Brown, S., Nicholls, R. J., Hanson, S., Brundrit, G., Dearing, J. A., Dickson, M. E., … Woodroffe, C. D. (2014). Shifting perspectives on coastal impacts and adaptation.
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The Intergovernmental Panel on Climate Change reports reflect evolving attitudes in adapting to sea-level rise by taking a systems approach and recognizing that multiple responses exist to achieve a less hazardous coast.

With the release of the Intergovernmental Panel on Climate Change (IPCC)'s Fifth Assessment Report (AR5)[1], climate change has again been identified as an important driver of change. Coasts are particularly vulnerable, as they are directly affected by rising sea levels, storminess and other climate drivers: this is accentuated by other issues and changes such as urbanisation, including indirect landward and seaward influences (for example, reduced water and sediment input due to dams). Adverse consequences include increased flooding, salinization, erosion, and wetland and biodiversity loss[1]. Several recent extreme meteorological events have caused catastrophic human and economic losses in coastal areas, such as Cyclone Nargis (Myanmar, 2008), Storm Xynthia (France, 2010), Hurricane Sandy (eastern United States, Canada and Caribbean, 2012) and Typhoon Haiyan (Philippines, 2013). Although coasts have always been hazardous places to live, global economic losses have significantly increased in recent decades[2]. Climate change is exacerbating those risks. This Commentary demonstrates how successive IPCC coastal chapters[1,3–6] have shifted from impacts towards adaptation, assessing the relative role of climate change within a broader environmental framework, with increasing clarity and nuance, despite continuing uncertainties.

Shifting towards a systems approach

Although coastlines are naturally dynamic, climate change is considered responsible for many impacts over the long term. However, other factors also play an important role[7], requiring a systems approach to understand the adaptation challenge (shown through the integral of drivers in Fig. 1). In 1990, when the IPCC released its First Assessment Report, projected coastal impacts of climate change were primarily qualitative. Quantitative impacts, where presented, were often large, and subject to considerable uncertainty. For example, between the First[3] (1990) and Second[4] (1995) Assessment Reports, the percentage of projected gross national product estimated to be required for protection from a 1 m sea-level rise in Kiribati decreased from 19% to less than 1%. This reflected significant changes in assessment methodology, including understanding of impact response and analysis of protection. Such adjustment to assessment methodology is an ongoing process[8].

Thinking has also progressed: Fig. 2 illustrates the evolving nature of IPCC reports with respect to coasts, determined by chapter headings, text content and keyword searches. Gone is the vagueness regarding potentially large impacts, with unknown or low confidence found in early reports where 'do nothing' was the assumed option. Instead, IPCC AR5 brings an optimistic message, increasingly highlighting the role of long-term adaptation and risk-management solutions. Following the lead of the Fourth Assessment Report (AR4)[6], AR5 places greater prominence on other drivers of change, including variable sediment supply, subsidence, population growth and economic development. The complex combinations of these, together with stakeholder engagement (that is, those who use or benefit from the coast) and appropriate adaptation requires further consideration. Such an integrated approach could form the basis for a coastal chapter in a potential sixth assessment report.

Wicked problems

As coasts are subject to a diverse range of land uses, stakeholders and investments, both internal and external to the coastal zone, this can create adverse physical, ecological and socioeconomic interactions, and generate potential for 'wicked problems' to develop. Wicked problems are those that are complex, challenging, have multiple feedbacks, are highly uncertain and have ambiguous solutions[9]. Indeed, solutions may generate further, unforeseen problems, leading to long-term coastal degradation[10,11]. For example, growing populations and economies need water. On deltas and alluvial plains, groundwater pumping can meet this demand. However, this can lead to significant subsidence. In Bangkok, several metres of subsidence resulted over just a few decades (in contrast, global sea-level rise was only 1.7 ± 0.2 mm per year[12]). Legislation regulating extraction subsequently reduced the rate of subsidence[13], but some subsidence continues, so Bangkok is left with a legacy of increased flood risk, demanding an adaptation response.

