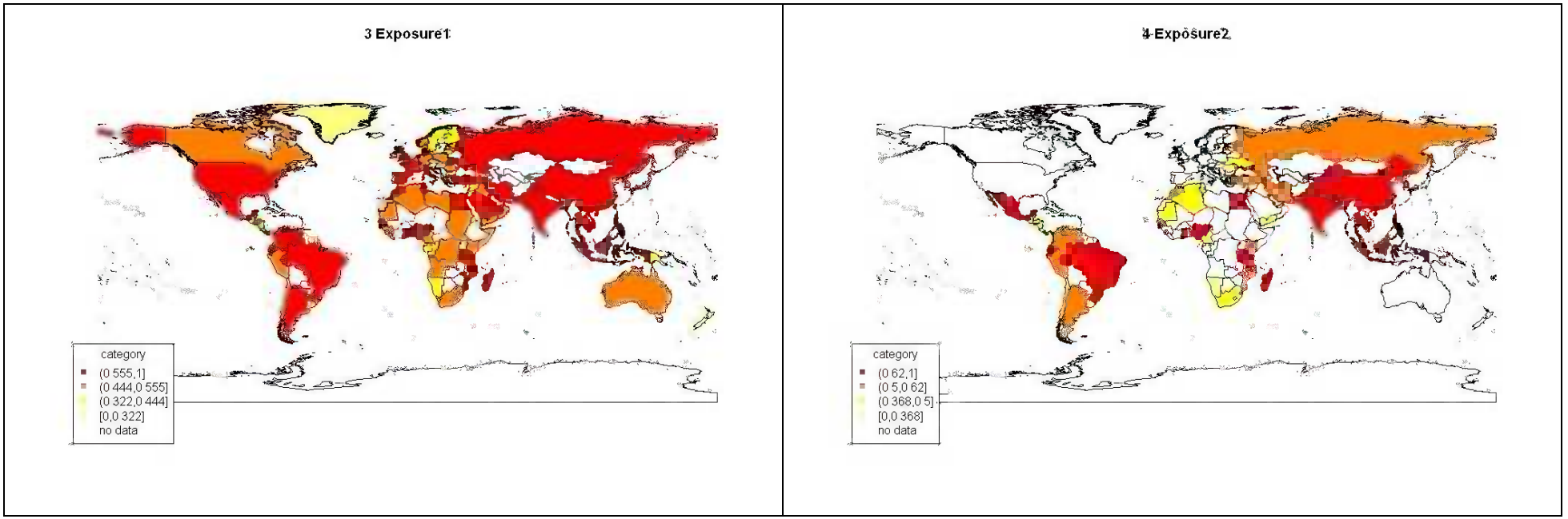


Figure 1. Charts of the calculated exposure metrics, as quartiles.

Table 3. Top 10 countries with respect to exposure metrics

Rank	Exposure metric 1	Exposure metric 2
1	China	China
2	India	India
3	Indonesia	Bangladesh
4	Bangladesh	Indonesia
5	Vietnam	Nigeria
6	Philippines	Philippines
7	Myanmar	Brazil
8	Japan	Pakistan
9	Egypt	Egypt
10	Thailand	Thailand
No. countries:	167	64

Data gaps
Key gaps identified within the process of estimating country-level exposure were:

- A need for accurate estimates of numbers of the poor within the coastal zone at a regional, country, and local level
- Coastal poverty data for SIDS
- Recent estimates of coastal zone population – LECZ data are available up to 2000
- Projected increases of poor specifically for coastal zone populations
- Behaviour of the poor in each country – do they migrate to the coast, or to coastal or inland cities?
- A need to identify and distinguish full time and part time fishers
- A need to ensure that the estimation of these values is consistent across countries (metadata)
- A need to stratify the fisheries and aquaculture employment by marine, estuarine and inshore (lake) fishers

4.2. Sensitivity

Sensitivity is usually defined as the intrinsic degree to which biophysical, social and economic conditions are likely to be influenced by extrinsic stresses or hazards. However, because change in ecosystem services may affect ecological and human requirements in different ways, sensitivity was defined in a slightly different way.

Sensitivity was evaluated as the opportunities for and reliance on ecosystem services at the country level. In many cases, a direct relationship between the availability of ecosystems services at a country level and the usage of those services in general and *by the poor* in particular, was not available across identified ecosystem services. Therefore, a general LECZ per capita estimate of ecosystem services was calculated where sufficient country level data were available. As discussed in section 3, comprehensive information on the ecosystem services at the country level was difficult to find. For example, information on mangroves at the country level was available from 120 countries – partly a result of the restricted environmental conditions required to allow mangroves to develop, and part an indication of the restricted information that is available on marine and coastal ecosystems services.

Acknowledging that comprehensive and direct data on potentially vital services were missing, a variety of different ecosystem service metrics were identified. These were considered for inclusion within the sensitivity metric calculation (Table 4).

Table 4. Measures available for different ecosystem services considered for the calculation.

Ecosystem service type	Measure	No. countries available
Provisioning	EEZ total catch	183
	Fish consumption per capita	86
	Fish as % total protein	141
	Per capita LECZ EEZ catch	169
Regulating	Mangrove area as % coastline	119
	Reef area as % coastline	103
Range of ecosystem services	Mangrove area	121
	Reef area	104
	Overall ecological footprint	116

Sensitivity calculation

The sensitivity metric selected for calculation was a composite of a number of measures. This attempted to capture the variety of different marine and coastal ecosystem services important to coastal poor, while balancing the sparse coverage of some of the metrics. The following data sets were selected:

- Fish as % total protein (the reliance of the country's population on provisioning services; see section 10.4)
- Mangrove area (as a composite of provisioning and regulating services; see section 10.7)
- Reef area (as a composite of provisioning and regulating services; see section 10.9)

The issues with these ecosystem service data sets are discussed further in section 10. From these, two metrics of sensitivity were calculated.

- The first concentrated on provisioning services, using fish as a % total protein. This metric covered 141 countries.

- The second metric used that variable, along with the two habitat metrics (mangroves and coral reefs), to include alternative ecosystem services. This selection reduced the number of countries to those specifically with mangrove and coral reef habitats, i.e. 64 countries.

The two different metrics demonstrates the sensitivity of this analysis to the data available, and the limited country-based information on marine and coastal ecosystem services.

The top 10 countries of sensitivity metric 1 include a high proportion of small island developing states, not easily identifiable from the corresponding world chart (Figure 2; Table 5). SIDS have a high reliance on fish as a source of protein, with few other options in the face of expensive-to-import alternative protein sources (see also section 6.4). From Figure 2, regional sensitivity is notable in southeast Asia and west central Africa.

Sensitivity metric 2 was dominated by those countries with high coverage of coral reefs and mangroves (Table 5). Regionally, sensitivity was notable in Asia, and western Indian Ocean (specifically Tanzania and Madagascar) (Figure 2).

Table 5. Top 10 countries relative to sensitivity

Rank	Sensitivity metric 1	Sensitivity metric 2
1	Maldives	Indonesia
2	Kiribati	Philippines
3	Japan	Australia
4	Samoa	Malaysia
5	Solomon Is.	Solomon Is.
6	Seychelles	Thailand
7	Iceland	New Caledonia
8	Malaysia	Fiji
9	South Korea	The Bahamas
10	Guyana	Myanmar
No. countries:	141	64

The sensitivity metric 1 includes South Korea within the top 10 sensitive nations. Notably, North Korea is not included in the analysis, due to data limitations.

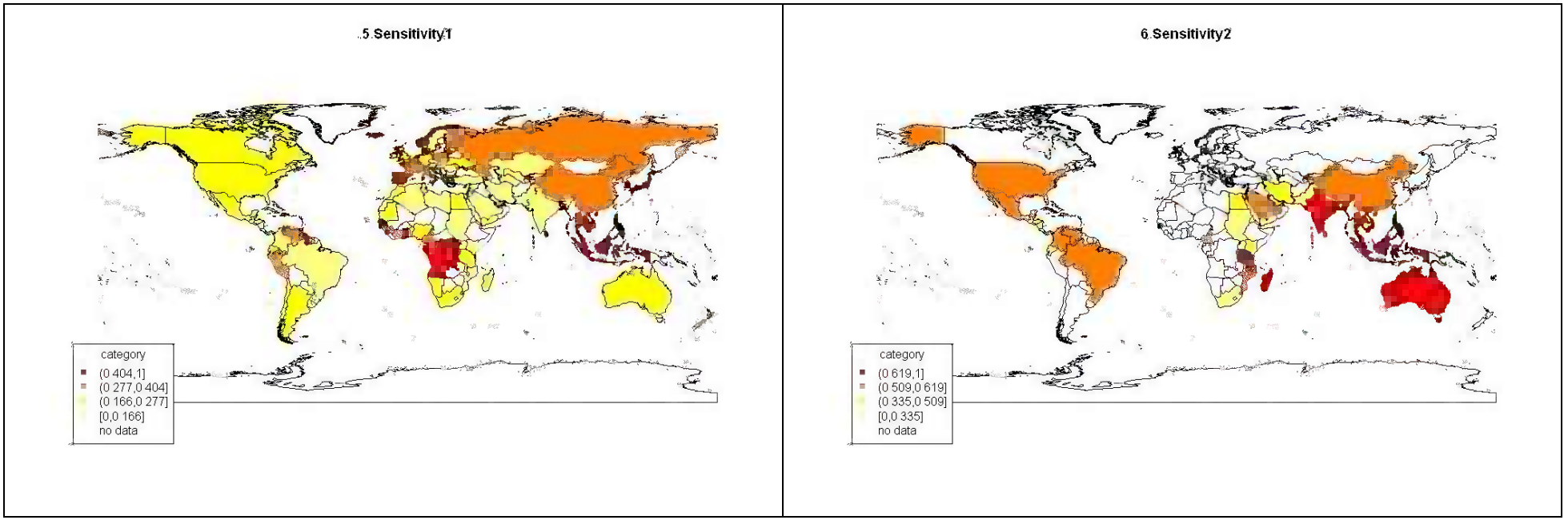


Figure 2. Charts of the calculated sensitivity metrics, as quartiles

Knowledge gaps

- There is a need to identify the relationship between the availability of ecosystem services at a country level, and the reliance on and usage of those services by the coastal poor
- While information on many direct provisioning services was frequently available at the country level, there was limited information available on other provisioning services, and directly on regulating, supporting and cultural services
- While information on habitats and structures providing a variety of cross-cutting ecosystem services of potential importance to the coastal poor were available (e.g. coral reefs, mangroves), information on the levels and trends specifically on those provided ecosystem services was lacking at the country level
- Snap-shots of the status of particular ecosystem services were available (in particular provisioning services, as noted). However, time series of information on these services was generally lacking. As a result, the trends and hence potential impacts of changes on the livelihoods and wellbeing of the poor could not be assessed.
- While the ecosystem services were not weighted within this analysis, their importance to the poor may vary considerably. For example, one may consider that cultural services, while being important, may not be rated as highly as those provisioning services that keep the poor alive. Obtaining weights for the different services from the poor themselves, e.g. through extended regional workshops, could prove useful to refine analyses.
- The measures of ecosystem service identified provide positive incidences. Whereas a critical factor is knowledge of those countries that should, could, or did have these ecosystem services but are now bereft. The poor in these countries are presumably more vulnerable as a consequence of this lack of ecosystem services. However, this would not be identified in the current analysis. Improved knowledge is therefore needed on historical state of ecosystem services. This could be documented either scientifically or through cultural memories.

4.3. Adaptive capacity

The index for adaptive capacity was calculated from 3 variables, the per capita GDP (143 countries), life expectancy (156 countries), and the civil liberties index (as a measure of governance; 154 countries) (see Figure 32).

Healthy life expectancy was the number of years a newborn child can expect to live in full health based on current mortality rates and the distribution of health states in the population. Countries with significant health costs are likely to find it socially and politically difficult to allocate resources to mitigate and to adapt to changes in ecosystem services, while those changes may imply greater pressures on the health of the population. The civil liberties index measures the 'freedom in the world' in 2007, based upon an annual survey of political rights and civil liberties. In more totalitarian societies, the reactivity to pressures from declining ecosystem services, and indeed a continual pressure on those services, is likely reduced (e.g. Burma in recent months). GDP is the sum of gross value added by all resident producers in the economy, plus any product taxes, less any subsidies not already included in product values. We used the total GDP, converted from local currency to 2005 US dollar value using purchasing power parity, as a measure of the size of the economy (PPP) (see section 10.15).

It is noteworthy that data for the calculation of adaptive capacity was often missing for small island developing states. This limited the analysis for these vulnerable countries.

The countries with the lowest adaptive capacity tended to be in the African continent (Figure 3; Table 6). Indeed, all 10 of the top 10 countries were from this continent. Low adaptive capacity scores were also seen in Iran, Pakistan, ex-Soviet states, and Papua New Guinea. Other Asian countries tended to be within the second quartile.

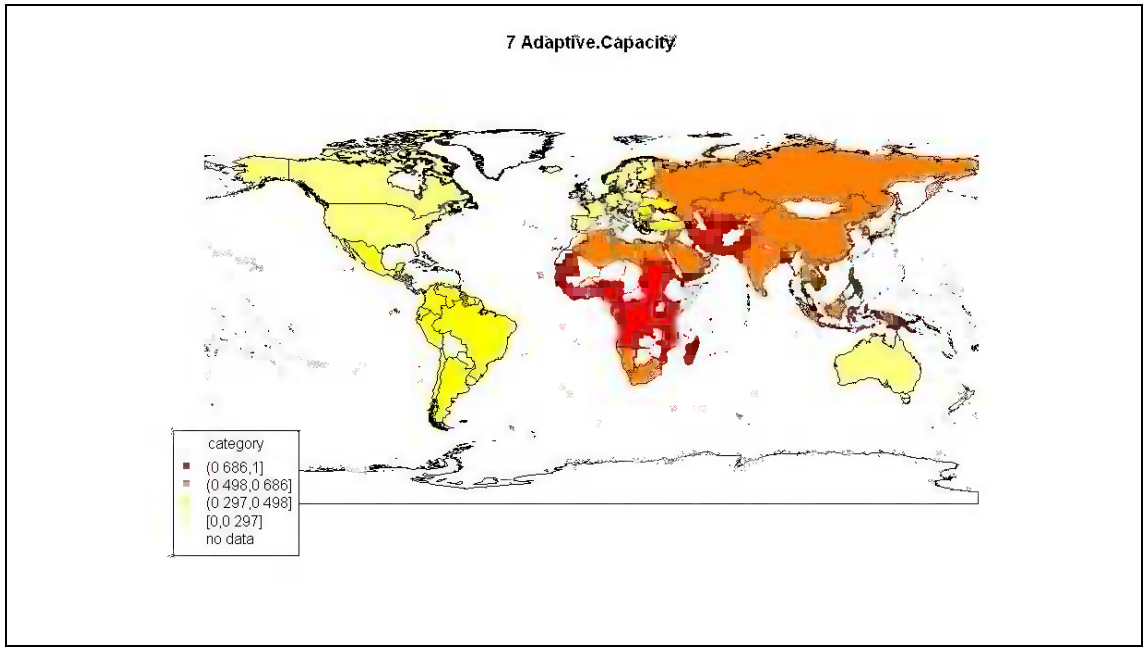


Figure 3. Chart of the calculated adaptive capacity metric, as quartiles.

Table 6. Top 10 countries relative to low adaptive capacity

Rank	Adaptive Capacity metric
1	Liberia
2	Guinea Bissau
3	Mozambique
4	Sierra Leone
5	Eritrea
6	Cote D'Ivoire
7	Cameroon
8	Angola
9	Nigeria
10	Guinea
No. countries:	132

Knowledge gaps

- While a range of adaptive capacity measures was available, these seldom encompassed small island developing states. This limited the analysis for these vulnerable nations.
- The adaptive capacity metrics used defined a country's ability to adapt to issues. These did not specifically relate to the adaptive capacity to changes and failures in marine and coastal ecosystem services
- Related to the point above, the country-level adaptive capacity metrics do not necessarily relate to the ability of the coastal poor in particular to adapt to changes in ecosystem services. These individuals may have developed separate coping mechanisms to deal with changes that are unrelated to the country-level metrics.
- There is considerable literature on adaptive capacity within the literature. However, there is a need to focus not on capturing the full array of adaptive capacity components, but on finding the single, most widely available, metric that correlates with the multivariate measures of adaptive capacity. For example, at a country level, GDP might correlate with, and explain, the majority of variance in all other multivariate adaptive capacity indices.

4.4. Vulnerability

The exposure, sensitivity and adaptive capacity components were normalised using a (natural) log transformation. All variables were standardised to a range between 0 and 1 as follows:

standardised variable = (actual value-minimum value)/(maximum value-minimum value).

For exposure and ecosystem service dependence, the country with the lowest value scored 0, and the country with the highest value scored 1. For adaptive capacity, the converse applied.

The Intergovernmental Panel on Climate Change and Millennium Ecosystem Assessment vulnerability assessment framework is qualitative and requires consideration of how the three variables (exposure, fisheries dependence and adaptive capacity) are combined to produce a vulnerability index. This framework assumes that the potential impacts (PI) of climate change are a function of both exposure (E) to climate change and dependence (D) upon the economic, production or livelihood systems of interest, such that PI = f (E, D). Vulnerability is the degree to which the potential impacts of climate change can be offset, reduced or modified by adaptive capacity (AC), such that V = f (PI, AC) or V = f((E, D), AC). Implicit in this scheme is that any vulnerability score is weighted half to adaptive capacity and one-quarter each to exposure and dependence. A more conservative approach is to avoid weightings altogether, by simply averaging the three components: exposure, fisheries dependence and adaptive capacity as V = f (E, D, AC). This approach was taken in the current study.

Given the range of exposure and sensitivity metrics available, four different vulnerability metrics were calculated:

- Vulnerability metric 1: Exposure metric 1, Sensitivity metric 1, Adaptive Capacity metric
- Vulnerability metric 2: Exposure metric 2, Sensitivity metric 2, Adaptive Capacity metric
- Vulnerability metric 3: Exposure metric 2, Sensitivity metric 1, Adaptive Capacity metric
- Vulnerability metric 4: Exposure metric 1, Sensitivity metric 2, Adaptive Capacity metric

The resulting vulnerability scores are presented in Figure 4, and the top 10 countries within each vulnerability metric are presented in Table 7.

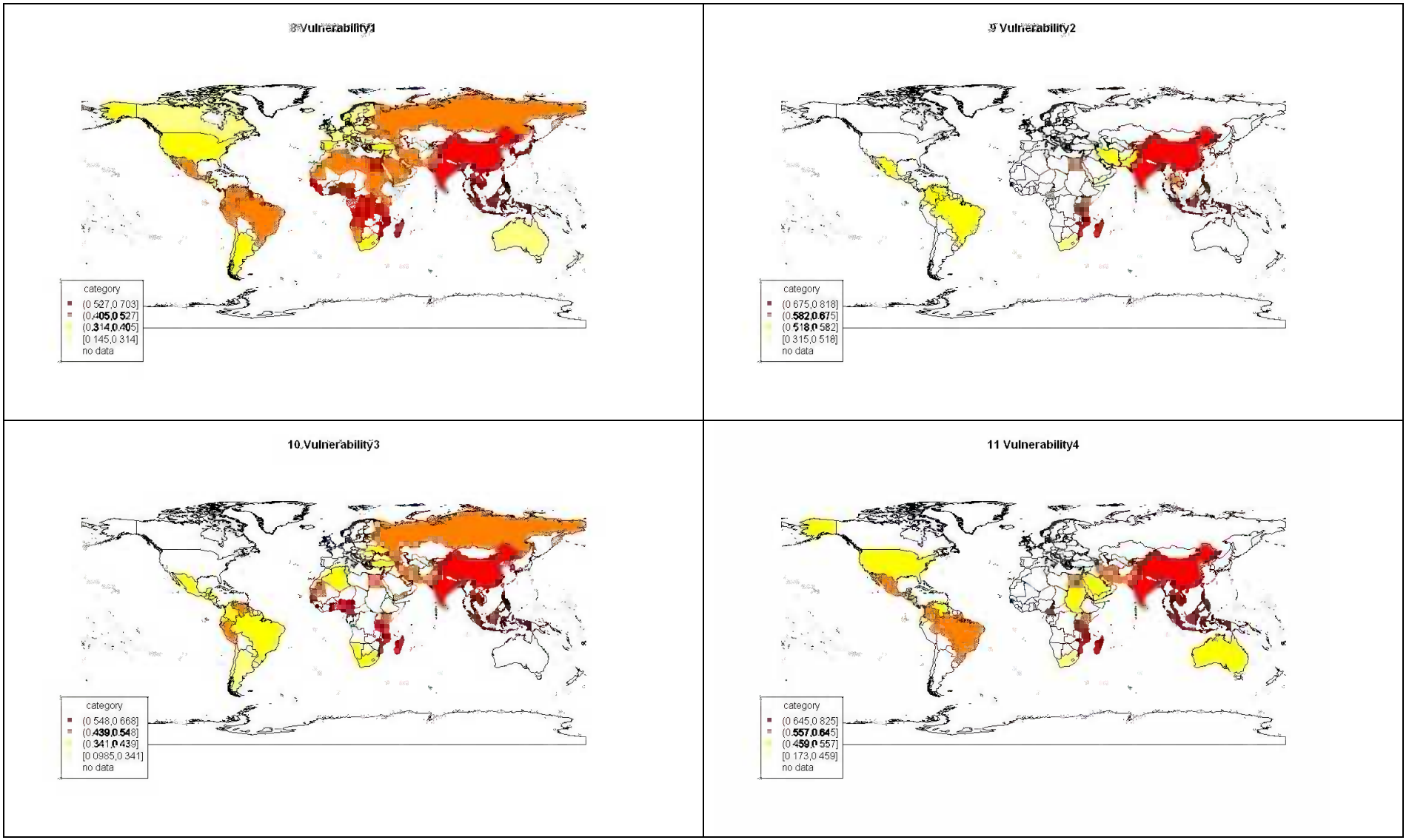


Figure 4. Chart of the calculated vulnerability metrics, as quartiles.

Table 7. Top 10 countries in overall vulnerability scores

Rank	Vulnerability 1 metric	Vulnerability 2 metric	Vulnerability 3 metric	Vulnerability 4 metric
1	Maldives	Indonesia	Cambodia	Indonesia
2	Cambodia	India	China	Philippines
3	China	Philippines	Bangladesh	India
4	Bangladesh	China	Sierra Leone	China
5	Indonesia	Tanzania	Nigeria	Vietnam
6	Sierra Leone	Mozambique	Philippines	Tanzania
7	Philippines	Bangladesh	Indonesia	Mozambique
8	Angola	Madagascar	Ghana	Thailand
9	Vietnam	Thailand	Senegal	Bangladesh
10	Nigeria	Cambodia	India	Malaysia
No. countries:	118	30	62	50

Vulnerability scores were relatively consistent between the different metrics calculated. The top 10 countries most vulnerable to changes in marine and coastal ecosystem services are concentrated in south and southeast Asia, and southeast Africa. Relatively high reliance on fish as a source of protein and low adaptive capacity scores meant west and central sub-Saharan Africa was also vulnerable under metric 1.

The vulnerability analysis performed suggests that the key areas for future work for poverty alleviation and a better understanding of the marine and coastal ecosystem services important to the poor should focus on south and southeast Asia, and south-eastern Africa.

It must be noted that the analysis may suffer from data loading, i.e. the result may in part be biased by a sub-Saharan focus on data collection related to poverty.

Small island developing states, while reliant on fish as a source of protein, had relatively low populations, and little information on adaptive capacity. Therefore these countries did not feature in the overall vulnerability analysis. However, they are highly vulnerable to changes in ecosystem services. This is discussed further in section 6.

5. Trend dynamics

The vulnerability analysis described in section 4 provides a snapshot of the current or recent situation within the countries examined, based upon available data. However, to identify future issues, the trends in the ecosystem services needs to be examined. For example it is projected that the world population will increase by around 40% over the next 40 years (UN, 2007), while increases may vary between different countries. This increase will undoubtedly put further pressure on marine and coastal ecosystem services.

The use of trend data is, however, open to considerable uncertainty. There is a need to ensure that the approaches used are consistent over time. This is not always the case as improvements in data collection, or changes in the interpretation of classes of data can lead to step changes that are difficult to interpret (see box 2).

Box 2. Data and trends

Data sources at the country level tend to derive from the data collection requirements of international organisations, such as the UN. These attempt to gather consistent information between countries and within countries over time. However, as shown by the Seas Around Us Project (SAUP), which is investigating the world's marine ecosystems, the time series of data may be open to considerable interpretation.

Data collection improves over time, which can result in step-changes in data. For example, when assessing data at the species or group level, improved data dis-aggregation can suddenly result in increases or decreases in levels as information is re-assigned from a generic 'other species' or group-level data bin (see figure). When analysing trends, therefore, these issues must be carefully considered.

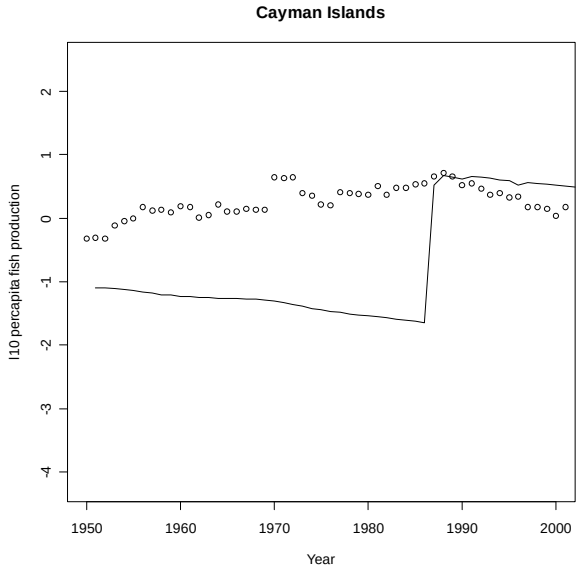


Figure of per-capita fish production over time for Cayman Islands. Line data based upon official FAO landings data. Dots represent interpreted time series from SAUP.

This ties in with the need to consider catastrophic shifts as well as long-term changes, and the reasons behind those changes need to be considered. It is difficult to project the likely impacts of longer term changes without this understanding. However, that mechanistic understanding is generally lacking.

5.1. Ecosystem services time series data available

This study examined the available time series of information on ecosystem services of likely importance to the coastal poor. It was noted early on that trend data were frequently not available. Many data sets and publications provided trends over a period that mask inter-annual fluctuations in the quantities looked at. Often this may have resulted from sporadic funding, or varying timing in surveys between countries. An example is the information available on mangroves (see Figure 5), where data were generally presented in a decadal time step. Further analysis of these data is presented specifically in section 6.1.

Current and past extent of mangroves by region (1980–2005)

Region	Most recent reliable estimate		1980	1990	Annual change 1980–1990		2000	Annual change 1990–2000		2005	Annual change 2000–2005	
	1 000 ha	Ref. year	1 000 ha	1 000 ha	1 000 ha	%	1 000 ha	1 000 ha	%	1 000 ha	1 000 ha	%
Africa	3 243	1997	3 670	3 428	–24	–0.68	3 218	–21	–0.63	3 160	–12	–0.36
Asia	6 048	2002	7 769	6 741	–103	–1.41	6 163	–58	–0.89	5 858	–61	–1.01
North and Central America	2 358	2000	2 951	2 592	–36	–1.29	2 352	–24	–0.97	2 263	–18	–0.77
Oceania	2 019	2003	2 181	2 090	–9	–0.42	2 012	–8	–0.38	1 972	–8	–0.39
South America	2 038	1992	2 222	2 073	–15	–0.69	1 996	–8	–0.38	1 978	–4	–0.18
World	**15 705**	**2000**	**18 794**	**16 925**	**–187**	**–1.04**	**15 740**	**–118**	**–0.72**	**15 231**	**–102**	**–0.66**

ftp://ftp.fao.org/docrep/fao/010/a1427e/a1427e04.pdf

Despite noting that year-to-year data are often not available, a composite of 5 year trends may provide sufficiently compelling evidence of change, while avoiding inter-annual variability. Indeed, aggregated longer time series may have greater power to detect small changes, while the cost of increasing survey effort to obtain frequent measurements may be outweighed by the low power of an individual country to detect change in the face of inter-annual variability. Decadal trends may therefore be more convincing:

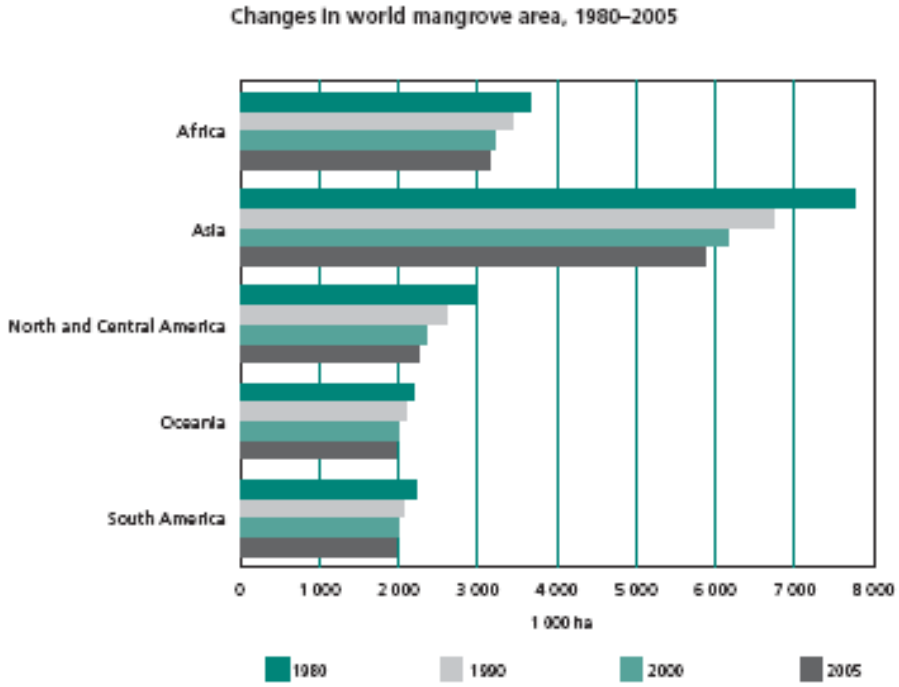


Figure 5. Summary of time series information available on mangrove area.

Therefore there is a need to consider the requirements for analyses – is the desired outcome knowledge of overall trends, or models to identify factors that may cause those trends? For the latter, annual data may perform better.

Time series data searches concentrated on that country-specific information available of relevance for marine and coastal ecosystem services. The resulting information is summarised in Table 8.

Time series information was sparser than individual snap-shots available for other ecosystem services. Long time series were generally only available from international databases maintained by organisations such as the United Nations (e.g. FAO FishStat). As noted within the vulnerability analysis, longer data time series available tended to focus on provisioning services from marine and coastal ecosystems, such as fish catches (the subject of annual data collection programmes worldwide). These were also available as direct measures of provisioning services, such as the per capita consumption of fish protein over time. Information for other groups of ecosystem service was highly limited, or had to be inferred through the development of proxies (e.g. coral reef area per km of coastline, as a proxy for coastal protection, a regulating service).

Table 8. Time series data identified at the country level, by ecosystem service area

Group	Data set	Time series	Source
Exposure	Population	1950-2050*	UN statistics division
	% population undernourished	2yr averages at irregular intervals	Earthtrends
	Rural population growth rate	1950-2030* (5 yr increments)	UN statistics division
	Number of people employed in fisheries and aquaculture	10-yr intervals from 1970 to 2000	Earthtrends
Regulating	Biological oxygen demand	1980-2002	Earthtrends
	Mangrove area	1990-2005, at irregular intervals	FAO
Provisioning	Daily per capita fish consumption	1961-2000	WRI
	Fish protein as % total protein supply	1961-2000	WRI
	Total fishery production	1950-2001	FAO Fishstat
Cultural	Tourism receipts	2000-2005	UNWTO
Adaptive capacity	Civil liberties index	1972-2006	Earthtrends
	Democracy Index	1950-2003	
	GDP	1960-2005	Earthtrends
	Per capita GDP change	1961-2005	Earthtrends
	Infant mortality rate	1960-2005 (10 or 5 yearly increments)	UN statistics division
	Fish trade exports	1976-2005	FAO Fishstat

* modelled population projections

5.2. Trends in data

Trends in time series data identified in this project were examined at a country level where sufficient data were available. In certain cases, trends were pre-calculated within the databases identified. In other cases, values represented pre-calculated averages over a period. For example, national poverty rate[4] percentages by country within the Earthtrends online database represent a summary from 1990-2004. These data are based on country surveys conducted between 1990 and 2004. The data presented here are taken from the most recent survey year available, are updated as new surveys are conducted. This happens sporadically on a country-by-country basis; hence the percentages are not directly comparable.

It was not the aim of this study to examine all available time series data. Instead, the data were used to illustrate some of the issues that arise when examining available data time series. For an example, see the analysis of available trends in estimated low elevation zone coastal populations, in section 10.2.

Overall trends are an important aspect of the pressures on coastal and marine ecosystem services. However, there is also the potential for drastic step-change, rather than smooth, increases or decreases in those services. With the available data, it is often difficult to identify whether perceived step-changes are real, or an artefact of the data available (see box 2 above). Given the number of countries within a data series (often over 200), it is not straightforward to assess what changes may be occurring at the country level. A preliminary approach is to graph the change between two data time steps, to see whether there is a difference in the distribution of change (see Figure 6). In this example, there is a notable difference in the pattern of change between 1970 and 2000 compared to 1970 and 1990, with a greater

[4] percentage of a country's rural population living below the country's established national rural poverty line

proportion of the countries showing a decline in the number of people employed in the fishing and aquaculture industries.

