Chapter 44. Estuaries and Deltas

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1. Introduction.

Estuaries and deltas are amongst the most heavily populated areas of the world (about 60 per cent of the world's population live along estuaries and the coast) making them the most perturbed parts of the world ocean (Kennish, 2002; Small and Cohen, 2004). Of the 32 largest cities in the world, 22 are located beside estuaries. They are adversely affected by invasive species, sedimentation (from soil erosion caused by deforestation, overgrazing, and other poor farming practices), overfishing, drainage and filling of wetlands, eutrophication due to excessive nutrients from fertilizer, sewage and animal (including aquaculture) wastes, pollutants including heavy metals (see Chapter 20), polychlorinated biphenyls, radionuclides and hydrocarbons from sewage inputs and diking or damming for flood control or water diversion. Estuaries and deltas provide protected harbours used as ports that are associated with introduced marine pests. They are foci of human attention, attracting potentially incompatible uses by society such as heavy industry, urbanization and recreation; they are affected by global sea-level rise and climate change (Crossland et al., 2005). Estuaries and deltas "form a major transition zone with steep gradients in energy and physicochemical properties at the interface between land and sea" (Jennerjahn and Mitchell, 2013).

More than 50 per cent of large river systems are affected by dams, based on a global synthesis on river fragmentation and flow regulation (Nilsson et al., 2005), with obvious consequences for the estuaries and deltas at their coastal termini. The mean age of river water at river mouths has increased from about two weeks to over one month on a global scale and to more than one year in extreme cases (Vörösmarty et al., 2003). Over the last few centuries, the global annual sediment flux into the coastal zone has increased by 2.3×10^9 tons due to human-induced soil erosion and decreased by 3.7×10^9 tons due to retention in reservoirs, the net effect being a reduction of sediment input by 1.4×10^9 tons (Syvitski et al., 2005). A major environmental consequence of river sediment starvation is erosion of the coast and attendant loss of habitat.

2. Major threatening processes.

Processes affecting the health and condition of estuaries and deltas may be classified into three broad categories that can interact:

(a) "Short-term" pressures associated with the near-term effects of human expansion (e.g., coastal development, land-based inputs of nutrients, over-fishing, aquaculture, and maritime operations);

(b) "Medium- to long-term" pressures associated with anthropogenic climate change (e.g., sea-level rise, increases in atmospheric heat and CO_2 fluxes into the oceans, a strengthening global hydrological cycle, and the increasing magnitude of tropical cyclones); and

(c) Extreme natural events.

A list of processes and impacts is given in Table 1 (see Chapter 44 Appendix, online only).

3. Social and economic considerations.

Estuaries are tourist attractions and provide a centrepiece for development (a harbour view). Estuaries and deltas provide natural harbours that are used for transport and industry as the ideal location of major port facilities. They have ecological importance to a diverse biota, including economic importance to commercial and subsistence fisheries. People value estuaries for recreation, scientific knowledge, education, aesthetics, and traditional practices. Boating, fishing, swimming, surfing, and bird watching are just a few of the numerous recreational activities people enjoy in estuaries and deltas. Their unique habitats make them valuable laboratories for scientists and students. Considering the sum of human activities that depend upon the existence of estuaries and deltas and their ecosystem services (e.g., Barbier et al., 2011), their total economic value to society is vast (Costanza et al., 1997; Costanza et al., 2014). Costanza et al. (1997) estimated their value at approximately 4.1 trillion United States dollars (equal to 6.1 trillion dollars in 2014 dollars).

Some indications of the social and economic value of functioning estuarine and deltaic ecosystems can be found from examples where human activities have impaired such functions. Economic losses due to anthropogenic changes in river discharge are one example. The down-stream consequences of dam-building are often not fully considered when the decision is taken to build a dam on a river system. The economic losses from reduced fisheries landings, due to the reduction in nutrients entering the Indian Ocean at the Sofala Bank fishery (Arthurton, 2002), following alteration to the Zambezi River freshwater flows, has been estimated at between 10 and 20 million dollars (Turpie, 2006). In an extreme case, the Colorado River, prior to the completion of the Hoover Dam in 1935, delivered a combination of nutrient-rich water and silt to the historic Delta, comprised over 2.5 million acres of wetlands, habitat for an estimated 400 species of plants and wildlife and home to some 20,000 Cocopah Indians (Glenn et al., 2001). All of the freshwater discharge was impounded behind dams by 1963; the wetlands dried up, affecting many dependent species. In 2014, an experimental release of 130 million m^3 of water allowed the restoration of the Colorado Delta to begin, although it will take many years to restore even part of the original wetland area (Witze, 2014).