Herein lies a paradox: economic and population growth can increase risk, but economic growth and prosperity promotes adaptive capacity. Additionally, large-scale groundwater mining, like that in Bangkok, has global implications as it increases global mean sea-level rise (albeit by a few tenths of a millimetre per year[12]). Therefore, although impacts could be local in scale over a decadal period, cumulatively they may have global significance over centennial periods. Despite this insight, other cities are repeating this mistake (for example, Jakarta). The challenge is to address the driver of the hazard while continuing to promote economic growth and sustain wellbeing. As shown in Fig. 1, strategic management needs to place priority on immediate impacts from human activities, but recognize larger-scale contexts such as climate change, addressing present, urgent issues, while simultaneously anticipating future challenges.

With millions of people using the coast, integrated management and legislation should help to balance multiple land uses and interests, while sustaining long-term environmental quality. Monitoring of the coast and mutual learning can help to identify potential problems before they arise, and allow adaptive responses to be planned. The coastal chapter of AR5[1] draws attention to the growing recognition of adaptation practice, integrated adaptation and synergies or antagonisms with climate mitigation. However, for wicked problems, it is sometimes challenging to see the root cause of a problem today (either physically or through the legacy of local decision-making in shoreline management), let alone far into the future. Wicked problems may not be physically driven, but could be entrenched, perhaps unwittingly, in present policy and priorities of decision-makers. As G. K. Chesterton wrote[14] in 1935, "It isn't that they can't see the solution. It is that they can't see the problem." If we are unsure of the complex processes and interactions of coastal change and policy implementation today, how can we address impacts, deal with uncertainties and, where necessary, plan adaptation for the future?

Adaptation in practice

As Fig. 2 shows, particularly since AR4[6], climate change is no longer recognized as a single driver of change in coastal zones, rather a systems approach to impacts and adaptation is undertaken. A range of adaptive responses are considered, so the system is seen in a wider context. The Thames Estuary 2100 Project, which assessed the best ways of protecting London from tidal flooding over the next century and beyond, provides a good example of an adaptation response, by producing a range of possible adaptation options and futures (right-hand side of Fig. 1). Termed adaptation pathways, these involve a time-independent sequence of actions responding to multiple drivers and uncertainties, and are guided by the magnitude of sea-level rise to determine when and where it is optimum to adapt[15]. Multiple future pathways keep adaptation responses open. Promoting learning about drivers and responses to change provides managers with a wider range of adaptation options.

The evolution of thinking on coastal systems has meant that adaptation has happened in ways not anticipated in early IPCC assessments. For example, small, low-lying remote islands are rightly seen as high-risk areas due to multiple climatic forcings and a limited ability to respond or protect themselves against hazards, particularly if access to finance is low[8]. However, the capital cities of many small