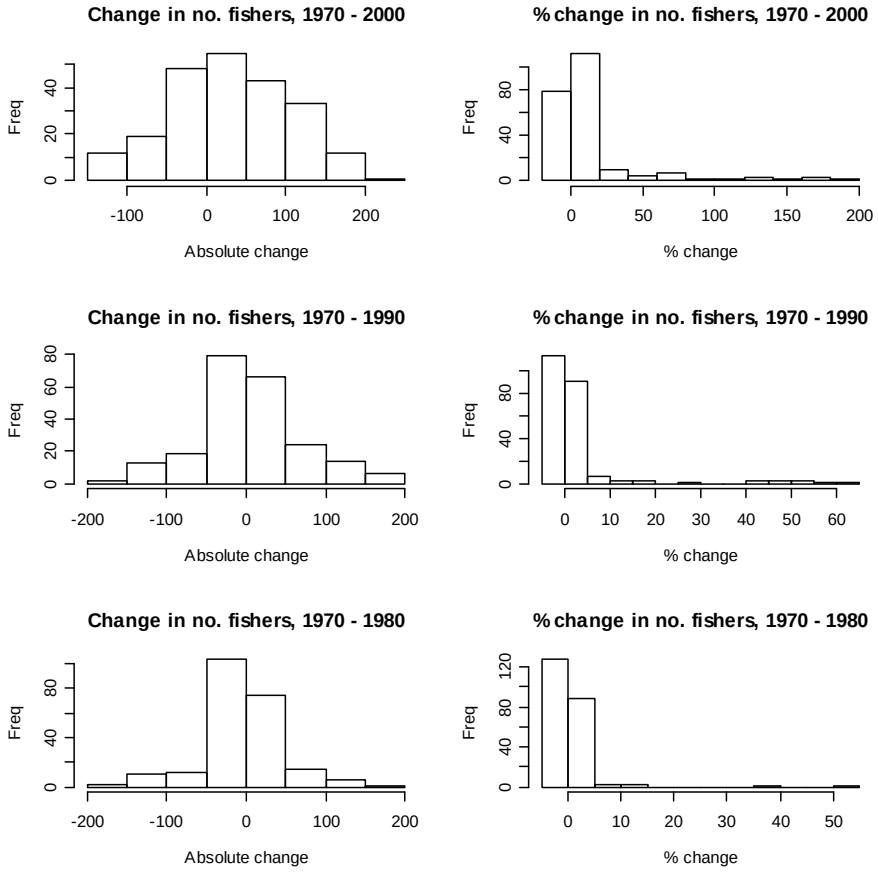


Figure 6. Rate of change within a country of the number of people employed in fisheries and aquaculture, by time step.

Particular countries can then be examined. Here, three key countries identified as vulnerable within the analysis performed in section 4.4 are investigated (Figure 7).

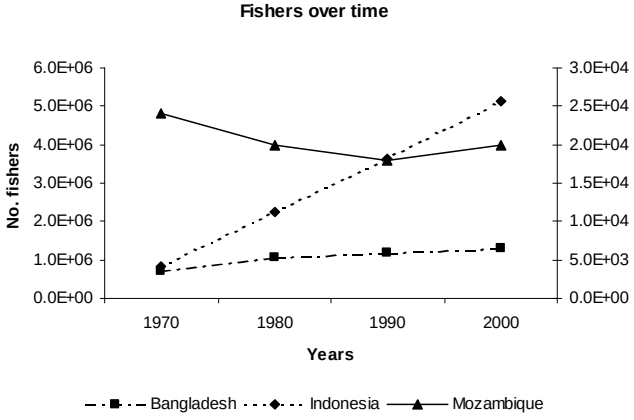


Figure 7. Graph of pattern in people involved in the fisheries and aquaculture industries, by country. Note Mozambique data is on secondary y-axis.

While these three countries each generally show consistent trends across the whole time series, decade-to-decade changes are visible. Data for Indonesia suggests a continual increase in fishers over the period. That for Bangladesh suggests that while increases in fishers continue, the rate has decreased over time. For Mozambique, declines between the 1970 and 1990 data points were confounded by a slight increase in the 1990-2000 period.

A similar analysis was performed to examine change in per capita fish consumption over time (Figure 8; see also section 10.4).

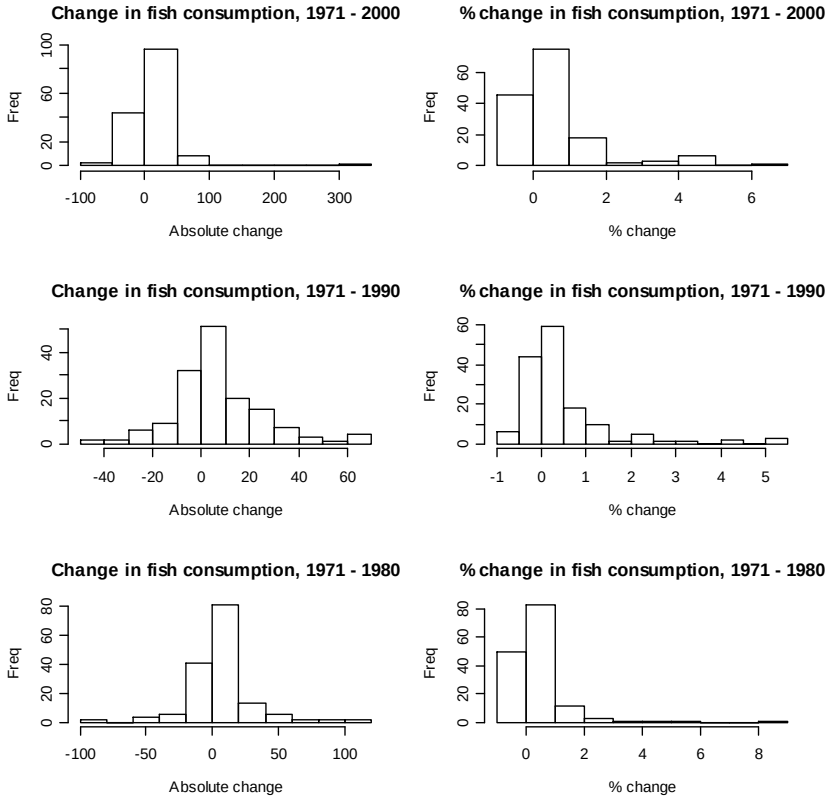


Figure 8. Rate of change within a country of the level of fish protein consumption (g.capita^{-1}.day^{-1}), by time step.

The histograms suggest that fish consumption has increased since 1970 across countries, with increases in over half the countries between the 1970s and 2000 of over 1%. This indicates the increasing pressure placed on marine and coastal provisioning services. When the trends are examined for the three key countries selected, however, different patterns are seen (Figure 9).

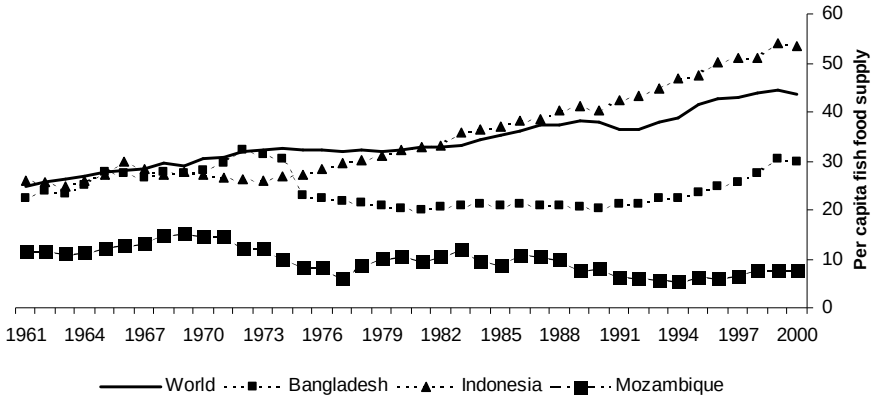


Figure 9. Per capita fish food supply over time for specific countries, and World average.

The per capita fish component of diet in Indonesia has been steadily rising since the 1970s, although it appears to have reached a plateau in 2000. Levels in Mozambique have shown a general decline over the period. Data for Bangladesh shows a step-change in the early 1970s. However, the reason for this is not known.

These examples illustrate trends that can be seen within country-specific data. As noted earlier, there is a need to understand the reasons for these changes (i.e. the mechanism) and hence whether changes – in particular step changes – are real or artefacts within the time series.

Knowledge gaps

- Fewer data sources presenting time series of information relevant to marine and coastal ecosystem services were available. Time series tended to concentrate on provisioning services. There is therefore a need to consider targeting data collection on key ecosystem services important to the coastal poor. These could be developed through participatory methods, and through community-science partnerships
- The efficacy of the time series available is generally not known, as they are generally based upon sampling techniques. Improved knowledge on the way data are collected is needed to accompany the data sets available (meta-data), which may allow step changes in the data series to be interpreted
- One of the biggest gaps in terms of realistic time series was that for population levels within the low elevation coastal zone. This data set was available for 3 years (1990, 1995, 2000) only, providing rough trends in the coastal population. In turn, as already noted above, this does not specifically provide information on the *coastal poor*
- The causes behind trends need to be understood. For example, decreases in the catch of fish, or the level of fish as a proportion of total protein intake, may result from a range of causes. Examples include overfishing, habitat destruction, movement of the population to alternative livelihoods, reductions in population, migration, war, changes in the survey technique or data collection quality, or cataclysmic events. Understanding the cause of change is therefore critical when interpreting trends in data.

6. Case studies

To illustrate some of the issues encountered during this investigation, a number of case studies are presented.

The first two of these focus on information available for mangroves and coral reefs. Both of these habitats offer a wide range of ecosystem services that cut across the different categories examined within this analysis. As will be shown, the issue identified is that while these habitats may be relatively comprehensively studied, since they are indicators of human impacts on the environment, the specific range of ecosystem services that are provided by these habitats, along with the trends in the specific services (rather than the habitats themselves) are less commonly monitored. It is therefore necessary to extrapolate results in order to suggest potential impacts of those changes on the ecosystem services and their importance to the poor.

There is also a tendency to lean towards segregation of ecosystems, as we have here. Coral reef ecosystems, soft sediment ecosystems, macro-algal beds, mangrove ecosystem, and open ocean ecosystems, for example, show interactions and synergies between them. For example: sediment and beach areas are composed mainly of grains of natural material such as coral; mangroves may trap high nutrient sediments which may otherwise lead to high turbidity and/or nutrient status that would have a negative impact on coral growth through light limitation and/or potential overgrowth by algae; corals reefs may provide physical protection to sediment areas in lagoons and mangrove nurseries. These examples illustrate the interconnectedness of tropical ecosystems. Damage or loss of any component may then have a negative effect on the other parts of the system. Integrated coastal zone management typically recognises that these are all components of a greater ecosystem. It is critically important, therefore, to view ecosystems - including humans and their activities - holistically, and manage them accordingly.

The last two case studies focus on countries, rather than specific ecosystem services. Bangladesh and small island developing states are highlighted due to their strong reliance on ecosystem service use by poor people, and the increasing threat faced by them under projected future conditions.

6.1. Mangroves

Humans derive a number of benefits from mangrove ecosystems, including direct products such as timber and fuel wood, and services such as support of fisheries and tourism and protection against coastal erosion (Hogarth, 2007). These habitats therefore provide services that cut across many of the ecosystem services that may support livelihoods of the coastal poor (Table 9). Direct uses cover provisioning and cultural services, while indirect uses cover supporting and regulating services (e.g. shoreline protection, nursery areas for fish, etc.).

Table 9. Non-exhaustive list of the variety of services offered by mangroves

Fuel	Charcoal, firewood
Construction	Timber, scaffolds, railway sleepers, mining props, boat building, dock pilings, beams and poles, thatch, matting, fence posts, chipboard
Fishing	Fishing stakes, boats, wood for smoking fish, tanning for nets/lines, fish poison, FADs
Textiles	Synthetic fibres (rayon), dyes, tannin for leather preservation
Food, drink	Sugar, alcohol, cooking oil, vinegar, tea substitute, fermented drinks, dessert topping, seasoning (bark), sweetmeats (propagules), vegetables (fruit, leaves)
Domestic	Glue, hairdressing oil, tool handles, musical instruments, rice mortar, toys, matchsticks, incense, cigarette wrappers, cosmetics
Agricultural	Fodder
Medical	Treatment of ringworm, mange, toothache, leprosy, sore throat, constipation, dysentery, diarrhoea, boils, bleeding lice, fungal infections, bleeding, fever, catarrh, kidney stones, gonorrhoea, etc.
Miscellaneous	Paper manufacture

The benefits of mangroves to the coastal community vary greatly between areas. Fringe mangroves may contribute relatively little to productivity, and hence may not be a significant source of provisioning ecosystem services, but may play an important role in regulating services. However, data seldom break down mangrove coverage into different types, with extents of different mangroves merely lumped together. This makes interpretation of trends more difficult.

Data are available for 120 countries on the area of mangroves. Slightly more limited time series data are available from 116 countries, taken from FAO reports (http://www.fao.org/docrep/010/a1427e/a1427e00.htm). Examining the pattern over time suggests that mangrove area has declined in 110 countries over the last 25 years – i.e. 95% of countries for which time series data are available. On average, 35% of total mangrove area has been lost in the last quarter century, and declines in mangroves have been greater than 50% in 14 countries (Figure 10). The greatest losses have occurred in Barbados (86% lost), Singapore (72%), and the Democratic Republic of Congo (69%).

It should be noted that the estimate of global loss calculated here is 10% greater than that identified within FAO literature (25%). This may result from variable quality control and poor transparency of data collection and statistical methods of aggregation and analysis (i.e. accompanying meta-data). Without this information, it is difficult to know whether this change in trend is real, or an artefact of changing data collection or aggregation.

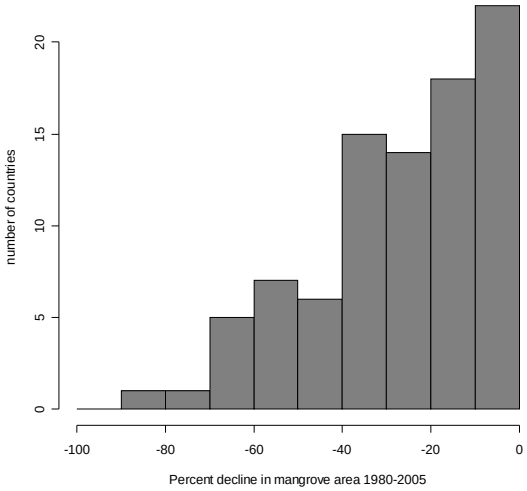


Figure 10. Percentage decline in mangrove area over the period 1980-2005 in each country.

Re-calculating this in terms of the average annual loss of mangroves, the average across countries is 0.5% per annum. The highest annual rate of loss is ~8%, in Barbados. When broken down into 'developed' and 'least developed' countries (as defined within the LECZ data set), there is a general similarity between the rate of mangrove area loss, with a peak between 0 and 2% per annum (Figure 11). However, least developed countries have a greater proportion of more rapid declines, while developed countries have a wider spread, with some countries (e.g. Mauritius) showing an increase in mangrove area over time. There was no relationship between the rate of mangrove loss and the Human Development Index for each country (graph not shown), suggesting that the state of country development is not related to mangrove loss - over the period 1980-2005, at least.

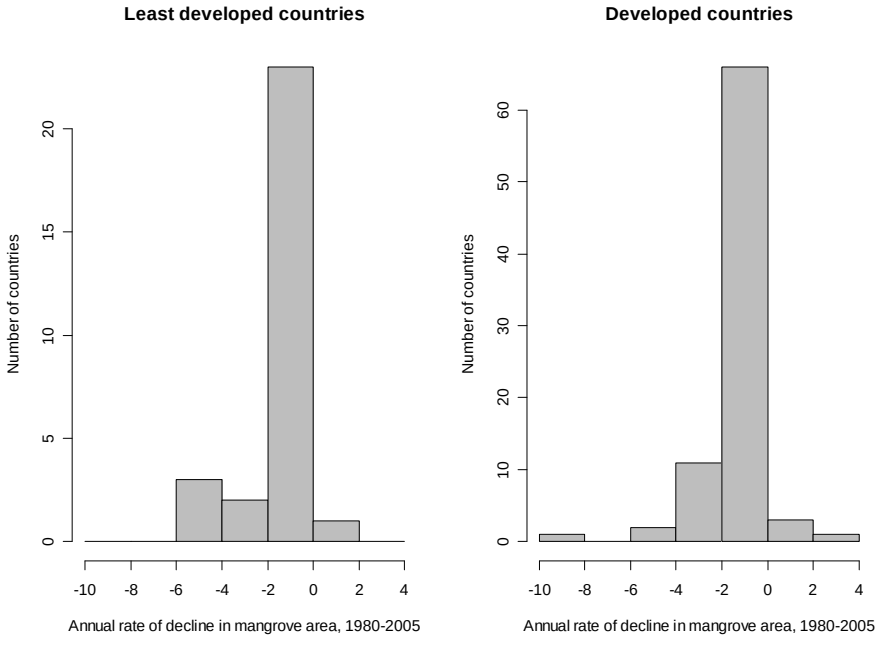


Figure 11. Annual rate of decline in mangrove area, across the period 1980-2005 for 'least developed' countries (left) and 'developed' countries (right).

Re-calculating the metric in terms of the number of people living along the coast (using the LECZ data set) provides a potential proxy for the per capita benefit that coastal people may be losing in terms of overall ecosystem services from mangroves. Calculated in this manner, the annual rate of loss of mangrove area per coastal person is 6.9%. However, many countries are losing mangrove ES at high rates (10-40% per year; Figure 12), mainly in Africa. This is a result of high rates of mangrove loss coupled with high rates of coastal population growth.

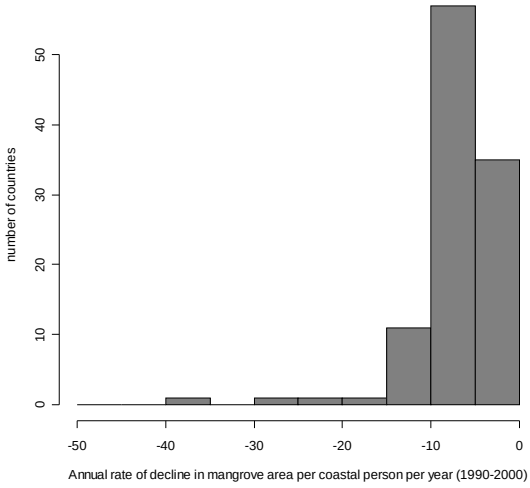


Figure 12. Annual rate of decline in mangrove area per coastal person per year (1990-2000).

The top 16 countries for mangrove loss per coastal person are: Peru, Solomon Islands, Benin, Angola, Mayotte, Bahrain, Mauritania, Cote d'Ivoire, Liberia, Barbados, Pakistan, Congo, Republic of the Congo, Democratic Republic of the Congo, Singapore and the United States.

The monetary value of mangrove ecosystem systems has been calculated (e.g. Costanza et al., 1997). Value estimates ranged from US$6,696/ha per year for waste treatment (e.g. assimilation of effluent from shrimp ponds) to US$162/ha per year for raw materials (e.g. timber, charcoal). This allows the actual value of ecosystem services to be calculated, and the impacts of their use and potential degradation to be assessed.

6.2. Coral reefs

Coral reefs provide another example of an environment that cuts across many types of ecosystem service. Due to their high productivity in otherwise relatively nutrient poor waters, coral reefs are the foundation of complex and diverse ecosystems that provide all four ecosystem services to coastal communities in tropical countries:

- Reefs provide provisioning ecosystem services, supporting a high density of fish used for local protein consumption, Indeed, coral reefs ecosystems may be considered a keystone resource, they provide a habitat that, except where protected for conservation, tourist development or other reasons is typically common property and available to all community members regardless of their economic status. Even those who lack access to the outer reef may benefit from shallow reefs and inshore lagoon areas. Those who do not usually fish, for example old folk and females, may take resources such as clams, edible seaweeds and fish trapped in pools. In some places, such as the SIDS, where there may be limited terrestrial resources, coral reefs are vitally important as a major and in some cases the only source of protein. In turn, these resources represent considerable potential income. The live reef fish trade, which concentrates on key coral reef fish, is estimated to be worth $810 million annually, while the export of key reef fish species such as snappers and groupers on the international market also provides income. Reefs also provide relatively poor communities with access to other valuable resources, such as precious corals,

high value species for the pharmaceutical industry (sea horses), natural pearls, foods such as beche de mer, etc. Often a fair value for these products is not realised at the community level, rather the benefits are accrued by middle men. Coral mining for the building industry provides income too, but may not be sustainable, especially if the removal of coral material jeopardises the biological and structural integrity of the reef. Hence special care should be taken in managing extraction of corals given that reefs provide cost effective shoreline protection against erosion and ameliorate the effects of heavy wave action and storm damage.

- Reefs provide regulating ecosystem services, protecting the shoreline from erosion due to waves. Reef structures provide sheltered waters in the form of atoll or fringing lagoons. Where the reef provides a breakwater service, it may protect mangrove areas and allow natural reclamation that would not be possible in exposed areas, and provides shelter for juvenile fish species.
- Reefs provide supporting ecosystem services, being a key area of local nutrient recycling and primary production.
- Reefs provide cultural ecosystem services, being a key focus of national tourist trades through recreation and aesthetic enjoyment. In turn, eroded reef material provides coral sand on beaches. Tourists are lured to tropical beaches by images of coral reefs, coral sand beaches and tranquil safe lagoons. None of this would exist without corals. There may be spin offs in terms of local employment and outlets for local products, and alternative livelihood opportunities for local communities as a consequence of tourist development.

As for mangroves, however, the specific ecosystem services (bar provisioning services) provided by this ecosystem are not specifically measured. However, the area of reef is commonly evaluated over time, allowing some inferences to be drawn.

Overexploitation is one of the principal threats to coral reef diversity, structure, function, and resilience, with many examples of resultant trophic and ecological changes. However, although it is generally held that coral reef fisheries are unsustainable, little is known of the overall scale of exploitation or which reefs are over-fished. Therefore, Newton et al. (2007) examined FAO Fishstat data to perform a meta-analysis of coral reef island nations. A considerable amount of pre-processing was required to extract estimates of the catches of coral reef related species[5] from these data. Using these data, they estimated the 'footprint' of coral reef fisheries, which compared island-specific human demand (per capita fish catch) with an island's coral reef area and assumed productivity. Results indicated that over half of island coral reef fisheries were unsustainable, with total catches 64% higher than can be sustained. The area of coral reef appropriated by fisheries exceeds the available effective area by 75,000 km^2, or 3.7 times the area of Australia's Great Barrier Reef.

Human population size was a strong indicator of exploitation level (Figure 13). Therefore, projected human population scenarios from the United Nations Population Division's medium-variant predictions for 2015, 2025, and 2050 were used to estimate the future footprint of coral reef islands. Population projections were available for all countries apart from Mayotte. Future footprint sizes were calculated with the projected landings and assuming no change in coral reef area and maximum-sustainable-yield value (5 $mt.km^{-2}.yr^{-1}$). Results suggested an extra 196,000 km^2 of coral reef might be required by 2050 to support the anticipated growth in human populations.

[5] i.e., those living predominantly on or near coral reef ecosystems and deriving energy from coral reefs and associated habitats for a major proportion of their lifespan

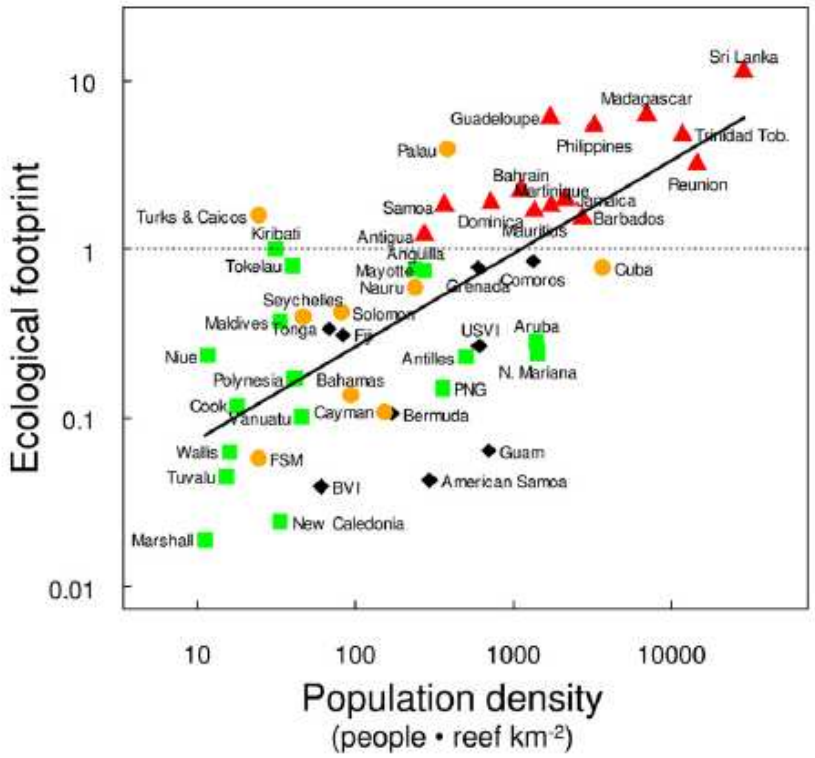


Figure 13. Relationship between coral island state population and ecological footprint.

The analysis focused on the impacts of fishing on coral reef productivity, and while it noted the potential impacts of future changes resulting from climate, it did not take these into account.

Although animals, corals have a symbiont algae that photosynthesises and is essential for the long-term well being of the coral polyp. When the coral loses its algae, for whatever reason, this is termed coral bleaching. Any stress, including increased temperature, may cause bleaching and there is concern that one consequence of climate change, elevated sea temperatures, will exacerbate an already serious problem in some parts of the world. However in high temperature seas including those in the Middle East, many species of coral appear to have adapted to higher ambient sea temperatures, and coral bleaching events are reported to have declined in some areas.

If the rate of sea level rise exceeds coral reef growth, there is a risk that corals will not be at optimum depths in terms of ambient light for photosynthesis, and so may grow more slowly, be further stressed and/or die. Elevated atmospheric carbon dioxide will alter seawater chemistry. It is expected to reduce pH and carbonate ions and alter the saturation state of calcium carbonate minerals. This will likely impact all calcifying species, including corals by reducing shell formation, slowing growth rates and hindering reproduction (Fabry et al., 2008a). Coral reefs are further threatened by human activities ranging from dynamiting and bleaching for fish, to reef walking by tourist, collisions with boats, anchor and fishing gear damage.

The potential future impacts of future fishing and climate change on reef fisheries yields have been examined (Dulvy et al., in prep). The paper explored environmental, biological and socio-economic correlates of average per capita coral reef fishery yields across 49 coral reef island nations. Human population density and reliance on fish for a protein source explained most variation in fishery yield. Highest yields occurred at lightly populated islands with high reliance on fish as a protein source. Lowest yields occurred on the most densely populated islands. Human population growth and coral reef loss scenarios were used to estimate the consequences for future fishery yields. Overexploitation and climate change had similar impacts on potential fishery yields, and both in combination are projected to reduce yields by ~24-38% by 2050. Fish abundance and community structure are a function of the architectural complexity of coral reefs. Consequently, the reduction in fisheries yield will depend on the time lag between loss in live coral cover and the collapse of reef architecture (Figure 14).

Clearly, where a reef provides food to a community that has few or no alternative sources of dietary protein, that reef is invaluable. Increasingly, to demonstrate their importance, natural resources are being given an economic value. For example UNEP-WCMC (2006), cite values per km of coral reef related to the service provided, the highest economic value reefs being those that support tourism and shore protection, lower values for fisheries and biodiversity. Evaluating the resource in dollar terms enables resource managers make a balanced consideration of the potential biological, social and economic consequences of any given measure.

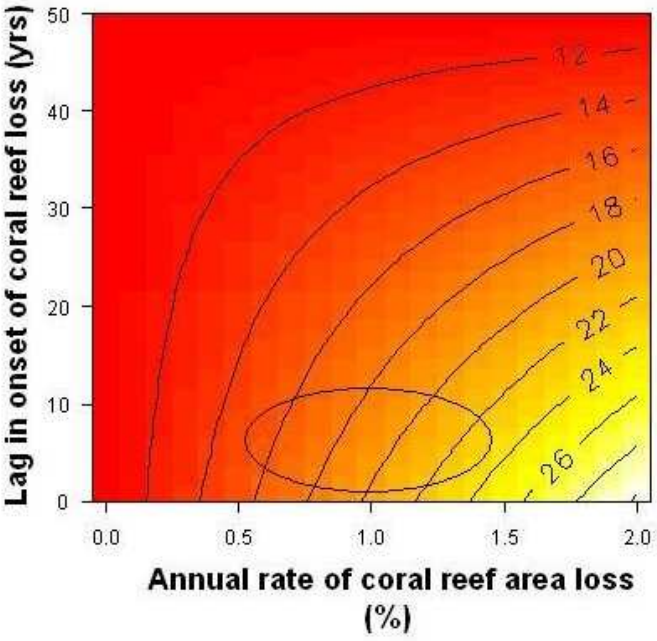


Figure 14. The increase in productivity of remaining reef required to deliver sufficient food to cope with the projected demand from population increases by 2050, under scenarios of different rates of decreasing coral reef area, and lags in the onset of coral reef loss. Increases are relative to 2000 overall production levels.

Available information on the other ecosystem services offered by coral reefs was more limited, and needed to be inferred from related measures. For example, coral cover per km of coastline can be used as a proxy for the regulating service provided by coral reefs. The potential importance of this service is indicated for small island states, which comprise the top 10 countries in this metric (see section 10.9).

6.3. Bangladesh – an extremely vulnerable coastal state

Bangladesh scores as a particularly vulnerable state as a consequence of its:

- Geography
- Climatic
- High levels of poverty
- Dense population
- Dependence upon ecosystem services

Geography

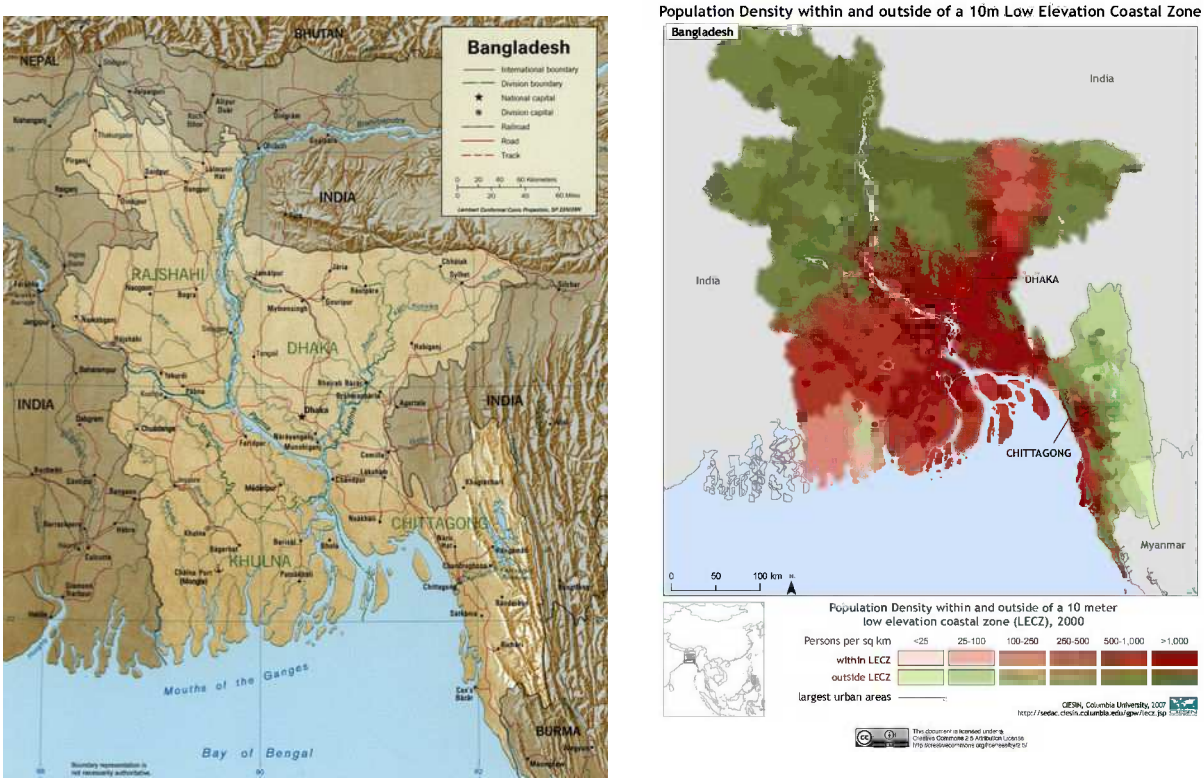


Figure 15. Chart of Bangladesh showing riverine inputs (left) and chart of population density inside and outside the LECZ (from CIESIN; right)

Bangladesh, with an area of 144,000 km^2, is located on a deltaic plain. 80% of this is fertile alluvial land, with very low elevation of 10 metres or less, decreasing towards the coast. Slightly less than 7% is covered by water when there is no flooding, and the country is dominated by a large river system that provides water for cultivation, a means of commercial and private transportation, and fishery products.

Situated at the northern shore of the Bay of Bengal where wave action is funnelled, Bangladesh experiences extreme marine events [cyclones, storm surges etc.], and is the downstream confluence of three major flood prone river systems fed by the Himalayas; the Ganges, Brahmaputra and Meghna. Flooding during the monsoon season causes hardship, loss of life and hinders development, but also deposits the fertile silt that supports agriculture and fisheries. Sediment that drops out suspension when the river meets the sea is also extending the Bangladesh coastline, at an estimated rate of around 20 km^2 per annum. The state-run Centre for Environment and Geographic Information Services (CEGIS), stated that the country could gain a further 1,000 km^2 by 2050.

