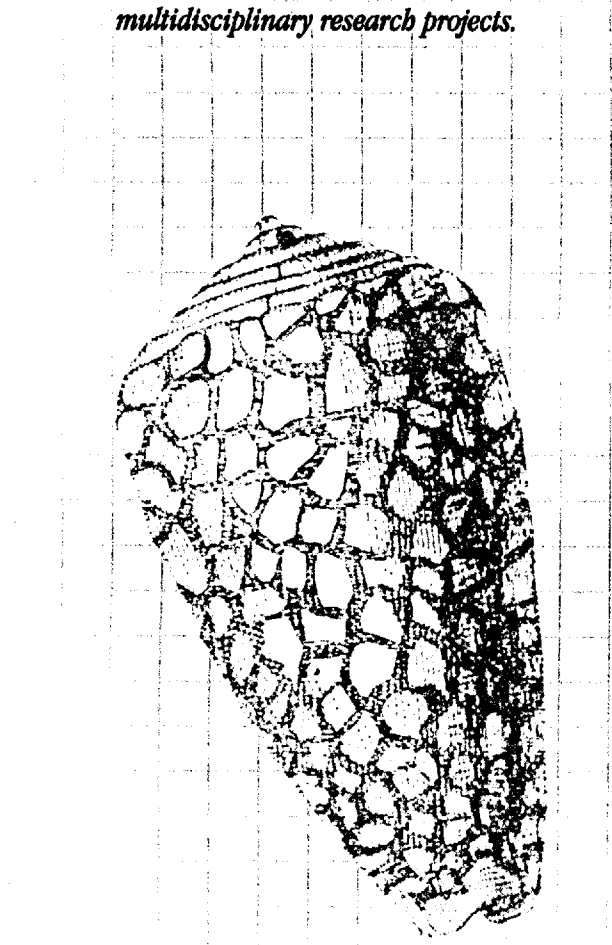
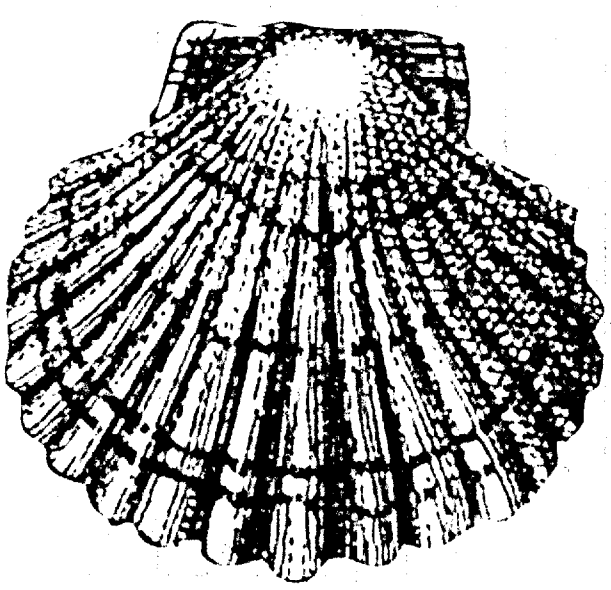
Earth Matrix

by Christopher Small and Joel E. Cohen

Hypsography Meets Demography: How Many People Can The Beach Support?

Editor's Note: Each issue of EARTHmatters will feature a section called "Earth Matrix," which will include articles co-authored by faculty and staff from different disciplines who are collaborating on cross-disciplinary projects. Following are three articles co-authored by Earth Institute-affiliated researchers who are working together on multidisciplinary research projects.





THE RAPID GROWTH OF EARTH'S HUMAN population, migration, and economic development are resulting in increasing numbers of people settling in areas at high risk from natural hazards. One of the most frequently cited consequences of global warming -- the projected rise in sea level -- has important societal consequences because a significant percentage of the world's population lives in large coastal cities or on coastal plains. What is this percentage? Even in the absence of a significant rise in sea level, global climate change is likely to have a significant impact on the inhabitants of coastal areas as a result of changing weather patterns and storm surges. It is necessary to know the number and location of people who could be directly affected in order to make realistic assessments of this impact.

To date, most studies of the societal impact of sea level rise and coastal hazards have been local or regional and generally focus on individual coastal cities or river delta communities. To put these studies into a global context and assess the cumulative impact of sea level rise and coastal hazards, it is necessary to conduct a systematic top-down analysis of the global distribution of population with respect to the physiography of the Earth's continental land masses.

Variations in Coastal Population Density

Estimating the distribution of the world's population with respect to elevation and distance from coastline may provide a starting point for assessing the socioeconomic consequences of sea level rise and coastal hazard, but it is important to consider additional factors. Variations in coastal population density will also determine the impact of coastal hazards. Are most coastal inhabitants residents of large cities or do a significant number reside in lower density communities? The topographic morphology of coastal areas will also have an effect on the impact of coastal hazards as well as future growth potential of some coastal populations.

