PERCENTAGE OF TOTAL POPULATION LIVING IN COASTAL AREAS		
Oceans, Seas and Coasts	**Coastal Zone**	**Core indicator**

1. INDICATOR

(a) Name: Percentage of Total Population Living in Coastal Areas.

(b) Brief Definition: Percentage of total population living within 100 kilometers of the coastline. A country might also consider percentage of population in the low elevation coastal zone (<10 meters elevation) or percentage of population in river deltas. See methodology for more information on defining the coastal zone.

(c) Unit of Measurement: %.

(d) Placement in the CSD Indicator Set: Ocean, Seas and Coasts/Coastal Zone.

2. POLICY RELEVANCE

(a) Purpose: This indicator serves two purposes. It quantifies an important driver of coastal ecosystem pressure, and it also quantifies an important component of vulnerability to sea-level rise and other coastal hazards.

(b) Relevance to Sustainable/Unsustainable Development (theme/sub-theme): Because of the economic benefits that accrue from access to ocean navigation, coastal fisheries, tourism and recreation, human settlements are often more concentrated in the coastal zone than elsewhere. Presently about 40% of the world's population lives within 100 kilometers of the coast. As population density and economic activity in the coastal zone increases, pressures on coastal ecosystems increase. Among the most important pressures are habitat conversion, land cover change, pollutant loads, and introduction of invasive species. These pressures can lead to loss of biodiversity, coral reef bleaching, new diseases among organisms, hypoxia, harmful algal blooms, siltation, reduced water quality, and a threat to human health through toxins in fish and shellfish and pathogens such as cholera and hepatitis A residing in polluted water.
Finally, it is important to recognize that a high population concentration in the low-elevation coastal zone (defined as less than 10 meters elevation) increases a country's vulnerability to sea-level rise and other coastal hazards such as storm surges.

(c) International Conventions and Agreements: The Millennium Ecosystem Assessment identified a number of international agreements relevant to coastal zone management, including the following:

- United Nations Convention on the Law of the Sea
- UN Regional Seas and Action Plans
- Global Programme of Action for the Protection of the Marine Environment from Land-based Activities

- Jakarta Mandate on the Conservation and Sustainable Use of Marine and Coast Biological Diversity
- Ramsar Convention on Wetlands of International Importance
- Chapter 17 of Agenda 21
- Paragraph 29 of the World Summit on Sustainable Development Plan of Implementation

In addition, there are 76 international coastal management plans in place which are relevant.

The conservation of biological diversity and the sustainable use of its components are among the primary objectives of the Convention on Biological Diversity (CBD). This indicator is of particular relevance to several articles of the CBD, e.g.: Article 6 - General measures for conservation and sustainable use; Article 7 - Identification and monitoring.

(d) International Targets/Recommended Standards: None.

(e) Linkages to Other Indicators: Many of the CSD core environmental indicators can be linked to this one, particularly those relating to urbanization, biodiversity, agriculture, fisheries, algae concentration, and fresh water quality. A directly linked social indicator is the population growth rate. It also may have implications for economic performance and GDP per capita.

3. METHODOLOGICAL DESCRIPTION

(a) Underlying Definitions and Concepts: The coastal zone can be defined in different ways depending on the focus of interest and the availability of data. Typically a combination of distance-to-coast and elevation data is used. The Millennium Ecosystem Assessment used 100 kilometers from the coast as the distance threshold and 50 meters as the elevation threshold, choosing whichever was closer to the sea. McGranahan, Balk and Anderson (2006 and 2007) use 10 meters elevation contiguous with the coast and no distance threshold; in most places this delineated an area closer than 100km from the sea, though in some areas it extended farther. In general distance-based measures are best suited for indicators used to denote coastal pressures, while elevation-based measures are best suited for indicators used to denote hazard vulnerability.

Another approach would be to assess the population size or percentage of population residing in delta areas, which are important areas at the land-ocean interface.

(b) Measurement Methods: To measure the percent of total population living in the coastal zone two underlying pieces of information are required: spatially disaggregated data on a country's population distribution and information on the spatial extent of the coastal zone.

A Geographic Information System (GIS) should be used to measure this indicator. Many different types of free and proprietary GIS packages exist. Using a GIS, the percent population in the coastal zone can be calculated in three steps.

i. To measure the population in the coastal zone, the population data of a country needs to be disaggregated such that the population within the zone can be distinguished from

the population in the rest of the country. Censuses usually offer population data disaggregated sub-nationally by administrative units, such as regions and districts. The smaller the geographic area covered by each unit, the better the precision can be in measuring where people live within the country.