Box 3. New land

Allocation of ecosystem services varies according to government policy and culture and may not be equitable. Government policy in Bangladesh is to award newly formed land to currently landless people. This is achieved through a complex local government appraisal system. This laudable approach to poverty alleviation is, however, offset somewhat by a conflicting, but arguably of equal importance, policy, whereby all new land is planted with mangroves by the forestry commission to consolidate and protect the new coastline. The forestry authorities tend to retain ownership of this land to ensure that protection(DFID Working Paper1).

Aside: Perhaps it would benefit all if the new owners of the land were given custody of the new forest, with the proviso that they forfeit their rights to harvest etc. if they do not manage it sustainably as recommended by the forestry agency.

Box 4. Flood productivity

More than 80 percent of the animal protein in the Bangladeshi diet comes from fish. Most commercial fishermen are low-caste Hindus operating at a subsistence level. Fish for local consumption generally are freshwater varieties.

During the floods, the consequent input of inorganic nutrients promotes primary productivity and fishery productivity. As the floods recede, fish are trapped in inland lagoons and are an accessible source of protein. The unpredictable seasonal nature of the flooded habitat selects for species with high rates of reproduction growth, early maturity, and high fecundity. Primary and fish production in the main channels are much lower in comparison. Given the high dependence of fish production on flooding events, anything that may affect the timing, extent and duration of the flood pulse or the quality of its water has a potential to significantly impact freshwater fish production (Hoggarth et al. 1996).

Climate

Bangladesh has a subtropical monsoon climate. From March to May, violent thunderstorms occur, with winds of up to sixty km per hour, and in the early summer and late monsoon season, storms with southerly winds of more than 160 km per hour produce wave heights to 6 meters in the Bay of Bengal, creating flooding in the coastal areas. Most of Bangladesh experiences high rainfall of >200 cm per annum, and close to the foothills of the Himalayas it may be more than 400 cm. Rainfall is not distributed evenly throughout the year, about 80% falling in the monsoon season when flooding occurs due to high river discharges. Despite this apparent abundance of water, around 2.7 million ha are vulnerable to annual drought; there is about a 10% probability that 41-50% of the country is experiencing drought in a given year. Global circulation models predict for Bangladesh an average temperature increase of 1.4 degrees centigrade by 2050, and an increase in monsoonal precipitation of 6.8%. Despite the higher rainfall, however, the elevated temperatures and increased evapotranspiration will exacerbate water stress conditions in drought prone areas (Selvaraju et al. 2006).

Stream flows in Bangladesh are correlated to rainfall in the upper catchments with typically a lag of about one month (Mirza & Dixit 1997). Links between different functional regions are difficult to investigate, although at a conceptual level, they are readily acknowledged. For example, drainage basins can provide functional links between climate change impacts in headwaters and the downstream areas they affect. At the same time however, downstream areas also may be responding to locally specific climate change impacts. Management that acknowledges these linkages is often termed ‘Mountain to the Sea’ and is clearly applicable here to the Ganges-Brahmaputra-Meghna system.

Although climate change is not likely to cause a significant increase in the number of major weather events [typhoons, cyclones etc], individual events will tend to become more severe, hence the effect is an overall increase in the number of *severe events*. It is also noted that the geographical distribution of these events may change as global cycles themselves alter as a consequence of climate change. [Presentation by Bob Watson, Chief Scientific Advisor, Defra].

Box 5. Salt water intrusion

Saline intrusion has direct consequences in terms of making freshwater undrinkable and unable to sustain non-saline tolerant plants and animals. It also has a direct physical consequence. Particulate matter carried downstream tends to flocculate and fall out of suspension when flow is reduced and/or it comes into contact with salt water. Where saline water penetrates upstream, there is likely to be increased deposition of sediment leading to enhanced upstream sedimentation in the river channels, with consequent drainage problems and increased flood risk in coastal areas. (Huq et al. 1996).

Loss of seasonal clues

The lives of people who make a living on the land or sea are guided by seasonal clues and expectations based on experience. By far the greatest seasonal impacts are monsoons and floods and changing weather patterns may make elements of traditional knowledge redundant and irrelevant.

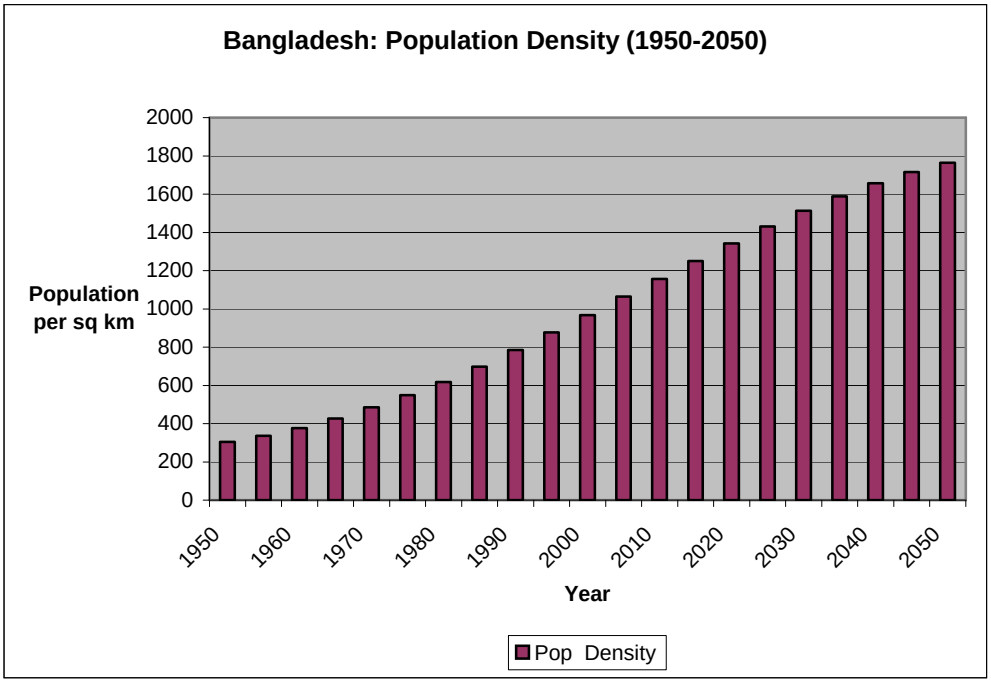
High levels of poverty

Despite steady economic growth at 5% annually over the last decade, half the population is considered to be in a state of poverty (World Bank, Bangladesh Development Series Paper No: 12, September 2006[6]). The European Commission estimates that 82.8 % of the population live on under $2 a day[7]. The Ganges-Brahmaputra-Meghna basin contains the largest number of the world's poor in any one region. The population is increasing steadily, and unless the current development trends are broken, poverty will become even more pervasive. The most populous part of the basin is shared by three countries: Bangladesh, India, and Nepal, who have in the past been unable to agree to an integrated development plan.

Dense population ~ high population with increased urbanisation

A recent World Bank report states "Bangladesh is highly vulnerable to the projected impacts of climate change, which will increase the already high risk of disasters, exacerbating existing vulnerabilities both to flooding and drought, and threatening agricultural productivity in coastal areas that face increasing salinity (World Bank, Bangladesh Development Series Paper No: 12, September 2006[8]).

Most of the projected population growth (100 million over the next 50 years) is anticipated to be urban; that notwithstanding, there will be a population increase throughout the country, and the urban population will place additional demands on coastal ecosystem services, to the detriment of coastal poor. Already it is noted that protected area cover is the smallest share of any country in SE Asia, coupled with one of the highest population densities in the world [9].



Population density (population per sq.km) Medium variant 1950-2050
Source: http://esa.un.org/unpp/

Disease

It is noted that whilst exposure to disease and illness is the same in Bangladesh as in other SE Asian countries, mortality is higher, and this is ascribed to poor environmental conditions, higher mortality incidence associated with diarrhoeal disease, and respiratory infections associated with a lack of potable

[6] www.worldbank.org.bd/bds
[7] http://www.eudelbangladesh.org/en/eu_and_country/BGDatglance/index.htm
[8] www.worldbank.org.bd/bds
[9] http://esa.un.org/unpp/

water and poor air quality (e.g., particulates, surface ozone, and lead) respectively. Confounding factors including migration, provision of clean water and air, nutrition, disease vector control, and health care, make it difficult to quantify anticipated health impacts due to climate change. Some increases in infectious diseases (e.g. giardiasis, cholera etc.) are possible due increased temperatures and flooding. Clearly, poor people may be more prone to contract disease, be less resistant and less able to afford treatment.

Ecosystem services

Downstream deposition of silt has created a shoreline characterised by mudflats, silt and mangroves. The consequent fertility and turbidity in nearshore waters precludes the growth of coral reefs. Indeed, the only significant coral habitat in Bangladesh is on a small offshore island, Narikel Jinjira (St. Martin's Island). Soft coastal sediments are highly productive, and provide food for a variety of species. In Bangladesh shellfish and prawns in particular provide food and revenue for coastal communities. Mudflats and especially mangroves provide nursery habitat for fish (Heitzman & Worden 1989).

Box 6. Benefits from mangrove

The Sunderbans mangrove system offers many benefits including:

- Building materials for rural houses, for furniture, for making boats and as fuel wood (Govt. of India, 1989).
- Mangrove associated herbs have medicinal values (Vannucci, 2004).
- Mangrove habitat is a natural buffer for tides and surges, and traps sediments, mitigating erosion (Bandyopadhyay1989). The protective value of mangroves is testified to by the relative consequences of the 26th December 2004 tsunami.
- Windbreak, reducing the impact of cyclonic storms (Bandyopadhyay1989).
- Natural sewage treatment and a carbon dioxide sink. (Banerjee, 1998; Govt. of West Bengal, 2002;).
- Nursery, breeding, feeding and spawning ground for many brackish water animal species including fish. Honey gatherers collect 500 quintals of honey and 30 quintals of wax on average per annum (Bose, 2004).
- A home for some endangered and globally threatened species, and offers a potential for ecotourism development. (Govt. of West Bengal, 2002).
- 6000t/ha mangrove litter is released per annum, decomposing to release organic nutrients the environment (Govt. of West Bengal, 2002).
- Restoration of mangroves offers opportunities to develop ecotourism, biological research, conservation education and may provide economic benefit to local communities (Patronobish, 2004).

Unsurprisingly, mangroves feature highly as an important environmental service in Bangladesh, and with 5,767 km^2, includes over 3% of the world total area (Spalding, 1997). Indeed the Sundarbans, shared with India, is the largest continuous mangrove area in the world. The Sundarbans mangroves provide timber for a variety of purposes, including pulp for the domestic paper industry, poles for electric power distribution, and leaves for thatched dwellings. Mangrove wood is utilised in construction because it is available, and given its high resistance to rotting and insect pests, it is an ideal natural construction material in the tropics. Mangrove cover in Bangladesh's Chokoria Sundarban forest fell from 7,500 ha in 1976 to just 973 ha in 1988, largely due to shrimp farm development (Hossain et al. 2001, Gain 2002, Vannucci (in Lacerda) 2002). This deforestation has reportedly had socio-economic impacts on over 90% of the local community (Hossain 2001). Direct employment supported by the Sundarbans is estimated to be in the range of 500,000-600,000 people for at least half of the year (ESCAP, 1987), and a large number of these people, who are directly employed in the industries that use raw materials from the Sundarbans (e.g., woodcutting; collection of thatching materials, honey, beeswax, and shells; fishing), may lose their sources of income as mangrove cover is lost.

Climate change is expected to exacerbate the current rates of mangrove loss. Mangrove species have varying tolerances of salt water, and form distinct zones, if salt water penetrates inland, less tolerant species such as *Heritiera fomes*, will be put at risk. Sea-level rise also may threaten a wide range of mammals, birds, amphibians, reptiles, and crustaceans living in the Sundarbans. Loss of mangroves will make the coastal area vulnerable to cyclonic storms and surges.

Perhaps surprisingly, for a country that has been the focus of science based aid, the world bank report (World Bank, Bangladesh Development Series Paper No: 12, September 2006) also notes "The current

paucity of environmental information and understanding in Bangladesh constrains decision making at all levels"; this reflects some aid agencies greater focus on agricultural (including aquaculture), industrial and infrastructure development, rather than the underlying factors relating environment and poverty in Bangladesh.

Massive delta formations as exemplified in Bangladesh, with large human populations are termed mega deltas. They are the subject of a regional study (http://www.megadelta.ecnu.edu.cn/main/default.asp). Previous work has generated a delta conceptual model, which is to be applied in a study of monsoon circulation and its impact on societal safety. That study notes a persistent gap between science, assessment, and policy. The project proposes to establish a regional database on monsoon-triggered precipitation, discharge, and landform change, etc., with a view to facilitating effective analysis to support good science based policy and management.

Key points

This brief overview clearly illustrates why Bangladesh is especially vulnerable to potential impacts from climate change and it stimulates the following thoughts:

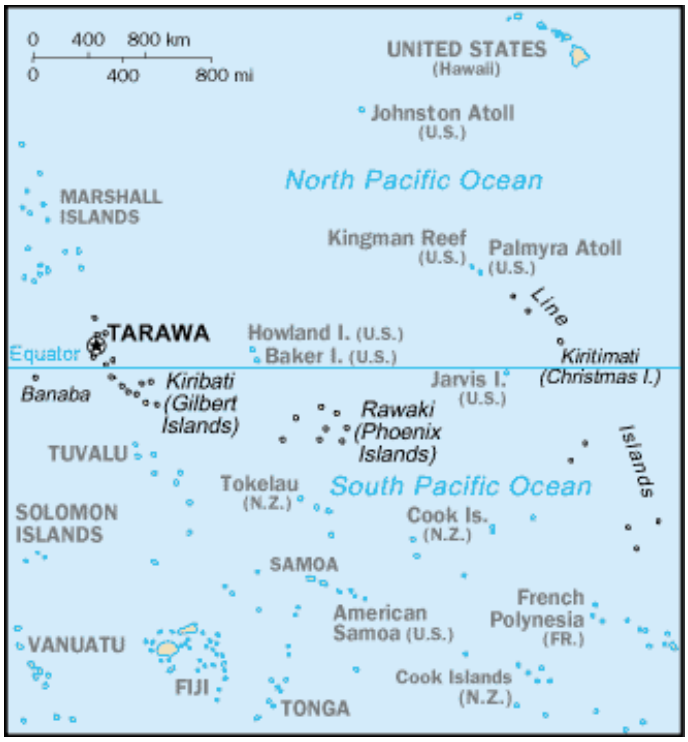
- Bangladesh is a perfect example of the importance of not limiting coastal management to the coast. The term 'Mountain to the Sea' is particularly apt for this state that depends upon and is threatened by rivers draining from the Himalayas and by the marine environment of the Bay of Bengal.
- Widespread pollution and resource degradation is a problem that extends to neighbouring and upstream states. Local, national and regional initiatives to address pollution issues are to be encouraged. Where more than one state shares a resource, joint management and associated data gathering and analysis at a regional, or sub-regional, level is a prerequisite.
- The indications are that flood events may be predicted from Sea Surface Temperature data in the pacific, and different aspects of flooding, e.g. snow melt in the Himalayas, may related to ENSO events. Hence the gathering, management, and sharing of data should also occur a global level.
- Although poverty linked with ecosystem services is the focus of this study, it is frankly hard to distinguish between poor people and those *relatively* better off people following catastrophic events, and if those events occur annually, the distinction between poor and less poor becomes less important.
-
- Within the country there is a debate on the feasibility of trapping sediment behind dams, and through planting trees, the stabilisation of forested high ground. It is unclear how seriously this imaginative option has been reviewed. It is assumed that the elevated forests would be initially protected from harvesters, and would ultimately managed for sustainable harvest. It isn't clear what resource it would be replacing. A clear benefit of damming would be greater control of discharges, and possible amelioration of downstream flooding events.
- There is no obvious affordable technology (unless the point above is considered) available at present to protect Bangladesh or its people, poor or otherwise from the likely negative impacts of climate change. However protection and development of mitigating ecosystems such as mangrove, demonstrably offers protection to the coast from marine climate events, and promotes natural coastal reclamation.
- Increased urbanisation is a demographic factor, but will not in itself necessarily relieve pressures and reliance on ecosystem services nor alleviate poverty. Indeed, a concern of urbanisation is the potential for increased demand on ecosystem services driven by end users who are remote from the ecosystem and the immediate consequences of over exploitation. Whereas communities utilising local resources may more readily relate their actions to the condition of the ecosystem.
- The simplistic use of, for example, $1 per day as an indicator or threshold of poverty, is challenged when comparing urban and rural populations. In some 'poor' coastal communities, especially remote communities, money is not necessarily used on a daily basis, rather it is to purchase those items that are not readily obtained locally such as fuel oil.
- Ecosystem services and poverty alleviation should not be viewed in isolation. A holistic integrated approach to problem solving is recommended. Social considerations significant in a caste organised social structure constrains the upward mobility of poor lower castes. A rapid decline in key common property resources such as marine fisheries, mangroves and freshwater resources will further limit opportunities for the poor.

6.4. Small island developing states

While this case study aims to be relatively generic, it focuses on Kiribati as a key example of the issues faced.

The Gilbert Islands were granted self-rule by the UK in 1971 and complete independence in 1979 under the new name of Kiribati. The US relinquished all claims to the sparsely inhabited Phoenix and Line Island groups in a 1979 treaty of friendship with Kiribati.

Kiribati is the largest atoll nation in the world, comprising 33 islands in the Gilbert, Phoenix and Line Island groups, extending across the equatorial pacific. The population is estimated at 110,356 (July 2008 est.), and urban drift is towards the capital Bairiki on Tarawa Island in the Gilberts.



The country faces a bleak prospect given the projected rise in sea levels, and probable loss of coral through factors associated with climate change. In a worst-case scenario, in the longer term the islands will disappear, due to sea level rise, erosion and reduced or non-existent coral reef growth. In the shorter term, increased salt water intrusion of the fresh water lenses on the islands may be expected, with a consequent reduction of fresh water upon which humans, livestock and coconuts are dependent. It is noted that copra comprises 62% of exports (copra, coconuts, seaweed and fish are the prime sources of export income, while there is additional income through remittances from Kiribati working in the shipping industry).

The complex relationship of factors that determine the likelihood of flooding is not the topic of this report, however, an indication of the potential severity of flooding events in Bairiki, Tarawa, for 3 sea-level rise scenarios [PASLR scenario IS92] is provided by Chaoxiong He (2001). His computations, for the year 2100, based on a 14-year storm event with a 52-knot wind, are summarised below:

Bairiki Tarawa	Sea-level Rise		
	IPCC 0.3m	IPCC 0.5m	IPCC 0.95m
% land area flooded	17	35	100

As Kiribati is remote from international markets, exporting is costly and increasingly so in the face of increasing fuel prices. In turn, tourism revenue currently accounts for more than 20% of GDP. With the increases global fuel prices, the increased cost of flights may deter visitors, and decrease valuable tourist income.

If the establishment of MPAs is considered a prime factor in providing buffers for ecosystem services, it is noteworthy that Kiribati has declared the largest MPA in the world, a 410,500 km^2 (158,453 $mile^2$) protected area in the Phoenix Island group that includes eight coral atolls seamounts and deep-water habitat.

The key future pressures on SIDS, as exemplified by Kiribati, are:

- As islands become uninhabitable, the Kiribati population will become more concentrated on the remaining islands with consequent social issues.
- Sea level rise and consequent loss of land area will result in saline intrusion and a reduced freshwater lens, and the reduced land area provides a smaller catchment for rainwater.
- Careless landfill waste disposal is an aggravating factor. Where landfill can potentially leach into the lagoon, there is a potential for disaster. Similarly, thoughtless removal of aggregate without consideration of the potential erosion effects following sediment drift may easily exacerbate a deteriorating situation.
- Currently 10% of the Kiribati GDP comes from overseas grants/aid – with reduced exports (reduced copra production and loss of island bases for fishing and mariculture) and reduced tourism (crowded urbanized pacific islands are not an attraction for most tourists) greater aid input will be required.
- A country may only declare an EEZ around permanently emergent land. With the potential loss of the Phoenix Island group due to sea level rise, the declared MPA will shrink and ultimately disappear, presumably to become a collection of seamounts accessible to other nation's fishing fleets.?
- The capital, Bairiki, is located in the west of the island group, and is the focus for urban drift. The socio-economic drivers behind this migration exacerbated problems of forced migration as other islands in the group become uninhabitable, and are no longer able to provide natural resources for the urban centres. It is anticipated that there will be increased pressures on neighbouring states that are physically closer to Bairiki than the easternmost islands of the archipelago.

7. Tradeoffs between ecosystem services

As demonstrated in the case studies on mangroves and coral reefs, many habitats provide more than one ecosystem service, providing provisioning services both directly and indirectly (e.g. as nursery grounds for young fish), regulating services (e.g. coastline protection), and cultural services (e.g. tourism). When considering the effects of the use of and impacts on specific ecosystem services, therefore, it must be noted that these will not be isolated. Impacts can be additive, subtractive, or multiplicative.

While links between ecosystem services have often been identified, the level of interactions and the consequences of change have not explicitly been examined. In this section a range of different trade offs that need to be considered are discussed.

7.1. User conflicts

User conflicts refer to a range of issues when considering marine and coastal ecosystem services. The range of user conflicts is illustrated through a range of examples.

Rich versus poor

Developments and desires of the local or global upper and middle classes can heavily impact the coastal poor. Beachfront development for both hotels and private housing can lead to conflict between the

wealthy and poor. The poor may be alienated or excluded from the beaches and reefs they fish from by the tourists and wealthy residents who can generate higher aggregate economic benefits from the same ecosystems. The way that coastal ecosystem services are distributed and degraded is currently making the poor poorer, more vulnerable and more marginalised and is undermining their ability and incentive to contribute to preserving the ecosystems services that sustain them (Newton et al., 2007).

Artisanal versus industrial fisheries

It is generally well understood by fisheries and coastal managers that there is a potential conflict between small-scale artisanal fishermen and large-scale industrial fishermen. Invariably there is concern that they are in competition for the same species, and there are complaints that large vessels fish indiscriminately and damage gear and sometimes the boats of inshore fishermen. A counter argument by industrial fishermen is that they are accessing a resource that is otherwise unavailable to the inshore fishermen, and that they offer increased employment and revenue [through licenses and/or landings] to the State. There are elements of truth in both points of view, and indeed their arguments are not mutually exclusive.

There are examples of fish resources that have been heavily impacted by industrial fleets. European purse seiners fished for tuna off the west coast of Africa, at levels that reduced its economic viability for that size of fleet. This led to a relocation of a proportion of the fleet to the Indian Ocean. Subsequent declines in those stocks have led to a further move to fish in the Pacific. Local small-scale fishermen do not have the facility to move on, and in examples where a locally exploited resource becomes exhausted there is a clear negative impact on local communities. Even if the resource was not directly available to the local fishermen, once it is no longer an economically viable fishery for industrial vessels, the state loses potential revenues from license fees and possible processing etc.

Many states legislate to ensure that local communities are not disadvantaged. This may include exclusion zones related to the sizes and numbers of fishing boats, where smaller boats have access to inshore waters and larger industrial vessels access outer waters. In American Samoa, the vast majority of the small ‘alias’ [Samoan catamarans] are operated by Samoans, while larger offshore boats were operated by non-Samoans. In favour of the local Samoan fishermen, it was agreed that there should be a limited entry program for all fishermen, but there was an opportunity for some small-scale fishermen to upgrade to join the larger fleet if an opportunity arose.

It should be noted however, that every case is different, and it should not be assumed that the offshore industrial fleet always has the greatest impact on a fishery. The apparently simple application of a designated zone to separate sectors of the fishery will not solve underlying issues relating to overfishing and competition. The same stocks of any given species may straddle the zones, migrate though them, and/or each may represent habitats for life stages of varying vulnerability and importance in terms of recruitment (e.g. juvenile habitat inshore or spawning aggregations offshore).

The tuna example provides a case study of the potential interactions between local and international governance of a migratory species. For example, in the western Indian Ocean, yellowfin tuna undergo a long migration from Madagascar, up the eastern coast of Africa, east past Seychelles and then through the British Indian Ocean Territory (Chagos Archipelago) before returning north of Madagascar. International stock assessments based on available data are performed under the auspices of the Indian Ocean Tuna Commission (IOTC), based in Seychelles. In turn, individual countries can licence the operation of industrial tuna vessels within their EEZs, gaining foreign income. However, vessels can also fish freely on the ‘high seas’ area outside country’s EEZs during the migration.

The United Nations Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks sets out principles for the conservation and management of those fish stocks and establishes that such management must be based on the precautionary approach and the best available scientific information. States should cooperate to ensure conservation and promote the objective of the optimum utilization of fisheries resources both within and beyond the exclusive economic zone. It detailed minimum international standards for the conservation and management of straddling fish stocks and highly migratory fish stocks; ensuring that measures taken for the conservation and management of those stocks in areas under national jurisdiction and in the adjacent high seas are compatible and coherent; ensuring that there are effective mechanisms for compliance and enforcement of those measures on the high seas; and recognizing the special requirements of developing States.

However, in practice countries have incentives to maximise local revenues through licensing. The focus is seldom on the local poor who can obtain direct benefit from these resources, but do not have any voice or input at international governance levels.

Local versus global

An increasing global market puts additional pressure on local resources. Increases in local economies, the arrival of external market drivers, improvements in technology, and in particular increases in coastal population numbers has massively increased the pressure on renewable reef resources. In turn, the trade in reef fish, both in the luxury food market (see below) and the general international trade, have increased the monetary value of reef fish catches, further increasing demand. Reef fisheries have therefore often moved from supporting local protein requirements to marketing fresh fish for catch and export, while cheaper imported fish or meat are supplied to the local tables.

An example of the conflicts that can arise through global markets is the live reef fish trade that supplies high value fish both for Chinese restaurants for sale as luxury items, and as ornamental fish for aquaria. Although the overall value of the trade is difficult to identify, numbers of around $810million per annum have been suggested. The large economic incentive to fish has led to a boom-and-bust pattern of exploitation. Depletion of the resource to very low levels has led to fishers moving to new areas to meet market demand. This has led to serial depletion of localised resources, which in turn has led to a rapid geographical expansion following the depletion of reefs near Hong Kong, to encompass the Indo-Pacific region.

The international live reef fish trade has often led to significant social conflicts. These conflicts can arise between operators and local fishing communities over prices, how the wealth is distributed amongst individuals and villages, the use of particular local fishing areas, as well as the impacts of destructive fishing methods used to obtain target species that affect other species in the area. Furthermore, once fisheries move on, local fishers have to deal with degradation of habitats and reduced fish resources.

Given the impacts of these fisheries, controls are needed to prevent the continued over-exploitation of resources, the associated degradation of the reef habitats and other species abundance, and impacts on the livelihoods of those that rely on them.

A further impact of the global market is the potential impact of global patterns on local fishery profitability. An example of this is the global fishmeal industry, which supports the animal feeds and aquaculture industry worldwide. It is produced mostly by reducing pelagic fish catches (e.g. anchovy, sardine, herring and sandeels) to a powder of high protein content (fishmeal). Rapid increases in demand from the aquaculture industry over the past two decades have contributed to a 3-fold escalation in the price of fishmeal (www.globefish.org).

Peruvian anchovy contributes 35% of the global production, with Peru and Chile producing 40% and 16% of the supply. Fishmeal is one of the most internationally traded commodities in the world: each tonne of fishmeal travels an average of 15,000 km to reach its end-user. This demonstrates the global nature of the market, which links developing and developed economies.

Stocks of peruvian anchovy are modulated by El Niño-Southern Oscillation (ENSO) events and by longer multi-decadal cycles (El Viejo) that favour anchovy over sardine and vice-versa (Chavez et al. 2003). With global environmental change increasing the intensity of ENSO events (Hansen et al. 2006), anchoveta production will be affected. The impacts of future climate change on the fishmeal market are the subject of a NERC QUEST study (“QUEST_FISH”; http://quest.bris.ac.uk/research/themes/QUESTFish.html).

Box 7. Global economy

It is interesting to note that although the global economy was discussed in general terms at regional workshops in Tanzania and the Philippines, the importance of oil price rises and the fall in value of the US dollar were not raised as a specific concerns. However, this can have serious implications for the coastal poor.

Increased fuel prices in the Philippines have caused people to take vehicles off the road, and taxi drivers to increase their fares. A less mobile work force clearly has a negative impact on the economy, but may also be expected to result in concentrating more people in the areas of employment in the cities, with consequent social pressures. Fishermen using motorised bankas may be expected to charge more for fish, a basic commodity and export in the Philippines. Imports and exports are likely to increase in price and as air fares increase, foreign and internal tourism is likely to be reduced.

As noted earlier, Kiribati earns around 5 million dollars from fishermen working on foreign merchant vessels. The Philippines has an exceptionally high overseas workforce. The Commission on Filipinos Overseas (2000) report that: "Of the 7.29 million overseas Filipinos, roughly 2.98 million are overseas Filipino workers, 2.37 million are permanent residents, and 1.94 million are classified as undocumented. Remittances amount to around 1 billion dollars per month (2006)
(http://www.poea.gov.ph/stats/faststats.html)

The drop in value of the dollar, means that any workers paid in dollars will likely experience a higher cost of living in their country of work and so have less money remaining to remit, and the remittances are worth less when changed into pesos in the Philippines.

Subtractibility of the ES benefits

The subtractability of the benefits of ecosystem service use describes where the use of a service for one benefit (e.g. provisioning) undermines the benefits of another ecosystem service (e.g. cultural).

An example of this subtractability is the use of coral reef material for building. The importance of coral reefs in coastal protection is often not fully appreciated until too late. The Maldives are low islands, with the capital, port and vast majority of its population based on Malé, an unusually square shaped island.

Coral landfill was used to engineer more land on the reef flat, but following a storm surge from off Australia that struck the island, the landfilled area was severely damaged. This was in part a result of the removal of protective coral for the landfill process. As a result, the area is now protected by an expensive sea wall, which serves the function that the coral reefs would have cost-effectively performed prior to being mined.

Elsewhere in the world, coral is taken to provide the lime needed in the production of concrete. In Fiji, close to the capital Suva, coral sand utilised during the early ‘90s in local concrete production was taken only by dredgers from an area where there would otherwise be navigation issues. This is clearly an eminently sensible synergistic integrated management strategy, demonstrating that the use of ecosystem services does not have to be subtractive if appropriately planned.

The establishment of Marine Protected Areas (MPAs) with the aim of protecting resources, maintaining biodiversity, and in some cases with spin-off tourism benefits, can have direct impact on the poor when closed areas limit their ability to fish or extend the distance they need to travel before they can undertake fishing (increasing costs). In sections 6 and 10.12, MPAs are discussed both in terms of global coverage, and as an example within the SIDS case study. As is noted, the presence of an MPA does not mean that it will be effective; there needs to be sufficient monitoring, control and surveillance to ensure that the closure is in force.

MPAs do not have to be implemented in a top-down fashion. In many countries, closures of areas to fishing can be a bottom-up activity. For example, in parts of the Pacific and South-east Asia, traditional Customary Marine Tenure (CMT) systems have allowed communities, or community leaders, to exert controls over local marine resources. In Fiji, for example, a system of CMT called ‘qoli qoli’ has been in place for many years, often as long as living community elders can remember (Cinner et al., 2007). In this situation, a system of ownership of specific sites or areas exists for specific individuals, families or communities. Access to the resource can be controlled, while rights to fishing can be allocated (e.g. Ruddle, 1996). These systems can maintain strong controls through penalties. These common-property arrangements limit marine resource use in many ways, through the closure of fishing grounds, gear restrictions, limited entry, and the protection of spawning aggregations (Colding and Folke, 2001).

7.2. Spatial trade-offs and impacts

The global analysis performed cannot easily identify upstream and downstream impacts on coastal and marine ecosystem services important to the poor. The geographic scale of analysis is too coarse. However, these impacts can be critical to understanding how ecosystem services will change in the future.

The Millennium Assessment, for reasons of clarity, defined the coast as a geographically tight narrow band. This diverges from most studies and would not be useful in the practise of integrated coastal zone management (ICZM). ICZM practitioners try to consider all potential factors as far as they may extend inland and out to sea.

The concept of management from the 'Mountain to the Sea is not a new one. It is assumed in Polynesian traditional management practise in Hawaii, and is entirely logical given that coastal catchments and associated run-off typically carries material towards the coast. The konohiki, or caretakers, managed a section of land from the mountains to the sea, referred to as the Ahupua'a. This conservation system managed exploitation, while allowing people to take what they needed for sustenance. Ahupua'a were often entire valleys, with the ridges between serving as boundaries. They varied in size on different islands from as little as 100 acres to more than 100,000 acres. This effective system is known as catchment management more recently in the west.

The conclusions in this report are naturally limited to the coastal region and do not necessarily imply connectivity with inland areas or open ocean. There is a need to integrate the various ESPA studies. This is also expressed within the case study on Bangladesh (section 6).

The extent of mountain to sea management may go beyond national boundaries, as may the associated issue of long-shore drift. Indeed major rivers passing through many countries may be managed holistically; a European example is the Danube River, which has its own management plan drafted by the ICPDR (International Commission for the Protection of the Danube River).

Urban-rural impacts

There may be a tendency to associate ecosystem services with rural populations. However people in cities, including poor, will take marine resources if they may. In Suva, Fiji, one of the major components of the inshore fishery in Suva qoliqoli (lagoon management area) is women fossicking on the reef and/or fishing from the shore or waist deep for small fishes that would constitute their main family meal [Beeching A J. MSc Thesis 1996]. This is not unusual – fishing may be more productive where nutrient sources are high, such as sewerage outfalls etc, and unless prohibited, fishermen will naturally congregate where catches are best. Similarly these sites may provide the highest growth rates for mariculture of molluscs etc.

The expansion of megacities such as Manila has not only direct impacts on local ecosystem services, as the city sprawls over previously unaffected areas, but also indirect effects. The increased food, water and sewage requirements of an expanding city must be met from some source outside the direct environment of the city. Downstream effects from cities such as effluent or waste, industrial or domestic may have a negative impact on natural systems. High biological oxygen demand [BOD] can be responsible for fish kills and nutrient inputs may trigger red tides of toxic micro-organisms.