Settlements built on broad, low lying river deltas are more vulnerable to floods and storm surges than those in non-fluvial environments. The growth potential of settlements in intermontane coastal basins, such as Los Angeles, is more topographically constrained than that of settlements located on broad coastal plains. Does continental physiography influence population distribution similarly in industrial and developing countries?

This leads to the larger questions of whether there exist global systematics in the spatial distribution of population and continental morphology and to what extent this distribution is controlled by other factors.

Underlying all of these questions is a basic lack of quantitative understanding of the relationship between human population and the physiographic form of the Earth's continents. Until recently, a global investigation of these questions would have required a synthesis of a variety of local studies conducted by different investigators at different times. As a result of the increasing availability of global scale digital datasets in a variety of different disciplines, it is now possible to systematically address questions like those posed above. Integrated analyses of these data are now providing new insights into the relationship between continental physiography and human population distribution.

Global Analyses of Populations and Physiography

By integrating elevation and demographic datasets it is now possible to conduct a systematic global analysis as well as comparative regional analyses of the relationship between population and continental physiography. These analyses in turn may be combined with observations and predictions of sea level rise and coastal climate variation to produce baseline estimates of the global impact of these scenarios.

Southeast Asia

Southeast Asia provides an interesting example of some of the basic physical factors influencing population distribution. The two maps at the top of page 9 show the combined continental and submarine topography of Southeast Asia (top) and the distribution of population (bottom). It is apparent from the elevation map on the top that the present position of the coastline (heavy black line) is quite different from the steep submarine slope that marks the actual edge of the continent where the South China Sea deepens from 200 to 1000 meters. The rugged topography of the Wuliang Shan mountains in the northwest extends southward into Vietnam creating a very narrow coastal plain in contrast to the much wider coastal plains to the north and east of the Gulf of Thailand. These major physiographic features in the elevation map are reflected somewhat in the companion population density map. Most, but not all, of the rugged mountainous regions are very sparsely populated. The densest concentrations of people are located along the coast and on low lying river deltas. A significant change in regional population density can also be seen across the border between Vietnam and China, north of Hainan Island.

Elevation Histograms

Some of the information contained in these maps can be combined and condensed into elevation histograms shown in charts between the map on page 9. The distribution of population with elevation is quite dramatic, showing that 80 million people in Southeast Asia live within 25 meters of sea level. It is difficult to predict the impact that a gradual 1 meter increase in sea level would have on this region, but it is clear that a 6 meter storm

surge could be devastating in a number of areas. Several of these areas are currently experiencing rapid population growth. The distribution of occupied land area with elevation shows that the population distribution is accommodated somewhat by the hypsography of the continent; there is more land area available near sea level than at any other elevation. When the population distribution is adjusted for the available land area, we can determine how average population density varies with elevation. Overall, sea level is still the "elevation of choice" with far more people per available area than any other elevation range. Population densities in the large cities are actually much higher than average population densities.

Wide Range and Long Term Objectives

We will extend such analyses both to other regions and globally to quantify coastal population distributions and produce more accurate estimates of the number and location of people at risk from coastal hazards worldwide. A longer term objective of this research is to incorporate additional physiographic factors into this type of analysis in order to assess the potential impact of a wider variety of environmental variables. Ultimately, we hope that the results of these analyses can help us develop a more accurate understanding of the relationships between the physical and socioeconomic components of the Earth.