If a country's census administrative units line up with the coastal zone, the population from these units can be summed to estimate the population of the zone. It is far more likely, however, that the geographic administrative units will not match the area of the coastal zone exactly. In these cases, creating a gridded surface of population can provide an estimate of the population in the zone. The vector layer of administrative units with associated population can be converted into a raster layer made up of grid cells of an assigned size (e.g., 30 arc-seconds which equates to an approximately 1 km grid at the equator). The population of an administrative unit is distributed evenly among the grid cells within that unit. On the edges, where a grid cell is split by two or more units, a proportional allocation method can be used to assign population to the grid cell based on the area of each unit that falls within the cell. Country's wishing to skip this step may use one of three ready made gridded population datasets – Gridded Population of the World (GPW), Global Rural-Urban Mapping Project (GRUMP), or Landscan – which are described in greater detail, along with other useful data sets, in Section 4.

ii. Once the population data are gridded, a suitable map of the coastline needs to be selected and the spatial extent of the coastal zone needs to be delineated. Ideally the population and coastline data sets will have matching coastlines. If not, the next paragraph describes a possible remedy. Here we illustrate the separate methods required for the three different measures of the coastal zone.

100 kilometer buffer: To calculate the 100 kilometer coastal buffer of the land area, the data must be projected into an equidistant map projection appropriate for the country. Due to the curvature of the Earth, this will be different for each country. The map projection used to create the 100 kilometer buffer for Iceland won't create an accurate 100 kilometer buffer for India. An equidistant map projection will minimize distortion so that distance calculations can be measured with relative accuracy (examples include Polar Azimuthal Equidistant Projection and Equidistant Cylindrical Projection). Using such an equidistant map projection, the next step is to calculate an inland buffer of 100 kilometers. Subsequently, convert the buffered layer into the same map projection as the population data. If the coastlines of your population and land area layers do not exactly match, one can also include in the 100 kilometer buffer a thin band extending from the coastline into the ocean.

Low Elevation Coastal Zone (LECZ): To calculate the land area contiguous with the coast that is 10 meters or less in elevation, the following data are required: a gridded elevation data set, a gridded representation of the country's land area, and coastal boundary file (i.e., coastline). The gridded elevation data can be used in conjunction with the gridded country land area (in the same projection and resolution) to create a mask of land area where the elevation is 10 meters or less. This mask can be converted to a vector layer. Using the low-elevation mask along with an vector coverage of the coastline, all of the polygons in the mask that are contiguous with the coast can be selected (thereby removing from consideration inland areas less than 10 meters in elevation). These selected polygons represent the LECZ and can be converted back into a grid to be used with the population grid.

iii. Once the population data are gridded and a coastal zone mask is created, both in the same projection and resolution, the coastal zone can be overlaid on the population grid and the GIS can be utilized to sum the population within that mask. This population can then be divided by the total country population (using the same data source as the gridded population data) and multiplied by 100 to obtain the percentage of the country's population in the coastal zone.

(c) Limitations of the Indicator: This indicator can be used in monitoring processes that affect coastal ecosystem pressures and coastal hazard vulnerabilities, but it does directly quantify such pressures and vulnerabilities. Quantification of pressures requires knowledge of the total population, not just percentages, and is further enhanced by information on environmentally significant human activities (e.g., industry, tourism, agriculture). In a similar vein, quantification of vulnerability requires information on the exposure to coastal hazards, the nature of the built environment, and measures of phenomena that affect coping capacity and resilience.

(d) Status of the Methodology: The methodology is described in section (b) above. Additionally, there are pre-prepared national-level data for two versions of this indicator available at: http://sedac.ciesin.columbia.edu/es/csdcoastal.html.

(e) Alternative Definitions/Indicators: Population density, rather than percentage of a country's population, provides more direct measurement of the pressures and impacts of human development in the coastal zone. Percentage of the coastal population that is urban can provide a proxy for how densely populated the area is. An alternate way to measure the relative human impact along the coastal zone is the length (or percentage) of the coastline that is built up. Two examples of data sources to provide this information are the Global Rural Urban Mapping Project (GRUMP) urban mask, or a land cover data set that includes urban areas as one of the land cover types (e.g., IGBP's Land Cover Characterization). The length of the coastline that is urban or 'built up' can then be divided by the total length of the coastline. Built up areas often result in the reduction and potential elimination of coastal ecosystems many of which provide services, such as buffering from coastal storms, and serve as important habitat for flora and fauna at the land-sea interface. In addition, the impermeable surfaces characterized by many built up areas reduce ground infiltration of rainfall, resulting in storm water discharge directly into coastal waters. The most appropriate coastal zone delineation to capture the direct consequences of built up areas might be an "immediate" coastal zone of 10 kilometers inland from the coast.

4. ASSESSMENT OF DATA

(a) Data Needed to Compile the Indicator: The two pieces of spatial data needed to measure this indicator are gridded population and a coastal zone delineation (or mask). Countries may have the most detailed and accurate population and coastal zone data available for their own country. Where these data are not available, or where data incompatibilities make integration difficult, there are freely-available global datasets that can be used. For example, the Socioeconomic Data and Applications Center (SEDAC) of the Center for International Earth Science Information Network at Columbia University