In relatively undeveloped areas the social safety net provided by family and community may be a vital survival factor. Often a family member(s) will move to the city to gain an opportunity to earn more cash to support the family. Indeed as indicated elsewhere, they may work overseas and send remittances home. The links between cities and urban areas are strong and there is much movement between areas, populations are not static.

A further issue for consideration under global-local effects is the potential impact of the global economy on the poor and their use of ecosystem services (see box 7).

8. Discussion

This report examines the range of data sources providing information on marine and coastal ecosystem services important to the coastal poor. It has identified information shortfalls and gaps, as well as raising a number of issues that require further work and research to address. These are discussed below.

8.1. General issues

The conclusions in this report are focussed on the coastal region and do not necessarily imply connectivity with inland areas or open ocean. While the ESPA programme has developed a thematic approach to the synthesis, there is a critical need to link these studies. Bangladesh, for example, is critically reliant on, and exposed to, upstream effects in the Himalayas and in neighbouring countries (see section 6.3). When selecting a geographic focus, therefore, the inter-connection between ecosystem services important to the poor that may be highly geographically separated, must be considered.

Some important areas in terms of ESPA appear not to be covered by the other synthesis reports. Notably, inland lakes, particularly those in sub-Saharan Africa are not identified or assessed. These provide considerable ecosystem services and livelihood options to some of the poorest people in the world. An example is the Democratic Republic of Congo. This country has a high number of fishers, but only a very short coastline. However, there are large freshwater resources in the country, contained primarily within the Rift Valley lakes along the eastern borders with Burundi, Rwanda, Tanzania, Zambia and Uganda, and within the extensive Congo River basin. The ecosystem services these African lakes provide the regional poor need to be considered within the future programme.

As noted within the case studies on coral reefs and mangroves, habitats can directly and indirectly provide a wide range of different ecosystem services important to the poor. While the habitats themselves may be studied in relative detail, providing a time series of information, in many cases the specific range of services resulting from changes in the habitat are difficult to disentangle, and their distinct trends tend not to be studied, either quantitatively or qualitatively. This change is important, particularly in light of the trade-offs that may result (section 7).

Although we have a qualitative grasp of the various linkages between ecosystem services and coastal poor, there is very little useful quantitative data to apply to those services and links; hence we lack a scientific basis for accurately predicting the consequences of changes in ecosystem services or society over time.

The current study, and other related studies (e.g. QUEST GSI), highlights the problem of how different measures of potential impacts are combined or aggregated. We may for example simply sum the spatial extent of coral reefs and mangroves, and value the resources in dollars. It may be more useful, however, to use a per capita change in human well-being for a given change in ecosystem service, or a proxy such as the change in area or in productivity of an ecosystem service.

Population levels were correlated with degradation in, for example, coral reef provisioning services. However, population *per se* was not cited as a significant issue within regional workshops (see box 8). This highlights the need to consider both scientific research and the opinions of regional experts and local stakeholders.

Box 8. Population

Population pressure whether due to growth or migration was not cited as a significant issue at the Manila workshop, indeed one participant stated that population per se was not an issue; ecosystem problems were rather related to resource availability. This viewpoint did not raise any immediate objections from the participants in that breakout group.

The Filipino macho culture encourages large families; fecundity is a measure of machismo. The predominantly Catholic population has a consequent largely non prophylactic approach to sex. Arguments in favour of high population growth may include larger families provide a greater social safety net for the poor, and/or may compensate for higher mortality rates; however, in the Philippines, even affluent, well educated and environmentally informed parents have large families.

Analysis of global data does indicate a clear correlation between loss of ecosystem services and an increase in affecting populations. It is noted that urban drift should not imply a reduced impact on the ecosystem service, it may drive increased demand on nearby resources, and introduce a greater emphasis on monetary value of those resources. Where resources become locally scarce and the value increases, there is a greater risk of the resources being exploited unsustainably. Those resources upon which there is a high dependence, such as potable water, food, construction materials etc.

Box 9. Regional Coastal Data Management

A good model for regional coastal data management exists in South East Asia. PEMSEA (Partnerships in Environmental Management for the Seas of East Asia) is a UN GEF funded programme established 14 years ago. Its members include all countries in the region with the exception of Burma [Myanmar]. Although the prime focus is integrated coastal zone management and as a repository of regional coastal data, they have evolved to an organisation that provides technical advice to member countries and acts as a venue for members to meet and discuss shared issues and options to resolve them. It is probably also fair to say that they are the most effective venue for regional fishery management in SE Asia. It is interesting to note that Plymouth Marine Laboratory (PML) is a partner in PEMSEA.

The value of the organisation as a repository of shared information, a venue for regional meetings focused on coastal issues and a centre to develop coastal management models is clear. PEMSEA is valued by the participating countries, as is demonstrated by funding issues. In 18 months time only the PEMSEA administration will be funded by the UN, the member countries and partnerships with industry will make up the shortfall to support the technical section. Notably, when North Korea's administrative membership was not included in the UN GEF grant, South Korea made up the difference.

Where countries in a region share a scientific & technical body, this helps to ensure a consistent approach to surveys, monitoring and management between countries that have different social and political structures.

Box 10. Deep-sea fishing

Deep sea fishing has been raised as a possible topic of interest in this study. Deep sea fishing is a general term which when applied in fisheries science refers to deep sea trawling or setting deep bottom long lines.

Deep sea fishing in the industrial fisheries sector is a concern, due to the potential damage that may be inflicted on seamounts, the resulting impacts on biodiversity, and due to the biological characteristics of some of the deepwater target species. Much of this fishing occurs in areas where there may be no legally binding international agreements on sustainable fishing. Species at risk of over-exploitation would include orange roughy [renowned for its longevity], alfonsino, and roundnose grenadier. Long-lived, late maturing species are at greater risk of overfishing and there will be a considerable lag-phase in any recovery programs that may be initiated.

There are moves afoot through UN actions to curtail deep sea trawling
(see http://www.terranature.org/bottomTrawling_UNmoratorium.htm).

It is unlikely that deep sea trawling in the industrial fisheries sector would have a direct bearing on the coastal poor, though loss of revenue through any existing fishery licensing agreements may affect the amount of revenue available to states with substantial numbers of coastal poor. If any of the products were processed and/or marketed in country there may also be increased unemployment. It is suggested that there has been increased pressure on deep-sea stocks because shallower more accessible stocks have been over-fished. A lack of food resources globally may be expected to impact humans, including coastal poor.

8.2. Geographic future focus

Overall, the vulnerability analysis suggest that key research on marine and coastal ecosystem services important to the poor should be focussed in the following geographic regions:

- Southeast Asia
- South Asia
- Southeast Africa

In addition, the analysis noted that small island developing states were poorly represented within the global data sets, but were especially vulnerable to changes in marine ecosystem services. They therefore also warrant further study.

The country-by-country analysis performed and presented within this report provides details on specific geographic foci for potential data collection, research funding, and aid, it must be noted that this approach cannot be used to identify micro-scale issues that may be equally – or more – important to the poor.

8.3. Key data gaps and future research

While a number of ecosystem services have been examined in the current study, the importance of key ecosystem services for the poor must be highlighted. These are the services that provide food, potable water, and shelter to the coastal poor.

Poverty definition

A key gap in knowledge was the lack of a single appropriate definition of poverty that could be applied to this analysis focused on marine and coastal ecosystem services and poverty alleviation. In turn, the lack of accurate estimates of the numbers of poor so defined within the coastal zone at a regional, country, and local level severely hampered the assessment. This was notable in particular for small island developing states.

Population estimates for the coastal zone were available from the LECZ data set up to 2000, and not later. More recent time series of estimates are required to identify future trends and pressures on coastal ecosystem services, and in particular of the coastal poor. In turn, a realistic time series for coastal poor population levels is needed.

Information on the behaviour of the coastal poor is lacking at the country level. For example, information on migration patterns within country, and the potential adaptation strategies to decreased supply of ecosystem services must be defined to understand future behaviours.

The metric of the population employed in fisheries and aquaculture needs to be refined to take into account the potential impact on ecosystem services of full and part-time fishers. In turn, there is a need to stratify these employment figures by marine, estuarine and as noted, inshore (lake) fishers.

Ecosystem services

A key gap was the need to identify the relationship between the availability of ecosystem services at a country level, and the reliance on and usage of those services by the coastal poor.

In turn, while consistent and time series information was frequently available on provisioning services available at the country level, there was limited information available on other provisioning services, and directly on regulating, supporting and cultural services. The need to collect this information should be weighted on their importance to the coastal poor. For example, as already mentioned, one may consider that cultural services, while being important, may not be rated as highly as those provisioning services that keep the poor alive. Obtaining weights for the different services from the poor themselves, e.g. through extended regional workshops, could prove useful to refine analyses.

The discrimination of data was a further limiting factor. For example, the estimation of a blanket 'mangrove area' does not take into account the different ecosystem services provided by different species of mangrove. The same consideration may apply to fish catches, where groups are merged into (for example) 'reef fish not elsewhere included'.

Related to this point, while information on habitats and structures providing a variety of cross-cutting ecosystem services of potential importance to the coastal poor were available (e.g. coral reefs, mangroves), information on the levels and trends specifically by ecosystem service was lacking.

Snap-shots of the status of particular ecosystem services were available (in particular provisioning services, as noted). However, time series of information on these services was generally lacking. As a result, the trends and hence potential impacts of changes on the livelihoods and wellbeing of the poor could not be assessed.

The measures of ecosystem service identified here provide positive incidences. However, global datasets are not readily available on ecosystems that are either lost or reduced to the point of being non-functional, for countries that should, could, or once had these ecosystem services. The poor in these countries are presumably more vulnerable as a consequence of this lack of ecosystem services. However, the absence of this data means they cannot be identified in the current analysis. Improved knowledge is therefore needed on the historical state of ecosystem services. This could be documented either scientifically or through cultural memories.

Adaptive capacity

While a range of adaptive capacity measures was available, these seldom encompassed small island developing states. This limited the analysis for these vulnerable nations. Information on island state adaptive capacity is likely available at the regional level from regional co-ordinating organisations.

Adaptive capacity metrics used within this study defined a country's ability to adapt to issues. These did not specifically relate to the adaptive capacity to changes and failures in marine and coastal ecosystem services. Development of targeted adaptive capacity metrics is therefore warranted. This should be focused on the ability of the coastal poor (rather than countries) to adapt to changes in ecosystem

services. These individuals may have developed coping mechanisms to deal with changes that are unrelated to the country-level metrics, which need to be studied.

Coastal poor are not necessarily static; there are numerous examples of coastal communities migrating to access particular resources that become available in certain locations or at certain times. Indeed people may migrate from inland to the coast and vice versa. Some communities are highly mobile, notably the Visayan sea gypsies in the Philippines, who may be landless, and live on large bankas, moving from island to island and region to region, fishing and diving.

Traditional knowledge and experience teaches poor communities how to cope with hardships due to climate and weather, and how to maximise exploitation of transient resources. Hilo, Hawaii, was the victim of a powerful tsunami around the middle of the last century. The first indication of a tsunami event is a backwash of water, exposing the foreshore. In Hilo; children rushed out to pick up stranded fish, and were exposed to the tsunami when it struck. Now there is formal tsunami education, reinforced by community and state wide story telling about those events and about the action that should be taken when a tsunami strikes. Another culture that has not experienced tsunamis may well make the same mistake that the schoolchildren made in Hilo. Bangladeshi's know when to plant crops, poor Filipino communities build 'bahay cubos' that are relatively easy to rebuild after typhoon damage. Pacific islanders know where and when resources will be available. For example, once a year, a nematode worm spawns male and female gametes known as palolo. The time and date of this event is judged by Pacific islanders themselves, who make the most of this once a year bounty.

Trend data

Analysis of trends requires a consistent time series of information. While this may not be directly required at a global level, time series are needed at a country level to identify trends in key services and to project future status. Limited data sources presenting time series of information relevant to marine and coastal ecosystem services were identified. Time series tended to concentrate on provisioning services. There is therefore a need to consider targeting data collection on key ecosystem services important to the coastal poor. These could be developed through participatory methods, and through community-science partnerships.

The drivers of trends need to be understood. For example, decreasing catch rates for fish, or a reduction in the amount of fish as a proportion of total protein intake, may result from any or a combination of the following; overfishing, habitat destruction, a shift in the population to alternative livelihoods, reductions in population, migration, war, changes in the survey technique or data collection quality, or cataclysmic events. It is therefore critical to review the causal factors of change before making assumptions based on crude trend data.

Without good metadata to accompany time series [and other] data, its reliability and limitations are unknown. There is a, potentially unfounded, assumption that major organisations check and assure the quality of the data that they hold. Good metadata may offer insights into the causal factors referred to above.

Future approaches

We have examined existing data sources to develop the analyses presented. However, there may be a number of existing and upcoming research programmes that could/will provide information to fill current gaps. Analysis of the plethora of research funding streams and their existing and pipeline projects was beyond the scope of the current situational analysis. However, the EU is promoting the establishment of a comprehensive study of natural and socio-economic research and resource use, as part of the maritime policy, as well as management in a cross-sectoral manner. Similar aspirations should be considered when considering and collecting data overseas.

Given that ecosystems and human activities are interrelated, the importance of holistic ICZM has long been recognised. It is, however, not comprehensively practised. Effective management should not be limited by political borders nor by pre-determined categorisations of demographic groups or ecosystem. Put simply, ICZM should extend inland and out to sea as far as the source of any potential impact on the coast.

The need to collect co-ordinated and consistent information is noted. A good regional example of this is PEMSEA (see box 9). This model could be transferred to other areas to facilitate standardisation of data

collection and promote cooperation and data sharing. This should aim to underpin improved coastal zone management.

Collection of information on a global, or indeed regional, country-by-country level may be beyond the scope and funding of most countries. However, the identification and use of representative countries as ‘indicators’ for the region may be an efficient use of available funding to monitor and assess ecosystem services at the required level.

Specific studies have produced a monetary evaluation of ecosystem services. For example, mangroves or live reef fish trade. Once a resource is given a monetary value, both politicians and local people better appreciate an otherwise overlooked resource. This approach could be considered for ecosystem services currently under pressure in key countries.

9. Annex 1. List of Ecosystem services and potential data sources identified, at different geographic scales

ES type	ES	Country by country	Regional	Global average
Supporting	Nutrient cycling	x		
	Primary productivity (and changes)	x		
	Secondary productivity (and changes)			
	Potential Teleost and elasmobranch fish production by body size class	x		
	World map of mangroves, seagrasses and coral reefs	x		
	Life cycle stage habitats (estuaries, mangroves, kelp, seagrass, mudflats.			
Regulating	Disease incidence and control			
	Sea level rise (and potential loss of homes, etc.)	x	x	x
	Coastal protection (e.g. from storms)	x	x	
	River flows/Hydrological Actual water balance	x		
	Catastrophes: Links to coastal and erosion protection. E.g. flooding	x	x	
	Increased pressure from population increases: i.e. urban landscape	x		
	Waste disposal and processing		x	
	Shoreline stabilisation/erosion control (linked to coastal protection)	x	x	
	Carbon sequestration/ Climate regulation (potential range of geog. scales)			
	Freshwater storage and retention	x		
	Pollution	x		
Provisioning	Fisheries (marine, freshwater, highseas)	x		
	Daily per capita fish consumption	x		
	Fish protein as % total supply	x		
	Freshwater/water quality	x	x	
	Actual renewable water resources (km^3 or m^3 per person)	x		
	Annual water withdrawals resources (km3 or m3 per person)	x		
	Aquaculture	x		
	Nutrition: amount, quality, sources (e.g. agriculture vs aquaculture/fisheries	x		
	Natural Materials – construction and extraction			
	Aquarium trade	x		x
	Medicines etc.			
	Salt production	x	x	x
	Invasive species		x	
	Desalination plants			

	Renewable energy production			
	Seaweed farming	x		
	Number of people employed in fisheries and aquaculture	x		
Cultural	Recreational uses (links to biodiversity)			
	Trade in goods and services	x		
	Tourism	x	x	
	Protection (e.g. MPAs)	x		
	Identity			x
	Educational	x		
	Aesthetics (linking to tourism and biodiversity)			
	Crafts (e.g. Seagrass mats, boat building, sculpture, stamps)			

ES type	ES	Country by country	Regional	Global average
Supporting	Nutrient cycling[10]	For ~ 800 locations, wind and other weather data available from http://www.ncdc.noaa.gov/oa/mpp/freedata.html. Annual and monthly river discharge available from 3500 sites around the world sites through: http://www.sage.wisc.edu/riverdata/ And by country from: http://www.rivdis.sr.unh.edu/download.html[11]		
	Primary productivity (and changes)	Data becoming available through Cefas project work, for 9x9km and 32x32 km world grid Also: http://oceancolor.gsfc.nasa.gov./ and http://web.science.oregonstate.edu/ocean.productivity/		
	Secondary productivity (and changes)			
	Potential Teleost and elasmobranch fish production by body size class (i.e. in the absence of any fishing)	Data becoming available through Cefas project work, for 9x9km and 32x32 km world grid		
	World map of mangroves, seagrasses and coral reefs	http://www.unep-wcmc.org/, including coral disease maps, seagrass maps, mangrove maps Mangroves: http://www.fao.org/docrep/010/a1427e/a1427e00.htm		
	Life cycle stage habitats (estuaries, mangroves, kelp, seagrass, mudflats.			

[10] Linked parameters include currents and tides (NOAA satellite data/GLOSS tide level databases), water temperature (NOAA satellite data/Colombia Uni oceanography data)

[11] Vörösmarty, C.J., B. Fekete, and B.A. Tucker. 1998. River Discharge Database, Version 1.1 (RivDIS v1.0 supplement). Available through the Institute for the Study of Earth, Oceans, and Space / University of New Hampshire, Durham NH (USA) at http://pyramid.unh.edu/csrc/hydro/.; Vörösmarty, C.J., B. Fekete, and B.A. Tucker. 1996. River Discharge Database, Version 1.0 (RivDIS v1.0), Volumes 0 through 6. A contribution to IHP-V Theme 1. Technical Documents in Hydrology Series. UNESCO, Paris.

Regulating	Disease incidence and control			
	Sea level rise (and potential loss of homes, etc.)	http://www.globalwarmingart.com/sealevel current data from: http://seamless.usgs.gov/	British Oceanographic Data Centre: http://www.bodc.ac.uk/data/online_delivery/international_sea_level/ available from sensors at specific sites around the globe.	Proudman Oceanographic Laboratory: http://www.pol.ac.uk/psmsl/author_archive/jevrejeva_etal_gsl/
	Coastal protection (e.g. from storms)	http://www.ldeo.columbia.edu/chrr/research/hotspots/coredata.html (details at Global Flood Hazard Frequency and Distribution)	Specific locations available from http://oceancolor.gsfc.nasa.gov/cgi/landsat.pl	
	River flows/Hydrological Actual water balance	Earthtrends http://earthtrends.wri.org/searchable_db/index.php?theme=2&variable_ID=694&action=select_countries		
	Catastrophes: acute but incidence and effect may be trending upwards. Increased storm activity on coast. Link to coastal and erosion protection. E.g. flooding	DRI (UNDP) Global Flood Mortality Risks and Distribution (again Columbia hotspots project)[12] http://www.emdat.be/ (Database of emergency events) SURVAS vulnerability database (http://www.survas.mdx.ac.uk/content.htm) - only 36 countries currently	Flood hazards: http://www.survas.mdx.ac.uk/content.htm. 36 countries currently available, many assumptions required.	
	Increased pressure from population increases: i.e. urban landscape – roads concrete houses supply links etc.	Earthtrends, FAO (global population available gridded at 1° square resolution, historical time series and projections at country level also available)		
	Waste disposal and processing		Europe: http://waste.eionet.europa.eu/facts/wastebase and related databases	

[12] gridded population data at http://sedac.ciesin.org/gpw/global.jsp

			(http://waste.eionet.europa.eu/facts/wastebase/international_databases) Australia: http://awd.csiro.au/ Asia – paper: http://www.ingentaconnect.com/content/klu/10163/2004/00000006/00000002/art00004 South Africa: http://wis.octoplus.co.za/?menu=16 Algeria, Egypt, Lebanon, Morocco, Jordan, Palestinian Territories Syria and Tunisia: http://www.metap-solidwaste.org/index.php?id=2	
	Shoreline stabilisation/erosion control (linked to coastal protection?)	Mangrove area (as % coastline length) FAO, 1990-2005 at irregular intervals	Barbier nature paper (focus on Thailand)	
	Carbon sequestration/ Climate regulation (global rather than local?)			
	Freshwater storage and retention (from MA)	Water Withdrawals: Withdrawals as a percent of internal water resources Earth trends http://unstats.un.org/unsd/environment/qindicators.htm		
	Pollution	Earthtrends: might be inferred from (e.g.) use of herbicides and fertilizers (e.g. also FAOStat)		
Provisioning	Fisheries (marine, freshwater, highseas)	FAO – fish, crustaceans, molluscs, other local sources Broken down by catches within EEZ, high seas (SAUP)		
	Daily per capita fish consumption	WRI (FAO), 1961-2000		
	Fish protein as % total supply	WRI (FAO), 1961-2000		
	Freshwater/water quality	http://unstats.un.org/unsd/environment/qindicators.htm (includes waste treatment at city level for many cities)	United Nations Global Environment Monitoring System	

			(GEMS) Water Programme: http://www.gemstat.org/ (patchy – only rivers, lakes and groundwater)	
	Actual renewable water resources (km^3 or m^3 per person)	Earthtrends		
	Annual water withdrawals resources (km3 or m3 per person)	FAO, Earthtrends http://unstats.un.org/unsd/environment/qindicators.htm		
	Aquaculture	Earthtrends & FAO e.g. seaweed aquaculture		
	Nutrition: amount, quality, sources (e.g. agriculture vs aquaculture/fisheries	Earthtrends FAOStat – food balance sheets: http://faostat.fao.org/site/345/default.aspx (country-by-country information)		
	Natural Materials – construction – gravel and sand extraction, coral [lime]/mangroves, etc? [also relates to regulation and production see above]			
	Aquarium trade	http://www.unep-wcmc.org/marine/GMAD/index.html (data from 45 wholesale importers and exporters) Trade in live corals (Earthtrends)		USA trade data, available under the Freedom of Information Act (FOIA), from the USFWS – as the largest importing country, these could be a good indicator of export trends from many countries (requests for data

				required).
	Medicines etc.			
	Salt production	http://www.saltinstitute.org/36.html (top 10 countries and grouped others) Data also available in expensive market research reports – e.g. http://www.roskill.com/reports/salt	European trade statistics: http://epp.eurostat.ec.europa.eu/newxtweb/mainxtnet.do (salt under SITC code 27830)	http://minerals.usgs.gov/ds/2005/140/salt.pdf
	Invasive species		Data by ecoregion provided in: Molnar *et al.* 2008 and database of marine invasives, available from: http://conserveonline.org/workspaces/global.invasive.assessment Some limited data from: http://www.issg.org/database/reference/index.asp Also: http://www.invasivespeciesinfo.gov/aquatics/databases.shtml (see Database: Assessing the Global Threat of Invasive Species to Marine Biodiversity)	
	Desalination plants			
	Renewable energy production			
	Seaweed farming	Earthtrends – aquaculture of aquatic plants: http://earthtrends.wri.org/searchable_db/index.php?theme=1		
	Number of people employed in fisheries and aquaculture	Earthtrends, 10-yr intervals from 1970 to 2000		
Cultural	Recreational uses (links to biodiversity)			
	Trade in goods and services	Earthtrends		
	Tourism	UN Stats (UN-WTO) – tourism expenditures, receipts, and arrivals for 166-208 countries (1999-2004) http://unstats.un.org/unsd/cdb/cdb_topic_xrxx.asp?topic_code=25	Caribbean data: http://www.onecaribbean.org/home/	

	Protection (e.g. MPAs)	Earthtrends UNEP-WCMC, Louisa Woods runs the most up to date database (l.wood@fisheries.ubc.ca, possibly now on IUCN USA) – www.mpaglobal.org Also World Database on Protected Areas: http://sea.unep-wcmc.org/wdbpa/		
	Identity			Literature reviews – very patchy
	Educational	Distribution and number of field stations, location of marine field expeditions (Coral Cay Conservation, Frontier, Green Force)		
	Aesthetics (linking to tourism and biodiversity)			
	Crafts (e.g. Seagrass mats, boat building, sculpture, stamps)			

Poverty measures

Measure	Data source
Ultra poor	
% below nominal poverty line	http://data.un.org/Data.aspx?q=poverty&d=MDG&f=seriesRowID:581
Population living on less than $1/day	Earthtrends CIA
Human dev/poverty index	Earthtrends CIA
Growth rate in rural areas	Earthtrends CIA
Nutrition	Earthtrends UN: http://data.un.org/Search.aspx?q=nutrition
Benefits from lack of resource: resource availability and conduits of supply. – i.e. a non-financial measure of poverty, more cultural measure	

Measures of adaptive capacity

Measure	Data Source
GDP	Earthtrends
Per capita GDP change	Earthtrends
Governance measure	Earthtrends: Level of democracy index Climate Analysis Indicators Tool (CAIT): http://cait.wri.org/
Civil Liberties Index	Earthtrends, 1972-2006
Trade in goods and services	Earthtrends
Further governance measure of empowerment: linked to local/community independence from central government or other top down organisations	Earthtrends: Level of freedom index
Experiential knowledge: e.g. been through it before – e.g. tsunamis, famines etc	
Fecundity: e.g. child mortality rate provides improved adaptive options	UN Data – crude birth rate (births/1000 population): http://data.un.org/Data.aspx?q=birth&d=PopDiv&f=variableID:53
Adaptation costs (capital and maintenance), for sea level rise	SURVAS vulnerability database (http://www.survas.mdx.ac.uk/content.htm) - only 36 countries currently

10. Annex 2. Summary of information identified in the current study

In this section, a summary of the information (e.g. ecosystem service, poverty measures, potential measures for use within estimates of adaptive capacity) is provided.

10.1. Coastal population

Summary and data source

A number of different estimates of population were available, including annual estimates and projections of total population at the country scale (e.g. FAOSTAT). To assess the importance of marine and coastal ecosystem services *for the poor*, however, a measure of the coastal population, and more specifically the coastal poor, is required (see section 10.3). Obtaining this measure for a large number of countries proved impossible; while estimates for individual countries may be available, a data set sufficient for the analysis proposed was lacking.

Therefore, a range of alternative metrics was developed. These concentrated on the low elevation coastal zone data set. The primary data source for this was the low-elevation coastal zone data set (http://sedac.ciesin.columbia.edu/gpw/lecz.jsp).

Geographic coverage

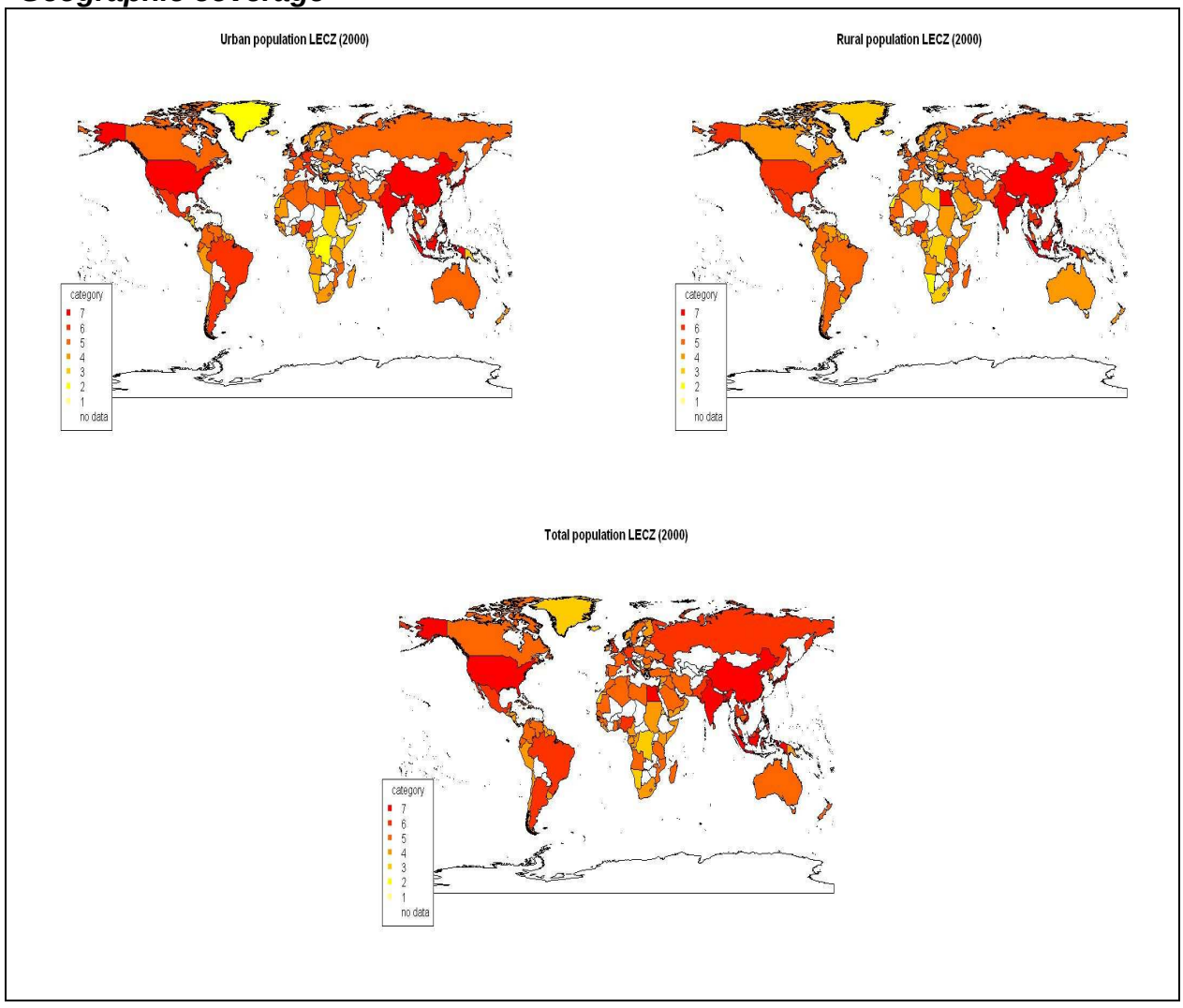


Figure 16. Charts of Urban (top left), rural (top right) and total (bottom) population estimates by country within the low-elevation coastal zone.

Table 10. Top 10 countries within each metric.

Rank	Urban	Rural	Total
1	China	China	China
2	India	Bangladesh	India
3	Japan	India	Bangladesh
4	Indonesia	Vietnam	Vietnam
5	United States	Indonesia	Indonesia
6	Bangladesh	Egypt	Japan
7	Vietnam	Myanmar	Egypt
8	Thailand	Philippines	United States
9	Egypt	Thailand	Thailand
10	Netherlands	Nigeria	Philippines
Total countries:	182	182	182

Key signals

Asian countries tend to dominate both the urban and rural (and hence total) populations within the low elevation coastal zone. Only two African countries (Egypt, Nigeria) are found within the top 10, and only Egypt consistently (primarily a result of the consistently low elevation across the country). In part, these countries tend to be most populous, and hence would be expected to fall into this category. However, the large number of coastal cities in these areas (e.g. Bangladesh, Philippines) also contribute.

Key gaps

Data for coastal population was available for most countries around the world. However, information for the majority of SIDS was lacking.

As noted in the main text, the population of the coastal zone that derives ecosystem services direct from the marine and coastal environment is not known across countries. In turn, the proportion of this population classed as 'poor' is ill defined. In times of hardship, the poor may migrate to the coast to take benefit from the ecosystem services (e.g. provisioning services) provided. Other studies have shown that the poor will migrate to the cities to find employment. Where both rural and urban areas are populous on the coast (e.g. China, Bangladesh, India), these may be particularly impoverished.

Key research issues

- Better calculation of the proportion of the poor within the coastal zone.
- Better estimation of the level of ecosystem services utilised by the poor.
- Better understanding of the migration potential of this component of the population.

10.2. Population increase in the coastal zone

Summary and data source

Low elevation coastal zone population estimates were available for 1990, 1995 and 2000. Therefore, the trend in the urban, rural and total populations was estimated, as a rough indicator of the potential for increased pressure on coastal zone ecosystem services.

Primary data source was the low-elevation coastal zone data set (http://sedac.ciesin.columbia.edu/gpw/lecz.jsp).