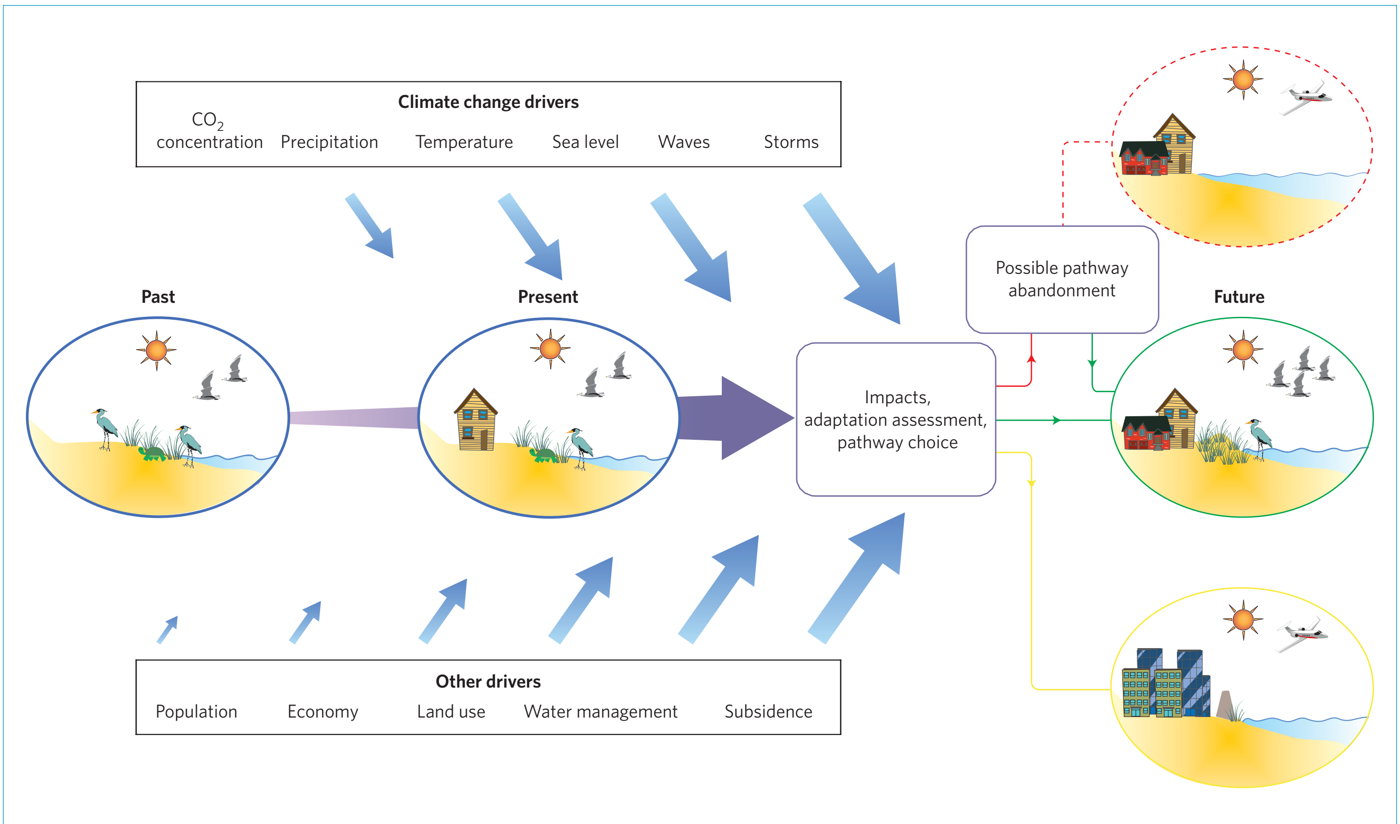

Figure 1 | A systems approach to long-term strategic adaptation policies and planning (adapted from Fig. 6.1 of the Intergovernmental Panel on Climate Change (IPCC)'s Fourth Assessment Report[6]). Climatic and non-climatic drivers influence coastal systems, and interact with each other, as denoted along the central 'time' arrow. Ellipses represent coastal systems, impacts and adaptation as a result of drivers and human choice. Adaptation response can reduce impacts, best assessed through adaptation pathways (here depicted by the different coloured future pathways and ellipses). Some adaptation pathways may ultimately end in an undesirable future (dashed ellipse), so to avoid this, an alternative pathway is sought.

