Estuarine, Coastal and Shelf Science 198 (2017) 311–319

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Unbounded boundaries and shifting baselines: Estuaries and coastal seas in a rapidly changing world

Keywords:
Estuaries
Coasts
Coastal seas
Global change
Environmental change
Climate change
Anthropocene

A B S T R A C T

This Special Issue of Estuarine, Coastal and Shelf Science presents contributions from ECSA 55; an international symposium organised by the Estuarine and Coastal Sciences Association (ECSA) and Elsevier on the broad theme of estuaries and coastal seas in times of intense change. The objectives of the SI are to synthesise, hypothesise and illustrate the impacts of global change on estuaries and coastal seas through learning lessons from the past, discussing the current and forecasting for the future. It is highlighted here that establishing impacts and assigning cause to the many pressures of global change is and will continue to be a formidable challenge in estuaries and coastal seas, due in part to: (1) their complexity and unbounded nature; (2) difficulties distinguishing between human-induced changes and natural variations and; (3) multiple pressures and effects. The contributing authors have explored a number of these issues over a range of disciplines. The complexity and connectivity of estuaries and coastal seas have been investigated through studies of physicochemical and ecological components, whilst the human imprint on the environment has been identified through a series of predictive, contemporary, historical and palaeo approaches. The impact of human activities has been shown to occur over a range of spatial and temporal scales, requiring the development of integrated management approaches. These 30 articles provide an important contribution to our understanding and assessment of the impacts of global change. The authors highlight methods for essential management/mitigation of the consequences of global change and provide a set of directions, ideas and observations for future work. These include the need to consider: (1) the cumulative, synergistic and antagonistic effects of multiple pressures; (2) the importance of unbounded boundaries and connectivity across the aquatic continuum; (3) the value of combining cross-disciplinary palaeo, contemporary and future modelling studies and; (4) the importance of shifting baselines on ecosystem functioning and the future provision of ecosystem services.

1. Introduction

Since the beginning of the 20th Century, human population growth and activities have exerted significant pressures on natural systems, which has led to anthropogenic-driven environmental change on a global scale (Meybeck and Vörösmarty, 2005; Waters et al., 2016; Rockstrom et al., 2009). These pressures include: (1) modification of the atmosphere and the climate through increasing greenhouse gas (GHG) emissions; (2) degradation and destruction of habitats (e.g. urban and agricultural expansion and seabed modification); (3) over-exploitation of resources (e.g. hunting, fishing and harvesting); (4) modification of the hydrological cycle (e.g. river-diversion, dam construction and freshwater abstraction); (5) introduction of invasive species; and (6) release of contaminants into the environment (from fossil fuel combustion, fertiliser applications, intensive agriculture, changing sediment yields and aquaculture) (Parmesan et al., 2013; Rockstrom et al., 2009). These pressures do not occur in isolation, they are linked and interact, leading to cumulative, synergistic and antagonistic effects on natural systems over a range of spatial and temporal scales (Steffen et al., 2007; Lotze et al., 2006; Scavia et al., 2002; Brown et al., 2013).

Global change is occurring rapidly (Waters et al., 2016; Rockstrom et al., 2009). In the last 50 years, world population has grown rapidly (from 2.5 billion in 1950 to 7.6 billion in 2017; United Nations, 2017) and the world's ecosystems have changed more extensively than in any other period in human history (Pimm et al., 1995; Ceballos et al., 2017). The Earth is currently experiencing a period of mass global species extinction (the sixth great extinction event; Ceballos et al., 2017), and atmospheric concentrations of GHG's have substantially increased (e.g. atmospheric CO_2 concentration has risen from 310 to 407 ppm since 1950; Scripps Institution of Oceanography, 2017) resulting in a rapid global warming (IPCC, 2013). Since 2010, new global record temperatures have been set in 2014, 2015 and 2016 (Hughes et al., 2017a). This rapid rate of change and the resultant impact on ecosystems has increasingly become an issue of global concern and has led to the proposal of a new geo-stratigraphic Epoch, where humans have become a global factor affecting ecosystems; the Anthropocene (Waters et al., 2016; Steffen et al., 2011).

All ecosystems are affected by human pressures; however, estuaries and coastal seas carry a disproportionate human load (Birch et al., 2015; Neumann et al., 2015). Globally, more than 600 million

https://doi.org/10.1016/j.ecss.2017.10.010
0272-7714/

people live in low-lying coastal regions (between 0 and 10 m above sea level; Mcgranahan et al., 2007), with more than 150 million people living within 1 m of high tide (Lichter et al., 2010). Many of these are concentrated in urban agglomerations, where population density continues to increase (between 1950 and 2000 the percentage of the world's population living in urban areas grew from 30 to 50%; Neumann et al., 2015, Steffen et al., 2007, Mcgranahan et al., 2007). In 2009 67% of the world's megacities (cities with more than 10 million inhabitants) were located on the coast, with an additional 80% having a coastal influence (von Glasow et al., 2013). Urbanisation and increased anthropogenic activity both on the coast and within catchments (e.g. aquaculture, fisheries, agriculture and land-use change) have resulted in habitat loss and modification and the release of contaminants, sediments and nutrients into estuarine and coastal systems (Meybeck and Vörösmarty, 2005; Sinha et al., 2017). These pressures look set to increase, as by 2025, the population in coastal zone megacities is projected to reach 301.7 million people (von Glasow et al., 2013).