Geographic coverage

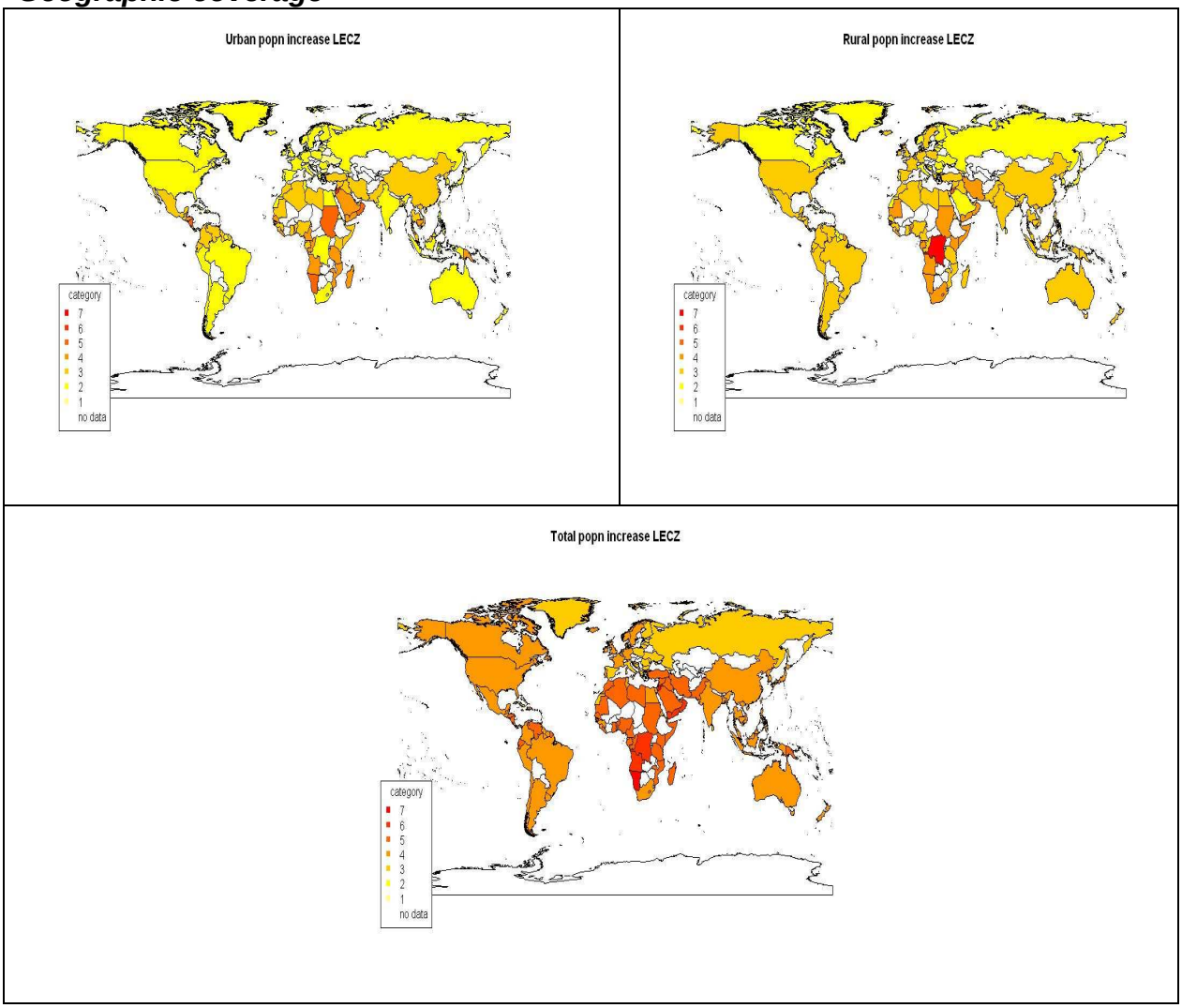


Figure 17. Charts of % increase in urban (top left), rural (top right) and total (bottom) population estimates by country within the low-elevation coastal zone.

Table 11. Top 10 countries within each population increase metric.

Rank	Urban	Rural	Total
1	Mayotte	DR Congo	Jordan
2	Jordan	Jordan	Mayotte
3	Namibia	N. Marianas	Namibia
4	Nicaragua	Macau	N. Marianas
5	Sudan	Mayotte	Oman
6	Solomon Is.	Yemen	DR Congo
7	N. Marianas	Aruba	Yemen
8	Oman	Namibia	Aruba
9	British Virgin Is.	Benin	Solomon Is.
10	Cape Verde	Somalia	Angola
Total countries:	177	182	182

Table 12. Bottom 10 countries within each population increase metric (showing declines).

Rank	Urban	Rural	Total
1	Equatorial Guinea	Malta	Niue
2	Latvia	South Korea	Latvia
3	Estonia	Togo	Equatorial Guinea
4	Kuwait	Trinidad and Tobago	Estonia
5	St. Kitts and Nevis	Niue	St. Kitts and Nevis
6	Ukraine	Sri Lanka	Malta
7	Bulgaria	Estonia	Kuwait
8	Moldova	Qatar	Ukraine
9	Romania	Bahamas	Bulgaria
10	DR Congo	St Kitts and Nevis	Moldova
Total countries:	177	182	182

Key signals

Major percentage increases in coastal population between 1990 and 2000 are not concentrated within particular regions, but are found across the world. Key hotspots are in SW Africa (Namibia and Angola), and the Yemen, as well as a number of small island states, where increases in the urban population are frequently found.

Increases (in particular) may represent general population increases – particularly for small island states where the whole country may well lie in the low elevation zone - as well as general increased migration to the coastal zone. This can be linked to the continued expansion of mega-cities such as Manila, which sit in the coastal zone.

Jordan showed the greatest increase in relative terms, with over a 90% increase in population in the LECZ from 1990 to 2000. Jordan has a very small coastline along the Red Sea (~27km), but this Gulf of Aqaba region is a centre for tourism and trade. In the face of increasing pressures and threats to the region, a National Strategy has been developed to attempt to achieve environmental protection (http://www.kinghussein.gov.jo/geo_env3.html).

Only 18 coastal countries (9% of those where data were available) showed a decline in the low elevation zone population. These were often ex-Soviet states, potentially a result of increased migration into major cities in search of employment. Declines were generally less than 13%. Monserrat showed a decline of 64% in the low elevation population, likely a result of the evacuation following the devastating eruption of Soufriere Hills volcano in 1995.

The Democratic Republic of Congo has a declining urban coastal population, but the highest increase in the rural population. Declines in overall coastal population are frequently within ex-Soviet states, as well as a number of SIDS, showing declines in both rural and urban populations.

Key gaps

Data for coastal population was available for most countries around the world. However, information for a number of SIDS was lacking.

A key gap is knowledge of the movement of the coastal populations. Where the population is migrating to the coast, is this increasing the pressure on ecosystem services? Where the population are moving into coastal urban zones, this is likely to increase the impact on the shoreline (e.g. directly through construction and through increased biological input into surrounding oceans) and an increased pressure on ecosystem services both from the direct location and the surrounding areas (e.g. imported food and materials), which may not be coastal or marine. There may therefore be remote impacts on the ecosystem services of a country through increased urbanisation. The degree of this impact is not known.

Key research issues

- Better knowledge of the migration pattern and habits of the coastal poor
- Better information and understanding of the impact of increased urban and rural populations on coastal and distant ecosystem services.

10.3. Poverty metrics

Summary and data source

Table 13. Poverty indicators identified

Indicator	Years	Source
Poor living on < $1 per day	2007	World Bank
Population below national poverty line		UNDP
Human Development Index	2005	Earthtrends
Life expectancy	2005	Earthtrends

Geographic coverage

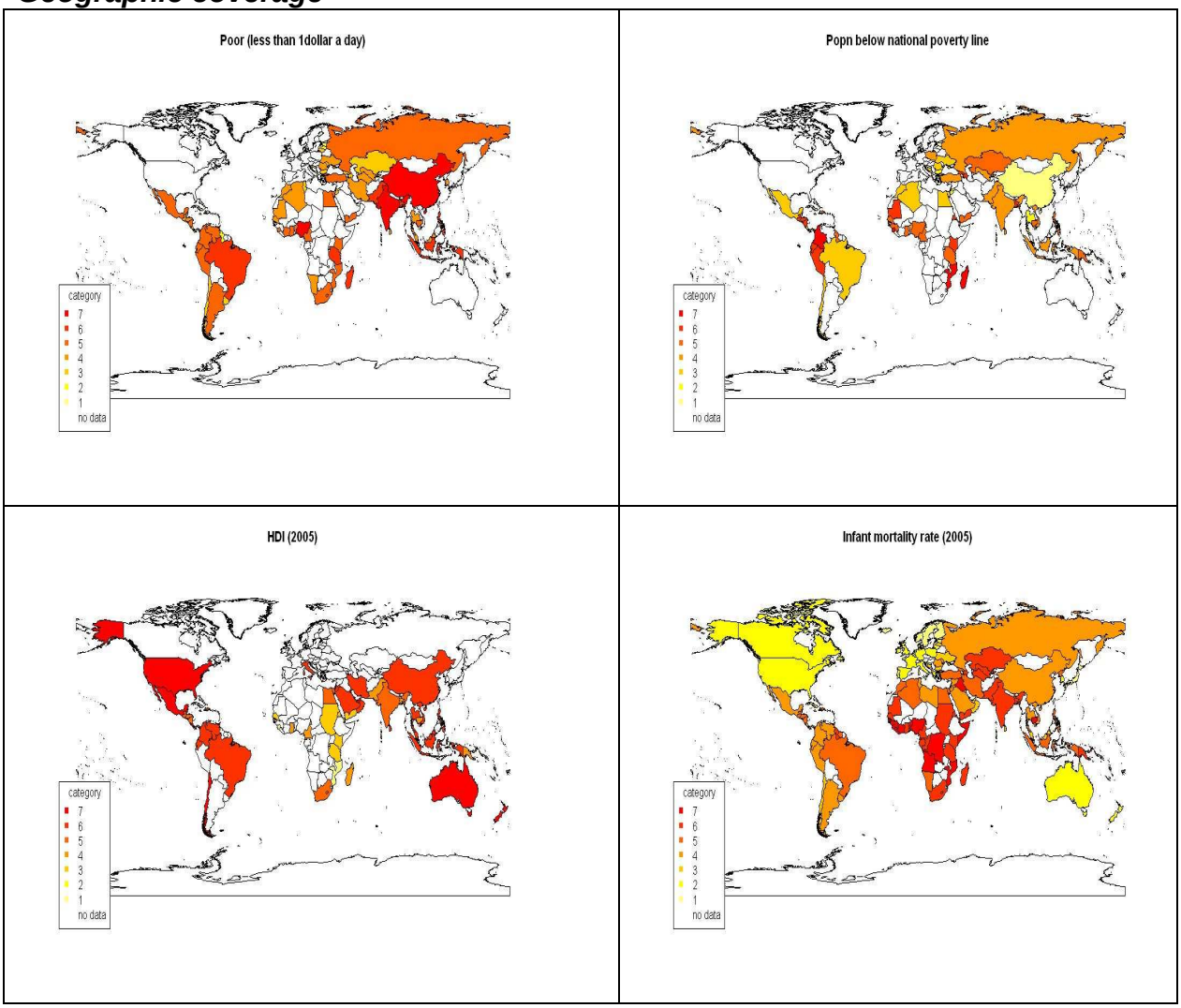


Figure 18. Charts of poverty indicators by country.

Table 14. Top 10 countries within each poverty metric.

	Poor <$1	Popn below poverty line	HDI	Infant mortality rate
1	Nigeria	Madagascar	Sierra Leone	Sierra Leone
2	Madagascar	Sierra Leone	Mozambique	Liberia
3	The Gambia	Mozambique	Tanzania	Angola
4	Tanzania	Colombia	Eritrea	Somalia
5	Sierra Leone	The Gambia	Senegal	DR Congo
6	Haiti	Guatemala	Yemen	Guinea Bissau
7	Nicaragua	Georgia	Djibouti	Equatorial Guinea
8	Ghana	Peru	Kenya	Cote D'Ivoire
9	Bangladesh	Eritrea	Sudan	Iraq
10	Mozambique	Kenya	Haiti	Nigeria
Total countries:	71	60	79	156

Key signals

There is general comparability between the different potential metrics of poverty. Countries in west and southeast Africa, and central America show relatively high levels of poverty and often accompanying low life expectancies. Central/east Africa generally shows a lower human development index.

Key gaps

Data on poverty metrics were generally limited, with no estimates for swathes of Africa (e.g. population below the national poverty line). This made estimation of population poverty indices difficult.

Although the metrics were generally consistent, the overall specific countries (rather than regions) varied notably. There is a need to identify a specific poverty indicator of direct relevance to the coastal poor. Indeed, it must be noted that generic indices such as the $1 a day presented here, are not necessarily representative. This is particularly true where individuals have no specific need or desire for monetary goods.

Key research issues

- Identify coastal-zone specific metrics for poverty at the country level

Calculation of coastal poverty

As noted in section 4.1, it was necessary to calculate the number of coastal poor by multiplying the LECZ population values in each country by country-level poverty metrics (namely % population living on <$1 per day, and % population below the poverty line). The results of this calculation are presented in Figure 19, and the top 10 countries presented in Table 15. These are discussed in detail within section 4.1.

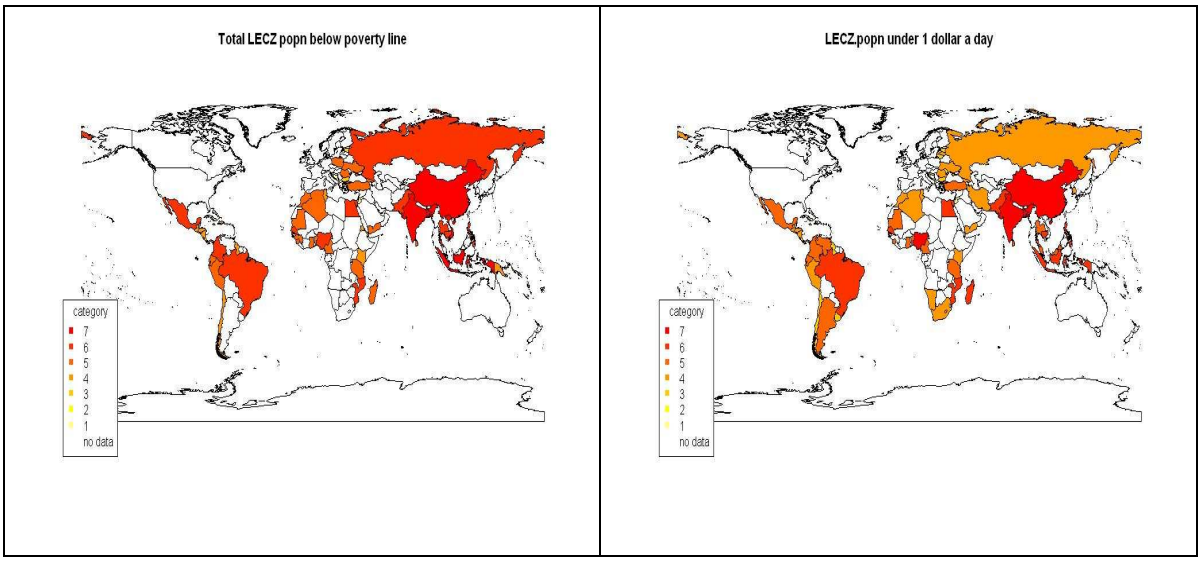


Figure 19. Geographic distribution of calculated coastal zone poverty metrics.

Table 15. Top 10 countries within each calculated coastal poverty metric.

Rank	Coastal Poor <$1	Coastal Popn below poverty line
1	Bangladesh	Bangladesh
2	India	India
3	China	Vietnam
4	Nigeria	Indonesia
5	Indonesia	China
6	Philippines	Philippines
7	Cambodia	Egypt
8	Brazil	Brazil
9	Egypt	Nigeria
10	Mozambique	Thailand
Total countries:	67	57

10.4. Marine fish crustacea and mollusc landings and consumption

Summary and data source

Data on the catch of marine fish, crustacea and molluscs were available by country from the FAO FishStat database. In turn, the catches were broken down into the specific catch taken from the Exclusive Economic Zone of a specific country by the Seas Around Us Project. These data were felt to better reflect the fish resources available to coastal populations, since they eliminated the influences of distant water fleets from a country (e.g. long-distance tuna vessels).

Using these data, a metric of the per capita availability of marine resources was calculated using the LECZ population figures. This did not take into account estimates of the poor within the coastal zone (felt to be insufficiently robust for use in this manner). The metric therefore assumes that the catch is equally available to the well-off and the poor within the coastal zone. This is a strong assumption, and unlikely to reflect the real situation.

A further two metrics were available from Earthtrends which indicated:

- the proportion of the total protein intake of a population that was comprised of fish protein. This represented the reliance of a population on the provisioning ecosystem service of the sea.
- the per capita consumption of fish (kg)

Geographic coverage

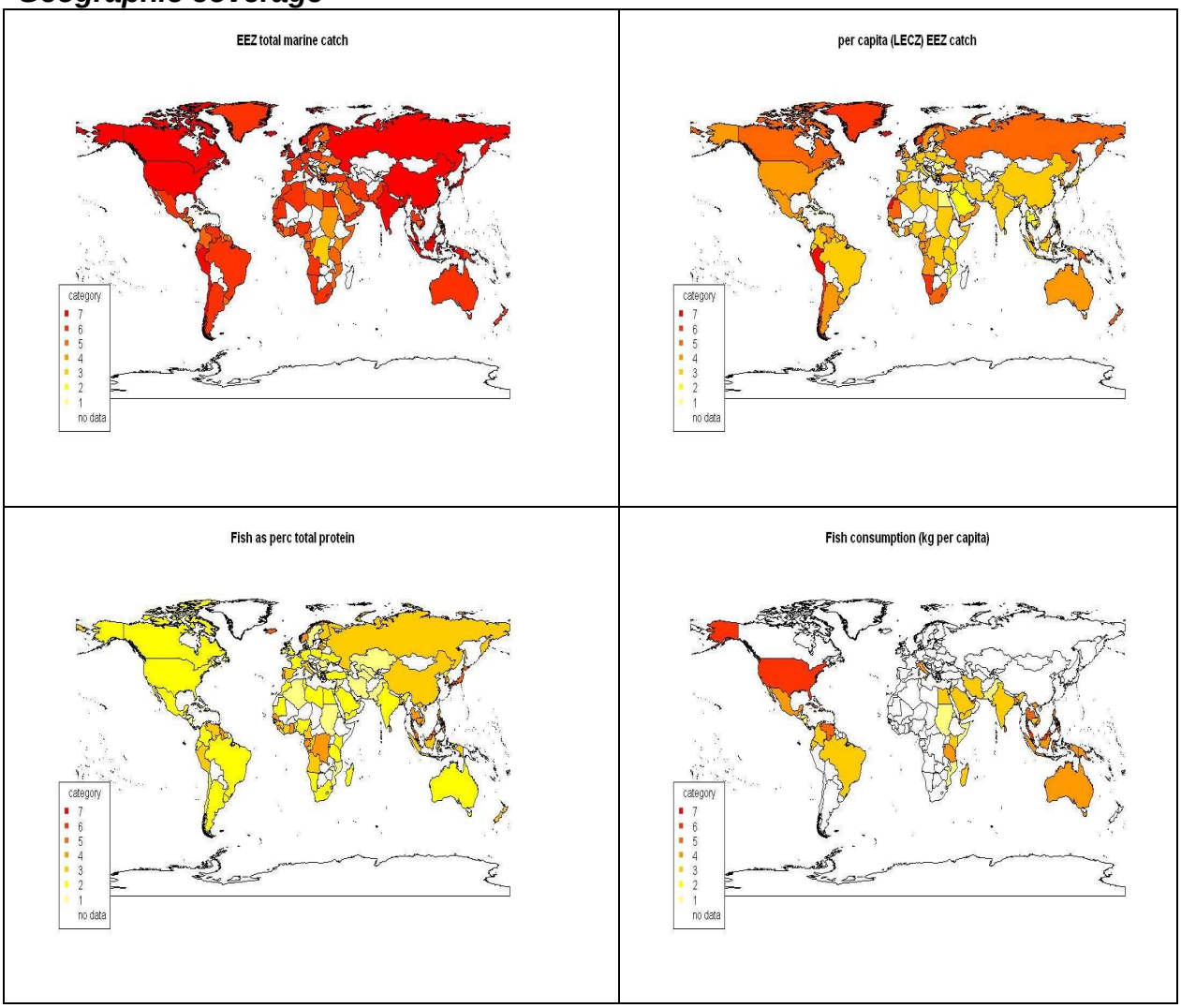


Figure 20. Charts of fish catch and consumption indicators by country.

Table 16. Top 10 countries within each fish catch and consumption metric.

Rank	EEZ catch	LECZ Per capita fish catch	Fish as % total protein	Per capita fish consumption (kg)
1	China	Faroe Is.	Maldives	Kiribati
2	Peru	Iceland	Kiribati	Maldives
3	Indonesia	Peru	Japan	Tokelau
4	United States	Western Sahara	Samoa	Tuvalu
5	Chile	Namibia	Solomon Is.	Palau
6	Russia	Greenland	Seychelles	Fed. States Micronesia
7	India	Chile	Iceland	Cook Is.
8	Japan	Norway	Malaysia	Jamaica
9	Norway	Seychelles	South Korea	Seychelles
10	United Kingdom	South Africa	Guyana	French Polynesia
Total countries:	183	169	141	86

Key signals

There was considerable variability between the metrics. This was largely a function of the inclusion of industrial fisheries within the EEZ catch, which was unavoidable with the data available. As a result, EEZ catch was dominated by nations with major demersal (e.g. Russia) and pelagic (e.g. Peru) fishing operations within their EEZ. It was notable that India was included within the top 10, however.

The metric of the total EEZ catch per capita (low elevation coastal zone population) represents the potential availability of fish protein to the coastal population. A similar developed-country dominance of the catch per coastal population was noted, a result of the high level of (frequently industrial or semi-industrial) catch within their EEZs. However, countries such as Western Sahara and Namibia (both of which have a high coastal population but also third country agreements for industrial vessels to fish in their EEZs) were also present. Likewise Seychelles, which has a very large EEZ and tuna fishery, was included.

More poverty-focused metrics were based on the consumption of fish as a source of protein. SIDS were dominant in both of these categories, forming the majority of the top 5 in each. This indicates the reliance these countries have on the local resources in the face of expensive imports. Data for the Maldives indicates that 54.8% of the protein intake is made up of fish protein, while for Kiribati estimates are 29.3%. This is perhaps not surprising given the expense of transporting alternative sources of protein to islands and the inability of very small island states (with limited space and often soil quality) to grow and develop alternatives. This clearly demonstrates the sensitivity of these SIDS to changes in the ecosystem services that the surrounding waters provide.

Key gaps

Data on fish catches and protein was generally available across countries, although the source of per capita fish consumption information was more limited. A key gap was the absence of a clear poverty-related fish catch metric. However, other studies (e.g. Newton et al., 2007) have developed catch metrics of e.g. coral reef-specific fish catches. Therefore, there is the potential to develop a more coastal- and poor-related metric for fish catch using FAO data, although this would take considerable time.

Key research issues

- Development of coastal poor-specific fish catch and consumption estimates

10.5. Fisheries exports

Summary and data source

Data on the level of marine fish, crustacea and molluscs exports were available by country from the FAO FishStat database. This information provides an indication of the reliance of countries on the coastal and marine ecosystem services for a source of foreign income (which can potentially be used to purchase cheaper protein from abroad if needed). A limited exporting level might suggest that all resources are consumed in country, and indeed may indicate that additional resources are required to be brought into the country to meet demand.

Geographic coverage

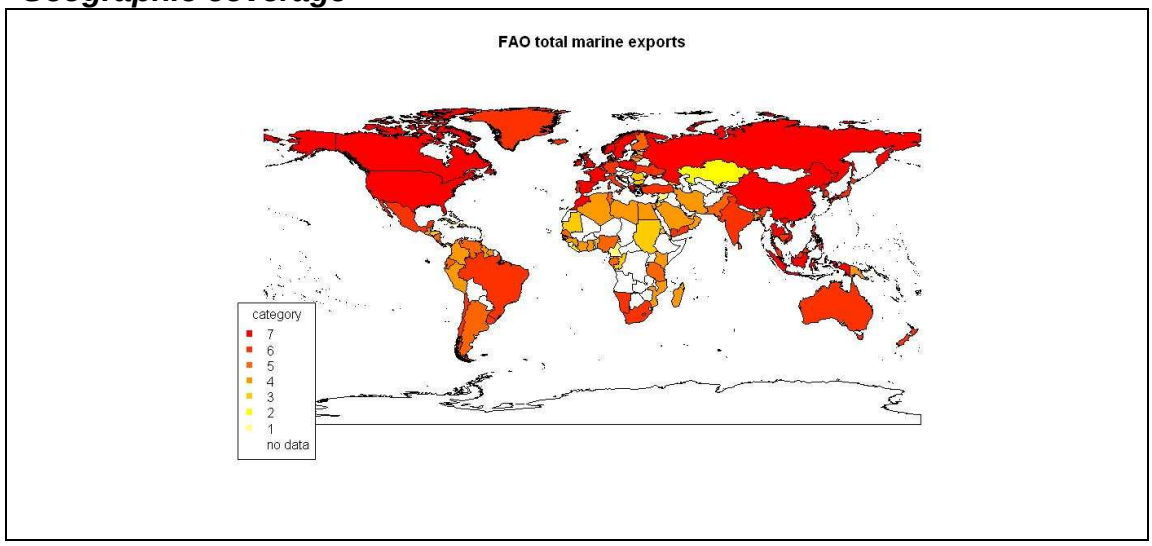


Figure 21. Charts of level of exports of marine fish, crustacea and molluscs by country.

Table 17. Top and bottom 10 countries exporting marine resources.

Rank	Top 10	Bottom 10*
1	United Kingdom	Cape Verde
2	China	Sierra Leone
3	Sweden	Syria
4	Denmark	Cook Is.
5	Thailand	Equatorial Guinea
6	Norway	Solomon Is.
7	Ireland	Cameroon
8	Spain	Kiribati
9	Vietnam	Vanuatu
10	France	Kuwait
Total countries:	171	171

* a number of countries had zero exports within the database. This may indeed indicate that no exports occurred. However, the bottom 10 here is comprised of those countries with >0 export levels.

Key signals

The top 10 exporters of marine catches were generally developed nations, with countries such as Vietnam relatively high due to considerable exports of commodities such as shrimp. The bottom 10 were developing countries, generally either in Africa and SIDS.

Key gaps

Information on fish exports can indicate the potential for foreign income. Indeed, some countries export valuable fish and import cheaper fish protein, or export valuable fish and retain the rest. However, the bottom 10 countries tended to be either African countries or SIDS, which may suggest that all fish catches are needed to provide protein to the population. However, the data do not allow this to be clarified.

Key research issues

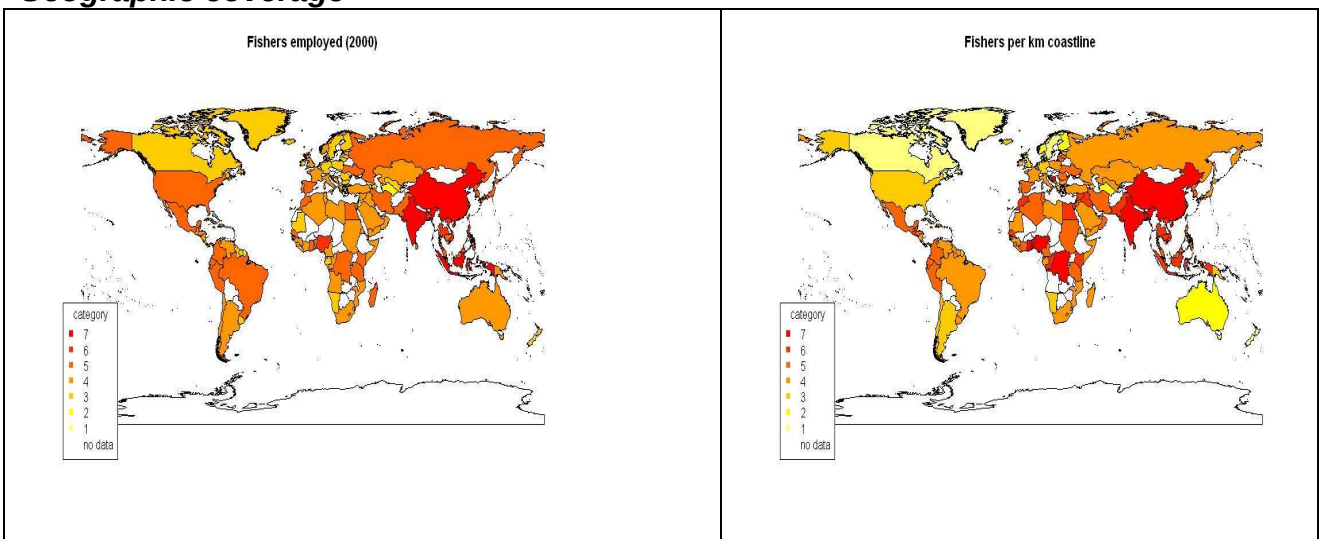
- Identify the use of marine catches for exports (and Foreign Exchange) or retention within country to feed the population
- Non-consumable natural resources can form a valuable and significant component of the export trade, including precious corals, pharmaceuticals, and the live reef fish trade. Information on these categories, while not included here, may be available through e.g. IUCN
- Identify the exported commodity – e.g. valuable large pelagics, shrimps, etc.

10.6. Fishers

Summary and data source

Data on the number of people involved within the fishing and aquaculture industries within each country were available from Earthtrends. This database provides absolute numbers of people for the year 2000. These numbers were scaled by the length of coastline, to provide a density metric, and by the number of people within the low elevation coastal zone, to provide a metric of the importance of fisheries for employment within this zone.

Geographic coverage



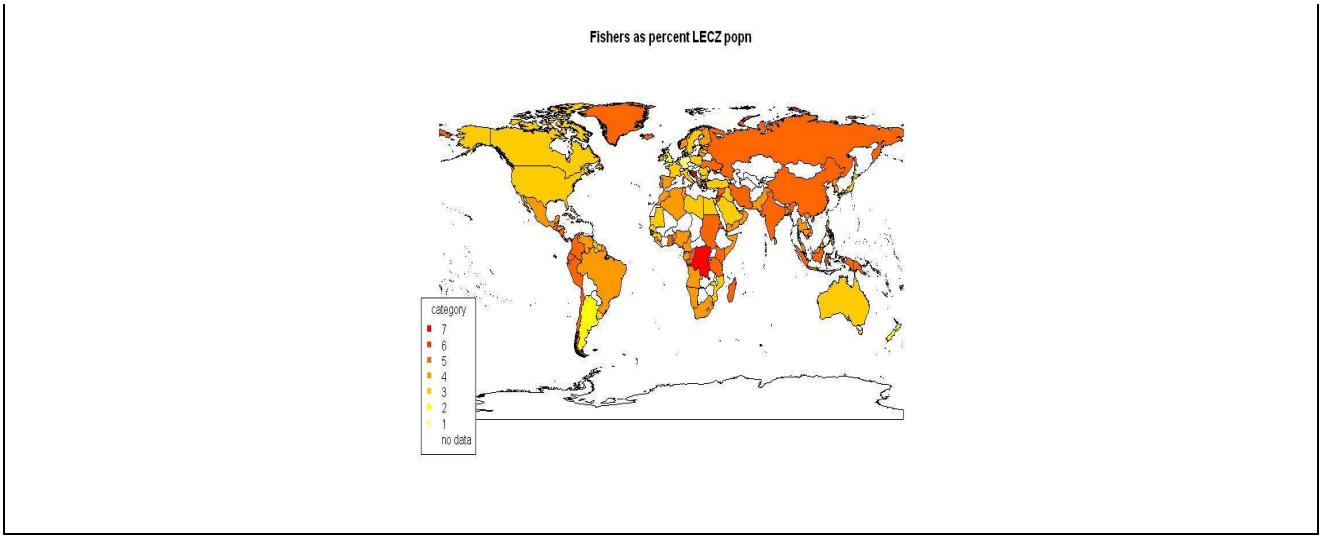


Figure 22. Charts of indicators of fisheries employment and density by country.

Table 18. Top 10 countries within each fisheries employment metric.

Rank	People involved in fisheries	Fishers/km coastline	Fishers as % LECZ population
1	China	Macau	DR Congo
2	India	Iraq	Niue
3	Indonesia	Pakistan	Faroe Is.
4	Bangladesh	Vietnam	Jordan
5	Vietnam	Cambodia	Croatia
6	Philippines	Indonesia	Grenada
7	Myanmar	Syria	Equatorial Guinea
8	Nigeria	Morocco	Ghana
9	Thailand	Sri Lanka	St. Lucia
10	Russia	Republic of Congo	St. Vincent and the Grenadines
Total countries:	183	176	177

Key signals

The number of people involved in fisheries and aquaculture provides both an indication of the importance of fisheries, as well as the size of the population. It was notable that developed countries, which tend to use less manpower-intensive industrial fishing approaches, tended not to be within the top 10 countries (the exception being Russia).

When scaled by the length of coastline, Macau had the densest fisher population, due to its small coastline length. A similar artefact resulted for Iraq and Syria. It was notable that Indonesia featured highly, despite its considerable coastline.

Scaling employment by the population within the coastal zone indicated that the Democratic Republic of Congo was highest (~6% of the coastal population being employed in fisheries or aquaculture). A number of SIDS were also present in the top 10.

The two scaled measures provide interesting contrasts. The Democratic Republic of Congo has a very short coastline (similar Macau) and hence is ranked first in the metric. However, DR Congo also has a relatively high number of fishers. This is somewhat counterintuitive until one remembers that the number of fishers metric includes both aquaculture and fishers in freshwater and inland lakes. The Democratic Republic of the Congo has a very small Atlantic Ocean coastline, with a concurrently modest marine production, accounting in the 1980s only for an estimated 2% of total national fish harvests (FAO figures).

Almost all of the marine production reported derives from artisanal units using canoes and beach seines. In contrast, there are vast freshwater fisheries resources in the country, contained primarily within the major Rift Valley lakes along the eastern borders with Burundi, Rwanda, Tanzania, Zambia and Uganda, and within the extensive Congo River basin. The information on the number of fishers reflected in available statistics does not breakdown fishers by their location (freshwater, marine), which has the potential to bias analyses. In turn, China, Bangladesh and Indian are ranked highly in terms of the number of fishers.km coastline^{-1}, and these countries include a large number of riverine and floodplain fishers, as well as (for China) industrial fishers. Fisher metrics therefore also need to identify the type of fishing being undertaken, be it full-time, part-time, industrial, subsistence etc.

In terms of the number of fishers as a percentage of the low elevation coastal zone population, DR Congo again ranks first, with 6% of the coastal population being classed as fishers. A number of islands are notable in the top 15, indicating the importance of marine resources to these SIDS. 1% of the 2000 coastal population of Niue were classed as fishers.