Some of the first and most severe impacts of climate change will come through greater storm surges caused by a combination of higher sea levels and stronger storms in some areas. In the absence of storm surge, a 20-80 cm rise in mean sea level will place 7 – 300 million additional people at risk of being flooded each year (Geneva Reports, 2009, No. 2, 138 pp. www.genevaassociation.org). Increases in storm surge will increase these numbers substantially. The Organization for Economic Cooperation and Development (OECD) estimates that, in the absence of adaptation, the population in 136 major port cities exposed to storm surges could increase from 40 million in 2005 to ~150 million in the 2070s, with exposed assets rising from 3,000 billion dollars to 35,000 billion dollars (Nicholls et al., 2008). By 2050, sea-level rise in the Ganges-Brahmaputra Delta could directly affect more than three million people and Bangladesh could lose nearly one-quarter of the land area it had in 1989 by the end of this century, in a worst-case scenario (Ericson et al., 2005). As a proportion of GDP, economic losses from flooding are much higher for developing countries than for developed countries (Ramcharan, 2007). Financial losses from weather events are currently doubling every 12 years at an annual rate of 6 per cent (UNEP, 2006). In the Sacramento Delta in San Francisco Bay, California, United States, global sea-level rise places about 500,000 acres of agricultural lands in the inner Delta at significant risk of flooding in the first half of the 21st century. Total losses for the wider area—including multiplier effects—could reach 1,800 jobs per year, 130 million dollars in value added, and nearly 14 million dollars in state and local tax receipts (Medellín-Azuara et al., 2012). These examples provide some context for the potential impacts of water abstraction and global warming and sea-level rise on ecosystem services upon which estuarine- and deltaic-based societies and economies depend.

4. Management and conservation.

Healthy estuaries and deltas maintain water quality that benefits both people and marine life. They provide a natural buffer between the land and ocean, absorbing floodwaters and storm surges. Estuaries and deltas help maintain biodiversity by providing a diverse range of unique habitats, including mangrove forests, salt marshes, mud flats and seagrass beds, which are critical for the survival of many species. Many species of commercially important fish and shellfish use estuarine and deltaic habitats as nurseries to spawn and allow juveniles to grow. Maintaining such ecosystem services is commonly declared as a management goal and is the focus of conservation efforts.

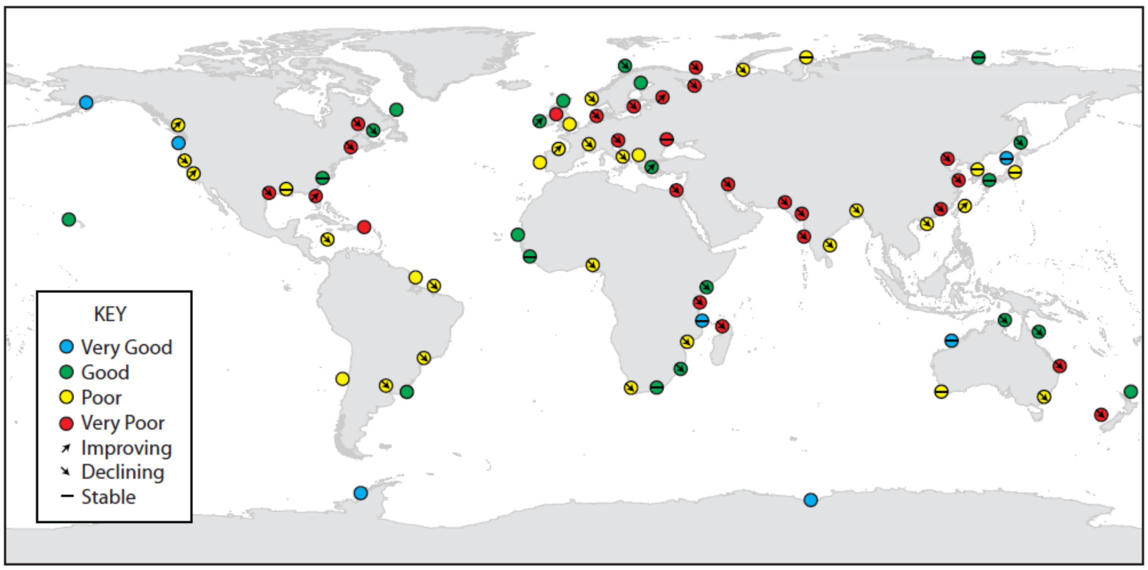
In considering the management of estuaries and deltas, the question of the number of estuaries and deltas on earth arises, given that an inventory of any asset is a prerequisite to its management. The number of estuaries and deltas, in turn, is dependent upon scale and definition of what constitutes an estuary or delta. In their estimate of river sediment discharge based on a 30 minute (55.56 km) grid, Syvitski et al. (2005) identified 4,464 river basins > 100 km^2 in area that are not covered by ice sheets of the Antarctica, Greenland and portions of the Canadian Archipelago and have a positive discharge to the ocean/sea. Given that every estuary or delta is associated with a river that discharges into the ocean/sea, and noting this size limit on catchment area, therefore about 4,464 estuaries and deltas are found on earth.