(CIESIN) has developed a digital database of global population distribution in 1990, 1995, and 2000. Known as Gridded Population of the World v.3 (GPW), this data set is available at a 2.5 arc-minute grid (equivalent to 21 km^2 at the equator), and its coastline closely matches the widely available coastline from the Digital Chart of the World (DCW). The Global Rural-Urban Mapping Project (GRUMP) is a related product that delineates urban areas using a variety of information sources (night-time lights, Digital Chart of the World, tactical pilotage charts, and classified satellite data), reallocating the population distribution of GPW to reflect higher densities in urban areas. GRUMP includes three data products: (1) a gridded population product at 30 arc-second resolution (1 km^2 at the equator), (2) an urban extents grid (or urban mask), and (3) a global points data set of all urban areas with populations greater than 1,000 inhabitants. The Oak Ridge National Laboratory's Landscan population distribution map represents a modelled distribution of the world's population on a 30 arc-second grid, starting with census data then using a number of parameters such as road networks, night-time lights, elevation, and slope to allocate population to grid cells. Users should be cautioned that because land cover and elevation are among the parameters that drive the population allocation model, Landscan may be less appropriate as a monitoring tool than population data sets that do not assume a particular relationship between population and these factors.
Several data sets useful for compiling the coastal zone delineation are listed in section (c) below.

(b) National and International Data Availability and Sources: The primary sources for gridded population distributions at global, continental and country levels are the Socioeconomic Data and Applications Center (SEDAC) and the Oak Ridge National Laboratory (ORNL). Data sources for coastal zone delineation are listed in section (c) below.

(c) Data References: The Web site for the Gridded Population of the World and the Global Rural-Urban Mapping Project is: http://sedac.ciesin.columbia.edu/gpw/. This Web site also has a grid identifying country areas (i.e., national identifier grid) on a 2.5 minute and a one kilometre resolution. Landsan can be downloaded from http://www.ornl.gov/sci/landscan/. The Digital Chart of the World coastline can either be acquired on an individual country basis from the Pennsylvania State University Map Library web site, http://www.maproom.psu.edu/dcw/, or by purchasing a CD-ROM from ESRI (http://www.esri.com). The Millennium Ecosystem Assessment has also produced a coastal boundary data set. For elevation data, Shuttle Radar Topography Mission (SRTM) 30 arc-second data can be obtained from http://www2.jpl.nasa.gov/srtm/, and GTOPO 30 arc-second digital elevation model data can be obtained from
http://edc.usgs.gov/products/elevation/gtopo30/gtopo30.html.

5. AGENCIES INVOLVED IN THE DEVELOPMENT OF THE INDICATOR

(a) Lead Agency: Center for International Earth Science Information Network at Columbia University (CIESIN), Palisades, NY, USA. The focal point is Mr. Marc Levy. tel. No. (+1-845) 365-8988, email ciesin.info@ciesin.columbia.edu.

(b) Other Contributing Organisations: the United Nations Environment Programme (UNEP) Global Programme of Action for the Protection of the Marine Environment From Land-based Activities (GPA) Coordination Office. The contact point is the GPA Coordination Office, tel. no. (+31 70) 311.4467 , fax no. (+31 70) 345.6648 and e-mail gpa@unep.nl.

6. REFERENCES

Agardy, Tundi and Jacqueline Alder (Coordinating Lead Authors), 2005, "Coastal Systems," chapter 19 in Rashin Hassan, Robert Scholes, and Neville Ash, eds, *Ecosystems and Human Well-Being: Current State and Trends, Volume 1*, Washington, DC: Island Press.

Agenda 21. http://www.un.org/esa/sustdev/agenda21.htm

Center for International Earth Science Information Network (CIESIN) of Columbia University. 2006. *CSD Coastal Population Indicator: Data and Methodology Page*. http://sedac.ciesin.columbia.edu/es/csdcoastal.html

IPCC Projected Changes in Global Sea-Level.
http://www.grida.no/climate/vital/24.htm

OSPAR Commission for international cooperation on the protection of the marine environment of the North-East Atlantic. http://www.ospar.org/

McGranahan, Gordon, Deborah Balk and Bridget Anderson. 2007. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment & Urbanization* 19(1): 17-37 (2007).

McGranahan, Gordon, Deborah Balk and Bridget Anderson. 2006. "Low Coastal Zone Settlement," *Tiempo* 59, 23-26.

The International Oceanographic Commission (IOC) Harmful Algal Bloom Programme.
http://ioc.unesco.org/hab/intro.htm

UNDP, UNEP, World Bank, World Resources Institute, 2000. *World Resources 2000-2001: People and Ecosystems: The Fraying Web of Life.* World Resources Institute, Washington, DC. http://www.wri.org/wr2000/

UNEP. 2006. *Marine and coastal ecosystems and human wellbeing: A synthesis report based on the findings of the Millennium Ecosystem Assessment*. UNEP. 76pp.
http://www.maweb.org//en/Products.Synthesis.aspx

UNEP Global Programme of Action for the Protection of the Marine Environment from Land-Based Activities. http://www.gpa.unep.org/

UNEP's Caribbean Environment Programme. http://www.cep.unep.org/

UNEP's Mediterranean Programme Action Plan. http://www.unepmap.org/

USGS Sea Level and Climate Change. http://pubs.usgs.gov/fs/fs2-00/