The composition of the top 10 countries was relatively consistent. Bangladesh and India feature in the top 2 in both scaled metrics. The ranking may, to a large extent, be driven by the large number of people both within a country and in particular within the low elevation coastal zone. The differences between the two scaled metrics are worth noting. In terms of coastline, the list is comprised of continental states, generally in Asia and Africa. In terms of the proportion of fishers within the coastal population, Africa is again prominent, along with island states.

Key gaps

Information on the number of people employed within the fisheries and aquaculture industries provides a metric of both the importance of ecosystem services to employment and income. However, data do not indicate the level of employment and income to the poor directly, and have the potential to be biased by coastline length or coastal population levels that may not necessarily be representative of the coastal poor. Official statistics on fishers may also not fully capture the number of subsistence or occasional fishers within a country, nor look at the more complex socio-economic questions.

Key research issues

- Identify the level of employment of the poor within fisheries and aquaculture
- Identify the number of subsistence and occasional poor fishers in countries where fisheries form an important source of protein to the poor
- Identify the distribution of fishers along the coastline
- Identify the fate of marine catches, e.g. sale, subsistence, distribution to the community
- Identify the financial status of fishers, to determine drivers for over-exploitation of ecosystem services
- Identify the link between coastal fishers and the trends in ecosystem services
- Track ecosystem services from capture to consumption – e.g. subsistence? Local consumption? Shipped to cities? Exported?

10.7. Mangroves

Summary and data source

Data on the coverage of mangroves was available from FAO studies of mangrove cover by country (ftp://ftp.fao.org/docrep/fao/010/a1427e/a1427e04.pdf). However, as noted earlier (see main text) the cover of mangroves does not provide information on the range of ecosystem services provided by that mangrove. In an attempt to provide an indication of one of the potential services – coastal protection – the mangrove cover was scaled to the length of coastline of each country. In the main text of this report, a case study of mangroves is presented, using per capita measures of mangrove cover to identify the potential level of ecosystem services available to the population and the potential threats to those services.

Geographic coverage

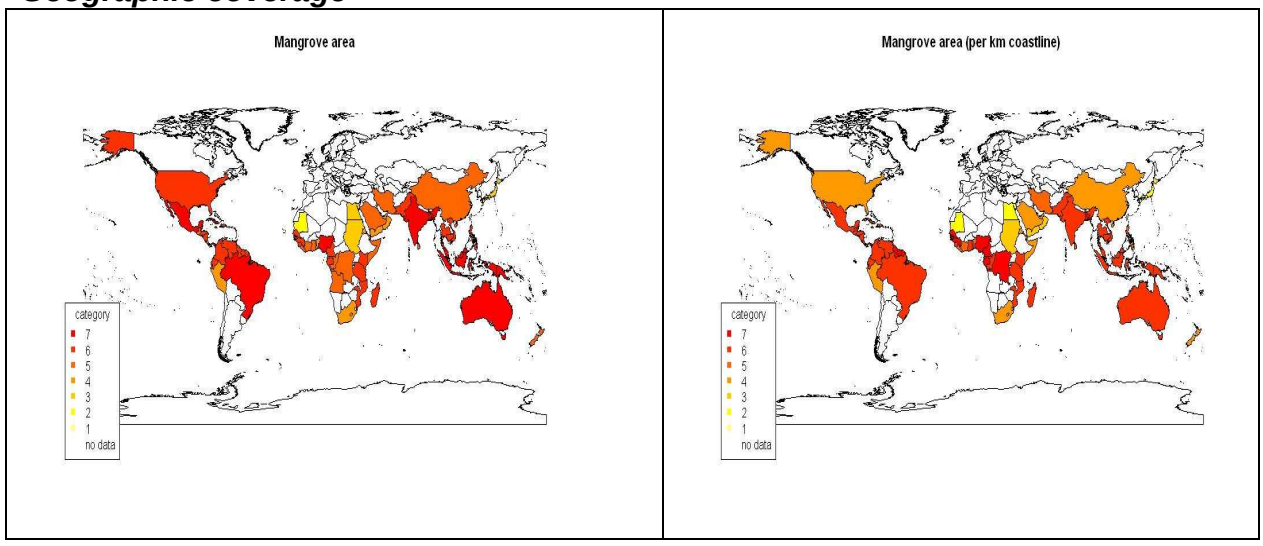


Figure 23. Charts of mangrove area (and area relative to coastline length) by country.

Table 19. Top 10 countries with mangrove cover.

Rank	Mangrove cover	Mangrove cover/km coastline
1	Indonesia	Nigeria
2	Australia	Suriname
3	Brazil	Guinea
4	Nigeria	Bangladesh
5	Mexico	Cameroon
6	Malaysia	The Gambia
7	Cuba	DR Congo
8	Myanmar	Senegal
9	Bangladesh	Guinea Bissau
10	India	Gabon
Total countries:	120	119

Key signals

In terms of total mangrove cover, the eastern Indian Ocean region (Indonesia and Australia) have the greatest cover. When scaled to the length of coastline, however, African countries (along with Bangladesh) show the greatest ratio, suggesting that mangroves in these countries have the potential to play a key role in coastline protection. In the main text, the potential rates of decline in per capita terms is examined (section 6).

Key gaps

As noted, while information on mangrove area is available, specific country-by-country information on the ecosystem services mangroves provide to those countries is lacking. These services may vary between countries, and may be interlinked – provision of building material is likely negatively related to the regulating service of coastline protection.

Key research issues

- Development of data on the specific ecosystem services provided by mangroves to the coastal poor
- Identify the key services provided by country

10.8. Tourism

Summary and data source

Tourism in coastal countries is often based upon the shoreline. It can represent an indirect cultural ecosystem service, but can also be a proxy for pressure on coastal ecosystem services. Data on tourism receipts (US$ millions) was available for 2005 from UN databases.

Geographic coverage

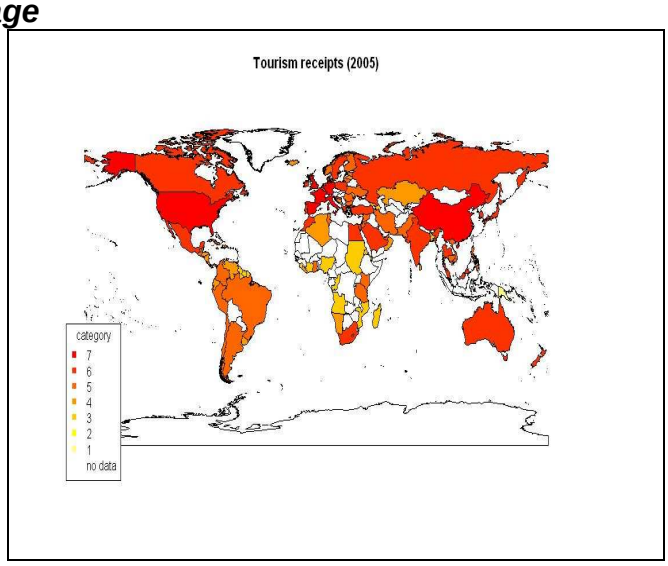


Figure 24. Charts of tourism receipts (US$ millions) by country.

Table 20. Top 10 countries by tourism receipts (US$ millions).

Rank	Tourism receipts
1	United States
2	China
3	Spain
4	France
5	United Kingdom
6	Germany
7	Italy
8	Australia
9	Turkey
10	Canada
Total countries:	143

Key signals

Examining the data, it becomes clear that tourism receipts are focussed in developed countries and is unlikely to be specifically linked to ecosystem services. The inability to identify the potential benefits and impacts of tourism, particularly linked to ecosystem services and the poor, limits the analysis.

Key gaps

The available data does not breakdown tourism into different types or locations (let alone its benefits and impacts), nor does it provide a potential link to the poor and the coastal zone.

The data do not specify whether the tourism is domestic or foreign. This in turn will be affected by the global economy and increased fuel prices (see above).

Key research issues

- Identify the importance of tourism to the coastal poor
- Identify the source of tourism (domestic or foreign)
- Identify trends in tourism, incorporating global economic effects

10.9. Coral reefs

Summary and data source

Data on the area of coral reefs within country waters was available from a variety of sources, including Reefbase. However, as noted earlier (see section 6) the cover of coral reefs does not provide information on the range of ecosystem services provided by that coral reef, nor trends in that coverage. In an attempt to provide an indication of one of the potential services – coastal protection – that coral reefs may provide, the coral reef cover was scaled to the length of coastline of each country. Further data were available from Earthtrends on the live reef trade in 2002 from countries (number of permits issued) indicating the potential benefits that countries may derive from reefs within their waters.

In the main text of this report, a case study of coral reefs is presented, using per capita measures of coral reef cover and productivity to identify the potential level of ecosystem services available to the population and the potential threats to those services.

Geographic coverage

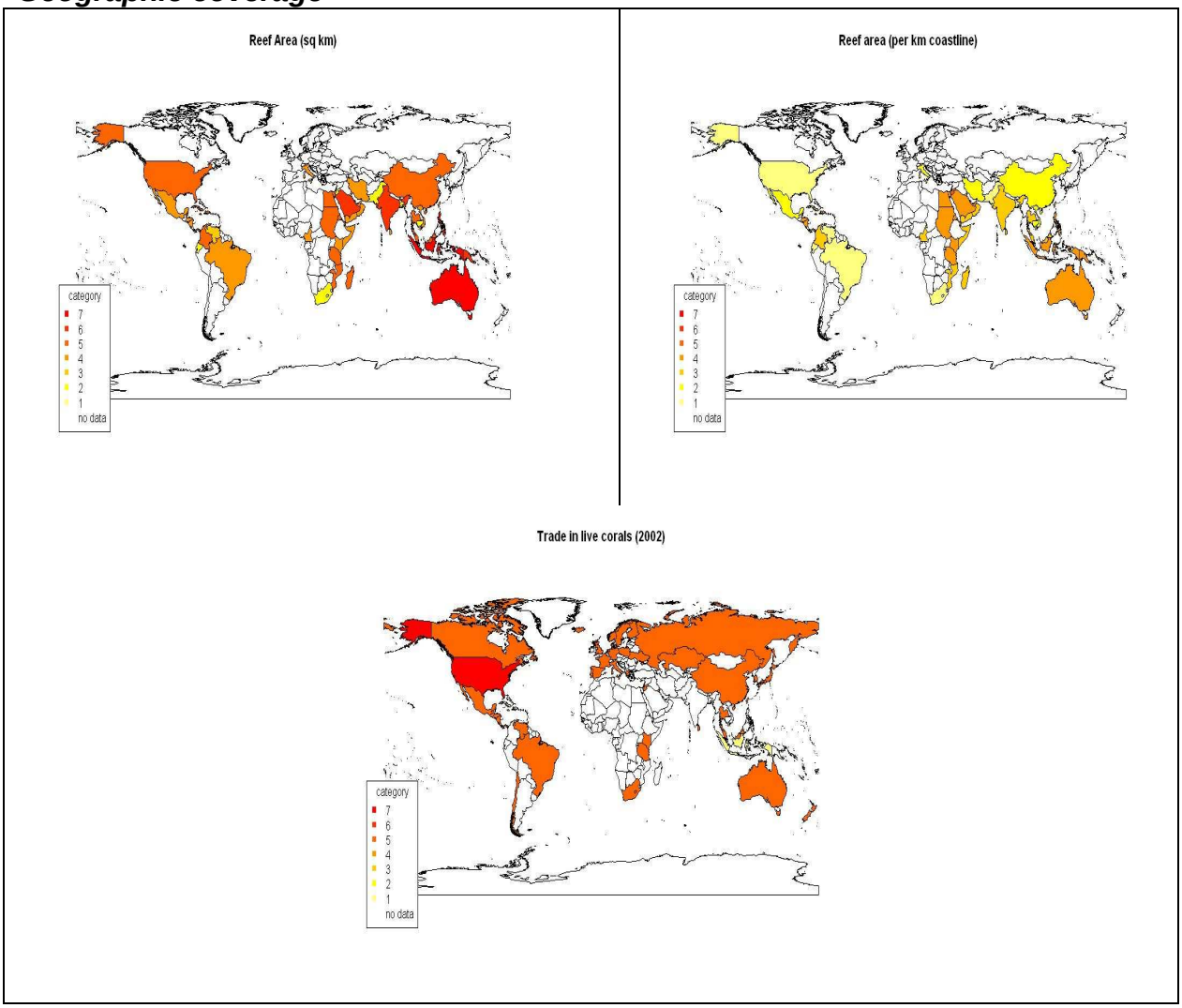


Figure 25. Charts of coral reef cover (top left) relative to coastline length (top right) and trade in live corals, by country.

Table 21. Top 10 countries with mangrove cover.

Rank	Coral cover (km^2)	Coral cover/km coastline	Trade in live corals (from)
1	Indonesia	British Virgin Is.	Indonesia
2	Australia	Tuvalu	Fiji
3	New Caledonia	New Caledonia	Tonga
4	Philippines	Cook Is.	Solomon Is.
5	Papua New Guinea	Wallis and Fortuna	Haiti
6	Fiji	Cape Verde	Vanuatu
7	Maldives	Maldives	Marshall Is.
8	Saudi Arabia	Federated States of Micronesia	Bahamas
9	Marshall Is.	Jamaica	Federated States of Micronesia
10	French Polynesia	Mayotte	Netherlands Antilles
Total countries:	104	103	59

Key signals

The degree of coral reef cover is notably high not only in Indonesia and Australia, but also in a number of Pacific SIDS. As a measure of potential coastal protection, the top 10 countries are all SIDS. In terms of the trade in live corals, there appears relatively little overlap with those countries that may rely on coral reefs for coastal protection, bar Federated States of Micronesia.

Key gaps

The data provide an insight into the potential degree to which coral reefs can provide ecosystem services, but do not provide information on the level of those ecosystem services, particularly those important to the poor. These services may vary between countries, and may be interlinked – provision of building material is likely negatively related to the regulating service of coastline protection. This is discussed further in section 7.1.

Reef area does not appear to distinguish between live versus dead and hard versus soft corals, each of which may provide different ecosystem services, or different degrees of the same ecosystem service.

Key research issues

- Development of data on the specific ecosystem services provided by coral reefs to the coastal poor
- Identify the key services provided by country

10.10. Natural disasters

Summary and data source

Data on natural disasters was available from a number of websites, primarily the International Disaster Database[13]. While not an ecosystem service, these measures present the potential natural problems that a country may face, and which the available ecosystem service must either regulate (e.g. floods and wave action) or provide provisioning services to recover from. Data were available for the period 2000-2008.

Information directly or indirectly relevant to coastal zone populations was available for a number of events

- Epidemics

[13] EM-DAT: The OFDA/CRED International Disaster Database - www.emdat.net - Universite Catholique de Louvain - Brussels - Belgium

- Extreme temperature events
- Flooding events

Geographic coverage

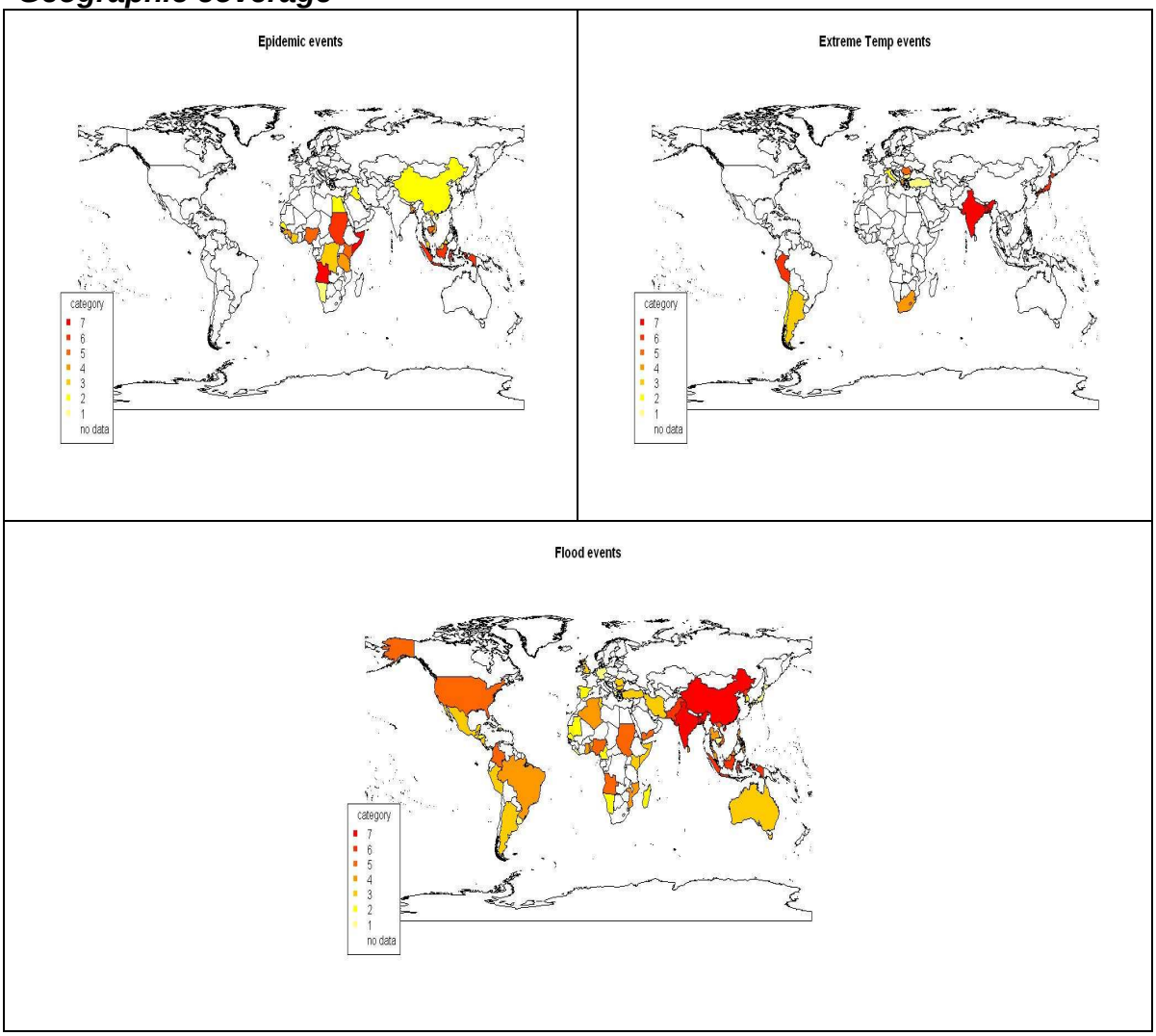


Figure 26. Charts of natural disaster frequency, by country.

Table 22. Top 10 countries with frequently occurring natural disasters.

Rank	Epidemics	Extreme temperatures	Floods
1	Angola	India	India
2	Somalia	Bangladesh	Bangladesh
3	Sudan	Peru	China
4	Indonesia	Japan	North Korea
5	Nigeria	Romania	Pakistan
6	Cambodia	South Africa	Indonesia
7	Kenya	Greece	Vietnam
8	Tanzania	Argentina	Colombia
9	Guinea	Italy	Sudan
10	Bangladesh	Chile	Angola
Total countries:	107	107	107

Key signals
Epidemics are most frequent in African countries, with seven of the top ten being in this continent. Asian countries also suffered from epidemics. For example, it has been shown that there is a correlation between climatic factors and dengue incidence in Metro Manila (Sai Su, 2008). Extreme temperature and flood events were most commonly experienced in Indian and Bangladesh.

Key gaps
While the data provide a potential measure of the severity and frequency of the natural disasters that a country may have to face, they did not provide a time series that allowed any change in the frequency of those events to be assessed. In turn, the potential for ecosystem services to regulate or assist in the recovery from those events was not explicit.

Knowledge of the frequency of extreme events does not necessarily indicate a problem. If these events are frequent, the country may have developed adaptation mechanisms to cope with these events. If the frequency of events is increasing, however, the potential for a country to recover between events is reduced.

Key research issues
- Information on the more specific locale of events would assist in identifying the significance for the coastal zone
- Development of a time series of the frequency of events would assist in planning of adaptation or mitigation strategies for the future

10.11. Biological Oxygen Demand

Summary and data source
Biological Oxygen Demand is a measure of the amount of oxygen required for bacteria to break down organic matter (e.g., sewage effluent) in water. If BOD is too high, fish and other aquatic organisms are deprived of the oxygen they need for survival. A high BOD typically means a large amount of available non-living organic material in the water. Non-living material includes all biological waste human or otherwise. In any coastal concentration of population, where sewage treatment is partial, lacking or ineffective, there may be locally very high levels of BOD. This may be mitigated if the discharge is not single point, or is offshore in deeper water [greater volume for dilution], or if there are strong coastal currents to facilitate transport and dispersal of the discharge.

Data on the biological oxygen demand provides a proxy for the intensity of industry and population density, and hence potential downstream impacts on coastal and marine processes. Excessive depletion of dissolved oxygen through a high BOD may cause marine renewable resources to avoid an area or in extreme cases may cause fish kills. Therefore high BOD may also indicate issues with provisioning services.

Country data were available from the Earthtrends database (from World Development Indicators) for 1995 only.

Geographic coverage

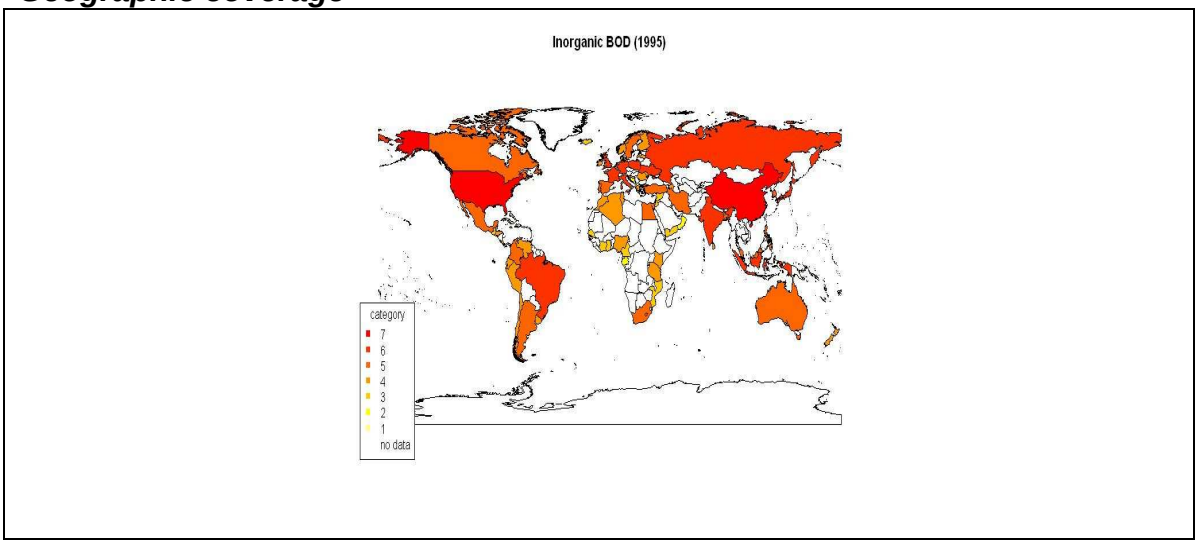


Figure 27. Chart of organic BOD level, by country.

Table 23. Top 10 countries with highest BOD levels in 1995.

Rank	BOD
1	China
2	United States
3	Russia
4	India
5	Japan
6	Germany
7	Indonesia
8	United Kingdom
9	Brazil
10	France
Total countries:	90

Key signals

While the majority of countries in the top 10 were developed nations, it is notable that both India and Indonesia, with rapidly developing economies and industry were present. This indicates the potential future pressure on marine and coastal ecosystem services.

Plotting the rate of change in the GDP of countries (2005) against the BOD data available showed a general trend of increasing BOD with increasing rate of GDP increase. Rapidly expanding industrial and agricultural sectors will therefore place a greater pressure on a country's marine and coastal ecosystem services.

Azerbaijan, with a per capita increase in GDP of 25%, is an obvious outlier. This appears more a result of low population increase in the face of an average GDP increase. It must be noted that the different time periods of the data available (2005 and 1995) make the results of this examination uncertain.

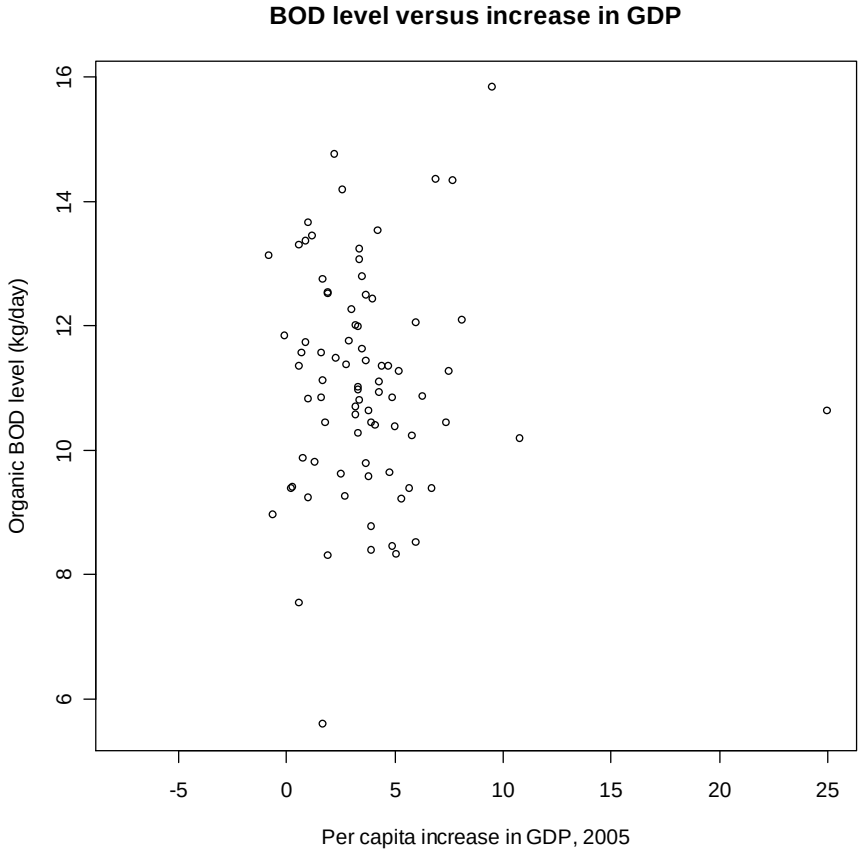


Figure 28. Plot of country level increase in GDP versus organic BOD

Key gaps

While the data provide a potential overall measure of the impacts of industry on aquatic ecosystem services, it does not provide information on the potential mechanisms through which this may occur. In turn, data were only available for 90 countries, with information for many African nations missing.

There is likely to be a diurnal factor in the level of BOD, given that photosynthetic organisms [plants] are net producers of oxygen during the day, but are net users of oxygen at night. The timing of BOD measurements may add to the variability seen between countries, while localised hot-spots may not represent the overall average for a country. This needs to be considered when looking at country-level data.

For example, localised issues can prove a serious problem within a country. American Samoa in the south Pacific, has its capital and the largest and third largest canneries in the world located in Pago Pago harbour, a large natural bay formed from a submerged caldera. When the industry was first established, a lot of waste from visiting fishing vessels and the canneries was discharged directly to the sea, as a consequence, the bay became very polluted, and even today, fishing is not permitted in the bay because of the high levels of heavy metals in the sediments. Over more recent years, the canneries have been obliged to take the waste out in barges to discharge in the open ocean.

Solutions to the problems of BOD linked to sewerage treatment may not necessarily be high tech. In recent years the use of constructed wetland areas, such as reed beds, has been promoted to enable low or negligible energy input natural sewerage treatment. Elsewhere take up of heavy metals by reeds is cited as effective mitigation for industries that produce highly polluting wastes, but caution is necessary when considering disposal of the now heavily polluted reed material (Healey and Crawley, 2002).

Key research issues

- Country-by-country and localised information on measures such as BOD, and their within-country variability is required
- Clear links between the potential impacts of industry and agriculture and downstream ecosystem services important to the coastal poor is needed

10.12. Marine Protected Areas

Summary and data source

Information on the number of marine protected areas present in the country's waters in 2006 was available from Earthtrends (UNEP-WCMC). The number of MPAs can indicate the ability of a country to initiate protective measures for their environment (and the Millennium Development Goals). It can also indicate the level of influence NGOs have within the country to drive such actions.

Geographic coverage

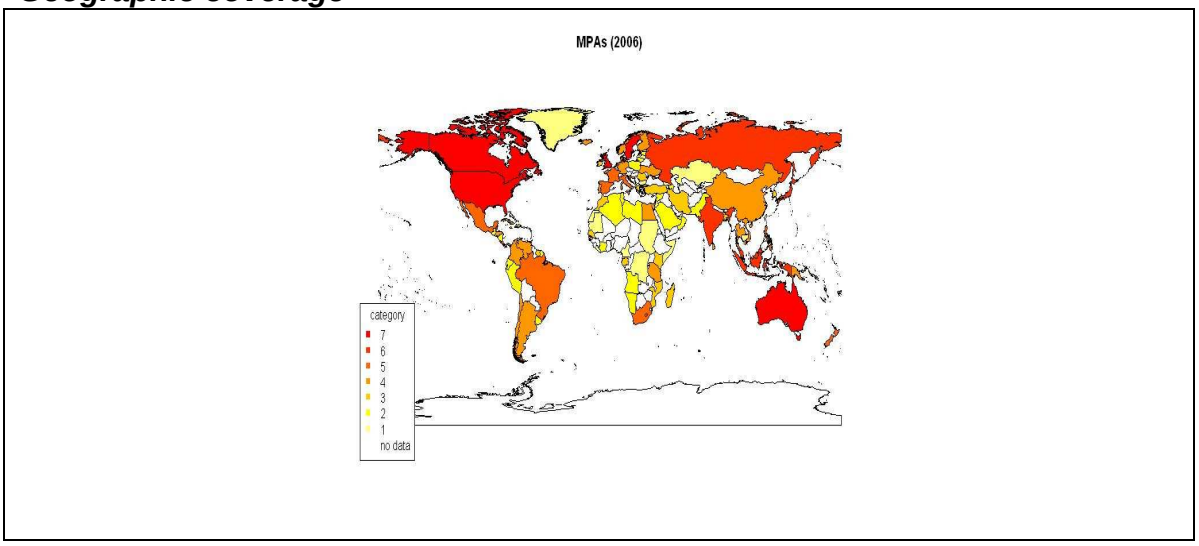


Figure 29. Chart of the number of MPAs within country's waters in 2006.

Table 24. Top 10 countries with the greatest number of MPAs in 2006.

Rank	MPAs
1	Sweden
2	United States
3	Australia
4	Canada
5	United Kingdom
6	Indonesia
7	Japan
8	Malaysia
9	India
10	Bermuda
Total countries:	158

The total area of MPA and the area of MPA relative to the Exclusive Economic Zone of each country was calculated using the estimates of MPA area from the UNDP's Millennium Development Goals Indicators (http://mdgs.un.org/unsd/mdg/Data.aspx) and available EEZ estimates from Earthtrends (Table 25 and

Table 26 respectively). This limited the comparison to 153 and 98 countries respectively. No relationship was found between the proportion of a country's EEZ designated as an MPA and the HDI index of the UNDP (not plotted).

When scaled by the EEZ of each country, the top four countries have relatively small EEZ areas. Both Australia and the US remain within the top ten, while Kiribati was just outside, ranked 11.

Table 25. Top 10 countries with the greatest area of MPAs.

Rank	Country
1	Australia
2	United States
3	Kiribati
4	Ecuador
5	Greenland
6	Russia
7	Colombia
8	Indonesia
9	Mexico
10	Canada
Total countries:	141

Table 26. Top 10 countries with the greatest area of MPAs relative to their EEZ.

Rank	Country	% EEZ area as MPA
1	Belize	18.7
2	Germany	16.7
3	Guinea-Bissau	12.4
4	Romania	12.3
5	Dominican Republic	10.6
6	Colombia	10.4
7	Australia	9.9
8	United States	7.8
9	Cuba	7.0
10	Sweden	5.5
Total countries:	98	

Key signals

While the majority of countries in the top 10 (in terms of the number of MPAs established) were developed nations, it is notable that India, Malaysia, Indonesia and Bermuda were present.

In terms of the area of MPA established, both developed and developing countries were within the top 10. Regression analysis showed no relationship between the area of MPA relative to total EEZ area and the Human Development Index of the UNDP.

MPAs have therefore been instigated around the world, in developed and developing nations. The numbers and area around the African continent appear much lower than elsewhere.

Key gaps

While the data provide a potential overall measure of the ability and readiness of Governments to react to environmental issues with interventions, it does not show whether these interventions were effective. For example, MPAs may be placed in non-critical areas, or may not be enforced.

MPAs may not be beneficial to the coastal poor, since they may prevent access to important fishing areas etc. Information was not available to identify any such conflicts.

Key research issues

- Information on the impact of MPA establishment on the coastal poor is needed

10.13. Seaweed aquaculture

Algae products have a wide range of uses. These include consumption as food, as a food additive to improve food texture, as the basis of agar used as a microbiological culture substrate, while seaweed may also be applied directly or processed as agricultural fertiliser, and is used in beauty preparations and health foods.

Kiribati is the 3rd biggest producer of Eucheuma, after Indonesia and Philippines (Kiribati 500-1000mt per year and other 2 countries between them 100,000mt). Seaweed farming faces significant economic, social and environmental constraints - for example 90% plus of production is on Fanning in the Line Islands south of Hawaii, since this island is populated by people trans-located from Tarawa and other islands. Everyone is therefore landless (the Government owns the island) and hence there is a considerable economic incentive to work.

Reliable quality and supply are essential aspects of seaweed culture. A good incentivised labour force is important, as are environmental and climatic factors. In Kiribati, the leeward slopes of the lagoons are less suitable for Eucheuma farming during periods of normal weather, due to limited water exchange. Conversely windward slopes of the Gilbert Group (such as on Abemama) have shown encouraging growth results. A seasonal pattern of farming is becoming more and more obvious, with environmental up-turns and downturns. A recently introduced kappaphycus seaweed variety appears to be more resilient to the impacts of El Niño cycles, which can cause harvest predictions to be unpredictable. [14]

Most seaweed farming is low technology and suited to the lifestyles of rural villagers who may have few other income generating opportunities.

