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Viewpoint

Transforming management of tropical coastal seas to cope with challenges of the 21st century

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ABSTRACT

Over 1.3 billion people live on tropical coasts, primarily in developing countries. Many depend on adjacent coastal seas for food, and livelihoods. We show how trends in demography and in several local and global anthropogenic stressors are progressively degrading capacity of coastal waters to sustain these people. Far more effective approaches to environmental management are needed if the loss in provision of ecosystem goods and services is to be stemmed. We propose expanded use of marine spatial planning as a framework for more effective, pragmatic management based on ocean zones to accommodate conflicting uses. This would force the holistic, regional-scale reconciliation of food security, livelihoods, and conservation that is needed. Transforming how countries manage coastal resources will require major change in policy and politics, implemented with sufficient flexibility to accommodate societal variations. Achieving this change is a major challenge – one that affects the lives of one fifth of humanity.

1. Introduction

Ever-expanding human impacts are continuing a substantial decline in the capacity of coastal marine ecosystems to provide crucial goods and services (MEA, 2005; Jackson, 2010; Lotze et al., 2006). In addition to local stressors such as overfishing and

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pollution, coastal seas now suffer from warming, ocean acidification, and catastrophic weather events directly related to our releases of greenhouse gases, particularly CO_2 (Doney, 2010). The deteriorating ecological capacity of coastal ecosystems to deliver services directly impacts coastal communities that depend on adjacent waters for their food and livelihoods.

Globally, tropical coastal seas share ecologies, environmental problems and solutions, fall predominantly within developing countries, and are home to more than one fifth of the global population. Here, we use the most up-to-date demographic data available to compute the number of people living within 100 km of a tropical coast, and the number expected there in 2050. We review current and projected trends in climate and ocean chemistry to visualize the tropical environment at mid-century, and, because loss of corals is one of the major changes occurring, we model the effects of loss of coral cover on fishery productivity in reef waters. These analyses collectively reveal how stresses on coastal seas will change and where priorities for management should lie: Tropical coastal waters, already subject to widespread degradation, are going to deteriorate further in their capacity to provide environmental goods and services unless we substantially improve management. More of the same is not enough.

Given this context, we explore technological issues in managing coastal development, fisheries, aquaculture, and pollution, and suggest ways to create a holistic management approach within jurisdictions and across regions. In doing this, we recognize the special challenges facing developing countries in providing for development and food security, while also advancing biodiversity conservation, as well as the imperative of building a management regime that is responsive to a changing environment. Our approach tailors solutions to communities' specific socio-political circumstances, includes a new perspective on marine spatial planning, and brings renewed attention to a suite of pernicious socio-economic factors, including the fact that costs and benefits are rarely distributed equitably across socio-economic classes (Daw et al., 2011). These issues must be substantially remedied to achieve real improvements in sustainability and quality of life for millions of coastal people.

2. Methods to anticipate trends and identify management priorities in tropical coastal seas to 2050

Many researchers have used modeling to predict the near term and longer term changes that may occur in response to climate shifts mediated by anthropogenic stressors. Our intention was to look specifically at how expected changes in the medium term will affect the health and productivity of tropical coastal seas, and in turn the effect on coastal communities and economies. Our approach is threefold: (1) a spatial analysis of projected human population growth in tropical coastal areas, (2) an attempt to predict impacts of local and global stressors on resource availability and livelihoods in the tropics, including the indirect effects of climate change on tropical nearshore fisheries, and (3) a prioritization, based on both these analyses, suggesting where and what kind of focused management is most urgently needed, with an accompanying recommended framework for action.

2.1. Population projections and potential impacts on tropical coastal seas

For spatial analyses of tropical coastal seas, we used Environmental Systems Research Institute's (ESRI) ArcGIS software suite (v. 9.3.1), including ArcInfo, ArcCatalog and ArcMap; ESRI ArcView (v. 3.2a); and QGIS (v. 1.80), defining the tropics as the area bounded by the Tropics of Cancer and Capricorn, 23°26′16″ latitude N and S respectively (Epoch, 2012), and coastal seas as those within the continental shelves (depths from 0 to 200 m in the Shuttle Radar Topography Mission (SRTM) 30 Plus, global, gridded terrain data) (Becker et al., 2009). SRTM 30 Plus is a globally seamless topography and bathymetry grid, comprised of the shuttle-based topography of the earth (SRTM) dataset, combined with bathymetry from a satellite-gravity model (Becker et al., 2009). Grid cell size is 30-arcseconds, which corresponds to about 926 m at the equator. We used the Millennium Coral Reef Mapping Project (2010) validated and unvalidated data layers of warm water coral, found primarily between 30°N and 30°S latitude, using all coral types represented in the data layer, and then converted the vector-based data layer to a 30 arcsecond cell sized grid in order to facilitate spatial overlay with the human population data.

The 2011 LandScan (Bright et al., 2012) global, gridded (30-arcsecond) dataset was used to represent terrestrial human population counts. This data layer is the highest resolution "ambient population (average over 24 h)" currently available (Bright et al., 2012), and is based on an algorithm which uses spatial data and image analysis technologies and a multi-variable dasymetric modeling approach to disaggregate census counts within an administrative boundary (Bright et al., 2012). Population counts are reported for each 30-arcsecond grid cell; since grid cells based on Euclidean coordinate systems are not uniform in area as one moves away from the equator, the values are numbers of humans per cell rather than their density.

We defined the terrestrial 'coastal region' as the region within 100 km of the shoreline regardless of elevation. We started with the Global Self-consistent Hierarchical High-resolution Shorelines (GSHHS) global coastline polygon data layer (NOAA, 2013), then deleted the Antarctic polygons as well as any polygons that did not intersect a polygon version of LandScan land delineation in the high resolution, level 1, GSHHS_h_L1 file. ArcCatalog was used to convert all polygon vertices from the edited GSHHS data layer into points in order to perform a geodesic buffer on said points, thereby accurately representing scale at any given point on the Earth's surface, regardless of a given point's distance from the equator. We created a geodesic buffer of 100 km around each of the GSHHS shoreline points and then converted the resulting buffered polygon file into a single, 30-arcsecond grid. Since the resulting grid depicted a 100 km buffer on both sides of the shoreline, and because the GSHHS shoreline did not perfectly align with the LandScan shoreline, we created a grid for the marine and the terrestrial sides of the 100 km buffer, using the LandScan grid as a mask.

The area, total population and corresponding population density were calculated for the following land regions:

- Terrestrial areas (excluding Antarctica), within 100 km of the global marine coastline.
- Terrestrial areas within the tropics.
- Areas within 100 km of the tropical marine coastline.

We also performed regional analyses, focusing on Southeast Asia, and then zoomed into a selected portion of the Indonesian archipelago within Southeast Asia, as a more localized case aligned with the analysis of potential fisheries impacts (see Box 1. Raja Ampat study).

The 100 km coastline buffer conserved scale at all locations on the globe, however area was not conserved as a function of latitude (Snyder, 1987). In order to calculate area accurately for all of the aforementioned regions, we transformed the native geographic coordinate system to Mollweide, which is a global equal area coordinate system (Snyder, 1987).