In addition to this rapid anthropisation of the coastal zone, global climate change, and its associated effects, pose further threat to coastal seas and estuarine ecosystems (IPCC, 2014). Whilst the specific impacts of climate change will vary geographically (based on regional contexts and the physical and geological setting; Perillo and Piccolo, 2011), coastal and estuarine systems around the world are becoming increasingly vulnerable to global sea level rise, increased temperatures, ocean acidification, changes in wind patterns and storminess and changes in the availability of water and nutrients from precipitation and runoff from land (Day et al., 2011; IPCC, 2014). Likely consequences of these changes include habitat loss through coastal erosion, coastal squeeze and marine transgression (Gutierrez et al., 2011; Jackson and Mcilvenny, 2011), enhanced risk of coastal eutrophication, harmful algal blooms and hypoxia (Sinha et al., 2017), reductions in water clarity (Capuzzo et al., 2015), landward incursion of saltwater into estuaries (Little et al., 2016) (and coastal groundwater aquifers; Ferguson and Gleeson, 2012) and corresponding movement of the turbidity maxima (Jalon-Rojas et al., 2015). The resulting impacts of these changes on ecology and biogeochemical cycling have consequences for the structure and functioning of estuaries and coastal seas (Hughes et al., 2017b; Elliott et al., 2015; Richardson et al., 2012).

Whilst we do not yet fully understand to what extent global change will affect estuarine and coastal processes (Richardson et al., 2012), it is clear that these systems face unprecedented pressures, which will affect human societies through the loss of the ecosystem services they provide (e.g. provisioning services such as food, fuel and fibre; regulating services such as nutrient cycling, atmospheric and climate regulation, waste processing, disease regulation and flood hazard regulation; and cultural services such as tourism, education, recreation, amenity and aesthetical values; Mea, 2005, Barbier et al., 2011). Coastal systems (including estuaries, continental shelf area, sea grass, coral reefs, mangroves and wetlands) are clearly valuable resources (total economic value estimated at ~US$ 575,011 per ha per year at 2007 price levels; de Groot et al., 2012), which face competing and often conflicting socio-economic and environmental demands. They are also complex systems, connected and naturally variable, governed by interacting geomorphological, hydrological and ecological processes acting at a range of temporal and spatial scales (Elliott and Whitfield, 2011; Whitfield and Elliott, 2011). The need to balance these socio-economic and environmental demands in a complex environment, whilst confronting the consequences of global change requires innovative multi-sectoral management approaches based on excellent and fit-for purpose multi-disciplinary science (Elliott and Whitfield, 2011).

With this objective in mind, the Estuarine and Coastal Sciences Association (ECSA) and the publisher Elsevier organised the 55th ECSA international symposium in London, UK on the 6th of September 2015. This multi-disciplinary symposium brought together 363 researchers and professionals from 223 institutions and 36 countries to discuss and address issues of outstanding scientific importance in the science and management of estuaries and coastal seas. The goal of the symposium was to synthesise knowledge from a variety of disciplines to stimulate future multi-disciplinary research and aid global environmental management of these systems in the face of multiple pressures (as outlined above). This Special Issue consists of 30 individual papers which are discussed in relation to main focus of the symposia; learning lessons from the past, discussing the current and forecasting for the future, addressing the impacts of global environmental change on estuaries and coastal seas across the globe.

2. Overview of the problem

The theme of the meeting and this Special Issue (SI) is based on a consensus that estuaries and coastal seas are changing, threatened and in a state of global decline due to multiple drivers resulting in interacting pressures which act over a number of spatial and temporal scales. These include the effects of global climate change (e.g. global sea level rise, increasing temperatures and ocean acidification; IPCC, 2014) and other human activities (e.g. invasive species, over-extraction of resources, habitat loss and alteration, introduction of organics, nutrients, pollutants and contaminants, marine litter and changes to water flow; Syvitski et al., 2005; Lotze et al., 2006). These pressures have been linked to the depletion of >90% of formally important estuarine and coastal species (i.e. large vertebrates and habitat-providing species; Lotze et al., 2006), the loss of >65% of coastal vegetated ecosystems (Lotze et al., 2006; Polidoro et al., 2010), water quality degradation (nutrient input into the oceans has trebled since 1970; Smith et al., 2003) and accelerated species invasions (Ruiz et al., 1997).

Estuaries are particularly vulnerable to these pressures as they are ‘open’ ecosystems with ill-defined and changing unbounded boundaries (Elliott et al., 2015). Estuaries are both connected to and part of a dynamic aquatic continuum, linking the terrestrial environment (through streams, rivers and run-off) with the continental shelf and open ocean (Elliott et al., 2015). Energy, organisms and matter flow within, through and between these unbounded systems (Hyndes et al., 2014), so pressures acting on a range of spatial (e.g. local, regional and global) and temporal (i.e. days, months and decades) scales converge and impact on estuaries (i.e. endogenic pressures emanating from within the system and exogenic pressures emanating from outside the system) (Raimonet and Cloern, 2017; Elliott, 2011). As a result, estuarine baselines are shifting. Marine transgression and saline incursion from global sea level rise are increasing the extent of marine influence inland (Little et al., 2016). Habitat loss and reclamation (e.g. managed realignment) are altering the morphology of the coastline, through changes to sediment erosion and deposition processes (Cazenave and Cozannet, 2014). Increased suspended sediments in the water column (through increased coastal erosion, decreased estuarine sediment sinks and changing weather patterns) are reducing water clarity in coastal seas, changing energy fluxes through the marine food web (Capuzzo et al., 2015). Increased temperatures and species introductions are resulting in species redistribution, turnover and range shifts, with consequences for functional biodiversity (Johnson et al., 2011; Lotze et al., 2006; Walther et al., 2009; Graham et al., 2014). Increasing chemical, organic and microbial pollution of coastal waters and sediments are leading to changing timings and extents of algal blooms and hypoxic zones (Sheahan et al., 2013).

These unbounded boundaries and shifting baselines have