- The activity is suited for both men and women.
- There are huge areas of sheltered and unpolluted waters suitable for seaweed farming in many Pacific island countries.
- Impacts of seaweed farming appear benign or even beneficial.
- The products can be sold fresh or dried, and are suited for eco-labelling.
- One drawback is long distances for transportation, firstly from outer islands to the main port, and secondly from the main port to European, North American or Japanese export markets. This is particularly relevant in the face of increasing fuel prices and globalisation of markets.
- The main drawback for kappaphycus aquaculture is that the farm-gate price must be sufficient, and payments be made on a sufficiently regular basis, to maintain grower interest compared with returns from other rural income sources like fishing or copra.

Shortages of carrageenan-producing seaweeds were suddenly experienced in mid-2007, resulting in a subsequent doubling of the price of carrageenan. Some of this price increase was due to increased fuel costs and a weak dollar (most seaweed polysaccharides are traded in dollars). The reason for weed shortages are less certain: perhaps it is a combination of environmental factors, sudden increases in demand, particularly from China, and some market manipulation by farmers and traders.

Summary and data source

Information on the level of seaweed aquaculture in 2005 was available from Earthtrends (FAO data). Seaweed aquaculture represents an alternative livelihood option to exploitation of alternative resources, providing employment as well as income to the country.

[14] Support to Seaweed Industry Project, Kiribati – 4th Annual Progress Report & Final Project Report. Simon Diffey, December 2006.

Geographic coverage

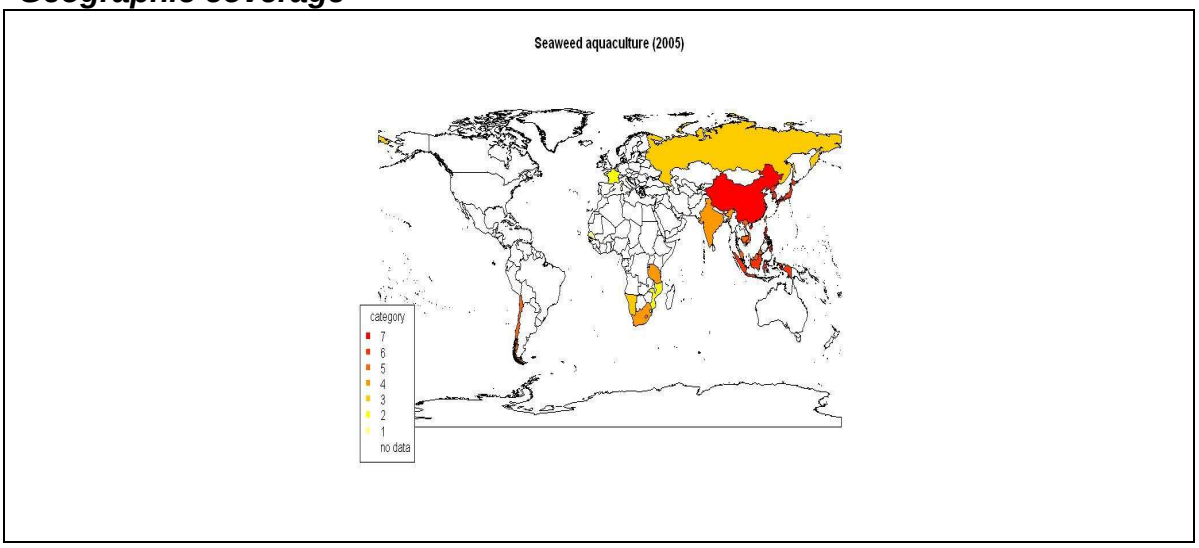


Figure 30. Chart of the quantity of seaweed produced by aquaculture in 2005.

Table 27. Top 10 countries with the greatest production of seaweed in 2005.

Rank	Seaweed aquaculture production
1	China
2	Philippines
3	Indonesia
4	South Korea
5	Japan
6	North Korea
7	Vietnam
8	Malaysia
9	Cambodia
10	Chile
Total countries:	27

Key signals

By far the greatest producer of seaweed was China. Major seaweed aquaculture was concentrated in the Pacific region. However, notable quantities were also produced in southern Africa.

Key gaps

While the information on seaweed aquaculture provides an indication of the potential for alternative livelihoods, it does not indicate either the level of employment, or the opportunities for the local poor to gain benefits from the process.

Financial benefit to the country could be calculated using appropriate seaweed-price indices. However, as noted, the grade of seaweed produced, and hence its value, varies between countries. Data available did not allow information on this to be identified.

Key research issues

- Information on the employment of local population within the seaweed aquaculture industry
- There is a need to identify other alternative livelihood options for the coastal poor in particular

10.14. Ecological footprint

Summary and data source

The ecological footprint identifies the relative level of a country's resource use relative to the renewable level of that resource. Ecological footprints greater than 1 indicate overexploitation. While information on the ecological footprint specific to marine and coastal waters was not available (although could theoretically be calculated for fisheries, for example see Newton et al., 2007), a measure of country ecological footprint was available for land-based resources from the UN GEO database. The measure also provides a potential proxy for the pressure that may come to bear on aquatic resources in the future, since overexploitation of land-based resources will tend to lead to a refocusing on alternative resources. The measure is calculated as the total area of productive land or sea required to produce all the crops, meat, seafood, wood and fibre it consumes, to sustain its energy consumption and to give space for its infrastructure.

Geographic coverage

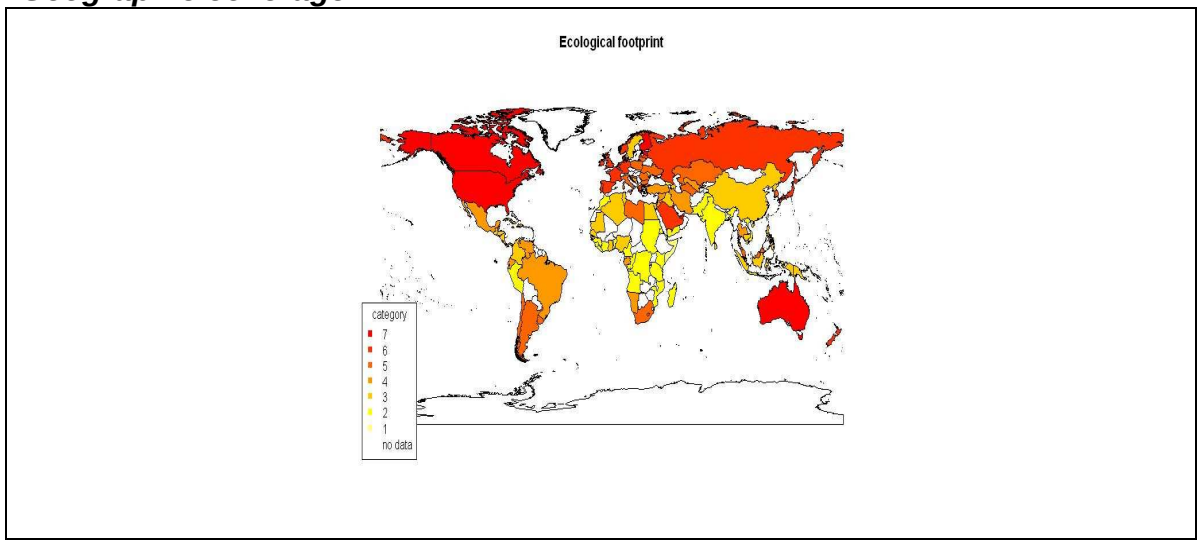


Figure 31. Chart of the ecological footprint (people/ha) of countries.

Table 28. Top 10 countries with the greatest ecological footprints.

Rank	MPAs
1	United Arab Emirates
2	United States
3	Kuwait
4	Australia
5	Finland
6	Estonia
7	Denmark
8	Canada
9	Ireland
10	Norway
Total countries:	116

Key signals
Middle eastern countries and key developed nations comprised the top 10 countries with footprints >6. In general, African countries tended to have footprints smaller than 1.

Key gaps
While the information on ecological footprint could be used as a proxy for future pressure and demand for resources, or the likelihood of a country to overexploit marine resources, the values available did not relate directly to marine and coastal resource use (although this could in theory be calculated). In turn, it did not indicate the use of resources by the coastal poor.

Key research issues
- Calculate the ecological footprint of the use of marine and coastal resources
- Calculate the ecological footprint of resource use by the coastal poor specifically

10.15. Adaptive capacity
Metrics for adaptive capacity are discussed in detail within section 4.3. The coverage of the data used to calculate the overall adaptive capacity metric were live expectancy, civil liberties index, and per capita GDP (Figure 32).

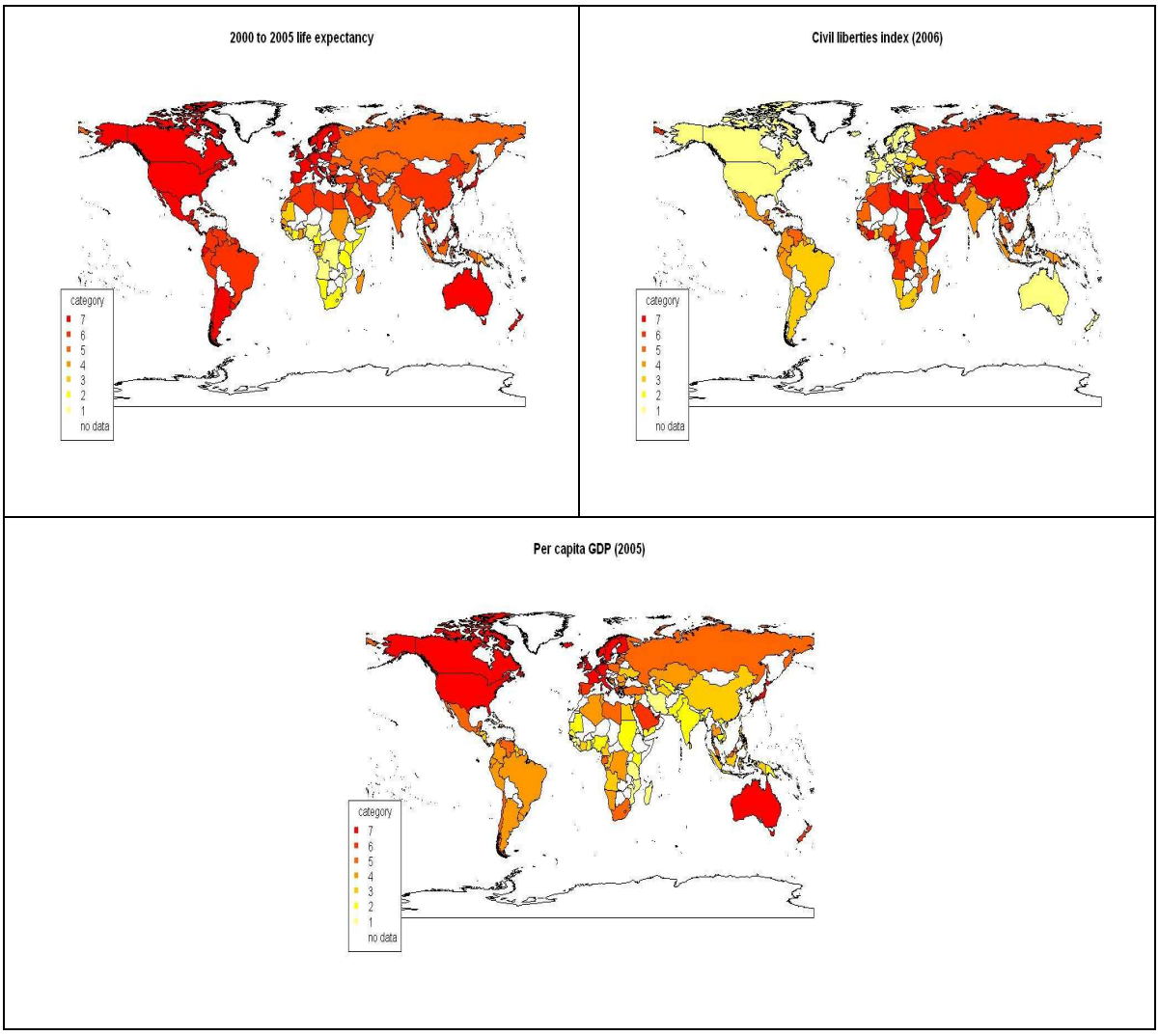


Figure 32. Metrics for adaptive capacity

Table 29. Top 10 countries within each adaptive capacity metric.

Rank	Life expectancy	Civil liberties index	Per capita GDP
1	Sierra Leone	Uzbekistan	Iran
2	Angola	Turkmenistan	Liberia
3	Mozambique	Sudan	Guinea-Bissau
4	Liberia	Somalia	Sierra Leone
5	DR Congo	Myanmar	Eritrea
6	Nigeria	Libya	Madagascar
7	Equatorial Guinea	North Korea	South Korea
8	Guinea Bissau	Cuba	The Gambia
9	Cameroon	Syria	Tanzania
10	Cote D'Ivoire	Saudi Arabia	Mozambique
No. countries	156	154	143

Key signals

African countries have a short life expectancy. In Sierra Leone, the life expectancy was 40.6 years, increasing to 46 years in Cote D'Ivoire. Indeed, the top 15 countries were in Africa.

The Civil Liberties Index identified the top 8 countries as level '7', indicating virtually no freedom. Freedom House (the source of this data) notes that a poor rating for a country "is not necessarily a comment on the intentions of the government, but may indicate real restrictions on liberty caused by non-governmental terror.". These countries were scattered around the globe, with no obvious specific clustering in particular continents.

In terms of GDP purchasing power parity, the lowest GDP nations were commonly in Africa. 2005 per capita GDP figures for Iran were ~ $161, rising to $335 in Mozambique.

Key gaps

It is noteworthy that data for the calculation of adaptive capacity was often missing for small island developing states. This limited the analysis for these vulnerable countries.

While the data indicate country-level adaptive capacity, they do not indicate the particular adaptive capacity of the local poor.

Key research issues

- Obtain adaptive capacity data for SIDS
- Evaluate the specific adaptive capacity of the coastal poor, and alternative livelihood options.

11. Annex 3. World Bank publications table

Country	Year of Report	Title	Focus	Source
Maldives	2007	Tsunami impact and recovery	Environmental disasters, tourism and fisheries, erosion, agriculture, and environmental damage.	http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2006/09/20/000090341_20060920113443/Rendered/PDF/37327.pdf
	1998	Coral reefs-challenges and opportunities for management	Included in regional environmental report on Conservation, Tourism, Coastal and Marine Resources	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=306313&menuPK=64187510&searchMenuPK=306340&theSitePK=306313&entityID=000009265_3980929125325&searchMenuPK=306340&theSitePK=306313
	1998	Tourism and the environment: case studies on Goa, India and the Maldives	Environmental and eco-tourism	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=306313&menuPK=64187510&searchMenuPK=306340&theSitePK=306313&entityID=000094946_99100712293543&searchMenuPK=306340&theSitePK=306313
	1994	Fisheries in the Maldives and Yemen	Brief improving livelihood for small-scale fishermen, coastal and marine resources, and fisheries.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=306313&menuPK=64187510&searchMenuPK=306340&theSitePK=306313&entityID=000011823_20040416112818&searchMenuPK=306340&theSitePK=306313
Cambodia		N/A		
China	2008, 2005, 2004, 1994	Agriculture reports	Number of reports: 5	
		Yellow River Basin Investment Planning Study	Small scale freshwater ecosystem service	http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/EASTASIAPACIFICEXT/CHINAEXTN/0,,contentMDK:20621939~pagePK:141137~piPK:141127~theSitePK:318950,00.html?filename=222r6111216.shtml
Bangladesh	2005, 2004, 1999, 1997, 1995, 1985	Agriculture reports	Number of reports: 7	

	1998	Sustainable aquaculture: seizing opportunities to meet global demand	Aquaculture, coastal and marine resources, fisheries	http://www.worldbank.org.bd/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295760&menuPK=64187510&searchMenuPK=295787&theSitePK=295760&entityID=000094946_00102805334371&searchMenuPK=295787&theSitePK=295760
Indonesia	2005, 2004, 2002, 2000, 1999, 1995, 1993, 1991, 1985	Agriculture reports	Number of reports: 13	
	2001	Supporting the web of life - biodiversity at the World Bank	Wetlands, environmental policy, forestry and biodiversity	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=226309&menuPK=64187510&searchMenuPK=287099&theSitePK=226309&entityID=000094946_01070604171868&searchMenuPK=287099&theSitePK=226309
Sierra Leone	1994, 1993	Agriculture reports	Number of reports: 2	
	1995	The urban challenge in national environmental strategies	Environmental policy and governance, urban development.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=367809&menuPK=64187510&searchMenuPK=367851&theSitePK=367809&entityID=000178830_98101912362326&searchMenuPK=367851&theSitePK=367809
Philippines	2000-2005	Philippines environment monitor	Degradation of coral reefs, mangroves, and seagrasses. Fisheries, vulnerable ecosystems.	http://www.worldbank.org.ph/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=332982&menuPK=64187510&searchMenuPK=333010&theSitePK=332982&entityID=000310607_20061013161233&searchMenuPK=333010&theSitePK=332982
	2004	Philippines environment monitor 2004: assessing progress	Progress of natural resource management, biodiversity conservation, pollution, and coastal and marine management.	http://www.worldbank.org.ph/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=332982&menuPK=64187510&searchMenuPK=333010&theSitePK=332982&entityID=000090341_20050811120213&searchMenuPK=333010&theSitePK=332982

	2000	Environmental costs of fossil fuels - a rapid assessment method with application to six cities	Fuel impacts on air pollution and climate change.	http://www.worldbank.org.ph/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=332982&menuPK=64187510&searchMenuPK=333010&theSitePK=332982&entityID=000094946_02081904011759&searchMenuPK=333010&theSitePK=332982
	1998	Coral reefs - challenges and opportunities for sustainable management	Threatened reefs, aquarium trade, marine management, and eco-tourism.	http://www.worldbank.org.ph/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=332982&menuPK=64187510&searchMenuPK=333010&theSitePK=332982&entityID=000009265_3980929125325&searchMenuPK=333010&theSitePK=332982
	1991	Fisheries and aquaculture research capabilities and needs in India : studies of Asia, Thailand, Malaysia, Indonesia, the Philippines, and the ASEAN Region	Examination of the organization and conduct of fisheries and aquaculture research at the national level and then proceeds to discuss cooperation in research in terms of regional and international mechanisms.	http://www.worldbank.org.ph/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=332982&menuPK=64187510&searchMenuPK=333010&theSitePK=332982&entityID=000178830_98101904140646&searchMenuPK=333010&theSitePK=332982
	1989	Environment and natural resource management study	Degradation and economical impact of inland, marine and freshwater resources, including fisheries.	http://www.worldbank.org.ph/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=332982&menuPK=64187510&searchMenuPK=333010&theSitePK=332982&entityID=000178830_98101903344319&searchMenuPK=333010&theSitePK=332982
Angola	1994	Agriculture reports	Number of reports: 1	
Vietnam	2005, 2002	Agriculture reports	Number of reports: 2	
	2007	Estimating global climate change impacts on hydropower projects	Impacts on hydropower and water resources in response to climate change	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=387565&menuPK=64187510&searchMenuPK=387593&theSitePK=387565&entityID=000158349_20070910103932&searchMenuPK=387593&theSitePK=387565
	2006	Vietnam : engagement of poor fishing communities in the identification of resource management and investment	Analysis and management strategies for poor fisherman communities and poverty reduction.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=387565&menuPK=64187510&searchMenuPK=387593&theSitePK=387565&entityID=000310607_20061018151533&searchMenuPK=387593&t

		needs		heSitePK=387565
	2002-2006	Vietnam environment monitor	Overview of water resources, biodiversity, quality, vulnerability and economic cost.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=387565&menuPK=64187510&searchMenuPK=387593&theSitePK=387565&entityID=000160016_20050503100015&searchMenuPK=387593&theSitePK=387565
	2005	Vietnam fisheries and aquaculture marketing study	Market study of domestic and export fisheries and aquacultural.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=387565&menuPK=64187510&searchMenuPK=387593&theSitePK=387565&entityID=000112742_20061109163312&searchMenuPK=387593&theSitePK=387565
	1998	Coral reefs - challenges and opportunities for sustainable management	Threatened reefs, aquarium trade, marine management, and eco-tourism.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=387565&menuPK=64187510&searchMenuPK=387593&theSitePK=387565&entityID=000009265_3980929125325&searchMenuPK=387593&theSitePK=387565
Nigeria	1999, 1996, 1994, 1993, 1989, 1985	Agriculture reports	Number of reports: 7	
	2003	Environmental flows : flood flows	Environmental policies, hydropower, irrigation and water supply development impacts on ecosystems.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=368896&menuPK=64187510&searchMenuPK=368924&theSitePK=368896&entityID=000333038_20080328013642&searchMenuPK=368924&theSitePK=368896
	1996	Decentralization and biodiversity conservation	Rural development and environmental management, eco-tourism and natural resources.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=368896&menuPK=64187510&searchMenuPK=368924&theSitePK=368896&entityID=000009265_3970311120441&searchMenuPK=368924&theSitePK=368896
Thailand	2002, 2000, 1998, 1987, 1986, 1985	Agriculture reports	Number of reports: 7	
	2006	Thailand - environment	Marine and coastal resource management,	http://www-wds.worldbank.org/external/d

		monitor 2006	fisheries	efault/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187282&theSitePK=523679&entityID=000310607_20071018093219&searchMenuPK=64187282&theSitePK=523679
	2001-2004	Thailand Environment Monitors	Biodiversity, wetlands, and forestry. Waste management, air quality	http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187282&theSitePK=523679&entityID=000012009_20050503142659&searchMenuPK=64187282&theSitePK=523679
	2000	Environmental costs of fossil fuels - a rapid assessment method with application to six cities	Fuel impacts on air pollution and climate change.	http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187282&theSitePK=523679&entityID=000094946_02081904011759&searchMenuPK=64187282&theSitePK=523679
	1999	Thailand: building partnerships for environmental and natural resources management : an environmental sector strategy note	Environmental trends and response, natural resources.	http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187282&theSitePK=523679&entityID=000012009_20040325145241&searchMenuPK=64187282&theSitePK=523679
	1994	Environmental assessment and development	Sustainability and policy.	http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187282&theSitePK=523679&entityID=000009265_3970716142822&searchMenuPK=64187282&theSitePK=523679
	1991	Fisheries and aquaculture research capabilities and needs in India : studies of Asia, Thailand, Malaysia, Indonesia, the Philippines, and the ASEAN	Examination of the organization and conduct of fisheries and aquaculture research at the national level and then proceeds to discuss cooperation in research in terms of regional and international mechanisms.	http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187282&theSitePK=523679&entityID=000178830_98101904140646&searchMenuPK=64187282&theSitePK=523679

		Region		
Senegal	2005, 1998, 1996, 1994	Agricultural reports	Number of reports: 4	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=296303&menuPK=64187510&searchMenuPK=296330&theSitePK=296303&entityID=000160016_20060824091559&searchMenuPK=296330&theSitePK=296303
	2003	Environmental flows : flood flows	Environmental policies, hydropower, irrigation and water supply development impacts on ecosystems.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=296303&menuPK=64187510&searchMenuPK=296330&theSitePK=296303&entityID=000333038_20080328013642&searchMenuPK=296330&theSitePK=296303
	1998	World resources 1998-99 : a guide to the global environment - environmental change and human health	Environmental policies, environmental threats associated with poverty, exposure to environmental risks, and those that affect human health.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=296303&menuPK=64187510&searchMenuPK=296330&theSitePK=296303&entityID=000009265_3981013134822&searchMenuPK=296330&theSitePK=296303
	1991	Fisheries and aquaculture research capabilities and needs in Africa	Evaluating the effectiveness of fisheries and aquaculture research in 7 countries	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=296303&menuPK=64187510&searchMenuPK=296330&theSitePK=296303&entityID=000178830_98101904140948&searchMenuPK=296330&theSitePK=296303
Ghana	2005, 2002, 1998, 1996, 1995, 1994, 1990	Agriculture reports	Number of reports: 7	
	1999	From "sacrilege" to sustainability: reforestation and organic farming in Forikrom, Ghana	Environmental policies, agricultural research, and crop management systems.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=351952&menuPK=64187510&searchMenuPK=351980&theSitePK=351952&entityID=000094946_99031910581537&searchMenuPK=351980&theSitePK=351952
	1998	Soil fertility management in Sub-Saharan Africa	Agricultural research, mineral resources and crop management.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=351952&menuPK=64187510&searchMenuPK=351980&theSitePK=351952&entityID=000009265_398071617255

				2&searchMenuPK=351980&theSitePK=351952
	1996	The economics of wildlife	Case studies of economic viability of wildlife management systems, wildlife as source of income and food.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=351952&menuPK=64187510&searchMenuPK=351980&theSitePK=351952&entityID=000094946_00011905344661&searchMenuPK=351980&theSitePK=351952
Democratic Republic of Congo	1998, 1996, 1994	Agriculture reports	Number of reports: 3	
	2001	Sustainable wood fuel supplies from the dry tropical woodlands	Land management, forestry, climate change, and drylands.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=349466&menuPK=64187510&searchMenuPK=349494&theSitePK=349466&entityID=000094946_02022804005465&searchMenuPK=349494&theSitePK=349466
Cameroon	2007, 1999, 1996, 1994, 1993, 1990, 1981-1983	Agriculture reports	Number of reports: 10	
	2007	The economic impact of climate change on agriculture in Cameroon	Environmental policy, climate change, and agriculture	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=343813&menuPK=64187510&searchMenuPK=343841&theSitePK=343813&entityID=000158349_20070920134147&searchMenuPK=343841&theSitePK=343813
	2003	Environmental flows: flood flows	Environmental policies, hydropower, irrigation and water supply development impacts on ecosystems.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=343813&menuPK=64187510&searchMenuPK=343841&theSitePK=343813&entityID=000333038_20080328013642&searchMenuPK=343841&theSitePK=343813
	2000	Cameroon - Forest sector development in a difficult political economy	Environmental policy, forestry and agriculture.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=343813&menuPK=64187510&searchMenuPK=343841&theSitePK=343813&entityID=000094946_00110405591366&searchMenuPK=343841&theSitePK=343813
Malaysia	2000, 1989	Agriculture reports	Number of reports: 2	

	1998	Biodiversity in World Bank projects : a portfolio review	Wetlands, agriculture, forestry, and biodiversity.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=324488&menuPK=64187510&searchMenuPK=324516&theSitePK=324488&entityID=000009265_3981013134500&searchMenuPK=324516&theSitePK=324488
	1995	An environmental and economic assessment of forest management options	Forestry and forest management.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=324488&menuPK=64187510&searchMenuPK=324516&theSitePK=324488&entityID=000178830_98101912360813&searchMenuPK=324516&theSitePK=324488
	1991	Fisheries and aquaculture research capabilities and needs in India : studies of Asia, Thailand, Malaysia, Indonesia, the Philippines, and the ASEAN Region	Examination of the organization and conduct of fisheries and aquaculture research at the national level and then proceeds to discuss cooperation in research in terms of regional and international mechanisms.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=324488&menuPK=64187510&searchMenuPK=324516&theSitePK=324488&entityID=000178830_98101904140646&searchMenuPK=324516&theSitePK=324488
India	2007, 2006, 2005, 2004, 2002, 1999, 1998, 1997, 1993, 1992, 1990, 1989, 1986, 1981, 1977	Agriculture reports	Number of reports: 21	
	2008	Inefficiency of rural water supply schemes in India	Water conservation	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000333037_20080723003033&searchMenuPK=295611&theSitePK=295584
	2007	Estimating global climate change impacts on hydropower projects	Impacts on hydropower and water resources in response to climate change	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&e

				ntityID=000158349_20070910103932&searchMenuPK=295611&theSitePK=295584
	2006	Overcoming drought: adaptation strategies for Andhra Pradesh, India	Modelling climate change risks and adaptation strategies in agriculture.	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000160016_20060911122737&searchMenuPK=295611&theSitePK=295584
	2004	Fuel wood consumption and participation in community forestry in India	Forestry and development	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000112742_20040723112710&searchMenuPK=295611&theSitePK=295584
	2003	Water conservation: irrigation	Water supply, quality and conservation	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000333037_20080328005000&searchMenuPK=295611&theSitePK=295584
	2003	Management of aquatic plants	Water quality and management	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000333038_20080328074512&searchMenuPK=295611&theSitePK=295584
	2003	Wetlands management	Wetlands, degradation and ecological function	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000333037_20080328012434&searchMenuPK=295611&theSitePK=295584
	2002	India: environmental sustainability in the 1990s - a country assistance evaluation	Water and air, pollution and quality.	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000094946_02082204120111&searchMenuPK=295611&theSitePK=295584
	2000	Environmental costs of fossil fuels - a rapid	Fuel impacts on air pollution and climate change.	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&t

		assessment method with application to six cities		heSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000094946_02081904011759&searchMenuPK=295611&theSitePK=295584
	2000	India - Alleviating poverty through forest development	Developing forests, degradation, biodiversity loss, and roles in poverty alleviation	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000094946_00081705302465&searchMenuPK=295611&theSitePK=295584
	1999	Rural water supply and sanitation	Water supply and systems	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000020953_20080407105332&searchMenuPK=295611&theSitePK=295584
	1998	Tourism and the environment	Environmental and eco-tourism	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000094946_99100712293543&searchMenuPK=295611&theSitePK=295584
	1998	Incentives for Joint Forest Management in India	Economic returns in forestry management and conservation	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000009265_3980219162808&searchMenuPK=295611&theSitePK=295584
	1998	Measuring the impact of climate change on Indian agriculture	Climate change models and sensitivity in agriculture and other sectors	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000009265_3980513112010&searchMenuPK=295611&theSitePK=295584
	1997	Why paper mills clean up: determinants of pollution abatement in four Asian countries	Pollution and water conservation	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000009265_3970625093935&searchMenuPK=295611&theSitePK=295584

	1996	Decentralization and biodiversity conservation	Rural development and environmental management, eco-tourism and natural resources.	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000009265_3970311120441&searchMenuPK=295611&theSitePK=295584
	1992	How restricting carbon dioxide and methane emissions would affect the Indian economy	Environmental policy, carbon pollution and climate change.	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000009265_3961003082326&searchMenuPK=295611&theSitePK=295584
	1991	Fisheries and aquaculture research capabilities and needs in India	Examination of the organization and conduct of fisheries and aquaculture research at the national level and then proceeds to discuss cooperation in research in terms of regional and international mechanisms.	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000178830_98101904140646&searchMenuPK=295611&theSitePK=295584
	1989	Shrubs in tropical forest ecosystems: examples from India	Wetlands, water conservation and land management.	http://www.worldbank.org.in/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=295584&menuPK=64187510&searchMenuPK=295611&theSitePK=295584&entityID=000178830_9810190413474&searchMenuPK=295611&theSitePK=295584
Tanzania	2004, 2000, 1999, 1998, 1996, 1994, 1991, 1989	Agriculture reports	Number of reports: 9	
	2006	Exploring the linkages between poverty, marine protected area management, and the use of destructive fishing gear in Tanzania	Marine protected areas, fisheries, and poverty.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=258799&menuPK=64187510&searchMenuPK=287363&theSitePK=258799&entityID=000016406_20060124164343&searchMenuPK=287363&theSitePK=258799
	2005	Study on growth and environment links for preparation of Country	Ecosystem service and natural resource management for development and poverty reduction	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=258799&menuPK=64187510&searchMenuPK=287363&theSitePK=258799&entityI

		Economic Memorandum (CEM) Vol 1-4		D=000310607_20071129162211&searchMenuPK=287363&theSitePK=258799
	2002	Biological resource management: integrating biodiversity concerns in rural development projects and programs	Biodiversity conservation and management	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=258799&menuPK=64187510&searchMenuPK=287363&theSitePK=258799&entityID=000094946_02090504023464&searchMenuPK=287363&theSitePK=258799
	2001	Nile River Basin : transboundary environmental analysis	Wetlands, water management and drought alleviation	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=258799&menuPK=64187510&searchMenuPK=287363&theSitePK=258799&entityID=000094946_02101704181770&searchMenuPK=287363&theSitePK=258799
	1998	Coral reefs - challenges and opportunities for sustainable management	Threatened reefs, aquarium trade, marine management, and eco-tourism.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=258799&menuPK=64187510&searchMenuPK=287363&theSitePK=258799&entityID=000009265_3980929125325&searchMenuPK=287363&theSitePK=258799
	1997	Land degradation in Tanzania : perception from the village	Soil degredation, agriculture, and environmental policy.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=258799&menuPK=64187510&searchMenuPK=287363&theSitePK=258799&entityID=000094946_0102140558047&searchMenuPK=287363&theSitePK=258799
	1990	Mapping of woodfuel resources in Tanzania using spot satellite data	Woodland resources	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=258799&menuPK=64187510&searchMenuPK=287363&theSitePK=258799&entityID=000009265_3961002095925&searchMenuPK=287363&theSitePK=258799
	1988	Tanzania - Woodfuel/forestry project	Woodland resources	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=258799&menuPK=64187510&searchMenuPK=287363&theSitePK=258799&entityID=000009265_3960928085116&searchMenuPK=287363&theSitePK=258799
Gambia	1999, 1994	Agriculture reports	Number of reports: 2	
	2001	Sustainable	Land management,	http://web.worldbank.org/exter

		woodfuel supplies from the dry tropical woodlands	forestry, climate change, and drylands.	nal/default/main?pagePK=51187349&piPK=51189435&theSitePK=351626&menuPK=64187510&searchMenuPK=351666&theSitePK=351626&entityID=000094946_02022804005465&searchMenuPK=351666&theSitePK=351626
South Korea	1981	Agriculture reports	1	
	2000	Korea: the environmental dimension of the crisis - a step back or a new way forward?	Environmental policy, and air and water pollution.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=324645&menuPK=64187510&searchMenuPK=324673&theSitePK=324645&entityID=000094946_00111006374545&searchMenuPK=324673&theSitePK=324645
Solomon Islands	2007	Agriculture reports	Number of reports: 1	
	2008	Optimizing fisheries benefits in the Pacific Islands: major issues and constraints	Coastal and marine management, and fisheries.	http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187282&theSitePK=523679&entityID=000333037_20080813022130&searchMenuPK=64187282&theSitePK=523679
	2006	Not if but when: adapting to natural hazards in the Pacific Islands Region - a policy note	Risk management of natural disasters	http://www-wds.worldbank.org/external/default/main?pagePK=64193027&piPK=64187937&theSitePK=523679&menuPK=64187510&searchMenuPK=64187282&theSitePK=523679&entityID=000160016_20060209164511&searchMenuPK=64187282&theSitePK=523679
Liberia	1994	Agriculture reports	Number of reports: 1	
Sri Lanka	2002, 1995, 1979	Agriculture reports	Number of reports: 3	
	2007	Estimating global climate change impacts on hydropower projects	Impacts on hydropower and water resources in response to climate change	http://www.worldbank.lk/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=233047&menuPK=64187510&searchMenuPK=287058&theSitePK=233047&entityID=000158349_20070910103932&searchMenuPK=287058&theSitePK=233047
	2005	World Bank response to the Tsunami disaster	Disaster assessment and response	http://www.worldbank.lk/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=233047&menuPK=64187510&searchMenuPK=28705

				8&theSitePK=233047&entityID=000160016_20050503112017&searchMenuPK=287058&theSitePK=233047
	1998	Piloting urban environmental change in Sri Lanka: Metropolitan Environmental Improvement Program	Environmental management	http://www.worldbank.lk/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=233047&menuPK=64187510&searchMenuPK=287058&theSitePK=233047&entityID=000094946_02082404015751&searchMenuPK=287058&theSitePK=233047
Guinea	1999, 1998, 1996, 1994	Agriculture reports	Number of reports: 4	
Egypt	2007, 2004, 1993	Agriculture reports	Number of reports: 3	
	2001	Nile River Basin : transboundary environmental analysis	Wetlands, water management and drought alleviation	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=256307&menuPK=64187510&searchMenuPK=287184&theSitePK=256307&entityID=000094946_02101704181770&searchMenuPK=287184&theSitePK=256307
Mozambique	1999, 1994, 1991	Agriculture reports	Number of reports: 4	
	1996	Integrated coastal zone management in Mozambique	Coastal zone resource management	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=382131&menuPK=64187510&searchMenuPK=382160&theSitePK=382131&entityID=000012009_20040213143458&searchMenuPK=382160&theSitePK=382131
	1991	Fisheries and aquaculture research capabilities and needs in Africa	Evaluating the effectiveness of fisheries and aquaculture research in 7 countries	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=382131&menuPK=64187510&searchMenuPK=382160&theSitePK=382131&entityID=000178830_98101904140948&searchMenuPK=382160&theSitePK=382131
	1991	Integrating environmental issues into a strategy for sustainable agricultural development	Natural resources and agricultural development	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=382131&menuPK=64187510&searchMenuPK=382160&theSitePK=382131&entityID=000178830_98101904140545&searchMenuPK=382160&theSitePK=382131

Togo	1999, 1994	Agriculture reports	Number of reports: 2	
Madagascar	1999, 1996, 1994	Agriculture reports	Number of reports: 3	
	1995	Valuing tropical forests: methodology and case study of Madagascar	Forestry, conservation, and environmental policy.	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=356352&menuPK=64187510&searchMenuPK=356380&theSitePK=356352&entityID=000009265_3970128120320&searchMenuPK=356380&theSitePK=356352
Guyana	2005	Guyana: Preliminary damage and needs assessment following the intense flooding of January 2005	Disaster response	http://web.worldbank.org/external/default/main?pagePK=51187349&piPK=51189435&theSitePK=328274&menuPK=64187510&searchMenuPK=328302&theSitePK=328274&entityID=000020953_20071023140434&searchMenuPK=328302&theSitePK=328274

12. Annex 4. Further exploring poverty and vulnerability in the coastal zone

1. Introduction

An effort was made to further explore available data in order to gain an improved understanding of where the coastal poor are and their vulnerability to specific changes. The analyses performed are presented in Section 2, which identifies areas where the data suggests there are high numbers of poor people, and Section 3, which tries to related this to the ecosystem services provided by mangroves and coral reefs, specifically in terms of vulnerability to possible floods.