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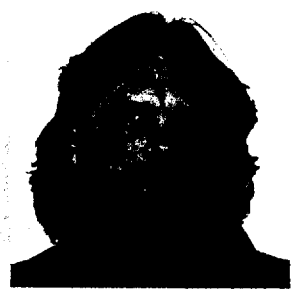
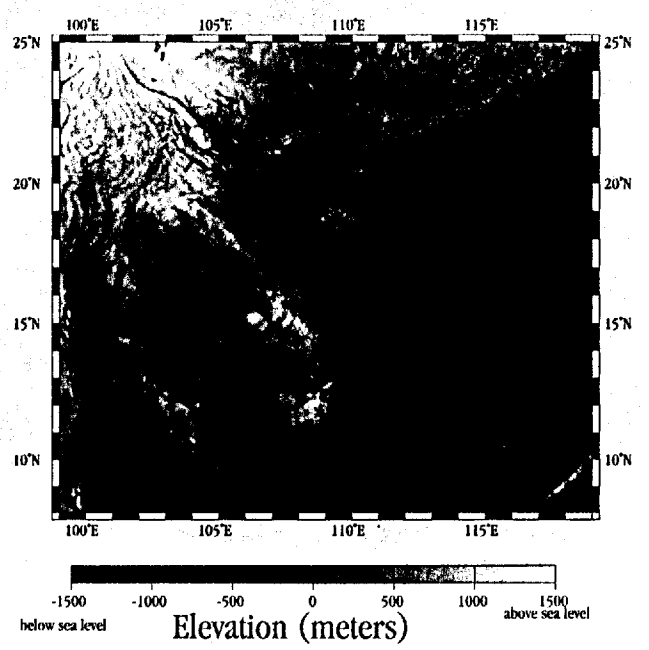
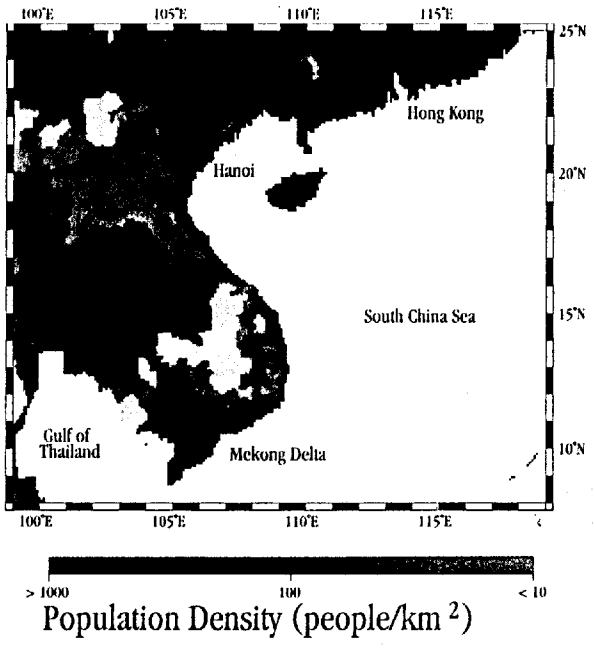
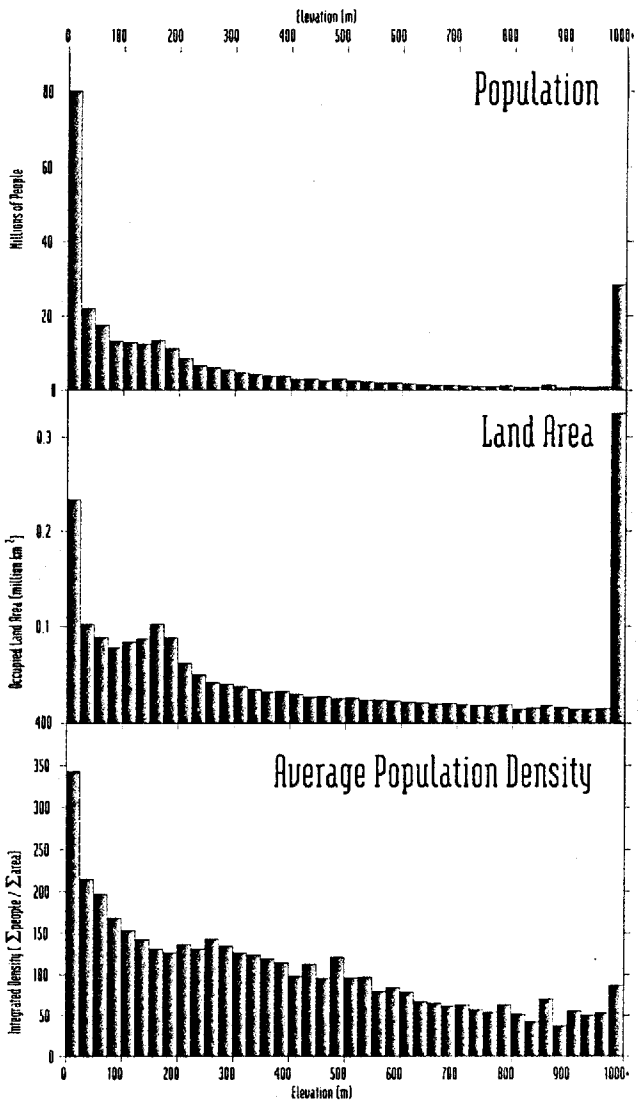
Joel Cohen *is Professor of Populations and head of the Laboratory of Populations at the Rockefeller University and Professor of Populations at Columbia University. He can be contacted at 1230 York Avenue, Box 20, Rockefeller University, New York, NY 10021-6399. Phone 212 327-8883; Fax 212 327-7974. email cohen@rockvax.rockefeller.edu*



Christopher Small *is an Associate Research Scientist at the Lamont-Doherty Earth Observatory, Columbia University. He can be contacted at 108D Oceanography, LDEO, Route 9W, Palisades, NY 10964. Phone 914 365-8354; Fax 914 365-8179. email small@ldeo.columbia.edu*







Preliminary results of a regional analysis of population and elevation for Southeast Asia. Approximately 48% of the population resides at elevations lower than 100 m and almost 27% lower than 20 m.