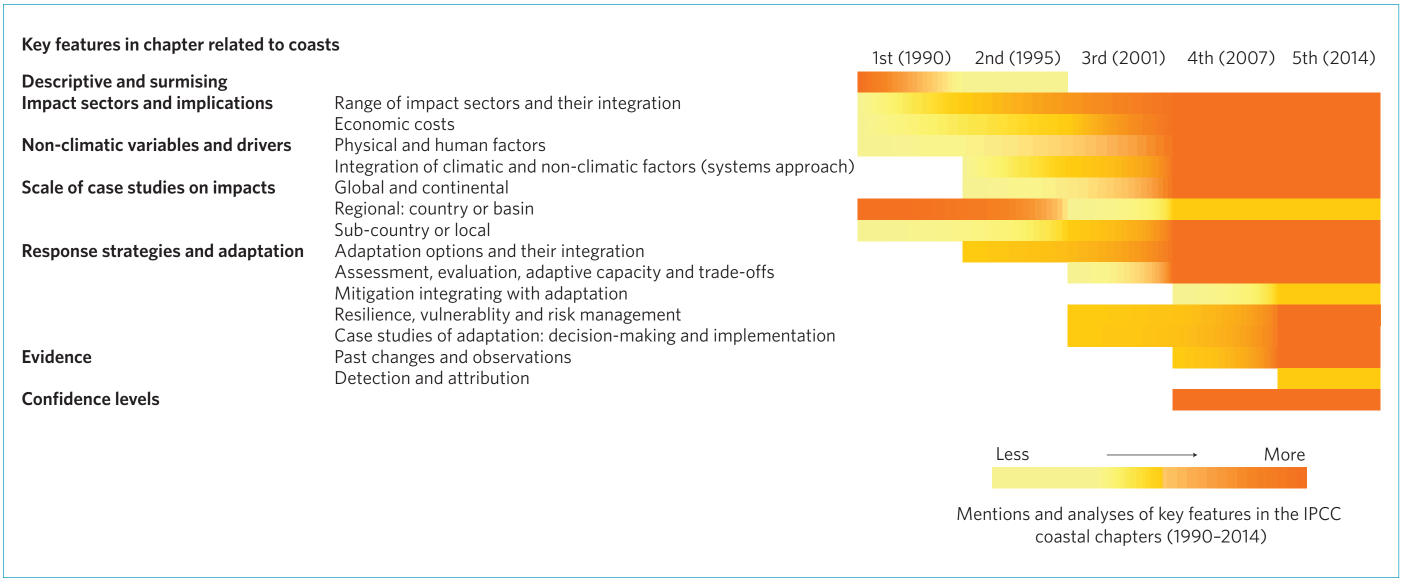

Figure 2 | Evolution of the Intergovernmental Panel on Climate Change (IPCC) coastal chapter from the First to Fifth Assessment Reports (1990–2014) and its methodological approaches[1,3–6]. Key features of the chapter were explored through chapter headings, text content and keyword searches.

islands (for example, Malé, Maldives) are densely populated, and over the long term, land-use pressures are creating as many problems as sea-level rise. Here, necessity is the mother of invention, and coastal dwellers and engineers have been ingenious by extending the habitable area through land claim, while taking into account sea-level rise. For example, the new island of Hulhumalé, adjacent to the Maldivian capital, has been claimed from a reef since 1997 to reduce land-use pressure on Malé taking into account sea-level rise. Hence for one island, adaptation to climate change has meant building upwards as well as outwards, but this is not the norm. Climate change is not the only focus, as other issues remain: proximity of settlement to the coastline, population pressure in cities, sediment shortages to defend islands and reclaim land, coral reef quality, water resources, human health, fisheries and maintaining income-generating activities such as tourism. As with other nations claiming land (for example, Singapore), sea-level rise can be incorporated into the design, but forward and long-term adaptation planning, incorporating local solutions, suitable finance, scientific understanding and engineering ingenuity, is required. Best practices of adaptation include an on-going learning process that should become a key aspect of practice and future IPCC reports.

The way forward

Multidisciplinary systems approaches to planning and sustainability practices puts coastal zone adaptation into a wider perspective. Adaptation pathways recognize multiple futures, partly shaped by decision-making (Fig. 1). The IPCC perspective has shifted from impacts to adaptation, reflecting a growing focus on integrated approaches to reducing risk that rely on flexible adaptation options and management. These aim to be effective regardless of how environments change. Coastal managers now need to implement a further shift to planning and implementation, with an emphasis placed on resilience, cost-effectiveness and working with nature. Furthermore, adaptive, sustainable planning should be undertaken in a wider socioeconomic development framework, taking into account human needs — many of which are more immediate than climate change. Rather than pointing the finger only at climate change and assuming it inevitably spells disaster, there is a need to better understand climatic and non-climatic drivers of coastal change and their interactions at different spatial and temporal scales. Finally, adaptation will reduce risk, but not eliminate it. Nevertheless, we can shift our expectations to better understand multiple interacting drivers of change and plan and implement more effective adaptive responses. ❐

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