2. Poverty, coastal zones and population

2.1 Methods

Ciesin global poverty data was used in developing estimates of poverty in coastal zones. This dataset is freely available online and uses infant mortality rates and for children under the age of five (Storeygard et al., 2008), and the prevalence of child malnutrition as the poverty rates. The data is served in gridded formats at 1/4th of a degree resolution. Gridded global population data at 1/4th degree resolution was also acquired from Ciesin website in grid format. Other data acquired were the digital elevation model (DEM) from the USGS website. Tiles of DEM data were downloaded and were mosaiced into a global DEM at 1km spatial resolution. To delineate the coastline, a buffer of 100km was created using the world shorelines data. This buffer was then overlaid with the digital elevation model to extract low lying areas (<=50m) within the 100km buffer.

UNDP'd Human Poverty Index 1 (HPI-1) uses mortality by age 40 as the proxy for poverty. This also correlates highly with infant mortality rates. We used the linear regression relationship between the two to convert infant mortality rates into mortality at the age of 40. The assumption here was that HPI-1 data would be a better estimation of proportion of poor people.

2.2 Analysis and results

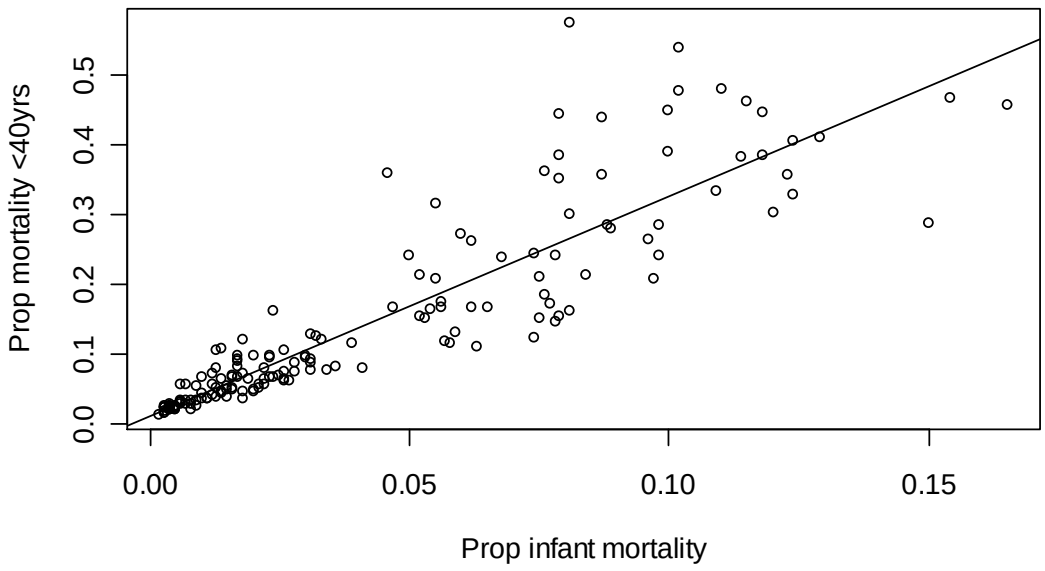


Figure 1. Correlation of mortality at the age of 40 and infant mortality rates plotted out for 172 countries from UNDP data. The regression function for the plot is: Mortality by 40 yrs = 0.0127 + 3.13872603*IMR

A poverty composite layer was then calculated by averaging the mortality rate at the age of 40 and child malnutrition rate. This poverty composite obtained was then multiplied with population data and population density to generate estimates of poor population density and counts.

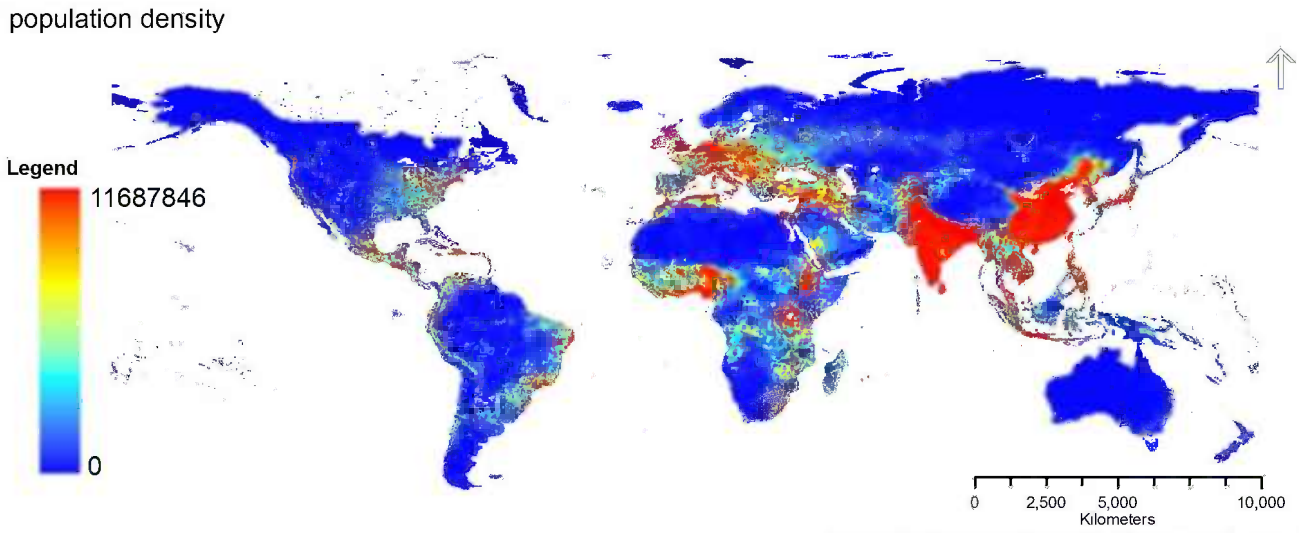


Figure 2. Population density

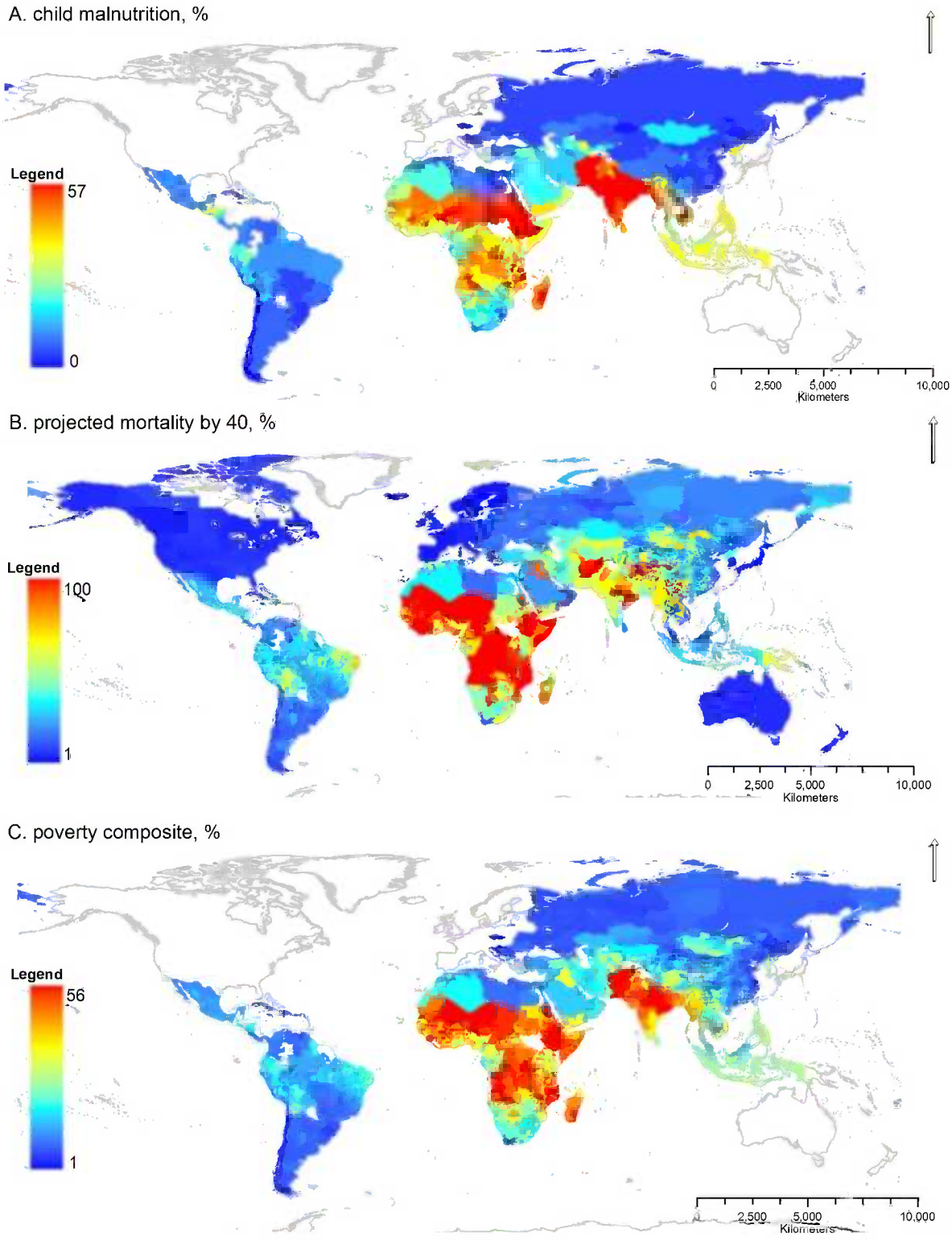


Figure 3. A. % child malnutrition rate , B. Mortality rates at age of 40, and C. a poverty composite layer

Table 1 shows that a high proportion of the coastal poor are concentrated in a few countries; 80% in 15 countries.

Table 1: Number of coastal poor in non-OECD countries

Country	Number of coastal poor	% of world's coastal poor	Cumulative %
India	68,226,700	27%	27%
Indonesia	33,768,000	13%	40%
Bangladesh	23,247,500	9%	50%
Vietnam	12,440,000	5%	55%
China	11,730,700	5%	59%
Philippines	11,247,000	4%	64%
Nigeria	8,897,690	4%	67%
Myanmar	6,209,340	2%	70%
Brazil	6,145,760	2%	72%
North Korea	3,899,890	2%	74%
Yemen	3,700,410	1%	75%
Thailand	3,543,730	1%	77%
Mozambique	3,107,610	1%	78%
Turkey	2,832,990	1%	79%
Sri Lanka	2,805,180	1%	80%
Others (90 countries)	50,474,223	19%	100%
Total (for 105 countries)	252,276,723		

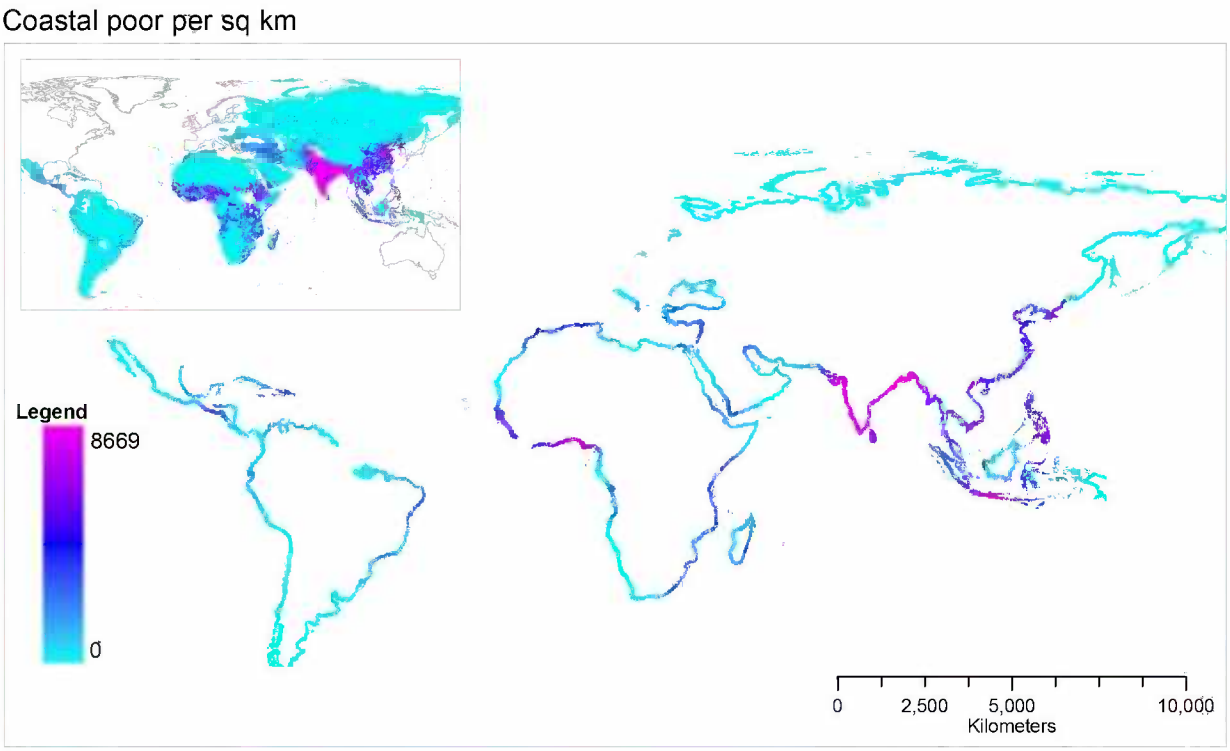


Figure 4. Coastal poor population and population density. Inset maps are global. Coast here is defined as 100km buffer from the shoreline.

3. Coastal poor, vulnerability, and ecosystem services

This analysis aimed to:

1. To extract number of poor people by country and region who benefit from the coral reef and mangrove ecosystem services
2. estimate coastal elevation vulnerability and to relate coastal poor population density with vulnerability
3. To determine poor people distribution along coastal elevation gradients, (to compare it with general coastal population layer)

3.1 Methods

The data used includes:

- Coastal Poor population density (calculated)
- Coastal poor population numbers (calculated)
- Global coral reef layer (Source: UNEP-WCMC)
- Global mangrove layer (1997); West and East Africa (2006) (Source: UNEP-WCMC)

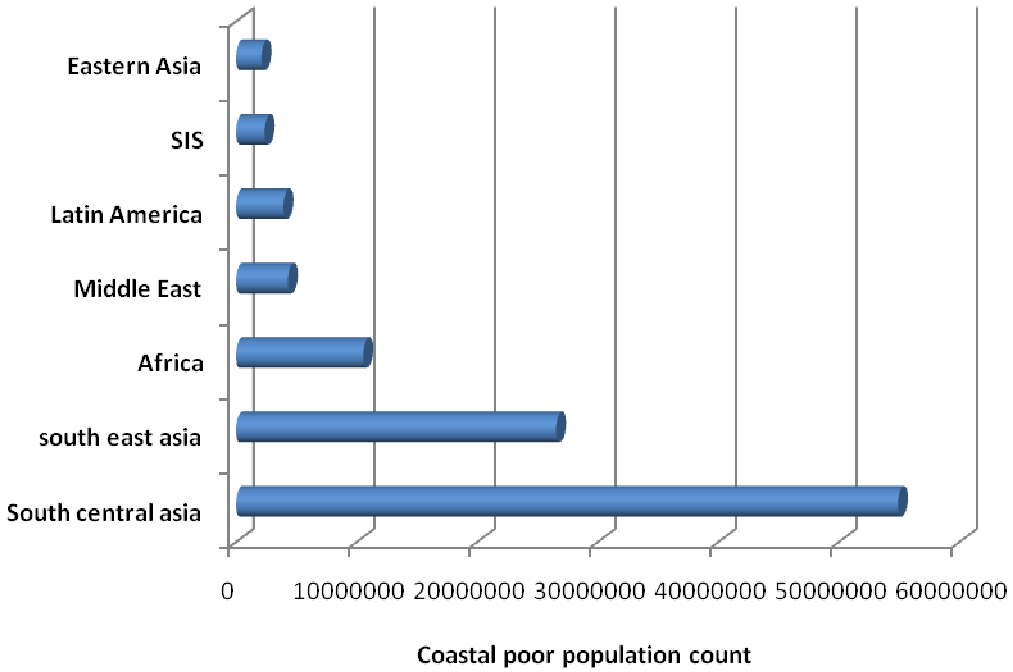
Distance layers were calculated from the mangrove and coral grids. A distance limit of 100km from coral or mangrove was established. We assumed that ecosystem services provided by corals and mangroves are available to coastal population not more than 100km from the coral reef and mangrove areas (note: the 100km distance is not filtered by elevation). Summaries of poor population within this zone were summarized.

To estimate the vulnerability of coastal poor based on elevation and coral reefs and mangroves ecosystems, elevation layer was normalized for vulnerability between >50 m was assigned zero and elevation of 1m a vulnerability index of 1. The values in between were assigned vulnerability based on a linear inverse vulnerability-elevation relationship.

The second assumption involved estimation of the amount of protection corals and mangroves provide hence balancing vulnerability of the coastal poor i.e. regulatory ecosystem services. Considering that vulnerability to flooding would depend on many other factors, elevation relative to the sea level being one of the major factors, we assumed that coral and mangrove ecosystems combined both would reduce vulnerability by only 30%. Thus vulnerability of low elevation coastal areas to flooding was estimated as follows:

0.70*vulnerability due to elevation + 0.15*mangroves presence/absence + 0.15*coral presence/absence. Thus, if an area has an elevation of 1m above sea level and is not within 100km from mangroves or corals, it would have a vulnerability of 1. Whilst if under the same elevation of 1m with either corals or mangroves present vulnerability would decrease to 0.85. If both mangroves and corals were present vulnerability would further decrease to 0.70.

3.2 Analysis and results



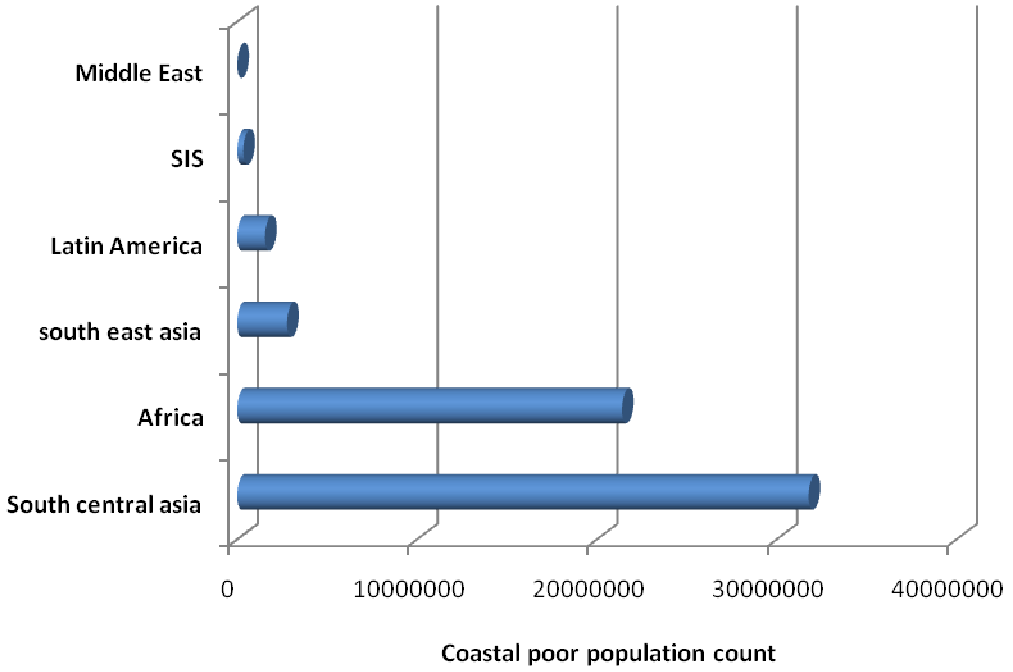


Figure 5. Coastal poor population within 100km of (top) coral reefs and (bottom) mangrove ecosystems.

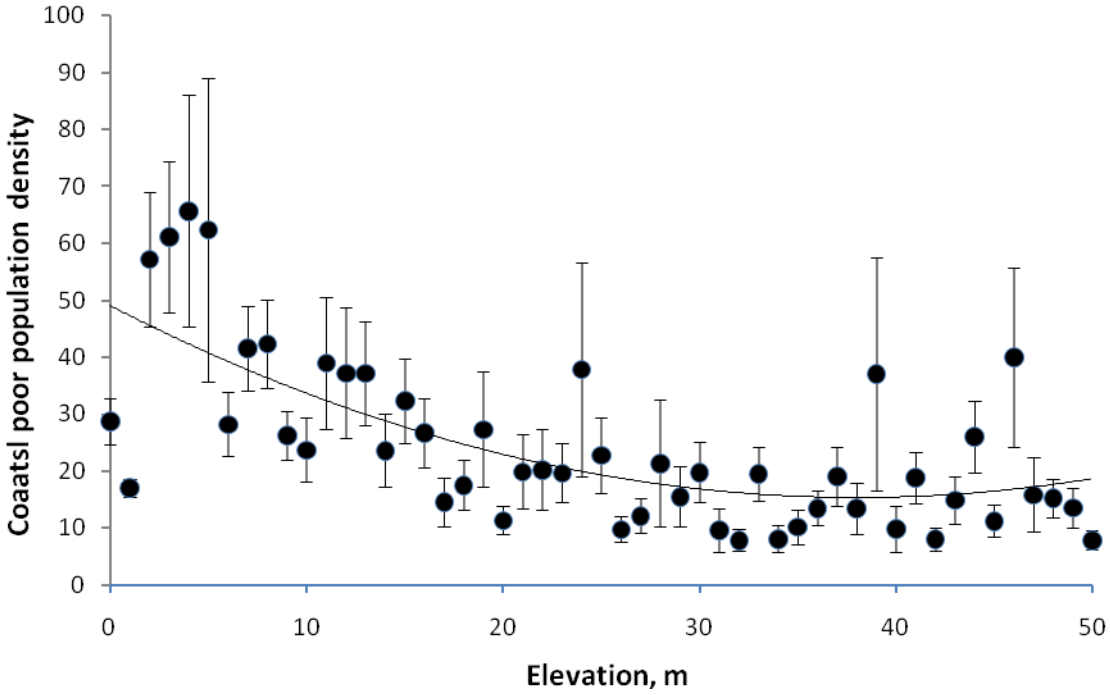


Figure 6. Coastal population density distribution along the elevation gradient

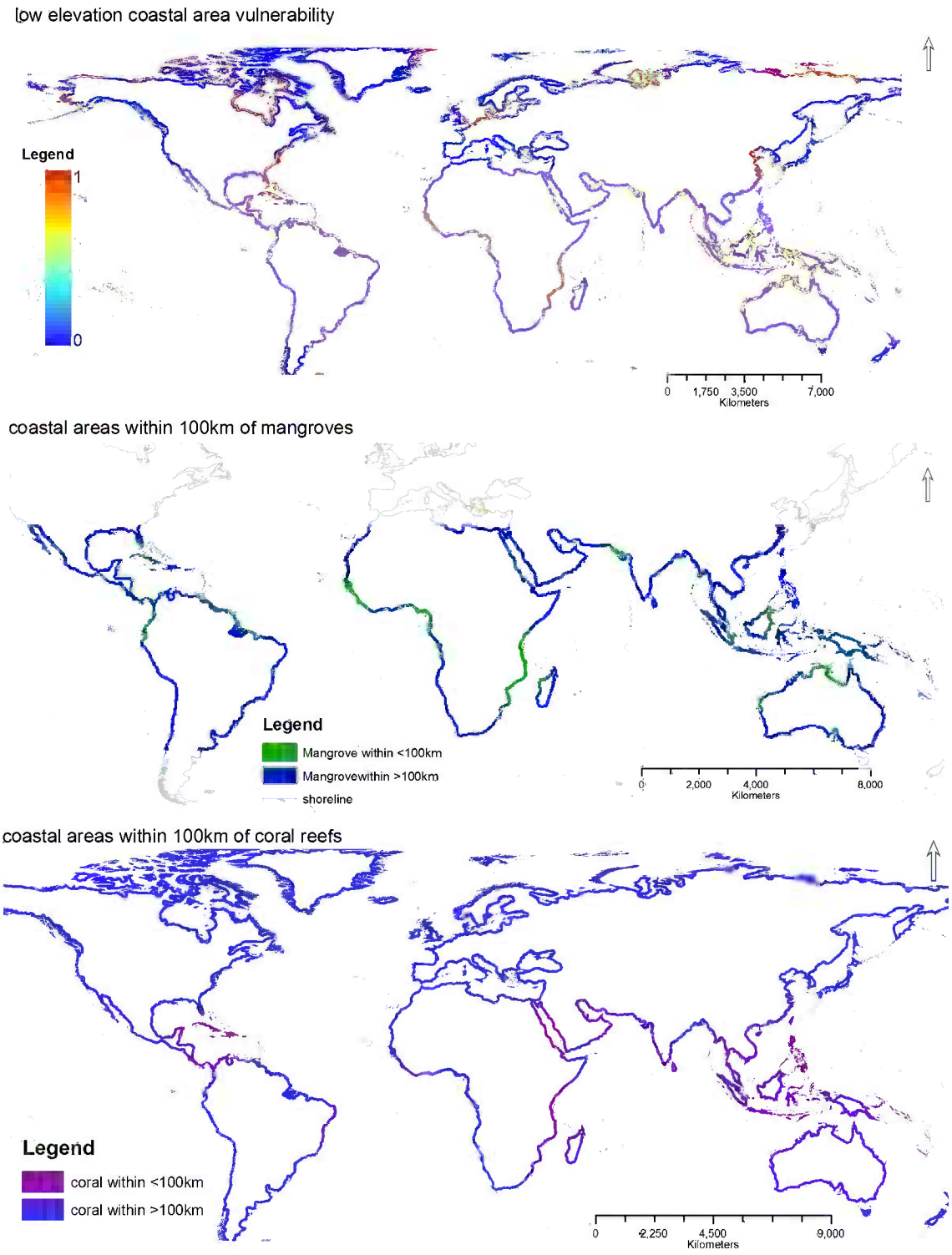


Figure 7. Top: vulnerability index [0,1] based on elevation, mid: coastal areas within 100km of mangroves; and bottom: coastal areas within 100km of coral reefs

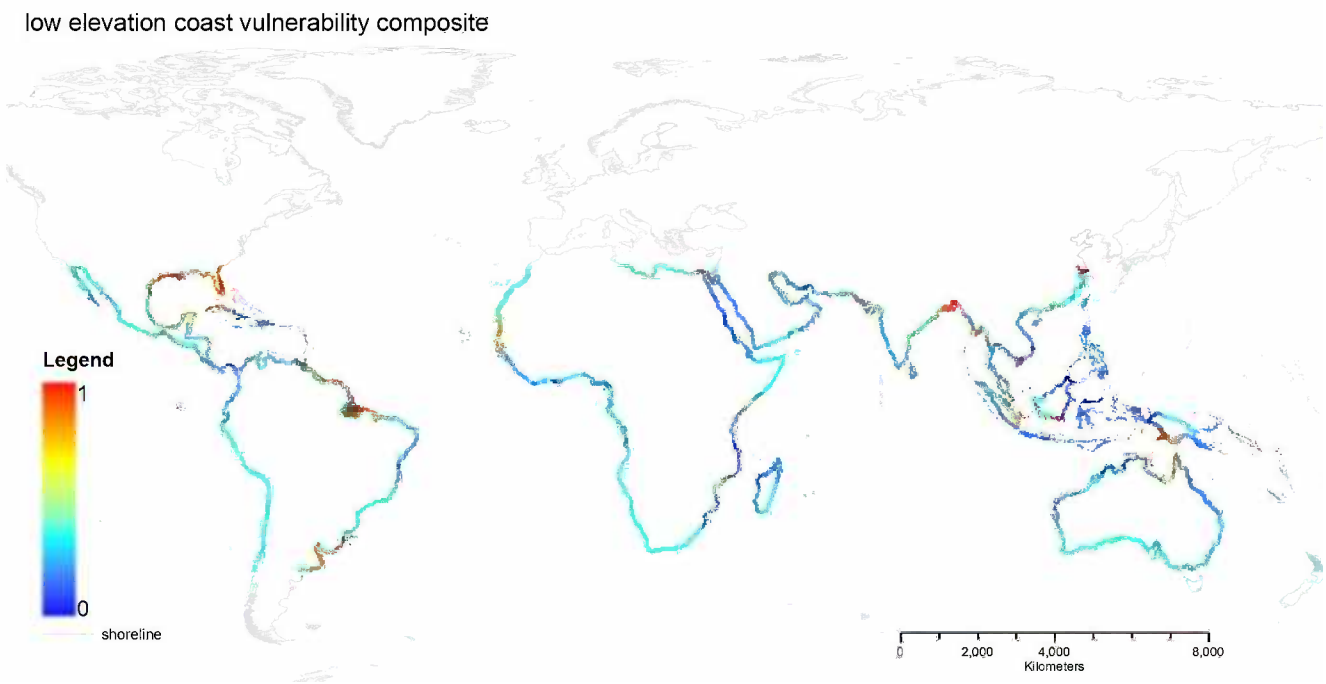


Figure 8. Vulnerability index [0,1] composite calculated from vulnerability based on elevation, and mangrove and coral presence absence.

References

Storeygard, A., Balk, D., Levy, M., and Deane, D. (2008). The Global Distribution of Infant Mortality: A Subnational Spatial Popul. Space Place 14, 209–229