A search on the IUCN Protected Areas database (http://protectedplanet.net) for “estuaries” yielded 275 results, of which 156 are in Europe (including 107 in the UK alone), 79 are in the Americas (including 53 in the USA), 19 are in Oceania, 11 in Asia and 10 in Africa. A similar search conducted for “deltas” found 210 results, of which 127 are in Europe (including 35 in Greece), 51 are in the Americas, 17 in Asia, 12 in Africa and three in Oceania. In terms of level of protection, only five out of 275 estuaries and 12 out of 210 deltas are in IUCN category Ia (Strict Nature Reserve) or Ib (Wilderness Area), with over 50 per cent in categories IV (Habitat/Species Management Area) and V (Protected Landscape/ Seascape). However, these figures may not capture all estuaries or deltas under protection since in the exact word “estuary” or “delta” must be contained in the place name for the search to recognize the location as containing as estuary or delta; so a place that is named as a “bay” or other term would not be counted. Furthermore, the protection of the marine habitat may not be effective if the catchment itself is not well managed. Nevertheless, the figures give some broad indication of the level of protection afforded to estuaries and deltas on earth.

5. Integrated assessment of the status of the habitat.

In order to produce a global, integrated assessment of estuary and delta condition, a literature search was carried out for papers and reports that have provided an assessment on estuarine and coastal habitats. Studies that reported on the condition of individual estuaries or groups of estuaries within a broad area were included. Where possible, the results given in the reports were converted into a report card score on a scale of 1 to 4 (Very Good, Good, Poor, Very Poor) and the date of assessment recorded (the criteria used to identify the condition category are given in Appendix, online only). In addition, a trend for overall condition was extracted (declining, stable or improving) and the timeframe over which the trend was observed was recorded. The raw data are recorded in a table (Appendix, online only).

Based on published assessments for 103 areas, the global condition of estuaries and deltas (Figure 1) is Poor overall (mean score of 2.07 out of 4). The published assessments gave a Very Poor rating in 31 areas, a Poor rating in 32 areas, Good in 31 areas and a Very Good rating in only eight areas (Table 2 in Appendix, online only). These results are biased by the fact that many studies are carried out in affected areas and hence the scores are skewed (i.e., the overall "Poor" rating is influenced by the many studies that are conducted on affected systems). On the other hand, many of the available assessments are based on only a few measured variables (typically related to water quality or fisheries) and they do not give an overall (integrated) picture of the health and condition of estuarine ecosystems. This factor can influence the outcome of a non-integrated assessment for systems in which the impact is not measured by the parameters used.



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 1. Estuarine and deltaic condition assessments based on reports for 100 regions (listed in Appendix).

For example, one of the six Very Good ratings (Table 2 in Appendix) was assigned by UKTAG (2008) for Estuaries and Lochs in Scotland based on the winter mean of dissolved inorganic nitrogen over a six-year period (2001-2006). However, the ecology of at least one of these Scottish lochs (the Firth of Clyde) has been described by Thurstan and Roberts (2010) as "a marine ecosystem nearing the endpoint of overfishing, a time when no species remain that are capable of sustaining commercial catches". Hence, whereas the water quality in this estuary may be rated as very good, the ecosystem has been significantly affected by over-fishing to the extent that an integrated assessment would likely give a rating of Very Poor for this estuary. Such cases serve to elevate the global score of "Poor" such that it is unrealistically positive.

Seventy-five studies reported a trend in terms of improving, stable or declining condition (Table 2 in Appendix). Out of those 75 studies, 46 (62 per cent) reported that conditions are declining, 19 (24 per cent) reported conditions were stable and ten (14 per cent) reported an improvement. On no continent does the number of estuaries showing an improving condition exceed the number of assessments of declining condition. Europe has the greatest number of studies that reported improving conditions (five), but only one area was reported to be in a “very good” condition; Africa, Australia and the South Pacific had no studies where conditions were improving. Asia (Japan) Australia and Africa each had one area where the condition was assessed as very good and stable.

6. Gaps in scientific knowledge

Out of the 101 areas assessed, only some are the subject of integrated assessments that include multiple aspects of estuarine environment, including habitats, catchment management, species, ecological processes, physical and chemical processes and socioeconomic aspects. Very few (about 10) areas had assessments that included all aspects of estuarine environments, to provide “fully integrated” assessments. There are 41 areas where assessments included at least three different aspects, producing partially integrated assessments. Another 25 areas had assessments concerned only with some aspect of estuarine water or sediment quality. Thus a critical gap in scientific knowledge is the availability of fully integrated environmental assessments for estuaries and deltas.

Out of the many possible aspects of the environment that could be assessed, water quality and biological aspects are most common, whereas socioeconomic aspects are assessed the least often, which is thus a knowledge gap. One other aspect of condition assessment is the trend (improving, stable or declining) that was assessed in 74 out of 103 areas. The assessment of trends is a critical piece of information for decision-makers, but which is missing in about 26 per cent of assessments. Furthermore, the time interval over which the trend is measured varies between studies, from one year to other arbitrary periods of human impact (as much as a century or longer). Thus the comparison of trends is confounded by differences in the time spans they relate to; international agreement on standards for reporting condition trends is needed to overcome this problem.

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